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DoD Corrosion Prevention and Control Program

Corrosion Control of Central Vehicle Wash Facility Pump Components Using Alternative Alloy Coatings

Final Report on Project F09-AR14

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Final report

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Under Project F09-AR14, “Innovative Corrosion Resistant Coatings and Materials for Pumps”

Abstract

Central Vehicle Wash Facilities (CVWFs) at military installations are essential for supporting the readiness of tactical vehicles. Steel wash-rack pumps are vulnerable to accelerated degradation where supply water is corrosive and infused with fines. Pump failure can occur with little warning, taking the CVWF out of service for unscheduled maintenance. This project tested two advanced coating materials on critical internal pump components to evaluate cost and performance. At the Fort Polk, LA, CVWF, internal components of one new pump were coated with a thermally sprayed cobalt alloy, and matching components in another pump were coated chemically with an electroless nickel (EN) material.

Both pumps were used for 15 months, then disassembled and inspected. No significant corrosion degradation of pump components was observed on either pump. However, pump components coated using the EN process performed slightly better than those coated using the thermally sprayed alloy. The EN coating produced more uniform results and was less expensive, so it may be preferred by DPWs. The return on investment (ROI) for the EN coating is 2.59. Both coatings are conservatively estimated to double pump service life when compared with the previous pumps, but the lack of service records precluded a firm, data-driven prediction.

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Preface

This demonstration was performed for the Office of the Secretary of Defense (OSD) under Department of Defense (DoD) Corrosion Prevention and Control Project F09-AR14, "Innovative Corrosion-Resistant Coatings and Materials for Pumps." The proponent was the U.S. Army Office of the Assistant Chief of Staff for Installation Management (ACSIM), and the stakeholder was the U.S. Army Installation Management Command (IMCOM). The technical monitors were Daniel J. Dunmire (OUSD(AT&L)), Bernie Rodriguez (IMPW-FM), and Valerie D. Hines (DAIM-ODF).

The work was performed by the Engineering and Materials Branch (CEERD-CFM) of the Facilities Division (CF), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). The ERDC-CERL project managers were Michael K. McInerney and Orange S. Marshall (retired). Significant portions of this work were performed by Concurrent Technologies Corporation (CTC), Johnstown, PA. At the time this report was prepared, Vicki L. Van Blaricum was Chief, CEERD-CFM; Donald K. Hicks was Chief, CEERD-CF; and Kurt Kinnevan, CEERD-CZT, was the Technical Director for Adaptive and Resilient Installations. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Ilker Adiguzel.

The following personnel supported this effort and are gratefully acknowledged for their assistance:

- Louis Karisny (retired) and Mel Dixon, Fort Polk Directorate of Public Works
- Richard Boillat and Colby Fox, Fort Polk Range Control

The Commander of ERDC was COL Bryan S. Green and the Director was Dr. Jeffery P. Holland.

Executive Summary

This Department of Defense (DoD) Corrosion Prevention and Control project involved the application of two corrosion- and erosion-resistant materials to critical internal components of Central Vehicle Wash Facility (CVWF) pumps at Fort Polk, LA. Two existing water pumps were removed and examined for corrosion and erosion damage. For the demonstration, two new pumps of similar quality and capacity were procured and tested, then disassembled in order to treat critical components in each with different protective materials—one with a thermally sprayed cobalt-based alloy coating and the other with an electroless nickel coating. The two new, modified pumps were then installed and monitored for a period of 15 months.

The pumps functioned properly throughout the fifteen-month evaluation period, with no problems or anomalies noted by facility users. At the end of the demonstration period, the pumps were rated for wear, erosion, and corrosion performance, and then returned to service. The ratings for components in both pumps were very similar, and in most cases yielded similar ratings. Therefore, the results imply that either of the demonstrated coatings would be suitable for protecting the pumps over the long term. However, the pump with components coated with electroless nickel performed slightly better than those treated with the thermal-spray alloy. Because the electroless nickel process is the less expensive of the two technologies, it may be preferable for this type of application.

The calculated return on investment (ROI) was 2.59 for the electroless nickel coating. The most important lessons learned were that weather and coating-procurement logistics can seriously impact the pump replacement schedule. A more efficient and affordable means of acquiring these technologies, such as application at the installation, would reduce CVWF downtime and provide a larger return on investment. It is suggested that longer-term inspection (between two and five years), the acquisition of more information on a facility's existing pumps, and/or the application of reliability models could help to more accurately project the life expectancy of the coated pumps.

1 Introduction

1.1 Problem statement

Large steel water pumps are used to pump water into the Central Vehicle Wash Facility (CVWF) for vehicle washing at Fort Polk, LA. The interior pump components can quickly corrode along the shaft and impeller housings due to alternating wet/dry exposure cycles in the pump wells. In addition, the presence of particulates within the wash water makes the effluent very abrasive to the materials and coatings conventionally used in such pumps. The lives of the pumps are also shortened by cavitation, a form of erosion-type corrosion caused by the formation and collapse of vapor bubbles near the metal/solution interface that is especially prevalent in pump impellers (Fontana 1986). When the bubbles implode due to high pressure they can generate an intense shock wave. Multiple continual implosions cause cyclic stress that create surface fatigue of the metal and cause cavitation corrosion.

These wash facilities are essential for military vehicle readiness. As a result of these corrosion and degradation problems, the CVWF pumps need to be replaced or refurbished about every ten years, which requires significant cost and manpower. If all primary wash pumps (usually two) degrade concurrently, facility operations may be completely suspended during maintenance and repair procedures.

Advanced coatings and materials are available that can reduce the corrosion and degradation of CVWF pump components. The enhanced corrosion resistance imparted by advanced coatings has already been demonstrated on CVWF components at other military installations (Kumar 2005, Kumar 2008, *Materials Performance* 2008). Pump components that utilize such coatings and materials will provide reduced life-cycle cost, reduced maintenance requirements, increased safety, and increased reliability of the CVWF. The application of corrosion-resistant materials and coatings could potentially extend pump service life by 20–30 years at substantial cost avoidance and improved CVWF readiness.

The DoD Corrosion Prevention and Control Program sponsored a demonstration of new coatings and materials on two pumps at the Fort Polk CVWF. There is a need for improved corrosion protection of pumps due to the corrosivity of the water used to supply the CVWF. Water samples have a high to very high Ryznar* index, indicating that mild steel is expected to experience heavy to intolerable corrosion. In this project, the U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) coordinated with the Fort Polk Department of Public Works to install two new pumps at the installation CVWF that incorporated advanced materials and coatings.

1.2 Objective

The objectives of this project were to (1) demonstrate and validate selected advanced corrosion-resistant steel housings and metallic coating systems applied to new wash rack pumps, and (2) document their performance and costs in comparison with those of currently used technology.

1.3 Approach

To successfully evaluate the new pump component coating technologies, it was necessary to undertake several tasks. These included an evaluation of the existing (old) pumps, selection of the necessary coatings and materials needed to provide enhanced erosion and corrosion protection to the new pumps, the assembly of the new pumps (including coating the selected components), and installation and monitoring of the new pumps.

The pump impellers and housings from one of the new pumps were coated with Stellite 6,† a cobalt-based alloy applied with the High Velocity Oxy Fuel (HVOF) process. The impellers and housings of the other new pump were coated with a nickel-based alloy deposited by an electroless process.

On both pumps, the surfaces of the shafts were sealed with a fluoroelastomer that is frequently used in corrosive applications. Other rotating

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* The Ryznar stability index (RSI) attempts to correlate an empirical database of scale thickness observed in municipal water systems to the water chemistry. Although the RSI was developed for municipal water systems it is relevant to CVWFs because of the similarities in piping and pumping.

- When the RSI is below 5.0, the water is considered to be potentially scale forming.
- When the value is from 5.0 to 7.0, the water is considered balanced and not corrosive or excessively scale forming.
- When the RSI is above 7.0, the water is considered to be potentially corrosive.

† Stellite is a registered trademark of Kennametal Stellite, Pittsburg, PA.

parts—the shaft and the shaft casing—were made from 316 stainless steel. In addition, stainless steel strainers were installed on the pump intakes.

Metrics and procedures for evaluating the condition of water pump components in terms of corrosion, erosion, cavitation, and degradation are described in Chapter 3.

2 Technical Investigation

2.1 Project overview

The Central Vehicle Wash Facility (CVWF) provides a rapid, economical method for washing tracked and wheeled tactical vehicles. The standard CVWF consists of a vehicle-preparation area, wash stations, and vehicle assembly area. Support infrastructure includes a control house, lighting, water-storage basins, water-supply pumps and piping, drainage, wastewater treatment, and electric service.

The North Fort Polk CVWF is shown in the figures below. Figure 1 is an overall view of the prewash facility; Figure 2 shows the center island water cannons, and Figure 3 shows the facility in use. Note that there are two prewash lanes at this facility. Each lane has primary cannons for exterior washing and sprayers for close-range, targeted cleaning. (Only the pre-wash facility is shown in these figures.) Each lane has two pumps— a larger primary "birdbath" pump for the cannons and a smaller wash pump for the sprayers. Standard design information for these facilities is given Unified Facilities Criteria 4-214-03, "Central Vehicle Wash Facilities."

Figure 1. Prewash area at North Fort Polk CVWF.

Figure 2. Water cannons on CWVF central island.

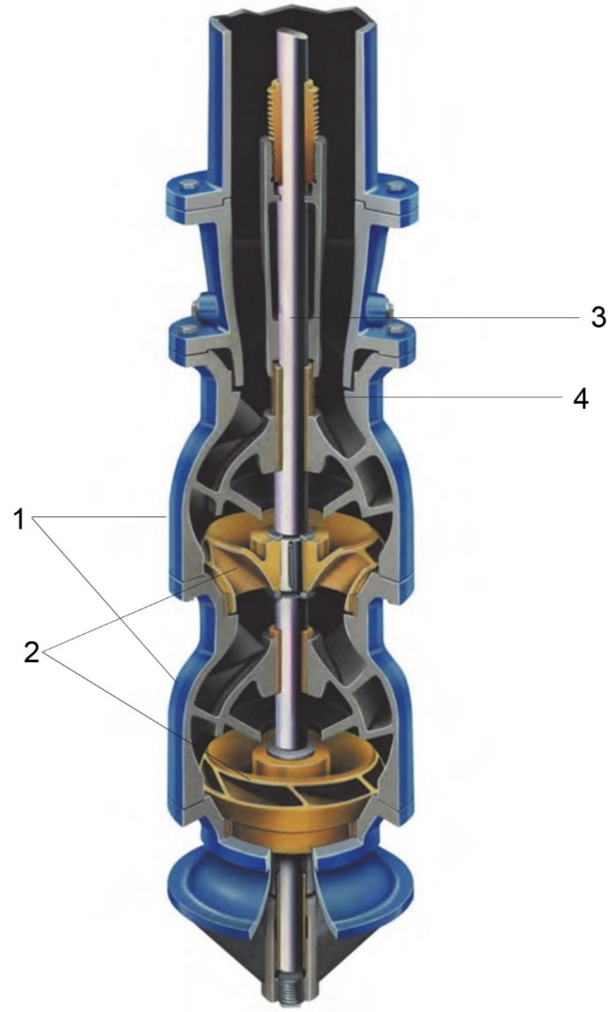
Figure 3. Military vehicle being cleaned at CVWF.

The CVWF pumping station is shown in Figure 4. Only the motors can be seen in this picture; the pumps are in the pit beneath the motors. The two larger prewash pumps are on the left and the two smaller wash pumps are on the right. The motor has been removed from one of the prewash pumps. The pump shaft is visible and the motor has been placed at the nearer left corner of the slab.

Figure 4. CVWF pumping station.

Both of the new prewash pumps installed at the Fort Polk CVWF were vertical pumps, each with a motor on top connected to a shaft running the length of a pump column pipe to drive impellers located in bowls beneath the column pipe. A cutaway diagram of pumps similar to both the old and the new pumps, showing the components that were evaluated under this effort, is shown in Figure 5 (Pentair n.d.).

Figure 5. Cutaway diagram of vertical turbine pump bowl assembly, showing pump bowls (1), impellers (2), shaft (3), and bearings (4). Reprinted with permission of Fairbanks Nijhuis, Kansas City, KS.



2.1.1 Inspection of existing pumps

The old pumps at the CVWF North Station were removed from their sumps and inspected for any damage related to corrosion, erosion, or cavitation. The components were evaluated, photographed, and rated.

2.1.2 Design of new pumps

The old pumps at the CVWF North Station were replaced with similar new pumps. Although the capabilities of the old and new pumps are the same in terms of pumping capacity, etc., the configurations are slightly different. The old pumps had five bowl sections, but the new pumps are a three-stage design with three bowl sections.

The pumps were built by Goulds ITT, under the direction of the contracted installer, Layne Christensen Company. After assembly and testing, the pumps were disassembled, and the critical components were sent to the respective facilities for coating.

2.1.3 Selection and deposition of coatings

A number of coatings and materials were used to enhance the corrosion- and erosion-resistance of the new pumps. To support the selection of appropriate materials and coatings, the corrosivity of the water was analyzed at the start of the project (see Appendix A).

The pump impellers and housings from one of the new pumps were coated with Stellite 6, a cobalt-base alloy applied with the High Velocity Oxy Fuel (HVOF) process. Such coatings have demonstrated considerable improvement over conventional materials in previous work (Kumar 2005).

The pump impellers and housings from the other new pump were coated with a nickel-based alloy deposited by the electroless process. Electroless nickel (EN) coatings have been used for corrosion control of components such as pump impellers for many years. As-deposited hardness of this coating is typically between 500–600 Vickers hardness, but hardness as high as 1,000 Vickers can be achieved through post-plating heat treatment (Henry 2008).

The surfaces of the shafts were sealed with a fluoroelastomer called Viton,* which is frequently used in corrosion-sensitive applications and meets ISO 9000 and ISO/TS 16949 registration.

Other rotating parts—the shaft and the shaft casing—were made from 316 stainless steel. In addition, stainless steel strainers were placed on all four pump intakes.

It had originally been planned that the new pumps would use bushings coated with an abrasion- and corrosion-resistant coating. Colmonoy,† a

* Viton is a registered trademark of DuPont Performance Elastomers, Inc., Wilmington, DE.

† Colmonoy is a registered trademark of Wall Colmonoy Corp., Madison Heights, MI.

chromium-boride–rich nickel alloy, previously used for this application. However, it was determined that this coating would not be necessary.

2.2 Fieldwork and pump installation

The coated pump components from both facilities were returned to the pump manufacturer, and the pumps were reassembled. The completed pumps were then painted and sent to Fort Polk for installation. The condition of the assembled new pumps before installation is shown in Figure 6.

Figure 6. New pump components being installed at Fort Polk CVWF.

The installation took place at the Fort Polk CVWF North Station in January 2011. Before installing the new pumps, Fort Polk "outside" electricians (electricians who work with outdoor high voltage equipment) were called to disconnect the primary power to the pump station. The north-side pump (hereinafter referred to as Unit 2) was disconnected and removed first. The old Unit 2 pump was placed on the ground, and the existing header was removed to be reused with the new pump. The disassembly of the old Unit 2 pump is shown in Figure 7.

Figure 7. Old (inoperable) Unit 2 pump disassembly.

The new Unit 2 pump was fitted with the header pipe that was removed from the old pump, but it did not fit properly and could not be used. A welder made a new header pipe that fit properly. The installation of the new header pipe is shown in Figure 8.

Figure 8. New Unit 2 pump header installation.

The bottom cap of the new south-side pump (hereinafter referred to as Unit 1) was removed to verify what type of coating was on the impeller prior to installation, as seen in Figure 9.

Figure 9. New Unit 1 first-stage impeller coating configuration.

It was noted that the sensor/heater power wires for the old Unit 1 motor were not connected. The decision was made to disconnect the new motor's sensor/heater wires. The electrician reconnected power to the pump site at the high-voltage electrical. Since the power panel had a lockout tag, the "inside" electricians (tradesman that work on electrical control panels and general indoor electrical items) were called to provide power to the new pump. No power or signal was detected from the switchgear to Unit 2.

While the electricians addressed the problem, work was initiated on Unit 1. This temporarily suspended wash rack capability operations. After pump station power was disconnected, the old Unit 1 motor was disconnected and removed, and the pump was then removed. The new pump was lowered into place and the strainer basket was installed, as seen in Figure 10.

Figure 10. New Unit 1 pump strainer basket installation.

The old Unit 1 pump was cut to expose the fifth-stage (top) impeller, which showed some signs of erosion and wear. The impeller was removed, and then the lower cap of the first stage was removed to expose the intake side of the impeller, as seen in Figure 11.

Figure 11. Old Unit 1 first-stage impeller.

The new header was painted and mounted to the pump. Then the Unit 1 header and pump were lowered and bolted into place, and the newly fabricated pump motor shaft was then attached to the old motor, as seen in Figure 12.

Figure 12. New Unit 1 pump installation with motor installed.

The old Unit 1 electric motor was lowered into place and connected to the power source. (This work had to be repeated after the rotation test.) The shafts of both pumps were connected to the motors and end play was adjusted. The pump station power was reconnected by the electricians. The Unit 1 pump (old motor) was started and the wash rack was reactivated. Nominal flow was verified by DPW personnel. The normal operation of the wash rack is seen in Figure 13.

Figure 13. North wash rack in operation.

The Fort Polk inside electricians continued to diagnose the problem with the Unit 2 pump motor power. At one point, they had a signal that should have enabled operation, but this signal could not be acquired again and the new pump motor did not operate. The installation crew cleaned up and left the site.

In February 2011, the power to the Unit 2 pump motor was restored by Fort Polk electricians, so the installation team returned to the site and ensured proper motor startup to comply with warranty requirements for the pump/motor.

2.3 Initial operation and monitoring

The new pumps were monitored for a period of 15 months, from January 2011 through April 2012. The DPW did not have remote monitoring technologies or any other means to monitor the functionality of the pumps during this time period. The DPW point of contact (POC) reported status monthly based on feedback from the Army units that used the pumps to wash their vehicles. Throughout the monitoring period, the DPW POC did not receive any negative feedback on the functioning of the pumps, and therefore assumed that they were functioning properly.

In June 2012 the demonstration pumps were removed and reevaluated. After the evaluation, the pumps were reassembled and reinstalled. In addition, electromechanical hour timers were installed in the control room for the pumps. The meters will measure the total hours of pump use, and this measurement will allow for an approximation of how much water is being sent to the pumps as well as how much the pumps are being used over a given time.

3 Discussion

3.1 Metrics

The pumps were evaluated visually, photographed, and rated according to ASTM B537, *Standard Practice for Rating of Electroplated Panels Subjected to Atmospheric Exposure*. This specification assigns a rating for the appearance of corrosion on metallic surfaces. The rating has two components: a protection component, which describes how well the coating has protected the substrate material; and an appearance component, which incorporates the protection component but also describes how well the coating has resisted staining and other unattractive effects. Both of the components range from 10, which is best (zero defects in total area), to 0, which is worst (greater than 50% defective in total area). The coatings were nonsacrificial protective materials of the sort that ASTM B537 is intended to evaluate. In addition, cavitation or erosion damage found on the pump surfaces after exposure was rated in accordance with ASTM D2809, *Standard Test Method for Cavitation Corrosion and Erosion-Corrosion Characteristics of Aluminum Pumps with Engine Coolants*. This specification also assigns a rating, from 10 (no damage) to 1 (pump casing leaking due to corrosion or erosion). Therefore, each pump section was rated on the basis of three different evaluations.

Appendix B, "Coating Evaluation Metrics," further describes the metrics and procedures to evaluate the condition of water pump components in terms of corrosion, erosion, cavitation, and degradation.

3.2 Results

The old pumps were inspected once, when they were removed from the sumps at the CVWF North Station. This inspection (henceforth the "old-pump inspection) captured the condition of the existing pumps, shafts, and external components after years of routine use. At that time, modifications to the proposed inspection areas were made, if necessary, to account for the non-flat surfaces of impellers, housings, etc. The new pump components were inspected twice. The first inspection was made before coating, and his henceforth referred to as the "new pump pre-coating inspection". The second inspection occurred immediately after coating but before installation, and is henceforth referred to as the “new-pump post-coating inspection.” The new-pump inspections were conducted on the same locations assessed on the old pumps.

3.2.1 Old pump inspection

The old pump inspection took place on 17–19 January 2011. The old pump inspection was conducted as part of the overall effort to remove the old pumps and replace them with the new pumps. Two pumps were involved: the north side pump (Unit 2), which was disconnected and removed first, and the south side pump (Unit 1), which was disconnected and removed afterwards.

The Unit 2 pump was evaluated first since it was the first to be disconnected and removed. All of the outer pump surfaces were found to be severely corroded. However, the steel was not perforated at any point, indicating that the corrosion was general rather than localized. The condition of the first stage of Unit 2 pump is shown in Figure 14.

Figure 14. Condition of first state of old Unit 2 pump.

Since more than 50% of the outer surfaces of the pump were corroded, all surfaces were given a rating of “0” for both protection and appearance in accordance with ASTM B537. Even the basket at the bottom of the first stage was severely corroded.

Despite the corroded appearance of the outer surfaces, the impellers from this pump were found to have minimal corrosion or erosion. Only very minor wear was observed. The condition of the first-stage impeller from this pump is presented in Figure 15.

Figure 15. Old Unit 2 pump first-stage impeller.

The condition of the impeller corresponds to a rating of 9 in accordance with ASTM D2809.

The ratings for the old Unit 2 pump are summarized in Table 1.

Table 1. Ratings for old pump components, Unit 2.

Component	Metric		
	ASTM B537–Appearance	ASTM B537–Protection	ASTM D2809
Stage 1 Bowl	0	0	n/a
Stage 1 Impeller	0	0	6
Stage 2 Bowl	0	0	n/a
Stage 2 Impeller	0	0	6
Stage 3 Bowl	0	0	n/a
Stage 3 Impeller	0	0	7

Component	Metric		
	ASTM B537–Appearance	ASTM B537–Protection	ASTM D2809
Stage 4 Bowl	0	0	n/a
Stage 4 Impeller	0	0	7
Stage 5 Bowl	0	0	n/a
Stage 5 Impeller	0	0	6
Shaft	7	7	9
Shaft casing	7	7	8
Basket	0	0	n/a

The Unit 1 pump was also found to be severely corroded when removed from the sump. Once again, no perforation of the outer surfaces was observed. The exterior condition of the bowls from the Unit 1 pump is shown in Figure 16.

Figure 16. Condition of old Unit 1 pump bowls.

Since more than 50% of the outer surfaces of the pump were corroded, all surfaces were given a rating of “0” for both protection and appearance in accordance with ASTM B537.

The impeller from this pump displayed some evidence of erosion. The condition of the first- and fifth-stage impellers from the old Unit 1 pump is presented in Figure 17 and Figure 18.

Figure 17. Old Unit 1 first-stage impeller.

Figure 18. Old Unit 1 fifth-stage impeller.

The condition of the first-stage impeller corresponds to a rating of 4 in accordance with ASTM D2809.

The ratings for the old Unit 1 pump are summarized in Table 2.

Table 2. Ratings for old pump components, Unit 1.

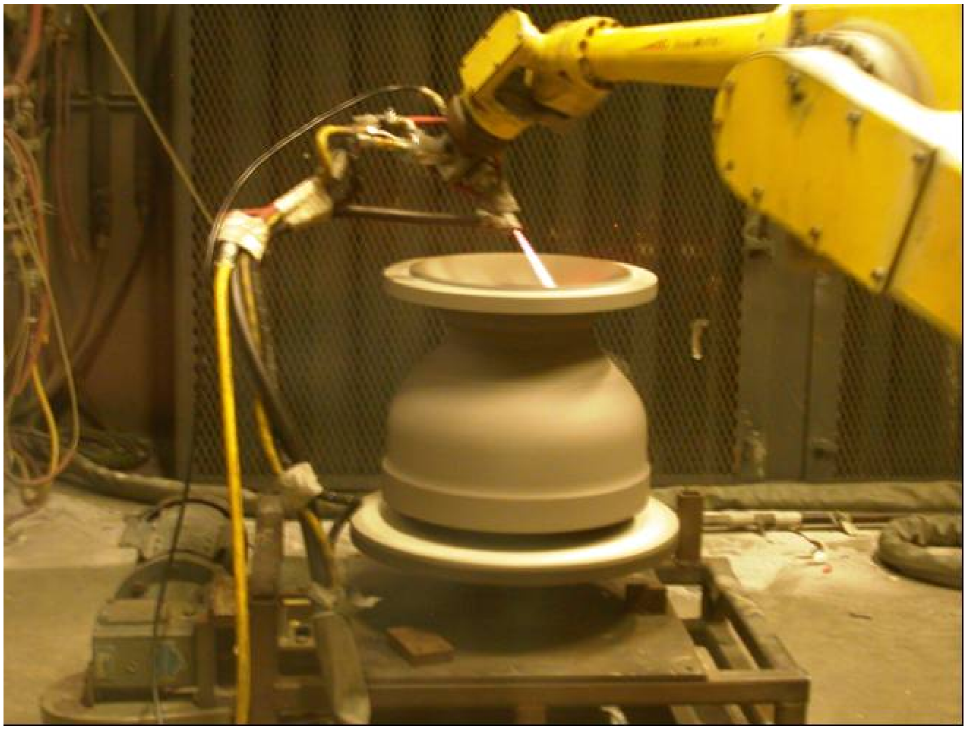
Component	Metric		
	ASTM B537–Appearance	ASTM B537–Protection	ASTM D2809
Stage 1 Bowl	0	0	n/a
Stage 1 Impeller	0	0	4
Stage 2 Bowl	0	0	n/a
Stage 2 Impeller	0	0	4
Stage 3 Bowl	0	0	n/a
Stage 3 Impeller	0	0	4
Stage 4 Bowl	0	0	n/a
Stage 4 Impeller	0	0	5
Stage 5 Bowl	0	0	n/a
Stage 5 Impeller	0	0	6
Shaft	8	8	8
Shaft Casing	7	7	8
Basket	0	0	n/a

3.2.2 New pump coatings

The coating-application process on all parts was supervised by CTC, ERDC-CERL, and Layne Christensen personnel. Where applicable, compliance with Society for Protective Coating (SSPC) standards SSPC-SP1 and SSPC-SP3 was confirmed.

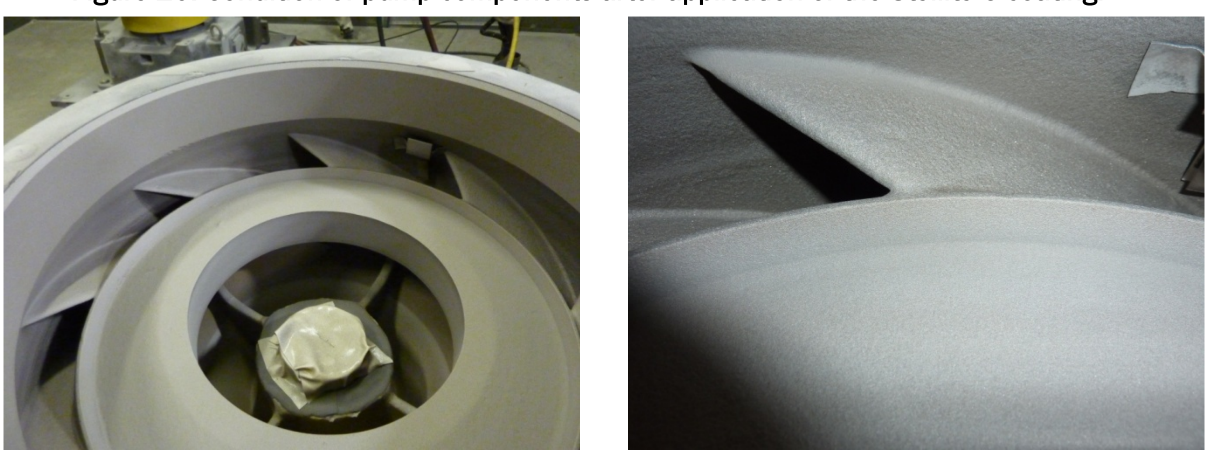
The new pump components were sent to two different facilities for coating. At one facility Stellite 6 coatings were applied to the pump components. Upon arriving at the site, the pump components were found to have a small amount of superficial surface corrosion. Prior to coating, the parts were grit blasted to provide a clean surface to promote coating adhesion. The parts were then coated using the HVOF thermal-spray process. HVOF is one of the most commonly used thermal-spray processes because it can be used to deposit a wide variety of materials as dense, well-bonded coatings. In the HVOF process, powdered material is fed into a gun, where it is combined with oxygen and fuel. The process of coating the underside of a pump bowl is shown in Figure 19.

Figure 19. Stellite 6 coating being thermally sprayed on underside of pump bowl.



A chemical reaction occurs when the oxy/fuel mixture is ignited and the powder is sprayed from the gun onto the substrate at a very high velocity and temperature (Kumar 2005). The parts were coated in accordance with the coater's internal specifications and industry best practices. The condition of the parts after application of Stellite 6 is shown in Figure 20.

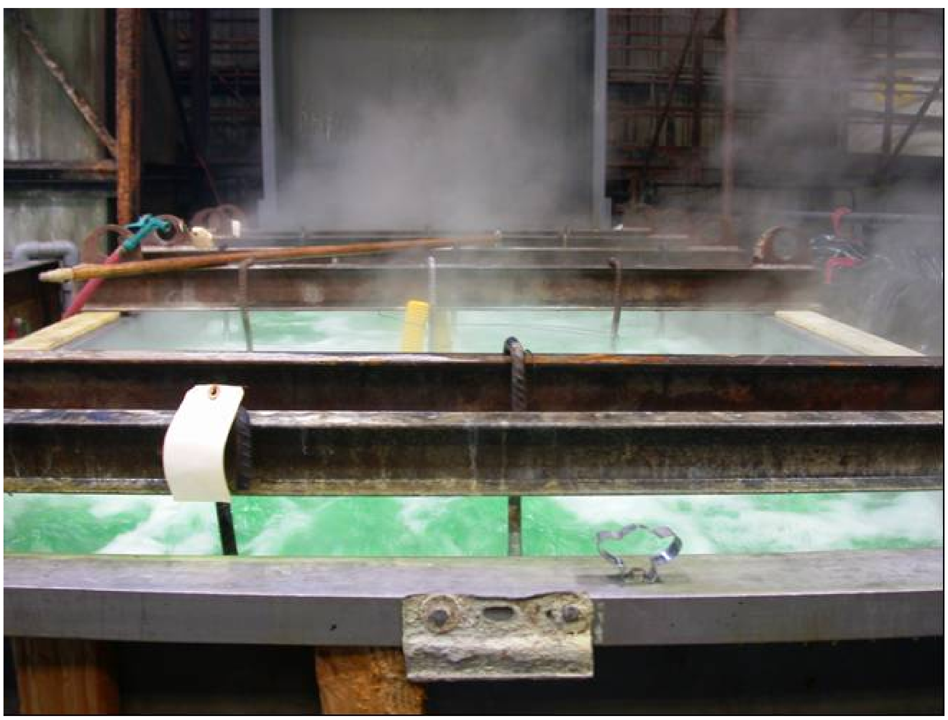
Figure 20. Condition of pump components after application of the Stellite 6 coating.



The specified thickness and adhesion of the Stellite 6 coating was confirmed with witness coupons, which are small plates made of the same material as the pumps that were coated alongside the pump components at the time of processing. The appearance was found to be acceptable by the coater. The pristine condition of the coated pump components corresponds to an overall rating of 10 in accordance with ASTM B537 – Appearance; ASTM B537 – Protection; and ASTM D2809.

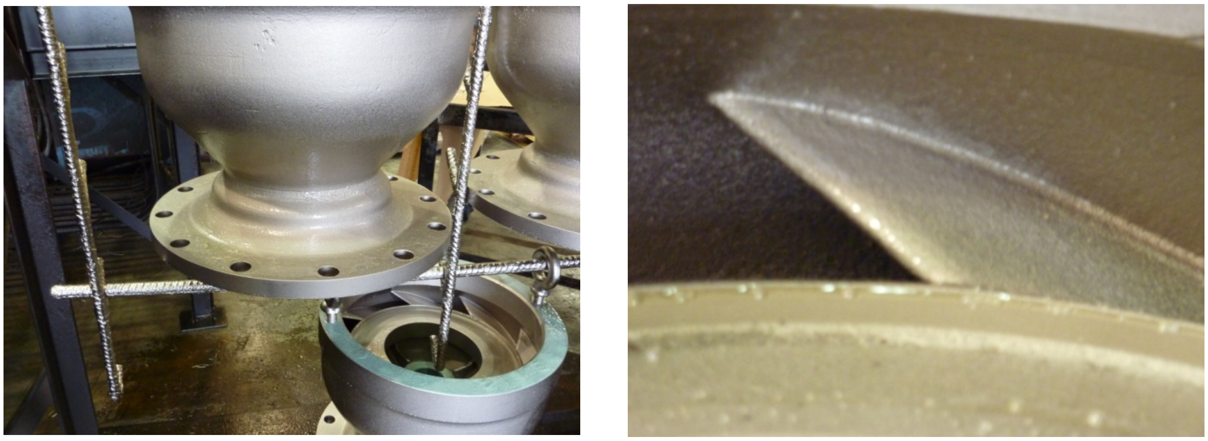
At the other facility, EN coatings were applied to the pump components. Upon arriving at the site, the pump components were found to be clean, with only very superficial surface corrosion evident in a few areas. EN is a plating process in which parts are coated with an alloy of nickel and phosphorus. Unlike traditional plating processes, EN coatings are not deposited using an electric current; instead, the deposited metal is chemically reduced from its ionic state and deposited onto the substrate (Henry 2008). In the process used for these pumps, a high-phosphorus EN bath was used. The resulting coating contained between 10 and 13% phosphorus, with the balance being nickel. After the parts were cleaned and etched in immersion processes, the parts were placed in the EN bath (Figure 21).

Figure 21. Pump components being plated in EN plating bath.



The parts were coated in accordance with the coater's internal specifications, SSPC standards, and industry best practices. The condition of the parts after EN plating is shown in Figure 22.

Figure 22. Condition of pump components after EN plating.



The pristine condition of the coated pump components corresponds to an overall rating of 10 in accordance with ASTM B537 – Appearance; ASTM B537 – Protection; and ASTM D2809. Coating thickness and adhesion were confirmed with witness coupons. The EN-coated parts were then heat treated for optimum wear and erosion resistance.

The coated pump components from both facilities were returned to the manufacturer and reinstalled. The completed pumps were painted and sent to Fort Polk for installation.

3.2.3 New pump inspection after 15 months of exposure

The new pump long-term inspection took place 14–15 June 2012 at the Fort Polk CVWF North Wash Rack. The new pumps were each removed from their sumps, disassembled, evaluated, reassembled, and replaced in their sumps.

3.2.3.1 Unit 1 pump

The overall outer surface condition of the Unit 1 pump after 15 months of service is shown in Figure 23. This pump contained components that were coated with the EN process.

Figure 23. Condition of outer surfaces of Unit 1 pump, after 15 months of service.

Some corrosion was noted in spots on the outer surfaces of the column pipe and the bowls, but it was not uniform over the entire surface. The corrosion did not perforate the material in any places.

The Unit 1 pump was then disassembled. The first-stage impeller had only minimal corrosion and erosion damage, as shown in Figure 24.

Upon removing the first-stage impeller from the pump bowl, some minor surface corrosion was evident. This corrosion was minimal, and it was easily wiped off. Minor erosion of the fins at the leading edges was noted, as shown in Figure 25.

Figure 24. Condition of Unit 1 first-stage impeller, after 15 months of exposure.

Figure 25. Condition of Unit 1 first-stage impeller after 15 months of exposure.

The second-stage impeller was removed and found to be in similar condition. The third-stage impeller exhibited minor uniform corrosion but no wear damage.

Nearly all of the pump bowl sections had some minor surface corrosion inside, but no wear or erosion damage. The second-stage bowl for Unit 1, after being removed from the pump assembly, is shown in Figure 26.

Figure 26. Condition of Unit 1 second stage pump bowl, after 15 months of exposure.

The stainless steel pump components — the strainer basket, the pump shaft, and the shaft casing — all showed minimal surface corrosion. This corrosion was mostly noted in the form of staining, which primarily impacted the appearance rating, but not the performance rating.

In summary, the Unit 1 pump components showed surface corrosion only. There was no appreciable surface damage, and minimal erosion damage was noted only on the leading edges of some impellers. The ratings are presented in Table 3.

Table 3. Fifteen-month ratings for new pump components, Unit 1.

Component	Metric		
	ASTM B537–Appearance	ASTM B537–Protection	ASTM D2809
Pipe Column	5	6	n/a
Stage 1 Bowl	5	6	9
Stage 1 Impeller	5	6	8
Stage 2 Bowl	5	6	9
Stage 2 Impeller	5	6	8
Stage 3 Bowl	5	6	9
Stage 3 Impeller	5	6	9
Shaft	8	9	n/a
Shaft Casing	8	9	n/a
Basket	7	9	n/a

Upon completing the evaluation, the Unit 1 pump was reassembled and replaced in the sump.

3.2.3.2 Unit 2 pump

The Unit 2 pump was then removed from the sump. This pump contained components that were coated with Stellite 6. The overall outer surface condition of the Unit 2 pump after 15 months of service is shown in Figure 27.

Figure 27. Condition of outer surfaces of Unit 2 pump after 15 months of service.

Some spot corrosion was noted on the outer surfaces of the column pipe and the bowls. The corrosion did not perforate the material.

The Unit 2 pump was disassembled and inspected. Like the Unit 1 pump components, the Unit 2 pump components had minor surface corrosion. The corrosion was minimal and easily wiped off. The third-stage impeller exhibited minor uniform corrosion. Upon removing this impeller, very minor wear on the leading edges was noted, as shown in Figure 28.

Figure 28. Condition of Unit 2 third-stage impeller after 15 months of exposure, showing minor wear on leading edges.

The condition of the Unit 2 pump components (EN coated) was slightly different from the condition of Unit 1 pump components (Stellite coated). In Unit 2, the edges of all bowl vanes showed dark staining, as seen in Figure 29.

Figure 29. Condition of Unit 2 first-stage bowl (left) and second-stage bowl (right) after 15 months of exposure, showing dark stains on vanes.

One hypothesis is that these areas might be surfaces where the thermal spray process did not fully coat the steel. Thermal spray application is inherently a line-of-sight process, and can be difficult to apply uniformly or completely to uneven or partially concealed surfaces. This hypothesis is circumstantially supported by comparison with the EN coating process, which involves full immersion in chemicals and coats all surfaces evenly; no similar dark spots were observed on Unit 1 pump components.

Another possible explanation for the dark spots is iron deposits, caused by sediment that slowly dripped down the submerged pump. It was noted that iron and other sedimentary material were present on all pump components.

As with the Unit 1 pump, the stainless steel components within the Unit 2 pump – the strainer basket, the pump shaft, and the shaft casing – all showed very minimal surface corrosion. This corrosion was mostly noted in the form of staining, which primarily impacted the appearance rating but not the performance rating.

In summary, the Unit 2 pump components showed surface corrosion only, with no appreciable surface damage and minimal erosion damage noted only on the leading edges of some impellers. It is noted that the appearance rating for the bowls for Unit 2 was lower than for those in Unit 1 due to the presence of the dark spots on the edges of the Unit 2 bowl vanes. The results of the ratings are presented in Table 4.

Table 4. Fifteen-month ratings for new pump components, Unit 2.

Component	Metric		
	ASTM B537–Appearance	ASTM B537–Protection	ASTM D2809
Pipe Column	5	6	n/a
Stage 1 Bowl	4	6	9
Stage 1 Impeller	5	6	8
Stage 2 Bowl	4	6	9
Stage 2 Impeller	5	6	8
Stage 3 Bowl	4	6	9
Stage 3 Impeller	5	6	8
Shaft	8	9	n/a
Shaft Casing	8	9	n/a
Basket	7	9	n/a

3.3 Lessons learned

The process of building and disassembling the new pumps, packing and shipping them out to be coated, then sending them back to the manufacturer for rebuilding and testing, and finally shipping them to Fort Polk for installation was very expensive and time consuming. For this process to be practical and cost-effective for DPW application, improved handling and application procedures would be needed. For example, onsite coating application would be more efficient, and would yield a higher return on investment for the pump coatings.

It was noted that DPW personnel do not have a way to directly monitor CVWF pump utilization data; they only receive general comments from users pertaining to whether they are functioning properly. To address this issue, timers were installed in the pump control panel so that the hours of operation can be tracked by DPW personnel for purposes of scheduling inspection or maintenance.

While the corrosion-mitigation benefits provided by the demonstrated coatings and materials were apparent in the short term (15 months of exposure), the longer-term impacts of using these coatings and materials could not be determined due to a lack of maintenance information for the old facility pumps. It is suggested that longer-term inspection (2–5 years), the procurement of additional information on the older pumps, and/or the application of reliability models should be used to more definitively determine the life expectancy of CVWF pumps.

4 Economic Summary

4.1 Costs and assumptions

Total project costs were $570,000. A rough breakdown of project expenses is presented in Table 5.

Table 5. Breakdown of total project costs.

Description	Amount
Labor	$70,000
Materials	$0
Contracts	$460,000
Travel	$20,000
Reporting	$15,000
Air Force and Navy Participation	$5,000
Total	$570,000

The field demonstration costs for this CPC project are shown in Table 6.

Table 6. Project field demonstration costs.

Item	Description	Amount
1	Labor for project management and execution	$164,893
2	Travel for project management	$45,000
3	Cost of two new pumps (including taxes)	$88,750
4	Cost of new motor (including taxes)	$86,631
5	Coat pump components with Stellite 6 via HVOF	$29,595
6	Coat pump components with electroless nickel	$11,131
7	Shipping costs (Ship pump components from factory to coating facilities and back to factory for assembly and testing; ship pumps to Ft. Polk)	$18,000
8	Pump (and motor) installation costs	$16,000
	Total	$460,000

Although performance of the two coatings was similar after the fifteen-month demonstration period, the EN coating was selected over Stellite 6 because its resulting coating was more uniform and it cost substantially less.

The economic analysis assumed installation of 50 pumps using EN coating technology. The Army has about 100 active Central Vehicle Wash Facilities (category code of 14962). If 25% of them install pumps using the new technology next time pumps need to be replaced, given that cost and performance benefits have been demonstrated, then 50 pumps will be affected. It is also reasonable to assume that the technology may be adopted for other military facilities that use similar pumps to move water where corrosive conditions prevail, such as seawater and river water intake, sewer lift stations, irrigation, cooling water, fire service, and water-reclamation systems.

Alternative 1 (Baseline Scenario). The estimated average life of the pumps using current technology under the conditions at the CVWF is 10 years. If the current pumps at the CVWF are replaced at Year 1, they will need to be replaced in Years 11 and 22 at a cost of $118,750 each, as shown under Baseline Costs (Column B) in the ROI spreadsheets (Table 7). Averaged annual maintenance cost for the existing units is $1,500 per year. Because these pumps are submerged and difficult to directly inspect, maintenance typically consists of checking output water pressure and cleaning the strainers and cages. This cost is included in the Baseline Costs for years between pump replacements.

Alternative 2 (Demonstrated Technology). The selected alternative pump technology is expected to double the service life of the units, from 10 years to 20 years. Corrosion-resistant pumps using the EN coating could be installed for $141,010 each. These units will require the same maintenance as conventional pumps as shown under New System Costs (Column D) in Table 7). After Year 22 the costs and benefits repeat, so no further analysis is needed.

4.2 Return on investment (ROI) computation

The ROI for this technology was computed using methods prescribed by Office of Management and Budget (OMB) Circular No. A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*. Comparing the costs and benefits of the two alternatives, the 22-year return on investment for pumps using the EN technology is projected to be about 2.59, as shown in and Table 7.

The original ROI estimate (from the project PMP) was 16.94. The difference between the initial and final ROI projections is attributed to lowering the current pump-replacement costs (based on actual cost data), reducing the new-system benefits and savings (based on more accurate information), extending pump service life (based on more accurate information), and reducing the annual maintenance cost (also based on more accurate information).

Table 7. ROI calculation for Alternative 2 with electroless nickel coating.

Return on Investment Calculation

Investment Required			570,000
Return on Investment Ratio	2.59	Percent	259%
Net Present Value of Costs and Benefits/Savings	9,033,461	10,509,735	1,476,274

A Future Year	B Baseline Costs	C Baseline Benefits/Savings	D New System Costs	E New System Benefits/Savings	F Present Value of Costs	G Present Value of Savings	H Total Present Value
1	5,937,500		7,050,500		6,589,397	5,549,188	-1,040,210
2	75,000		75,000		65,505	65,505	
3	75,000		75,000		61,223	61,223	
4	75,000		75,000		57,218	57,218	
5	75,000		75,000		53,475	53,475	
6	75,000		75,000		49,973	49,973	
7	75,000		75,000		46,703	46,703	
8	75,000		75,000		43,650	43,650	
9	75,000		75,000		40,793	40,793	
10	75,000		75,000		38,123	38,123	
11	5,937,500		75,000		35,633	2,820,906	2,785,274
12	75,000		75,000		33,300	33,300	
13	75,000		75,000		31,125	31,125	
14	75,000		75,000		29,085	29,085	
15	75,000		75,000		27,180	27,180	
16	75,000		75,000		25,403	25,403	
17	75,000		75,000		23,745	23,745	
18	75,000		75,000		22,193	22,193	
19	75,000		75,000		20,738	20,738	
20	75,000		75,000		19,380	19,380	
21	5,937,500		7,050,500		1,702,696	1,433,906	-268,790
22	75,000		75,000		16,928	16,928	
23							
24							
25							
26							
27							
28							
29							
30							

5 Conclusions and Recommendations

5.1 Conclusions

Two vertical turbine pumps that incorporated new corrosion and erosion resistant coatings and materials were designed, built, and installed at the Fort Polk CVWF North Station. The pumps were monitored for a period of 15 months, then removed, inspected, and reinstalled. The corrosion and erosion damage on the pumps treated with each technology was found to be negligible after 15 months of exposure.

The wear, erosion, and corrosion attack on the components within both pumps were very similar, and in most cases yielded similar ratings. Therefore, the results indicate that either of the demonstrated coatings would be suitable for protecting the pumps in the long term. However, the pump with components coated using the EN process performed slightly better than those coated using the HVOF thermal-spray method. Considering that EN coating is the less expensive and more uniform of the two processes, it may be preferred by DPWs when all other factors are approximately equal. A limitation of the thermal-spray process is that it is inherently a line-of-sight process, and can be difficult to apply uniformly or completely to uneven or partially concealed surfaces.

When compared to the older pumps, the incorporation of new coatings and materials clearly provided reduced wear, erosion, and corrosion benefits. It is expected that these coatings and materials will provide significantly improved pump reliability and performance.

Unfortunately, the results of this project cannot be used to accurately predict how long the coated pumps will operate compared to the older (uncoated) pumps. One reason for this is that Fort Polk DPW personnel were not able to provide a definitive answer as to how old the original pumps were, or when the last time was that they were pulled for maintenance. They could not find any records of pump repairs or replacements; the only available information about pump age and maintenance history was through "word of mouth." DPW personnel could only state that the facility was commissioned on 1 July 1982 and that the pumps "might be about the same age," assuming that they have not been replaced since that time.

5.2 Recommendations

5.2.1 Applicability

EN and Stellite 6 coating technologies would be applicable to other locations were pumps are exposed to similar corrosive environments such as seawater and river water intake, sewer lift stations, irrigation, cooling water fire service, and water-reclamation systems.

5.2.2 Implementation

Implementation of this technology throughout DoD could be facilitated through revisions of Unified Facilities Guide Specification (UFGS) Section 43 21 39, *Pumps: Water, Vertical Turbine* (April 2008). Section 2.4.4.1, "Pump Bowls," could be modified to include an EN coating in addition to porcelain enamel:

> NOTE: Pump bowls will normally be unlined cast-iron, but if the quality of the water or pump characteristics requires bowls to be lined, include the requirement for one of several proven coatings: porcelain enamel or electroless nickel
>
> Bowls shall be of close-grained cast-iron and shall have integrally cast vanes with smooth, streamlined water passageways. [The pump bowls shall be lined with porcelain enamel.] [or] [The pump bowls shall be coated with electroless nickel.]

Section 2.4.4.2, "Impellers," could be modified to include an EN coating in addition to porcelain enamel:

> NOTE: Impellers will normally be bronze, but coated cast-iron impellers should be used if the quality of the water or pump characteristic requires coating.
>
> [Cast-iron impellers shall be coated with porcelain enamel.] [or] [Cast-iron impellers shall be coated with electroless nickel.]

Section 2.4.4.3, "Pump Shafts," already requires stainless steel shafts.

Section 2.5.2.1, "*Pump Bowls*," could be modified to include an EN coating in addition to porcelain enamel:

> NOTE: Pump bowls will normally be unlined cast-iron, but if the quality of the water or pump characteristics requires bowls to be lined, include the requirement for one of several proven coatings: porcelain enamel or electroless nickel.
>
> Pump bowls shall have integrally-cast vanes with smooth, streamlined water passageways, and shall be constructed of close-grained cast-iron, [and shall be lined with porcelain enamel] [or] [and shall be coated with electroless nickel].

Section 2.5.2.2, "*Impellers*," could be modified to include an EN coating in addition to porcelain enamel:

> NOTE: Impellers will normally be bronze, but coated cast-iron impellers should be used if the quality of the water or pump characteristic requires coating.
>
> [Cast-iron impellers shall be coated with porcelain enamel.] [or] [Cast-iron impellers shall be coated with electroless nickel.]

Section 2.5.2.3, "*Pump Shafts*," already requires stainless steel shafts.

Implementation could further be supported through efforts to incorporate these technologies into Unified Facilities Criteria (UFC) UFC 4-214-03, *Central Vehicle Wash Facilities* (16 January 2004).

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Appendix A: Water Analysis

Water samples were collected at each of the three retention ponds at the start of the project to determine the water corrosivity. Two of the ponds are clearly visible in Figure A1. The northeast pond is in the foreground, the southwest pond is in the background and north pond is to the right in the center (behind the trees) of the photograph. The pumping station, where the pumps are located, is in the center of the photograph, between the northeast and southwest ponds.

Figure A1. Photograph of CVWF water sources, with facility in background.

Note that two of the samples have a very high Ryznar index indicating mild steel is expected to experience intolerable corrosion. The third has a high Ryznar index indicating mild steel is expected to experience heavy corrosion.

Figure A2.Water quality results for north pond.

Illinois State WATER Survey (1895)

WATER SAMPLE ANALYSIS
Lab Number: *821247*

[redacted]

Analyst:	*JLO*	***Facility:***	*CERL*
Sample Type:	*Cold Distribution*	***Attention:***	*Ms. Susan Drozdz*
Location:	*Ft. Polk, N Wash Rack*	***Additional Information:***	
Date Collected:	*05/24/10*		*ATP = 8,082 RLU* *Bacteria = 500,000 c/mL*

Parameter	***Value***		***Units***
M Alkalinity (as CaCO3)	58		mg/L
Hardness (as CaCO3)	60		mg/L
Calcium (Ca)	18.53		mg/L
Magnesium (Mg)	2.49		mg/L
Sulfate (SO4)	5		mg/L
Chloride (Cl)	5		mg/L
Nitrate (NO3)	1.2		mg/L
Iron (Fe)	0.16		mg/L
Copper (Cu)	0		mg/L
Zinc (Zn)	0		mg/L
Molybdenum (Mo)	0		mg/L
Aluminum (Al)	0		mg/L
Sodium (Na)	2.9		mg/L
Potassium (K)	0.4		mg/L
Boron (B)	0.06		mg/L
Strontium (Sr)	0.09		mg/L
Barium (Ba)	0.05		mg/L
Manganese (Mn)	0.08		mg/L
Polyphosphate (PO4)	0		mg/L
Orthophosphate (PO4)	0.02		mg/L
Total Dissolved Solids	64		mg/L
pH	8.0	lab	pH units
pH Temperature	22.5	lab	deg. C
Silica (SiO2)	1.9		mg/L
Ammonia (NH4)	0.3		mg/L

Comments

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Iron, Copper and Zinc :Low, good.

Langelier Calcium Carbonate Saturation Index:
-0.26 @ 21.1 degrees C.

The negative number indicates that the water has a tendency to dissolve calcium scale.
Ryznar Index: 8.69 which indicates that mild steel is expected to experience heavy corrosion.
Aggressive Index: 11.43 indicates that the water was moderately aggressive to asbestos/cement material.
Larson Index: 0.21 which indicates that chlorides and sulfates do not contribute to mild steel corrosion.

ATP, a measure of biological activity including algae: High.

Aerobic Bacteria: High.

Charles D. Curtiss, Assistant Chemist Charles D. Curtiss *Phone: 217/244-7391*
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Figure A3. Water quality results for northeast pond.

Illinois State WATER Survey (1895)

WATER SAMPLE ANALYSIS
Lab Number: *821248*

[redacted]

Analyst:	*JLO*	***Facility:***	*CERL*
Sample Type:	*Cold Distribution*	***Attention:***	*Ms. Susan Drozdz*
Location:	*Ft. Polk NE Wash Rack*	***Additional Information:***	
Date Collected:	*05/24/10*	*ATP = 3,038 RLU*	
		Bacteria = 10,000 c/mL	

Parameter	***Value***		***Units***
M Alkalinity (as CaCO3)	58		mg/L
Hardness (as CaCO3)	59		mg/L
Calcium (Ca)	18.60		mg/L
Magnesium (Mg)	2.52		mg/L
Sulfate (SO4)	5		mg/L
Chloride (Cl)	5		mg/L
Nitrate (NO3)	1.0		mg/L
Iron (Fe)	0.04		mg/L
Copper (Cu)	0.02		mg/L
Zinc (Zn)	0.01		mg/L
Molybdenum (Mo)	0		mg/L
Aluminum (Al)	0		mg/L
Sodium (Na)	2.9		mg/L
Potassium (K)	0.6		mg/L
Boron (B)	0.04		mg/L
Strontium (Sr)	0.10		mg/L
Barium (Ba)	0.05		mg/L
Manganese (Mn)	0.04		mg/L
Polyphosphate (PO4)	0		mg/L
Orthophosphate (PO4)	0.01		mg/L
Total Dissolved Solids	64		mg/L
pH	7.4	lab	pH units
pH Temperature	21.1	lab	deg. C
Silica (SiO2)	1.8		mg/L
Ammonia (NH4)	0.2		mg/L

Comments

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Iron, Copper and Zinc :Low, good.

Langelier Calcium Carbonate Saturation Index:
-0.87 @ 21.1 degrees C.
The negative number indicates that the water has a tendency to dissolve calcium scale.
Ryznar Index: 9.24 which indicates that mild steel is expected to experience intolerable corrosion.
Aggressive Index: 10.53 indicates that the water was moderately aggressive to asbestos/cement material.
Larson Index: 0.21 which indicates that chlorides and sulfates do not contribute to mild steel corrosion.

ATP, a measure of biological activity including algae: High.

Aerobic Bacteria: Somewhat high.

Charles D. Curtiss, Assistant Chemist Charles D. Curtiss *Phone: 217/244-7391*
Monday, August 23, 2010

Figure A4. Water quality results for southwest pond.

Illinois State WATER Survey (1895)

WATER SAMPLE ANALYSIS
Lab Number: *821249*

[redacted]

Analyst:	*JLO*	***Facility:***	*CERL*
Sample Type:	*Cold Distribution*	***Attention:***	*Ms. Susan Drozdz*
Location:	*Ft. Polk, SW Wash Rack*	***Additional Information:***	
Date Collected:	*05/24/10*	*ATP = 9,950 RLU* *Bacteria = 5,000 c/mL*	

Parameter	***Value***		***Units***
M Alkalinity (as CaCO3)	2.47		mg/L
M Alkalinity (as CaCO3)	64		mg/L
Hardness (as CaCO3)	64		mg/L
Calcium (Ca)	20.01		mg/L
Sulfate (SO4)	5		mg/L
Chloride (Cl)	5		mg/L
Nitrate (NO3)	0.7		mg/L
Iron (Fe)	0		mg/L
Copper (Cu)	0		mg/L
Zinc (Zn)	0.01		mg/L
Molybdenum (Mo)	0		mg/L
Aluminum (Al)	0		mg/L
Sodium (Na)	1.5		mg/L
Potassium (K)	0.5		mg/L
Boron (B)	0.03		mg/L
Strontium (Sr)	0.10		mg/L
Barium (Ba)	0.05		mg/L
Manganese (Mn)	0.05		mg/L
Polyphosphate (PO4)	0		mg/L
Orthophosphate (PO4)	0.01		mg/L
Total Dissolved Solids	69		mg/L
pH	5.8	lab	pH units
pH Temperature	22.3	lab	deg. C
Silica (SiO2)	1.5		mg/L

Comments

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Iron, Copper and Zinc :Low, good.

pH: EXTREMELY LOW

Langelier Calcium Carbonate Saturation Index:
-2.58 @ 21.1 degrees C.
The negative number indicates that the water has an extremely strong tendency to dissolve calcium scale.
Ryznar Index: 10.64 which indicates that mild steel is expected to experience intolerable corrosion.
Aggressive Index: 9.31 indicates that the water was highly aggressive to asbestos/cement material.
Larson Index: 0.19 which indicates that chlorides and sulfates do not contribute to mild steel corrosion.

ATP, a measure of biological activity including algae: Very High.

Aerobic Bacteria: Slightly high.

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Appendix B: Coating Evaluation Metrics

Overview

This appendix describes the procedure to evaluate the condition of water pump components from the standpoints of corrosion, erosion, cavitation, and degradation.

Pump evaluation metrics

There are a number of ASTM, ANSI, ISO, U.S. Military, SAE, and other specifications regarding pump design and testing. The ones most relevant to this project are listed below. Some strictly laboratory-based tests for the erosion and cavitation of pumps were identified, but they were found to be poor matches for this particular project. The best fits for assessing erosion-corrosion damage in the pumps was found to be ASTM B537 and ASTM D2809. The latter was originally meant to evaluate aluminum automotive engine coolant pumps, but provides a useful scale for rating erosion-corrosion damage.

1. ASTM B537, Standard Practice for Rating of Electroplated Panels Subjected to Atmospheric Exposure, ASTM International, West Conshohocken, PA, 1997.
2. ASTM D2809, Standard Test Method for Cavitation Corrosion and Erosion-Corrosion Characteristics of Aluminum Pumps With Engine Coolants, ASTM International, West Conshohocken, PA.
3. Totten et al, Tribology of Hydraulic Pump Testing, http://www.astm.org/DIGITAL_LIBRARY/STP/SOURCE_PAGES/STP1310.htm
4. ASTM D2882, Standard Test Method for Indicating the Wear Characteristics of Petroleum and Non-Petroleum Hydraulic Fluids in Constant Volume Vane Pump (Withdrawn 2003), ASTM International, West Conshohocken, PA.
5. ASTM F998, Standard Specification for Centrifugal Pump, Shipboard Use, ASTM International, West Conshohocken, PA.
6. ASTM F1510, Standard Specification for Rotary Positive Displacement Pumps, Ships Use, ASTM International, West Conshohocken, PA.
7. ANSI/HI 9.6.6, Rotodynamic Pumps for Pump Piping, http://estore.pumps.org/Rotodynamic-Pumps-for-Pump-Piping-ANSIHI-966-P127C0.aspx

Inspection techniques

The pumps were evaluated visually, photographed, and rated according to ASTM B537, Standard Practice for Rating of Electroplated Panels Subjected to Atmospheric Exposure. ASTM B537 assigns ratings of 0 to 10 (10 being the best, 0 being the worst) for two aspects of observed coating performance. “Protection” is determined by how well the coating protects the substrate from corrosion. “Appearance” incorporates the Protection aspect but also accounts for other visual aspects of corrosion performance (e.g., staining, dripping) that might be considered detrimental, but not a protection defect. The new pump coatings are protective, non-sacrificial coatings of the sort that ASTM B537 is meant to evaluate. The inspections may require some modifications to account for the use of specimens that are not the standard size 4”x6” flat panel coupons that are specified in ASTM B537.

If cavitation or erosion-corrosion is present on the pump surfaces after exposure, the damage will be rated in accordance with ASTM D2809, Standard Test Method for Cavitation Corrosion and Erosion-Corrosion Characteristics of Aluminum Pumps with Engine Coolants. This specification also assigns a rating from 10 (no damage) to 1 (pump casing leaking due to corrosion or erosion).

Sample groups and inspection areas

The surface of each pump, new and old, was inspected at several locations. The inspection locations conformed to areas of the pumps that incorporate new protective coatings. Areas included impellors, housings, and bushings.

The old pumps were inspected once, when they were removed from the sumps. At that time, modifications to the proposed inspection areas (e.g., to account for the non-flat surfaces of impellors and housings) were made if necessary and noted. The same locations were inspected on the components of the new pumps.

Visual inspection procedure

The old pumps were removed from the sumps; evaluated visually, photographed, and rated according to ASTM B537 and, if applicable, ASTM D2809. The old pumps were inspected once, and captured the condition of the existing pumps shafts and external components after years of standard use.

The new pump components were inspected three times. The first inspection occurred before coating, the second inspection occurred immediately after coating but before assembly and installation. In both cases, the inspections was conducted identically to the old pump inspections, and in corresponding locations.

After the new pump precoating and postcoating inspections, the new pumps were installed and operated for a fifteen-month period. At the end of this period, they were removed from the sumps, and evaluated. The pumps were reinstalled after evaluation.

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14. ABSTRACT

Central Vehicle Wash Facilities (CVWFs) at military installations are essential for supporting the readiness of tactical vehicles. Steel wash-rack pumps are vulnerable to accelerated degradation where supply water is corrosive and infused with fines. Pump failure can occur with little warning, taking the CVWF out of service for unscheduled maintenance. This project tested two advanced coating materials on critical internal pump components to evaluate cost and performance. At the Fort Polk, LA, CVWF, internal components of one new pump were coated with a thermally sprayed cobalt alloy, and matching components in another pump were coated chemically with an electroless nickel (EN) material.

Both pumps were used for 15 months, then disassembled and inspected. No significant corrosion degradation of pump components was observed on either pump. However, pump components coated using the EN process performed slightly better than those coated using the thermally sprayed alloy. The EN coating produced more uniform results and was less expensive, so it may be preferred by DPWs. The return on investment (ROI) for the EN coating is 2.59. Both coatings are conservatively estimated to double pump service life when compared with the previous pumps, but the lack of service records precluded a firm, data-driven prediction.

15. SUBJECT TERMS
Corrosion and anti-corrosives; Steel--Corrosion; Metals--Cavitation erosion; Metal coating; Turbine pumps; Fort Polk (La.); Central Vehicle Wash Facility; electroless nickel; thermal spray

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