The Effect of Feathering on Coating Performance

From *JPCL*, June 2019

By Patrick Cassidy and Michael Kibler, Elzly Technology Corporation; and Cameron Miller, Paul Slebodnick and James Martin, U.S. Naval Research Laboratory

Fig. 1: Feathered intact legacy coating in preparation for maintenance painting. *Figures courtesy of the authors.*

Feedback from waterfront personnel performing maintenance painting for the U.S. Navy has consistently questioned the Navy's requirement for performing feathering. NAVSEA Standard Item (NSI) 009-32[1] defines feathering as tapering the edges of tightly adhering old paint at an approximate 30-degree angle into the newly prepared bare metal surface and requires that the contractor "feather edges of well-adhered paint remaining after cleaning for all surface preparation methods."

The requirement is impractical because feathering at a 30-degree angle on a 20-mil-thick coating would only give a 40-mil-wide feathered border. Performing and inspecting work to this requirement is not feasible. Feathering is a time-consuming and laborious process, which is further complicated by the legacy requirements, causing extensive rework on maintenance-painting jobs. Figure 1 shows an example of feathering performed as part of surface preparation to SSPC-SP 3[2]prior to application of the repair coating system in a void space.

The U.S. Naval Research Laboratory performed an industry survey to better define feathering and improve or clarify the Navy's requirements. During this literature review, a February 2015 article in JPCL written by Mark Dromgool was found[3]. The article focuses on effective maintenance-painting practices for offshore structures and states the following.

"Importantly, the surface preparation ought not to include feathering the edges of the existing coating as this will stress the bond at the critical point: the juncture where the coating has been fractured and where the bare substrate is exposed. By all means, ensure that the edge that has been reached is sound, but then stop there. The only areas [to feather are] where an adverse aesthetic situation might exist in highly visible areas. The extra time and effort to perform a low yielding task like feathering edges would be better spent on actual surface preparation on other breakdown zones."

This position on the importance (or rather unimportance) of feathering was unique in the literature review, as feathering seemed to be a best practice both in industry and within the military when performing repair work. Feathering was commonly cited as important for smooth transition and adequate adhesion of new coating systems and for ensuring legacy coatings were sound and adherent.

NRL designed a program to test the hypothesis that feathering does not affect repair coating system performance. No quantitative data was found to support or refute the need for feathering, only anecdotal data. The objective of the NRL test program included the following:

- Determine the impact of feathering on long-term coating performance in repair areas;
- Collect metrics associated with the labor costs for performing feathering;
- Define feathering and the optimal feathering process that can be contractually invoked by the Navy without incurring increased rework costs; and
- Weigh the potential benefits of feathering with the associated costs in a cost-benefit analysis to determine if feathering is a value-added step in the repair process.

EXPERIMENTAL PROCEDURE

To ensure that the evaluation of feathering was comprehensive, testing was broken down into two different scenarios: laboratory testing and an industrial demonstration on a mock ballast tank.

Primary surface preparation in this effort was defined as the method/tool used to remove the failed legacy coating and achieve the specified SSPC surface-preparation cleanliness standard on the exposed substrate area. The primary surface preparation method was used to remove all compromised coating around the repair area until intact, tightly adherent paint was reached. Feathering was defined as a secondary preparation step performed after the primary surface preparation method was complete.

The testing defined three primary surface-preparation methods for performing coating repair.

1. Spot-abrasive blasting with 36-mesh virgin aluminum oxide mineral grit. Spots met SSPC-SP 6 level of cleanliness[4].
2. Spot power-tool preparation using a needle gun. Spots met SSPC-SP 15 level of cleanliness[5].
3. Spot power-tool preparation using a bristle-impact tool. Spots met SSPC-SP 15 level of cleanliness.

The feathering procedures were defined based on the literature review and industry best practice for feathering.

1. Power-tool feathered: Feather 1–2 inches back from the bare substrate onto the intact coating to create a smooth transition using a rotary sander or grinder with 100-grit paper.
2. Hand-tool feathered: Scuff sand by hand, a 1-inch-wide strip around the border of the intact coating with a 100-grit sanding block.
3. Not feathered: No secondary preparation required.

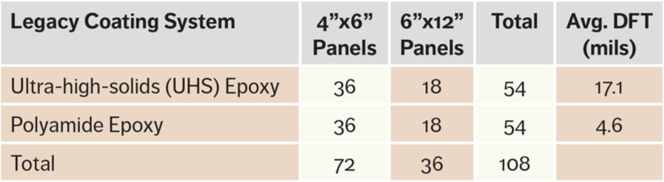
LABORATORY TESTING

Specimens And Matrix

A total of 108 steel panels (ASTM A36 grade[6]) were abrasive-blasted to SSPC-SP 10[7] cleanliness using garnet abrasive to a 2–3-mil surface profile. Profile-depth readings were taken on each panel in accordance with ASTM D4417 Method B[8]and SSPC-PA 17[9]. The average profile was 2.7 mils.

Two different types of legacy coatings were used on the panels (Table 1). Coatings were applied via airless spray in accordance with the manufacturer product data sheets. Dry-film-thickness (DFT) measurements were taken on each panel in accordance with ASTM D7091[10] and SSPC-PA 2[11].

Table 1: Legacy Coating Application Matrix.



Legacy Coating System	4”x6” Panels	6”x12” Panels	Total	Avg. DFT (mils)
Ultra-high-solids (UHS) Epoxy	36	18	54	17.1
Polyamide Epoxy	36	18	54	4.6
Total	72	36	108	

Artificial Pre-Weathering

A razor knife was used to score the holiday area, exposing bare substrate. All panels were then pre-weathered by subjecting them to 300 hours in ASTM G85-A5 cyclic-salt-fog testing[12].

Primary Surface Preparation And Feathering

Upon removal from salt fog, the holiday in each panel was spot-prepared with the primary surface preparation method. Multiple solvent wipes and freshwater rinses were used as necessary to meet the cleanliness standard.

Spot-blasted panels and power-tooled panels were prepared to SSPC-SP 6 and SP 15 cleanliness standards, respectively (Fig. 2). Surface-profile depth was measured as before. The average profile of the spot abrasive-blasted panels was 2.1 mils, the average profile of the needle-gun panels was 2.5 mils and the average profile of the bristle-impact panels was 1.4 mils.

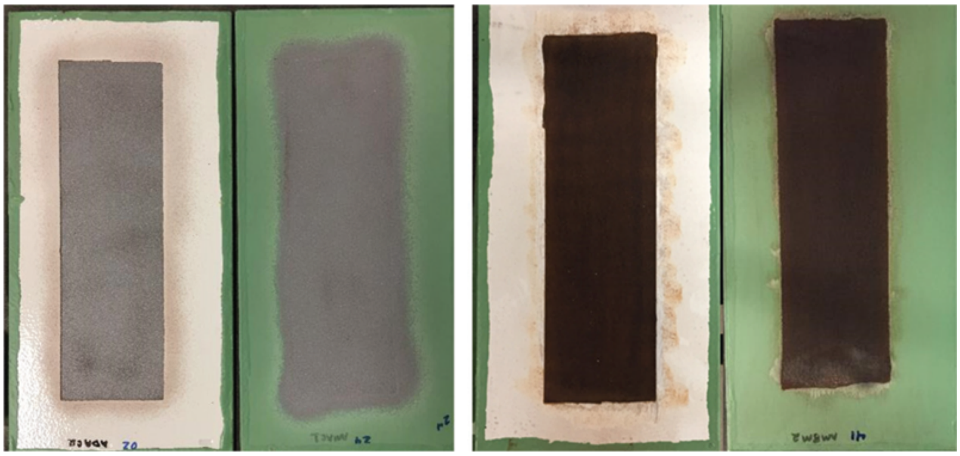


Fig. 2: Panels after primary surface preparation. From left, two spot-abrasive blast and two power-tool methods.

One-third of each set of panels was feathered in accordance with each of the three secondary feathering procedures listed previously.

The non-feathered panels maintained their original appearance because no secondary preparation was performed. The amount of time to complete the primary and secondary preparation on each panel was timed and recorded.

A high-solids (HS) epoxy repair coating system was applied using a ¼-inch-nap synthetic roller in a single coat to each panel in accordance with the manufacturer’s product data sheets. The average DFT in the repair area was 9.3 mils. Panels were scribed using a 1/8-inch-diameter-mill bit so that the scribe intersected the repair area diagonally, extending past the transition zone.

Half of the panels were subjected to 10 cycles (20 weeks) of modified ASTM D5894 cyclic salt fog/UV exposure test[13]. The test included a one-day exposure each week in a refrigerated chamber at a temperature of ~-20 C, which is the modification from ASTM D5894. The other panels were subjected to an alternate natural seawater exposure, consisting of a 12-hour dry/12-hour wet cycle, for 20 weeks.

INDUSTRIAL MOCK-BALLAST-TANK DEMONSTRATION

To gain experience and test data in an industrial environment and augment the laboratory testing, a demonstration was conducted on a mock steel ballast tank located in Norfolk, Virginia.

All prior loose and failed coating was removed from the mock tank. The average DFT of the existing coatings on the mock tank was 41.2 mils with readings ranging from 21.7–63.5 mils depending on the location. Twenty-one 1-foot squares were laid out across the tank walls, seven squares for each feathering method. A razor knife was used to score the coating system down to the steel around the periphery of the square. Multiple coats of legacy paint were present.

A heat-induction unit and a 4.5-inch, coarse, rapid-strip disc were used to remove the coating from inside the test patch. The test patches were sprayed with artificial seawater weekly to pre-weather for one month and allow the buildup of corrosion product and undercutting of the exposed coating edges.

After the pre-weathering step, the entire tank was washed with freshwater to remove salt and rust deposits via low-pressure water-cleaning (LP WC) as defined by the SSPC-SP WJ surface preparation standards[14]. All patches were then prepared to SSPC-SP 15 using a bristle-impact tool. All loose and failed coating was removed until tightly adherent coating was reached. The edges of the coating were probed with a dull putty knife to determine adherence. Profile depth was measured as before. Average profile depth was 1.7 mils.

Seven test patches were prepared per the feathering methods described previously (Fig. 3). The amount of time to complete the primary and secondary preparation steps on each test patch was recorded. A final solvent wipe was completed, and soluble salt readings were taken using the Bresle patch method on every test patch with an average result of 65 microsiemens.

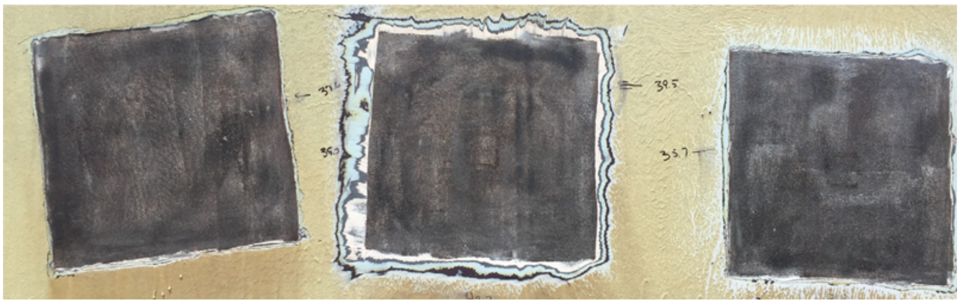


Fig. 3: Mock-tank test patches after secondary (feathering) surface preparation.

One coat of the same UHS epoxy repair coating used for lab testing was applied to test patches 1–14. The repair coating was overlapped a minimum of 2 inches onto the intact coating on all sides. One coat of the polyamide epoxy repair coating used for lab testing was applied to test patches 15–21. A second coat of polysiloxane topcoat was applied to test patches 15–21 to complete the two-coat system (Fig. 4). All coatings were applied using a ¼-inch-nap synthetic roller. The average DFT of the one-coat UHS epoxy repair system was 15.1 mils and the average DFT of the two-coat epoxy/polysiloxane repair system was 12.5 mils.

Fig. 4: Mock tank after repair primer.

RESULTS

Laboratory Testing

VISUAL/DESTRUCTIVE RATINGS

Laboratory test panels were destructively inspected after 20 weeks of exposure in the two respective environments. Panels were rated visually for rust-through and blistering in accordance with ASTM D61015 and ASTM D71416, respectively. Cutback was measured at the maximum point of visual corrosion product after destructive removal of the coating adjacent to the scribe. All panels were probed for coating disbondment at the coating transition area and in the center repair area. Figure 5 shows the results of destructive testing and visual inspection of the laboratory panels subjected to twenty weeks of cyclic accelerated testing.

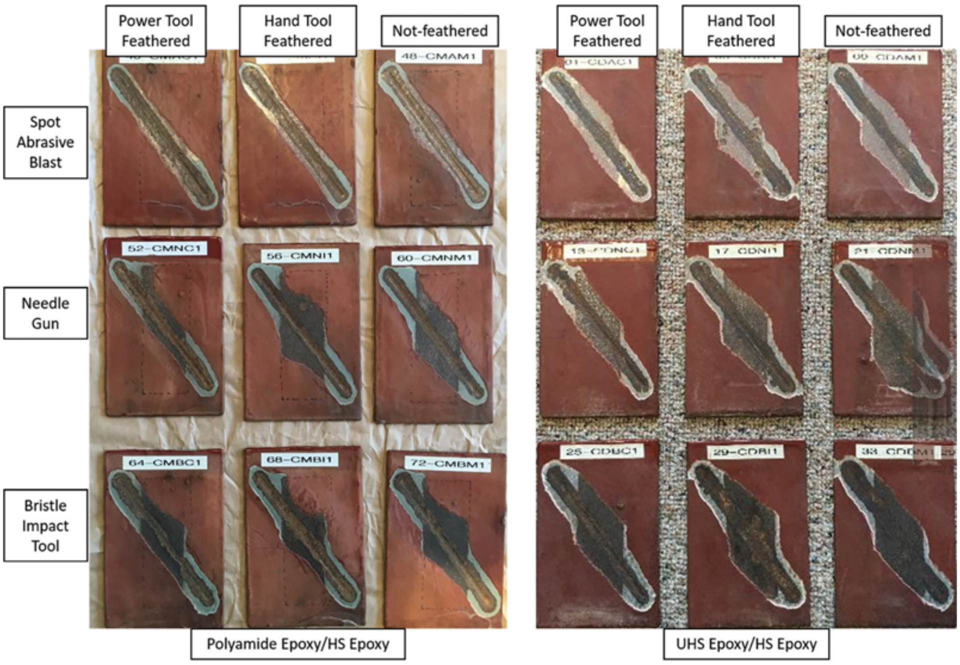


Fig. 5: Visual results after 20 weeks of cyclic accelerated testing.

Figure 6 shows the results of the destructive testing and visual inspection of the laboratory test panels subjected to 20 weeks of alternate seawater immersion.

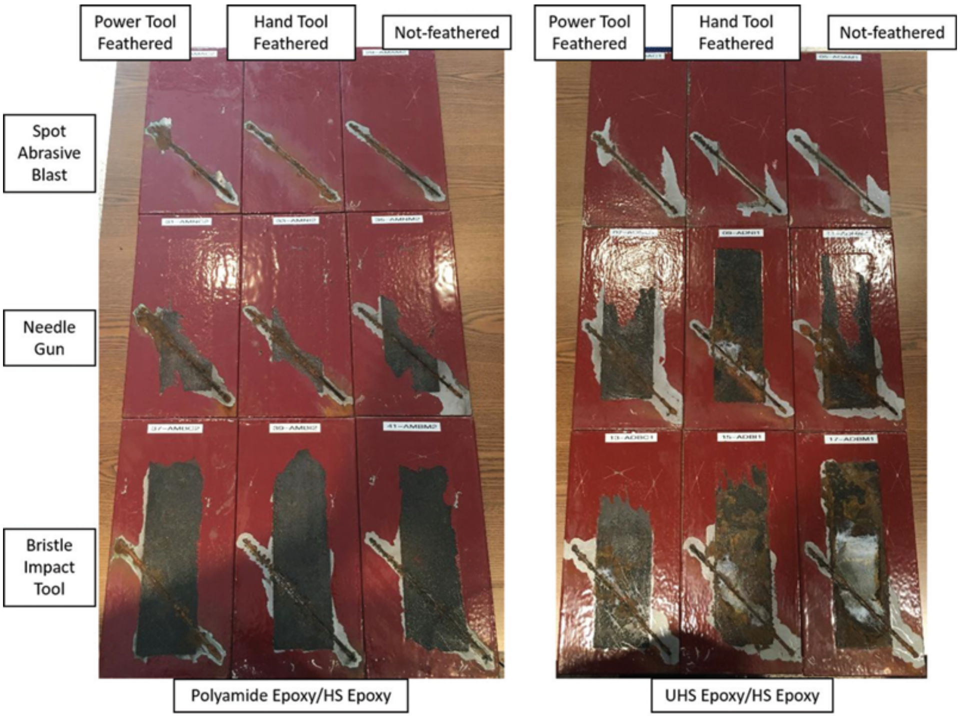


Fig. 6: Visual Results after 20 weeks of alternate seawater immersion testing.

AVERAGED QUANTITATIVE RESULTS

The maximum cutback measured at the scribe was averaged across the coating systems and binned into two groups: primary and secondary prep methods. The data was then plotted against each unique primary/secondary method in order to identify any independent variables that might be influencing coating performance (Fig. 7). The cyclic testing showed little variation for both methods; however, alternate immersion panels showed significantly more cutback when tool use was the primary prep method and when power-tool feathering was employed.

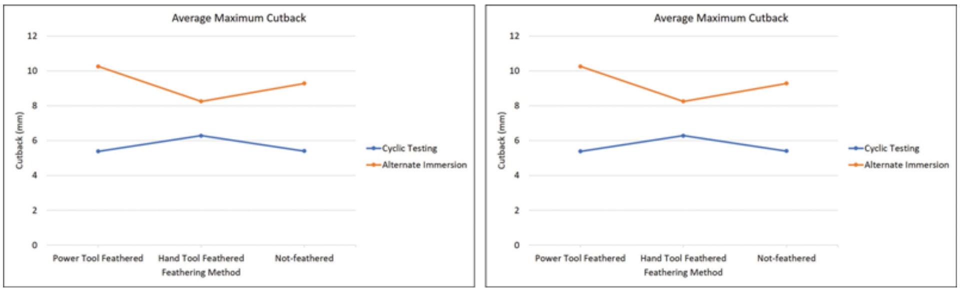


Fig. 7: Cutback results from immersion and cyclic testing.

The rust-through ratings were also averaged and binned in the same manner. A rating scale of 0–10, where 10 equals no rust-through, was used to assign a condition for each panel. Alternate immersion did not distinguish any performance differences in terms of primary or secondary preparations methods. The cyclic testing again showed that the best primary prep method was spot-abrasive blast, as one would expect (Fig. 8).

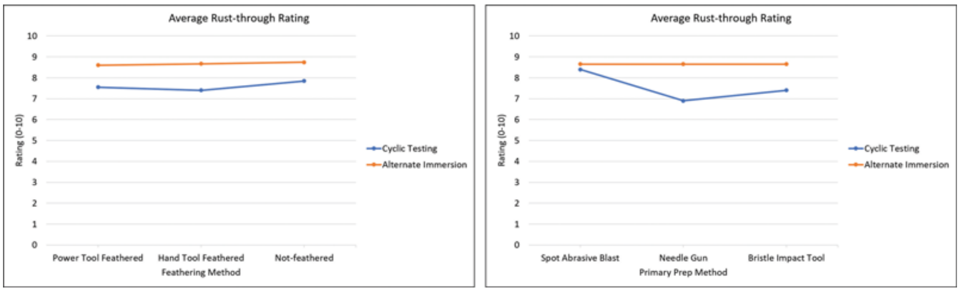


Fig. 8: Rust-through rating for immersion and cyclic testing.

Finally, blister ratings were averaged and binned as above; a visual blister rating of 0–10 was assigned to each panel, where 10 equaled no blistering. ASTM D714 size and density ratings were combined and normalized for plotting purposes; the blister data is plotted in Figure 9.

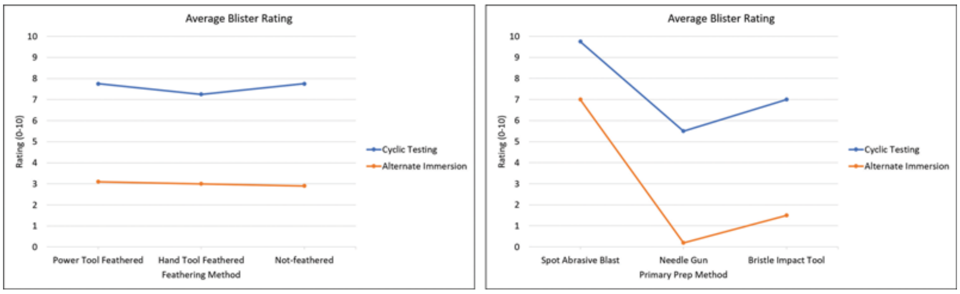


Fig. 9: Blister results from immersion and cyclic testing.

Both cyclic and full-immersion testing exhibited the same trends with both prep methods. There was little difference observed across the three feathering methods.

Overall, the evaluations showed no notable variation between the feathering methods except in cutback rating where the standard power-tool feathering method proved to be a detriment. It should be noted that power-tool feathering was noticeably worse when used in combination with spot-abrasive blast as the primary prep method. This phenomenon is observed because the blasted profile is polished by the rotary tool.

STATISTICAL FINDINGS AND CONCLUSION

Statistical software was used to perform analysis of variance (ANOVA) general linear model (GLM) with Tukey Honest Significant Difference (HSD) post-hoc tests. This was done on the averaged values to determine the significant independent variables (i.e., feathering method, primary prep method) influencing the inspection ratings and measurements (the dependent variable) seen in each experiment to a 95-percent confidence band ($p < 0.05$).

None of the feathering methods was identified as being statistically significant from any other feathering method. In other words, we can say with 95-percent confidence that of the three feathering methods employed, there is no difference in performance. Spot-abrasive blasting was identified as being statistically significant in terms of better overall coating performance when compared to the two power-tool preparation methods, which was expected.

Analysis of the data showed an average labor savings of 15 percent by not feathering. The savings differed based on the coating type. The higher film thickness and tougher UHS epoxy was harder to feather and increased primary and secondary preparation time indicating the savings afforded by not feathering may be higher for UHS coatings.

INDUSTRIAL MOCK-BALLAST-TANK DEMONSTRATION

The industrial mock-ballast-tank demonstration was inspected at 12 months after the repair coatings were applied. The mock tank had been sprayed with artificial seawater twice a week for two months to simulate sea spray. Each test patch was rated visually for rust-through and blistering as before. The test patches were probed for lifting edges or disbondment at the transition area. Tables 2 and 3 show the results of the inspection for rust-through and lifted coating. There was no evidence of blistering observed.

Table 2: Industrial Demonstration Inspection Results by Feathering Method, 12 Months.

Feathering Method	Avg. ASTM D610 Rating	% of Test Patches with Lifting Coating
Power-Tool-Feathered	9.57	14%
Hand-Tool-Feathered	9.57	71%
Not-Feathered	9.71	14%

Table 3: Industrial Demonstration Inspection Results by Coating System, 12 Months.

Coating System	Avg. ASTM D610 Rating	% of Test Patches with Lifting Coating
One-coat	9.43	43%
Two-coat	10	14%

The rust-through results are an average of the rating of all seven test patches for the particular feather method. Rust-through was observed predominantly in the bare steel repair area immediately adjacent to the intact legacy coating. This phenomenon held true for all areas whether feathering was performed or not. All feathering methods showed equivalent minor coating breakdown. The hand-tool-feathered areas showed the greatest amount of lifting. The areas repaired with the two-coat system showed no breakdown and very little lifting, while the one-coat UHS epoxy primer showed minor breakdown and more substantial lifting. This suggests that a two-coat system (even with a lower overall DFT) may perform better in repair scenarios than a single-coat repair system. Analysis of the productivity data showed that on average, the non-feathered test patches took 10–20 percent less time to prepare than the hand-tool-feathered or power-tool-feathered patches.

CONCLUSIONS

The current Navy requirement in NSI 009-32 for feathering to a 30-degree angle is not achievable from a technical standpoint and is impractical to perform and inspect. By changing this requirement to a 1–2-inch border on the intact coating around the repair area, the quality assurance and quality control inspection requirements are reduced and simplified. This will prevent disagreements between contractors and inspectors over the intent and definition of the legacy requirement, with the end result being less rework.

NRL testing showed that feathering as a secondary-surface-preparation step is a non-value-added step in the touch-up process (i.e., feathering does not positively impact coating service life for the associated cost). Feathering is not necessary for spaces that do not require aesthetically pleasing repair coatings such as tanks and voids, and machinery spaces, as feathering has been shown to not influence nor increase the longevity of the coating system. Laboratory testing and the industrial demonstration both showed consistent results when comparing the performance of non-feathered repair areas to feathered repair areas. The laboratory testing and the industrial demonstration both showed between 10–25-percent labor savings when feathering was not performed.

It should be stressed that removal of the feathering step does not nullify the requirement to remove all loose paint and corrosion product, which shall be performed to the specified SSPC surface-preparation standard using the primary preparation method. The data does show that instead of feathering, time would be better spent cleaning and preparing the surface to a higher surface-preparation cleanliness level or applying additional paint to the repair area. For example, there was a noted susceptibility across all feathering methods for pinholes to develop at the transition area from intact coating to bare steel. Application of a stripe coat along the repair perimeter to mitigate this effect might add more value than performing feathering. This would not necessarily need to be a step added to the process but could be applied just prior to the full coat.

Based on the outcome of this testing, changes will be made to the feathering requirements in NSI 009-32 and NSTM 631 in which feathering will be defined as being used primarily for cosmetic or aesthetic reasons and will no longer be required in tanks, voids, machinery spaces or bilges.

ABOUT THE AUTHORS

Patrick Cassidy has been working in the corrosion and coatings industry for over 10 years and is currently a Senior Engineer with Elzly Technology Corporation. He has been involved in a diverse number of programs including coatings research, field investigation and application of corrosion control products. Cassidy is an SSPC-certified NAVSEA Coatings Inspector, a SSPC-certified Thermal Spray Inspector, a NACE-certified Shipboard Corrosion Inspector, and has completed additional training in NAVSEA Cathodic Protection Design. In 2015, he was profiled in the JPCL annual bonus issue, “Coatings Professionals: The Next Generation.”

Michael Kibler is a Staff Engineer at Elzly Technology Corporation and has worked in the corrosion and protective coatings industry for two years. He is an SSPC-certified NAVSEA Coatings Inspector and a NACE-certified Shipboard Corrosion Inspector.

Cameron Miller began his career at the Naval Research Laboratory in 2007 where he is currently a Material Research Engineer at the Center for Corrosion Science and Engineering. Over the past eight years his work has focused primarily on testing and development of Navy deck coatings with a focus on heat-resistant technologies.

Paul Slebodnick is employed by the NRL in the Washington, D.C., Center for Corrosion Science & Engineering, under the Marine Engineering Section. He currently leads research programs in developing technologies for the United States Navy that produce maintenance reductions and reduce Ships Force workload. Slebodnick is responsible for demonstrating new technologies aboard Fleet combatants to determine readiness with in-service evaluation of the technologies prior to transitioning to the Fleet. He also leads Engineering for Research and Development of Tank Coatings under Naval Sea Systems Command, Technical Warrant Holder for Coatings and Corrosion Control—Ships, SEA-05P in Washington, D.C.

James Martin has been with the NRL for over 18 years. He is the head of the Marine Coatings Technology and Systems section Code 6138. Martin is responsible for introducing coatings technology to the Fleet through applied research and development, testing and demonstrations. He has been active in addressing Fleet concerns from both maintenance and new construction with respect to coatings.

REFERENCES

1. Naval Sea Systems Command Standard Item 009-32 FY-19 CH 2, “Cleaning and Painting Requirements; accomplish,” 26 March 2018.
2. SSPC-SP 3, “Power Tool Cleaning,” Pittsburgh, Pa., 2018.
3. M. Dromgool, “Effective Maintenance Painting Practices for Offshore Structures,” JPCL, February 2015.
4. SSPC-SP 6/NACE No. 3, “Commercial Blast Cleaning,” Pittsburgh, Pa., 2007.
5. SSPC-SP 15, “Commercial Grade Power-Tool Cleaning,” Pittsburgh, Pa., 2013.
6. ASTM A36 “Standard Specification for Carbon Structural Steel,” West Conshohocken, PA., ASTM International.
7. SSPC-SP 10/NACE No. 2, “Near-White Metal Blast Cleaning,” Pittsburgh, Pa., 2007.
8. ASTM D 4417 “Standard Practice for Field Measurement of Surface Profile of Blast Cleaned Steel,” West Conshohocken, Pa., ASTM International.
9. SSPC-PA 17, “Procedure for Determining Conformance to Steel Profile/Surface Roughness/Peak Count Requirements,” Pittsburgh, Pa., 2015.
10. ASTM D 7091 “Standard Practice for Nondestructive Measurement of Dry-Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals,” West Conshohocken, Pa., ASTM International.
11. SSPC-PA 2, “Procedure for Determining Conformance to Dry Coating Thickness Requirements,” Pittsburgh, Pa., 2015.
12. ASTM G 85 “Standard Practice for Modified Salt Spray (Fog) Testing,” West Conshohocken, Pa., ASTM International.
13. ASTM D 5894 “Standard Practice for Cyclic Salt Fog/UV Exposure of Painted Metal, (Alternating Exposures in a Fog/Dry Cabinet and a UV/Condensation Cabinet),” West Conshohocken, Pa., ASTM International.
14. SSPC-SP WJ-4/NACE WJ-4, Light Waterjetting, Pittsburgh, Pa.
15. ASTM D 610 “Standard Practice for Evaluating Degree of Rusting on Painted Steel Surfaces,” West Conshohocken, Pa., ASTM International.
16. ASTM D 714 “Standard Test Method for Evaluating Degree of Blistering of Paints,” West Conshohocken, Pa., ASTM International.

Tagged categories: **Feathering**; **Patrick Cassidy**; **Performance testing**; **Surface Preparation**; **U.S. Navy**

Comment from Stuart Ross, (6/14/2019, 11:50 AM)

The human error factor plays the most significant role in weather or not a coating/repair fails prematurely or performs according to it's life expectancy. Not including an abrasive blast repair, feathering a repaired area 'should' ensure that no future corrosion cells are hiding under the (irregular) edges of a coating. Conversely, will a hot, tired, or lazy worker physically check 100% of the exposed coating edges of a repair with a dull putty knife to confirm tight adherence, if it is not visibly lifting? Doubtful. While I respect the findings of the laboratory tests under controlled conditions, Imho, feathering in this case is more of a visual sign that all exposed edges have been addressed and no visible moisture or other agent has entered into or under the existing coating system unnoticed.

Comment from Patrick Cassidy, (6/17/2019, 10:00 AM)

Stuart, great comments. I agree with you that human factors play a huge role in this and every other coating and surface prep process. What we saw in our testing was that feathering did not provide any more guarantee that the edge was ready for coating application than not feathering (i.e., there was just as much coating failure at the edge, and lifting coating, when feathering as when not feathering). Performing touch-up painting is difficult and time consuming. In our experience the feathering step did not seem to be a visual sign that all exposed edges had been addressed, as coatings still failed when feathering was performed. Feathering should not be used as a QA/QC step. The worker should be in the habit of using the primary prep method or tool to ensure they reach sound intact tightly adherent coating per the SSPC SP standard. Finally, while half of this testing was conducted in the lab, the other half was done in the field using real shipyard workers under real conditions on a mock ballast tank, and a third study (not included here, but can be found in our SSPC 2019 Conference Paper) was done on ship using shipboard maintainers. So two thirds of the results are "real world" results, not controlled lab conditions. Thanks again for the comments.