EFFECT OF WET BLAST INHIBITORS ON COATING PERFORMANCE

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Introduction

The basic idea behind the application of high performance coatings to metals is to protect them from corrosive materials and provide a pleasing appearance. However, before these benefits can be fully realized, the metal surface must be properly cleaned. Or, to put it another way, the performance of a coating system is only as good as the surface preparation.

Over the past years surface cleanliness has been determined by visual specifications. Organizations such as the Steel Structures Painting Council and the National Association of Corrosion Engineers, in addition to the Swedish Standard 05 59 00, have issued written and visual standards to define surface cleanliness. But what about the hidden unseen enemy? What about the surface contamination caused by chlorides and sulfates that are still present after the classical, traditional surface preparation of dry abrasive blasting?

This paper will deal with the removal of these salts by wet jet abrasive blasting and the variations in coating performance caused by different inhibitors used in this cleaning technique.
Discussion

The effect on coating performance caused by water soluble salts, such as chlorides and sulfates, had been discussed as long ago as July, 1966, by K. A. Chandler in the article "The Influence of Salts in Rusts on the Corrosion of the Underlying Steel" (1) and as recently as June, 1987, by Dwight G. Weldon and his association in the article "The Effect of Oil, Grease, and Salts on Coating Performance - A Laboratory Evaluation" (2). During the intervening 21 years, there have been various articles and technical papers discussing this subject.

From such statements as "unfortunately, it must be stated that, with the blasting technique of today, it is not possible to clean rusty steel surfaces to the degree of cleanliness that is described as 'metal clean'" (3) and "the prospects for removal of salts on the steel surface increased considerably when the blasting is combined with washing with water" (4), it became obvious that a new cleaning technique of surface preparation had to be developed. These remarks were made in 1976 and 1982 respectively, and during this interval techniques such as (a) alternating dry blasting and water rinsing (up to two or three times each), (b) high pressure water blasting, (c) sand injection into water, or (d) water injection into sand, were all tried with limited success. Either the system did not properly clean the surface or it was not cost effective when compared to the conventional dry blast technique. The newest technique to be utilized is the wet jet abrasive blasting concept. This
differs from other wet/dry systems because the water acts as an accelerator to the abrasive as well as a dust suppressor.

However, when water and abrasive are used in combination with each other in the cleaning of a steel surface, it is necessary to include a water soluble flash rust inhibitor to the blasting water. Otherwise, the steel would flash rust and would not be "clean" when it was time to apply the protective coating system. The addition of this inhibitor has caused some concern regarding the effects upon the adhesion/cohesion of the coating system to the water/abrasive/rust inhibited cleaned surface and the ultimate performance of the coating system.

In order to allow the owner, specifier, or engineer to have comfort in the use of steel prepared in the above manner, it was necessary to initiate a test program to determine what effects, if any, would be realized. Woodson reported on such a program in 1987 (5). Using this data as a starting point, additional test work has been completed in accordance with the procedures discussed in the Scope section of this report.

Scope

In order to properly evaluate the adhesion/cohesion properties of a protective coating system, it was necessary to identify certain parameters to which the coatings would be subjected:

A. New steel substrate or uncontaminated steel that is normally provided in new construction.
B. Old steel substrate or severely contaminated steel that normally occurs in maintenance/repair projects.

C. Protective coating systems that are exposed to atmospheric environments.

D. Protective coating and/or lining systems that are exposed to immersion conditions.

It must be noted that the primary intention was to determine the practical relationship between various grades of surface preparation and adhesion/cohesion values of the coating systems tested under laboratory conditions. Product performance or determining a system's resistance to acidic, caustic, solvent, or immersion exposures was not a major concern of this study. A thorough and investigative analysis should always be conducted on a long term basis for corrosion resistance; however, this report emphasizes the relationship between the degree of cleanliness of the steel substrate and the adhesion of a specific generic coating system.

The generic coating systems tested were as follows:

1. Three coats; inorganic zinc silicate primer + epoxy polyamide intermediate + aliphatic urethane/acrylic or epoxy polyamide/acrylic finish coat. Average film thickness - 9.0 to 10.0 mils DFT.

2. Three coats; epoxy polyamide primer + epoxy polyamide intermediate + aliphatic urethane/acrylic finish coat. Average film thickness - 10.0 to 12.0 mils DFT.

3. Two coats; epoxy amine primer + epoxy amine finish coat. Average film thickness - 6.0 to 8.0 mils DFT.
4. Three coats; phenolic/epoxy amine primer + phenolic/epoxy amine intermediate + phenolic amine finish coat. Average film thickness - 12.0 to 15.0 mils DFT.

5. Five coats; vinyl butyral wash primer + vinyl primer + vinyl intermediates + vinyl finish coat. Average film thickness - 8.0 to 10.0 mils DFT.

6. Two coats; epoxy coal tar/polyamide. Average film thickness - 15.0 to 17.0 mils DFT.

7. Four coats; alkyd (long oil) primer + intermediates + finish coat. Average film thickness - 6.0 to 8.0 mils DFT.

These seven generic coating systems were selected due to their use throughout the industry as atmospheric or immersion type systems for new construction and maintenance projects. Eight manufacturers of high performance coatings, based either domestically or overseas, contributed their effort, support, and product systems for conducting these test evaluations.

Test Procedures

All tests were performed on 1/4" x 4" x 6" flat steel (Hot Rolled A 36) panels. A minimum of three panels were prepared for each coating system submitted for testing.

I. New Steel Substrate
Surface preparation consisted of five grades that all conform to the basic requirements of Steel Structures Painting Council SSPC-SP 5 "White Metal". These various "grades" were identified as follows:

A. Dry blast only.

B. Wet blast without inhibitor, and allow steel surface to flash rust.

C. Wet jet abrasive blast with sodium nitrite inhibitor injected into fresh blasting water.

D. Wet jet abrasive blast with formulated alkanol amine inhibitor injected into fresh blasting water.

E. Wet jet abrasive blast but apply a passivating compound (poly-valent ionic/acid) after blasting.

All test panels were allowed to air dry for a minimum of four hours after blasting and prior to the application of the coating system.

The anchor profile, as specified by the coating manufacturer, varied from 1.0 mils to 3.0 mils dependent upon the generic type of coating to be tested. All anchor patterns were checked with a profile comparator and tape.

II. Contaminated Steel Substrate

Test panels were dry blasted to white metal in accordance with SSPC-SP 5, with a 1.5 mil anchor profile. Microscopic examination (50X) did not reveal any residue or surface contaminants. A corrosive solution, comprised of 3% sea water (utilizing distilled water as the medium) and 1%
sulfuric acid, was sprayed on the test panels three times each day for 14 days. These treated panels were exposed to outdoor temperatures of 73 degrees F to 98 degrees F. The test panels, after 14 days, were severely corroded and deeply pitted, clearly showing the adverse affects of chemical attack. The "contaminated" test panels were divided into groups and the surface prepared as follows:

1. Dry blast to white metal
2. Wet jet abrasive blast to white metal including a formulated alkanol amine inhibitor in the blast water.

It must be noted that the "contaminated" dry blasted panels oxidized rapidly within one hour and had to be reblasted a second time before the application of the coating system. However, the wet jet abrasive blasted, inhibitor prepared panels retained their white appearance for the required four hour dry time prior to coating application.

A SEM-EDX qualitative analysis was conducted on both types of surface preparation prior to the coating application. The analysis of the "contaminated" steel panel prior to blast cleaning indicates the presence of 31,500 ppm chlorides (presumably ferric and sodium even through the SEM-EDX cannot distinguish between the two) and sulfur. The contaminated steel panels, immediately after dry blasting, indicates the presence of 4,500 ppm chloride still present on the substrate. Sulfur is not indicated. Finally, the contaminated steel, immediately after wet jet abrasive blasting, does not show the presence of any chlorides or sulfur.

Mixing and Application of Coating Systems
All coating materials were mixed, thinned (if applicable), strained, and applied in strict accordance with the manufacturer's detailed recommendations. Test panels, both new steel and contaminated steel, were coated by utilizing conventional spray equipment as follows:

1. Pressurized pot, double regulated;
2. DeVilbiss PMC Gun, 765 A/C, E Needle;
3. Clean, filtered air, free of moisture or oil contaminants.

Wet film thickness and dry film thickness were closely monitored to ensure the required film build of each coat. Cure time between coats, if applicable, was a minimum of 24 hours. Coated test panels were exposed to climatic weather conditions (75 degrees to 95 degrees F) for a period of 21 days prior to adhesion testing and cabinet exposure.

Adhesion/Cohesion Testing

Primary requirements for adhesion/cohesion testing are in accordance with ASTM D 4541 (modified). The adhesion test apparatus used in this evaluation was a tensile tester manufactured by the United Calibration Corporation. It has a 20,000 psi cell load and can measure with accuracy to one-tenth of one pound per square inch. Adhesion/cohesion values were obtained from each test panel and recorded. The average of the three readings for each system or grade was the number used for all calculations and graphics.

Cabinet Exposure Testing
All selected test panels were subjected to a Q.U.V. accelerated weathering exposure cabinet (ASTM G 53) and salt spray (fog) exposure cabinet (ASTM B 117). Test panels were alternated every 168 hours (7 days) between cabinets until the test panels had a cumulative exposure of 2500 hours (104 days).

Test Results and Conclusions

A. Adhesion/Cohesion; New Steel Surface Preparation Grade A - G

The seven (7) generic systems tested under the above criteria displayed a failure mode, or break, in cohesion and not adhesion.

System 1: Inorganic zinc silicate primer + epoxy polyamide intermediate + aliphatic urethane/acrylic or epoxy polyamide/acrylic finish coat.

Result: Cohesion break in primer and intermediate coat. Approximately 1.5 mils DFT of zinc primer remain tightly adhered to steel substrate. "Pull" values range from the lowest average (650 psi) Grade C, to the highest average (1215 psi) Grade B and D. Clearly indicates that the flash rusted steel and formulated alkanol amine (inhibited) steel provided higher "pull" values than the other three grades.

System 2: Epoxy polyamide primer + epoxy polyamide intermediate + aliphatic urethane/acrylic finish coat; or

System 3: Epoxy amine primer + epoxy amine finish coat.
Result: Cohesion break in primer and intermediate coat. Approximately 4 mils DFT (minimum) of the epoxy primer remain tightly adhered to the steel substrate. "Pull" values range from the lowest average (420 psi) Grade C, to the highest average (1150 psi) Grades B and D.

System 4: Epoxy phenolic/amine primer + epoxy phenolic/amine intermediate + epoxy phenolic/amine finish.

Result: Cohesion break in intermediate coat. Approximately 8 mils DFT of primer/intermediate remains tightly adhered to the steel substrate. "Pull" values range from the lowest average (912 psi) Grade C, to the highest average (1345 psi) Grade B.

System 5: Butyral wash primer + vinyl primer + vinyl intermediates + finish.

Result: Cohesion break in vinyl primer (second coat). Approximately 1.5 mils DFT of second vinyl primer and wash primer remain tightly adhered to the steel substrate. "Pull" values range from the lowest average (288 psi) Grade D, to the highest average (353 psi) Grade A.

System 6: Two (2) coats epoxy coat tar/polyamide.

Result: Cohesion break in first coat. Approximately 6 mils DFT of the first coat remain tightly adhered to the steel substrate. "Pull" values range from the lowest average (430 psi) Grade E, to the highest average (768 psi) Grades B and D.

System 7: Alkyd (long oil) or alkyd/phenolic primer + alkyd (long oil) or alkyd/phenolic intermediate and finish.
Result: Cohesion break in primer. Approximately 1.5 mils DFT of the alkyd prime remain tightly adhered to the steel substrate. "Pull" values range from the lowest average (355 psi) Grade A, to the highest average (1248 psi) Grade A.

Conclusion: New steel (adhesion/cohesion)

1. Failure mode in all systems is cohesion, not adhesion.
2. Systems 1, 2, 3, 4, and 6 surface preparation; Grade B (flash rusted steel) and Grade D (wet jet abrasive blast + formulated alkanol amine inhibitor) displayed significant and higher "pull" values than the other three grades. Therefore, it is reasonable to assume from this data that two distinct factors have enhanced adhesion:
   A. Mechanical, or the "anchoring" of a coating film to the roughened substrate;
   B. Special, or absorption forces at the interface or possibly the chemical affinity of certain coating components toward the metal itself, i.e., hydrogen bonding, etc.

B. Adhesion/Cohesion and Exposure Testing of Contaminated Steel

The primary purpose of this test is to determine if permeation of moisture through the coating film will adversely react with residual compounds remaining in the interstices of the substrate, thereby
substantiating the technical premise that removal of soluble salts is just as vital as adequate anchor profile to obtain the required adhesion.

Selected test panels with surface preparation consisting of dry abrasive blasting or wet jet abrasive blasting were coated with systems 2, 3, 4, 5, and 6. They were then subjected to 2500 hours of accelerated cabinet exposure. Adhesion/cohesion values were obtained before cabinet exposure and will also be obtained after the exposure is completed. At the time of the writing of this paper (after 700 hours of accelerated cabinet exposure testing), all test panels are showing minor degradation of the coating film. The majority of the test panels that were dry blasted are also showing some indication of the penetration. However, none of the wet jet abrasive blasted test panels are showing any evidence of penetration. These observations were determined under 50X magnification.

References


