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EFFECTIVENESS OF RUST REMOVERS FOR USE AT NAVAL SHORE FACILITIE--ETC(U)

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CONTENTS

INTRODUCTION

Proper preparation of the surface prior to painting is essential to achieve maximum life of a coating. The best quality paint will not perform effectively if applied on a poorly prepared surface. Painting over rusty or poorly prepared steel surfaces is regarded as poor practice and should be avoided. Abrasive blast cleaning is, by far, the most thorough and effective mechanical treatment. However, it is often impractical or impossible to do this because of environmental and economical reasons, location, or equipment limitations. Maintenance personnel are frequently required to resort to other methods of surface preparation.

One of the available methods is to use a chemical rust remover. Industry has introduced a variety of rust removers that can be applied over rusty surfaces to remove rust and mill scale from steel surfaces. Thus, it has become necessary to appraise the relative merits of some of these products to ascertain their suitability for use by the Navy.

In Fiscal Year 1972, the Civil Engineering Laboratory (CEL) included an investigation of 13 different rust removers or rust converters in work sponsored by the Naval Facilities Engineering Command. Ten rust removers and three rust converters were selected for this investigation.

These rust removers and rust converters were applied to rusted steel test panels to remove or convert rust and were then top-coated with government specification coating (MIL-P-15328, TT-P-645, and TT-E-489E). The coated test panels were placed on exposure racks at the three CEL marine atmospheric exposure sites: Kaneohe, Hawaii; Kwajalein, Marshall Islands; and Port Hueneme, California. Their performances were compared with the same coating systems applied to sandblasted-to-white-metal steel test panels exposed simultaneously.

This report presents the results of 5 years of exposure at the three exposure sites.

TEST PROCEDURE

Panel Preparation

All test panels were of mild steel, 6x12x1/8 in., providing approximately 1 sq ft of overall area. The new test panels were washed with methyl ethyl ketone to remove any rust inhibitive oily substance on the surfaces, then placed on exposure racks at the Port Hueneme exposure site for 4 weeks to allow rusting to take place. During the rusting procedure the test panels were turned over each week to obtain uniform rusting.

Each rust remover or converter was applied on both sides of the 14 rusted test panels according to instructions provided by each manufacturer. Some of the rust removers or converters were applied differently than others, as required. The rust removers were then washed off with clean water and then rinsed with methyl ethyl ketone to remove the residual water from the test panels to dry them quickly.

After rust removal, all test panels were top coated with a government specification paint (MIL-P-15328, TT-P-645, and TT-E-489E) applied to both sides of the test panels by means of an automatic horizontal-transverse paint spraying machine, resulting in a uniform paint thickness for each set of panels. The control standard coating system was applied over white metal sandblasted steel* (System 14). After coating, the panels were dried as required. Appendix A lists the rust removers or converters, their sources, the coating systems, and their thickness.

To allow evaluation of adhesion loss and coating blistering associated with corrosion resulting from abrasion damage that exposes bare metal and to accelerate the weathering process, two diagonal cuts were made through the coating to expose the steel substrate. These scribes, made in the shape of an "X" on one side of the coated test panel, extended from about 1-3/8 in. from each corner. Four coated test panels, two scribed and two unscribed, from each coating system were exposed to the marine atmosphere at each of the three test sites, with the scribed side facing up.

CEL Exposure Locations

Each of the three marine atmospheric environments (Port Hueneme, Kaneohe, and Kwajalein) presents different combinations of weathering factors such as rainfall, temperature, humidity, solar radiation, wind, and salt spray in varying intensities and duration. Thus, these three different geographical locations provide an opportunity for simultaneous exposure studies of identical coatings under differing conditions.

Kwajalein. Kwajalein is located near the center of the tropical zone at $8^{\circ}44'$ north latitude. The exposure racks are about 100 feet from the surfline at high tide and hold the test panels at a 45-degree angle to the horizontal, facing the prevailing east-northeast wind that carries large amounts of salt spray to the panels. Rainfall is plentiful, averaging over 10 in./mo during 8 months of the year; total annual rainfall is about 105 inches. The annual average temperature range is 81° to 83°F, and wind velocity is between 8 and 21 mph.

Kaneohe. The exposure racks at Kaneohe face east-northeast into the prevailing wind and are about 200 feet from the surf and up a knoll about 40 feet above sea level. The test panels are placed at a 45-degree angle to the horizontal. The wind often carries small amounts of fine sand, which has a slight abrasive action on the coating surfaces. This

*Steel Structures Painting Council Surface Preparation No. 5, "White Metal Blast Cleaning," Steel Structures Painting Manual, Vol. 2, "Systems And Specifications," SSPC, Pittsburgh, Pa., 1973, pp 61-64.

test area is at 21°21' north latitude near the northern edge of the tropical zone (the Tropic of Cancer is 23°27' north latitude). The Kaneohe test site has a slightly greater variation in temperature than does Kwajalein with average annual temperature ranging between 73° and 79°F. The monthly rainfall varies from 1 to 9 inches; annual total rainfall averages about 43 inches.

Port Hueneme. This test site is located on a pier where the specimens are exposed at a 45-degree angle to the horizontal, facing west. The pier runs parallel to a north-south rock jetty (breakwater), which is about 300 feet to the west of the pier. The surf breaks against this jetty, and the prevailing west wind carries ocean spray onto the test specimens. The wind carries a considerable amount of fine sand and dust, which has a slight abrasive action on the coating surfaces. Port Hueneme is at 34°7' north latitude (10°40' north of Tropic of Cancer). The annual average rainfall is about 12 inches and falls predominantly during 5 months in the winter. The average annual temperature is from 51° to 65°F.

RATING OF COATING SYSTEMS

Inspections were made of the exposed coatings annually and their performances rated. Photographs of the coatings were taken annually. The assigned ratings are tabulated in Appendix B.

Ratings were assigned by CEL personnel in accordance with ASTM Standards, where applicable. A numerical rating system was used for recording the degree of protection given by a coating. A rating of 10 indicated complete protection, a rating of 0 indicated no protection. For example, if the metal substrate had lost protection over 10% to 20% of its surface the coating was given a rating of 8. In this report, a protection rating of 7 indicates coating failure and that maintenance or recoating is necessary. An E in the Appendix B tabulation indicates the rating was based on coating performance at the edges.

Chalking is evident as a removable powder evolving from the coating film at, or just beneath, the surface resulting from breakdown of polymer by the action of ultraviolet light. To determine the chalking rating, a 4-inch stroke is made with a clean, dry cloth across the surface of a coating. The spot of powder on the cloth is compared with photographic reference standards (ASTM Designation D659-44); the degree of chalking is then rated from 10 (no powder on the cloth) to 2 (the powder completely covers the spot). Because the amount of chalking present on the coating film at the rating time was affected by recent rainfall, the recorded rating represents a maximum rating for chalking.

The degree of rusting is rated in accordance with ASTM Designation D610-43 which provides photographic reference standards. Both Type I (rusting without blistering) and Type II (rusting with blistering) are rated from 10 (no rusting) to 0 (completely rusted).

The blister size is also designated 10 to 2: 10 indicates no blisters, 8 indicates the smallest blister easily seen with the unaided eye, and 6, 4, and 2 represent a progressively larger sized blister. Size 2 represents a blister diameter of about 1/4 in. Blister frequency is reported as dense (D), medium dense (MD), medium (M), and few (F), where "dense" represents complete surface coverage and "few" only occasional blisters. Thus, a rating of 2/M would represent blisters of 1/4-in. diameter, covering approximately one-fifth to one-quarter of the surface.

Undercutting is a type of coating deterioration in which adhesion of the coating film to the metal panel is destroyed by the formation of corrosion products. In most cases these products would be rust inasmuch as steel panels are used. Undercutting most frequently occurs at the scribes or edges of the panels where coating protection is least. Undercutting in these areas is rated 10 (no undercutting), or 8, 6, 4, 2, representing progressively greater areas affected by the undercutting. A rating of 5 would indicate that 50% of the designated area was affected by the undercutting.

TEST RESULTS

Observation during the rust remover applications and performance during the 5 years of exposure at the three CEL exposure sites are presented below. Three years of exposure at Kwajalein usually provide enough data so that inferior coating systems can be identified. However, longer term exposures are normally required to better identify superior coatings. After 5 years of exposure it is possible to select the best system or the superior systems that have continued to give satisfactory protection at Kwajalein. The coatings that fail during these additional 2 years can be ranked in protective quality, depending on whether they fail during the fourth or fifth years at Kwajalein and on the condition of the coatings at Kaneohe during these same periods.

System 1

This system consisted of a proprietary rust remover, Rustbuster #211, and three government specification coatings (wash primer MIL-P-15328, primer TT-P-645, and finish TT-P-489E).

Rustbuster #211 is a medium duty, general purpose grade of metal cleaner compared to the heavy duty rust remover used in System 2. The rust remover formed a dry film on the test panels 15 minutes after the application. The dried film, however, peeled back at the edges of some of the test panels. After 1 hour, a second application was made and left standing for another hour; the remaining rust was removed from the panels satisfactorily. Flash rust set in quickly unless the panels were rinsed with clean water and dried with methyl ethyl ketone. One coat of the wash primer, two coats of the primer, and one coat of the finish coat were then applied. Total average dry-film thickness was 8 mils (0.008 in.).

Protection of unscribed panels provided by this system were fair to excellent (ratings of 8+, 9-, and 10) during the 5 years of marine atmospheric exposure at the Kwajalein, Kaneohe, and Port Hueneme test sites, respectively. The performances of the unscribed panels were almost as good as the sandblasted control standard system, System 14, which were rated 9-, 9-, and 10 during the same period of exposure.

Protection provided by this coating system to the scribed panels during the 5 years of exposure were fair to good (ratings of 8-, 8, and 9-) at the Kwajalein, Kaneohe, and Port Hueneme test sites, respectively. The performances of the scribed panels were as good as or slightly better than System 14 which were rated 7, 8+, and 8, respectively, at the three test sites during the same period of exposure. The rating of 7 of System 14 indicated failure of the control standard to protect the test panels from the corrosion attack during 5 years of exposure at Kwajalein.

System 2

This system consisted of a proprietary rust remover, Rustbuster HD, and the three government specification coatings.

Rustbuster HD, designed for heavy duty metal cleaning, was supplied by the same manufacturer as System 1. It was much easier to apply and did not peel off as did Rustbuster #211. System 2 also required two applications to remove the rust from the rusted test panels satisfactorily.

After rinsing with water and drying with methyl ethyl ketone, the panels were coated with the same three government specification coatings (one coat of MIL-P-15328, two coats of TT-P-645, and one coat of TT-E-489E) as the previous samples. Total dry-film thickness was 7.5 mils (0.0075 inch).

Protection of the unscribed panels provided by this system were fair to good (8+, 9-, and 9+) during the 5 years of exposure at the Kwajalein, Kaneohe, and Port Hueneme exposure sites, respectively. The protection provided by this system was slightly less than that provided by control standard System 14 during the same period.

The scribed panels coated with this system failed after 4 years of exposure at Kwajalein because of heavy rusting, blistering, and undercutting at the scribed areas. The performance of this system at Kaneohe and Port Hueneme was fair (8 and 8+, respectively) during the 5 years of exposure.

System 3

This coating system consisted of a proprietary rust remover (Devcon Rust Jelly) and three government specification coatings.

This product meets requirements of Military Specification MIL-C-10578C. The consistency of this product appeared to be very light, and when it dried the dried film appeared to have shrunk slightly, exposing the unprotected edges of the panels. This rust remover required two coats to remove the rust from the rusted panels satisfactorily. After rinsing with water and drying with methyl ethyl ketone, the test panels were coated with one coat each of the three government specification coatings. Total dry-film thickness was 6.5 mils (0.0065 inch).

Protection of the unscribed panels provided by this system was good to excellent (ratings of 9, 9, and 10) during the 5 years of exposure at the Kwajalein, Kaneohe, and Port Hueneme exposure sites, respectively. The protection provided by this system was as good as that provided by the sandblasted control standard System 14 during the same period.

The scribed panels failed after 2 years of exposure at Kwajalein. The protection provided by this system at the Kaneohe and Port Hueneme exposure sites was rated fair (8+ and 8, respectively) during the 5 years of exposure.

System 4

This coating system consisted of a proprietary rust remover (Acco Naval Rust-Removo) and the three previously described government specification coatings.

This material was heavy jelly-like and could not be just brushed on but needed to be patted on with a spatula and then spread with a brush to cover the surface of the test panels. A second coat applied after 1 hour of standing was required to remove the rust from the panels satisfactorily. Although the manufacturer claimed that the rust remover leaves rust-inhibitive film on the treated surface, flash rust appeared on the surface soon after the panels were rinsed with water and dried with methyl ethyl ketone. The panels were then coated with one coat each of the government specification coatings as for the previous systems. Total dry-film thickness was 6.5 mils (0.0065 inch).

The unscribed coating system provided good to excellent protection (ratings of 9, 9+, and 10, respectively) during the 5 years of exposure at Kwajalein, Kaneohe, and Port Hueneme test sites. The protection provided by this system was as good as that provided by control standard System 14 during the same period.

The scribed panels failed after 4 years of exposure at Kwajalein. The protection was fair (8+ and 8, respectively) at the Kaneohe and Port Hueneme test sites during the 5 years of exposure.

System 5

This coating system consisted of a proprietary rust remover (Rust-clean 3764) and the same three government specification coatings.

This product was also in gel form but lighter and easier to apply than the Acco Naval Rust-Removo. It adhered better on the edges of the panels but removed the rust more slowly than the Rust-Removo. This product meets Military Specification MIL-C-19647A. Three government specification coatings were applied after rinsing the panels with water and drying with methyl ethyl ketone. Total dry-film thickness was 6.5 mils (0.0065 inch).

Protection of the unscribed panels provided by this system were good to excellent (ratings of 9, 9, and 10, respectively) during the 5 years of exposure at Kwajalein, Kaneohe, and Port Hueneme. The protection provided by this system was as good as that provided by control standard System 14 during the same period of exposure.

The scribed panels failed after 4 years of exposure at Kwajalein. The protection was fair at Kaneohe and Port Hueneme (ratings of 8+ and 8+, respectively) during the 5 years of exposure.

System 6

This coating system consisted of a proprietary rust remover (Oakite Jelcid) and three government specification coatings.

This product meets Military Specifications MIL-STD-107E and MIL-M-10578C Type II. This product is a heavy-bodied liquid material. It was applied by brush but can be applied with a roller. Two applications were made, the second after 1 hour of standing. After the panels were rinsed with water and dried with methyl ethyl ketone, remaining rust spots were sanded manually. One coat each of the three government specification coatings were then applied as for the previous systems. Total dry-film thickness was 6.5 mils (0.0065 inch).

Protection of unscribed panels provided by this coating system were good to excellent (ratings of 9, 9, and 10, respectively) during 5 years of exposure at Kwajalein, Kaneohe, and Port Hueneme. This system also provided protection as good as control standard System 14 during the same period of exposure.

The scribed panels failed after 4 years of exposure at Kwajalein. The protection was fair (ratings of 8+ and 8, respectively) at Kaneohe and Port Hueneme during the 5 years of exposure.

System 7

This coating system consisted of a proprietary rust remover (Naval Jelly) and the three government specification coatings.

This product was also a heavy-bodied liquid. It was applied by brushing and removed the rust in the same way as the Oakite Jelcid. Second applications were made after 1 hour of standing. This product removed the rust more effectively than other rust removers tested. No re-rusting of the panels occurred after the rust remover was rinsed with water and dried with methyl ethyl ketone. One coat each of the government specification paints were applied on the treated test panels. Total dry-film thickness was 6.5 mils (0.0065 inch).

This coating system provided fair to excellent protection (ratings of 8, 8+, and 10-, respectively) to the unscribed panels during the 5 years of exposure at Kwajalein, Kaneohe, and Port Hueneme.

The scribed panels failed after 4 years of exposure at Kwajalein. The system provided fair protection (ratings of 8 and 8) to the scribed panels at Kaneohe and Port Hueneme during 5 years of exposure.

System 8

This coating system consisted of a proprietary rust converter (Carboline Rustcon 230) and a government specification finish coat (TT-E-489E).

Unlike the previously discussed rust remover samples, this product was classified as a rust converter because it was claimed that this product will produce a protective coating upon application by chemically converting the tightly adhering rust to a protective coating and provide a sound base for subsequent painting. This product was applied over a brush-off sandblasted rusty surface as recommended by the manufacturer. After the rust converter was dried, two coats of government specification finish coat (TT-E-489E) were applied. This system differed from other systems in that wash primer and primer were omitted as recommended by the manufacturer. Total dry-film thickness was 6.0 mils (0.006 inch).

This product provided very poor protection to the unscribed panels as well as the scribed panels during the 5 years of exposure at the three CEL test sites. The unscribed panels failed during the third and fifth year of exposure at Kaneohe and Kwajalein, respectively, because of heavy rust and blistering. The system provided fair protection (rating of 8) to the unscribed panels at Port Hueneme during the 5 years of exposure.

The scribed panels failed only after 1 year of exposure at Kwajalein and Kaneohe and failed after 4 years of exposure at Port Hueneme because of heavy rust, blisters, and tuberculation.

System 9

This coating system consisted of a proprietary rust remover (Manganesed-Phospholene No. 7) and three government specification coatings.

This product is a very light liquid and can be applied by brushing, spraying, or dipping. This product required 2 hours of continuous brushing before rust was satisfactorily removed from the surface. This product reacted with the metal surface and left a gray surface after the treatment which is said to act as a protective film against re-rusting of the surface and enhances paint adhesion. This product meets Military Specifications MIL-STD-107E and MIL-M-10578C. It recommends sanding-off rust and mill scale from the surface prior to application if they are too heavy. After rinsing with water and drying with methyl ethyl ketone, the treated panels were coated with one coat each of the three government specification coatings. Total dry-film thickness was 7.0 mils (0.007 inch).

This product provided fair and excellent protection (ratings of 8+, 8+, and 10-) to the unscribed panels during the 5 years of exposure at Kwajalein, Kaneohe, and Port Hueneme, respectively.

The scribed panels failed after 4 years of exposure at Kwajalein because of heavy rusting and blistering along the scribed areas. It provided fair protection (rating of 8) during the 5 years of exposure at Kaneohe and Port Hueneme.

System 10

This coating system consisted of a proprietary rust remover (Turco Metal Glo #3H) and the three government specification coatings.

This product was a viscous liquid, slightly in gel form and required 2 hours of continuous application with a stiff bristle brush to loosen the rust from the test panels. The treated panels required some sanding of the remaining rust after rinsing off the rust remover with water. This product was not an effective rust remover compared to other rust removers under investigation. After rinsing with water and drying with methyl ethyl ketone, the treated panels were coated with one coat each of the government specification coatings as other systems. Total dry-film thickness was 6.5 mils (0.0065 inch).

The conditions of the unscribed panels were fair to excellent (ratings of 8+, 9, and 10-) during the 5 years of exposure at Kwajalein, Kaneohe, and Port Hueneme, respectively.

The scribed panels failed after 4 years of exposure at Kwajalein because of heavy rusting and blistering. The condition of the scribed panels at Kaneohe and Port Hueneme was fair (ratings of 8) at the end of 5 years of exposure.

System 11

This coating system consisted of a proprietary rust remover (Far Best #5703) and the same three government specification coatings.

This product, a viscous liquid and in slightly gel form, was similar to the previous rust remover, Turco Metal Glo #3H. The product was too mild and required continuous brushing with a stiff bristle brush to remove heavy rusting from the panels. It was an ineffective rust remover and required sanding of some remaining rust from the surface. After the treated panels were rinsed with water and dried with methyl ethyl ketone, they were coated with one coat each of the government specification coatings. Total dry-film thickness was 7.0 mils (0.007 inch).

The conditions of the unscribed panels were fair to excellent (ratings of 8+, 9, and 10-) during the 5 years of exposure at Kwajalein, Kaneohe, and Port Hueneme, respectively.

The scribed panels failed after 3 years of exposure at Kwajalein because of heavy rust and blistering along the scribed areas. Protection of the scribed panels at Kaneohe and Port Hueneme were fair (ratings of 8) during the 5 years of exposure.

System 12

This coating system consisted of a proprietary rust converter (Ospho) and three government specification coatings used in the previous systems.

This product is also classified as a rust converter because the manufacturer claimed that this product reacts with existing rust and converts it to an inert iron phosphate which acts as a protective film against further corrosion of the substrate. Although the manufacturer recommends letting the product stand overnight after application, it appeared to react fairly rapidly with the rust when applied on the test panels. However, rust began to reappear when the treated surface was rinsed with water. The three government specification coatings were then applied to the treated panels. Total dry-film thickness was 6.5 mils (0.0065 inch).

The conditions of the unscribed panels were fair to good (ratings of 8, 8+, and 9-) during the 5 years of exposure at Kwajalein, Kaneohe, and Port Hueneme, respectively.

The scribed panels, however, failed after 3 years of exposure at Kwajalein and Kaneohe because of heavy rusting and blistering. The scribed panels at Port Hueneme were fair (rating of 8) during the 5 years of exposure.

System 13

This coating system consisted of a proprietary rust converter (Actan) and the same government specification coatings as the previous coating systems.

This product is also classified as a rust converter because the manufacturer claims that it "reacts with iron-oxide (rust) and forms a protective barrier, metallo-organic coating, on metallic substrate and passivates the ferrous surface from further corrosion." It can be applied by brushing, rolling, or spraying. The treated panels were left outside for 7 days as directed by instructions provided. The panels were then rinsed with water, dried, and the three government specification coatings were applied. Total dry-film thickness was 6.5 mils (0.0065 inch).

Conditions of the unscribed panels were fair to good (ratings of 8, 9, and 8+) during the 5 years of exposure at Kwajalein, Kaneohe, and Port Hueneme, respectively.

The scribed panels, however, failed after only 1 year of exposure at Kwajalein and after 4 years of exposure at Port Hueneme because of heavy rusting, blistering, and undercutting along the scribed areas. These panels did not fail (rating of 8+) at Kaneohe during the 5 years of exposure. The failure of the rust converter to protect the Kwajalein and Port Hueneme panels was similar to Systems 8 and 12, which also used rust converters.

System 14

This coating system consisted of the three government specification coatings, wash primer MIL-P-15328, primer TT-P-645, and finish coat TT-E-489E. The specification coatings were the same as those of the previous systems except that the coatings were applied over the sandblasted-to-white steel panels instead of over rust remover- or converter-treated panels. This system was prepared as a control standard for comparison with the performance of other systems. Total dry-film thickness was 7.0 mils (0.007 inch).

Conditions of the unscribed panels were good to excellent (ratings of 9-, 9-, and 10) during the 5 years of exposure at Kwajalein, Kaneohe, and Port Hueneme, respectively.

The scribed panels failed after 4 years of exposure at Kwajalein. Condition of the scribed panels was fair (rating of 8- and 8) during the 5 years of exposure at Kaneohe and Port Hueneme, respectively.

DISCUSSION

Except for the rust converters - Systems 8, 12, and 13 - most of the rust removers were claimed to be applicable not only for removing rust from steel and cast iron surfaces but also capable of removing corrosion product or tarnish from aluminum, stainless steel, chrome, copper, bronze, and brass surfaces. Some of these products were also recommended for removing rust stains from porcelain, concrete, or marble, although such claims were not investigated under this work.

Number of applications and time required to remove the rust from the surfaces depends on the thickness and degree of corrosion. All rust removers tested here required two applications or continuous scrubbing with a bristle brush to remove the rust satisfactorily. Most of these rust removers were left standing overnight before rinsing down with water. Removal of the rust from vertical surfaces was very difficult because most of the rust removers slowly slid down from the top to the bottom while standing.

Most of the rust removers contained phosphoric acid to remove the rust plus detergent, wetting agents, or organic solvents to assist in removing soil and oil. Phosphoric acid cleaning is an excellent time-tested method of removing oil and rust. The phosphoric acid etches the surface and chemically reacts with it producing a thin layer of iron phosphate. This thin layer temporarily retards re-rusting of the treated areas and provides a sound base for subsequent coatings. However, during the experiment, the flash rust appeared in most instances soon after rinsing with clean water. After 5 years of the atmospheric exposure, however, the results indicated that the slight amount of flash rust did not affect the performance of the coating systems seriously, and the test panels were protected as well as the sandblasted-to-white control standard panels were.

Rust converter Systems 8, 12, and 13 did not provide good protection during the 5 years of exposure at the three CEL test sites. Some of the scribed panels treated with the rust converter failed soon after 1 year of exposure at Kwajalein, as shown in Appendix B. However, the idea of developing an effective corrosion-preventive coating such as a rust converter is a good one, and a need exists for such a product in the Navy for maintenance and cost reduction. Therefore, development or research on such products should be encouraged.

CONCLUSIONS

1. Most of the rust removers tested under this work removed the rust very slowly from the test panels, and the time required to remove the rust varied among the rust removers tested. In most cases, the rust removers needed to be left standing overnight to remove the rust satisfactorily.

2. In most instances, flash rust reappeared after rinsing off the rust removers. However, reappearance of the flash rust did not affect the performance of the coating systems seriously, and the cleaning systems provided protection as good as that provided by the sandblasted control panels. Therefore, as a group, any of these rust removers tested were judged satisfactory for Navy use.

3. All three rust converters tested provided poor protection compared to that provided by the rust removers. Therefore, their use is not recommended at the present time.

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Appendix A

COATING SYSTEMS, THEIR SOURCES, AND FILM THICKNESS

System No.	Trade Name	Type	Source	Coating System	Use	No. of Coats	Total Thickness (mil)
1	Rustbuster #211	Rust Remover	Permaspray Mfg. Corp.	Rustbuster #211	Rust Remover	2	–
			League City, TX 77573	MIL-P-15328	Wash Primer	1	0.5
				TT-P-645	Primer	2	4.0
				TT-E-489E	Finish	2	3.5
							TOTAL 8.0
2	Rustbuster HD	Rust Remover	Permaspray Mfg. Corp.	Rustbuster HD	Rust Remover	2	–
			League City, TX 77573	MIL-P-15328	Wash Primer	1	0.5
				TT-P-645	Primer	2	3.5
				TT-E-489E	Finish	2	3.5
							TOTAL 7.5
3	Devcon Rust Jelly	Rust Remover	California Hardware Co.	Devcon Rust Jelly	Rust Remover	2	–
			500 East 1st Street	MIL-P-15328	Wash Primer	1	0.5
			Los Angeles, CA 90022	TT-P-645	Primer	1	2.5+
				TT-E-489E	Finish	2	3.5
							TOTAL 6.5+
4	Acco Rust-Removo #R301	Rust Remover	General Industrial Co.	Acco Rust-Removo #R301	Rust Remover	2	–
			1780 Montrose Avenue	MIL-P-15328	Wash Primer	1	0.5
			Chicago, IL 60613	TT-P-645	Primer	1	2.5+
				TT-E-489E	Finish	2	3.5
							TOTAL 6.5+
5	Rust Clean 3764	Rust Remover	Octagon Process, Inc.	Rust Clean 3764	Rust Remover	2	–
			596 River Road	MIL-P-15328	Wash Primer	1	0.5
			Edgewater, NJ 07020	TT-P-645	Primer	1	3.0
				TT-E-489E	Finish	2	3.0
							TOTAL 6.5
6	Oakite Jelcid	Rust Remover	Oakite Products, Inc.	Oakite Jelcid	Rust Remover	2	–
			544 South 6th Avenue	MIL-P-15328	Wash Primer	1	0.5
			City of Industry, CA 91744	TT-P-645	Primer	1	2.5+
				TT-E-489E	Finish	2	3.5
							TOTAL 6.5+
7	Naval Jelly	Rust Remover	Meredith Separation Co.	Naval Jelly	Rust Remover	2	–
			Naval Jelly Bldg.	MIL-P-15328	Wash Primer	1	0.5
			310 West 9th Street	TT-P-645	Primer	1	2.5+
			Kansas City, MO 64105	TT-E-489E	Finish	2	3.5
							TOTAL 6.5+

(continued)

System No.	Trade Name	Type	Source	Coating System	Use	No. of Coats	Total Thickness (mil)
8	Rustcon 230	Converter	Carboline Company 328 Hanley Industrial Ct. St. Louis, MO 63144	Rustcon 230 TT-E-489E	Converter-Primer Finish	1 2	2.5+ 3.75 TOTAL 6+
9	Manganesed-Phospholene No. 7	Rust Remover	Western Reserve Laboratories 1348 St. Clair Avenue Cleveland 14, OH 44114	MP-7 MIL-P-15328 TT-P-645 TT-E-489E	Rust Remover Wash Primer Primer Finish	2 1 1 2	– 0.5 3.0 3.5 TOTAL 7.0
10	Turco Metal Glo #3H	Rust Remover	Turco Products Division (Purex Corp. Ltd.) 24600 South Main Street Wilmington, CA 90744	Turco Metal Glo #3H MIL-P-15328 TT-P-645 TT-E-489E	Rust Remover Wash Primer Primer Finish	2 1 1 2	– 0.5 2.5+ 3.5 TOTAL 6.5+
11	Far Best #5703	Rust Remover	Far Best Corporation 6715 McKinley Avenue Los Angeles, CA 90001	Far Best #5703 MIL-P-15328 TT-P-645 TT-E-489E	Rust Remover Wash Primer Primer Finish	2 1 1 2	– 0.5 3.0 3.5 TOTAL 7.0
12	Ospho	Converter	Rusticide Products Co. 3125 Perkins Avenue Cleveland, OH 44114	Ospho MIL-P-15328 TT-P-645 TT-E-489E	Converter Wash Primer Primer Finish	2 1 1 2	– 0.5 2.5+ 3.5 TOTAL 6.5+
13	Actan	Converter	Centerchem, Inc. Empire State Bldg. Suite 6208 350 Fifth Avenue New York, NY 10001	Actan MIL-P-15328 TT-P-645 TT-E-489E	Converter Wash Primer Primer Finish	2 1 1 2	– 0.5 2.5+ 3.5 TOTAL 6.5+
14	Control	Sandblasted-to-White Metal	San Diego Coatings Co. 2646 Main Street San Diego, CA 92113	Control MIL-P-15328 TT-P-645 TT-E-489E	Wash Primer Primer Finish	1 1 2	0.5 3.0 3.5 TOTAL 7.0

Appendix B

RATING DATA FOR RUST REMOVERS

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting		Protection	Blistering	Undercutting
							I	II			
1	Kwajalein	1	9	8	10	10	9(E)	9(E)	8+	D(f)	10
		2	9	6	6/F(E)	10	6(E)	5(E)	8	2/MD	10
		3	8+	10	6/F(E)	9(E)	5(E)	5(E)	8	2/MD	8
		4	8+	6	6/D(E)	8(E)	3(E)	5(E)	8	2/D	7
		5	8+	7	6/D(E)	7(E)	3(E)	4(E)	8–	2/D	4
	Kaneohe	1	9+	10	10	10	10	10	9	6/F	10
		2	9+	8	10	10	9(E)	10	8	6/M	10
		3	9+	6	10	10	8(E)	9(E)	8	6/M	10
		4	9	6	10	10	7(E)	8(E)	8	6/M	9
		5	9–	8	10	10	4(E)	6(E)	8	6/M	9
	Port Hueneme	1	10	10	10	10	10	10	10	10	10
		2	10	6	10	10	10	10	9	8/F	10
		3	10	6	10	10	10	10	9–	6/F	10
		4	10	6	10	10	10	10	9–	6/F	10
		5	10	6	10	10	10	10	9–	6/F	10
2	Kwajalein	1	10	8	10	10	10	10	8	2/F	10
		2	9	6	10	10	8(E)	9(E)	8	2/M	10
		3	8+	8	10	10	6(E)	8(E)	8–	2/D	8
		4	8+	8	10	9(E)	6(E)	8(E)	8–	2/D	7
		5	8+	8	10	8(E)	6(E)	8(E)	6–	2/D	4
	Kaneohe	1	10	8	10	10	10	10	9	6/M	10
		2	9	8	D(f)[a]	10	9(E)	9(E)	8+	6/M	10
		3	9	6	MD(f)	10	8(E)	9(E)	8	6/M	10
		4	9	6	MD(f)	10	7(E)	9(E)	8	6/M	10
		5	9–	8	MD(f)	10	5(E)	8(E)	8	6/M	9
	Port Hueneme	1	10	6	10	10	10	10	10	10	10
		2	9+	6	10	10	9(E)	10	9–	8/F	10
		3	9+	6	10	10	9(E)	10	8+	8/F	9
		4	9+	6	10	10	9(E)	10	8+	6/F	9
		5	9+	6	10	10	9(E)	10	8+	4/F	9

(continued)

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting		Protection	Blistering	Undercutting
							I	II			
	Kwajalein	1	9+	8	10	10	9(E)	10	8	2/M	10
		2	9	6	10	10	9(E)	10	8–	2/MD	10
		3	9–	6	10	10	9(E)	10	6	2/D	5
		4	9	6	10	10	9(E)	10	—	—	—
		5	9	6	10	10	9(E)	9(E)	—	—	—
3	Kaneohe	1	9	8	10	10	9(E)	10	9	6/MD	10
		2	9	6	8/F(E)	10	9(E)	9(E)	8+	6/MD	10
		3	9	6	10	10	9(E)	9(E)	8+	6/MD	9
		4	9	8	10	10	9(E)	9(E)	8+	6/MD	9(E)
		5	9	8	10	10	9(E)	9(E)	8+	6/MD	8
	Port Hueneme	1	10	8	10	10	10	10	10	8/F	10
		2	10	8	10	10	10	10	8+	6/F	10
		3	10	6	10	10	10	10	8	2/F	9
		4	10	6	10	10	10	10	8	2/F	9
		5	10	6	10	10	10	10	8	2/F	8
	Kwajalein	1	9+	8	10	10	9(E)	10	8+	2/M	10
		2	9	8	10	10	9(E)	10	8	2/M	8
		3	9	8	10	10	9(E)	9(E)	8–	2/D	5
		4	9	8	10	10	9(E)	9(E)	8–	2/D	4
		5	9	8	10	10	8(E)	9(E)	6	2/D	2
4	Kaneohe	1	9+	8	10	10	9(E)	10	9	8/MD	10
		2	9+	6	8/F(E)	10	9(E)	10	8+	6/MD	9
		3	9+	6	8/F(E)	10	9(E)	10	8+	4/MD	9
		4	9+	6	8/F(E)	10	8(E)	9(E)	8+	4/MD	9
		5	9+	6	8/F(E)	10	6(E)	8(E)	8+	4/MD	8
	Port Hueneme	1	10	8	10	10	10	10	9+	8/F	10
		2	10	6	10	10	10	10	8+	8/F	10
		3	10	6	10	10	10	10	8	2/F	9
		4	10	6	10	10	10	10	8	2/F	9
		5	10	6	10	10	10	10	8	2/F	8

(continued)

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting I	Rusting II	Protection	Blistering	Undercutting
	Kwajalein	1	9+	8	10	10	9(E)	10	8+	2/M	10
		2	9	6	10	10	9(E)	9(E)	8	2/MD	10
		3	9	8	10	10	9(E)	9(E)	8	2/D(f)	6
		4	9	4	10	10	9(E)	9(E)	8	2/D	6
		5	9	6	10	10	9(E)	9(E)	6	2/D	2
5	Kaneohe	1	9+	8	10	10	9(E)	10	9	6/M	10
		2	9	6	10	10	9(E)	10	8+	4/M	10
		3	9	6	10	10	9(E)	9(E)	8+	4/M	10
		4	9	8	10	10	9(E)	9(E)	8+	4/M	10
		5	9	8	10	10	8(E)	9(E)	8+	4/M	9
	Port Hueneme	1	10	8	10	10	10	10	10	8/M	10
		2	10	6	10	10	10	10	9–	6/M	10
		3	10	6	10	10	10	10	8+	6/M	10
		4	10	6	10	10	10	10	8+	6/M	10
		5	10	6	10	10	10	10	8+	6/M	9
	Kwajalein	1	10	8	10	10	10	10	8	2/F	10
		2	9+	8	10	10	9(E)	10	8	2/M	8
		3	9	8	10	10	9(E)	10	8–	2/MD	5
		4	9	6	10	10	8(E)	10	8–	2/D	5
		5	9	6	10	10	8(E)	9(E)	5	2/D	3
6	Kaneohe	1	9+	8	10	10	9(E)	10	9	6/MD	10
		2	9	6	8/F(E)	10	9(E)	10	8+	6/MD	10
		3	9	6	9	10	9(E)	9(E)	8+	4/MD	9
		4	9	6	9(E)	10	8(E)	9(E)	8+	4/MD	–
		5	9	8	9(E)	10	7(E)	8(E)	8+	4/MD	–
	Port Hueneme	1	10	8	10	10	10	10	10	8/F	10
		2	10	6	10	10	10	10	8+	6/M	10
		3	10	6	10	10	10	10	8+	6/M	9
		4	10	6	10	10	10	10	8	4/M	9
		5	10	6	10	10	9	10	8	2/F	9

(continued)

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels		
			Protection	Chaiking	Blistering	Undercutting Edges	Rusting I	Rusting II	Protection	Blistering	Undercutting
7	Kwajalein	1	9	8	10	10	9(E)	9(E)	8	2/F	10
		2	8+	6	10	10	8(E)	9(E)	8	2/M	9
		3	8	8	10	10	7(E)	8(E)	8–	2/D	6
		4	8	6	10	10	7(E)	8(E)	8–	2/D	5
		5	8	8	10	10	6(E)	7(E)	4	2/D	3
	Kaneohe	1	9+	8	10	10	8(E)	10	9	6/MD	10
		2	9	6	10	10	8(E)	9(E)	8	6/MD	10
		3	9	6	10	10	8(E)	9(E)	8	6/MD	9(E)
		4	8+	6	10	10	6(E)	8(E)	8	6/M	9
		5	8+	8	10	10	4(E)	6(E)	8	6/M	9
	Port Hueneme	1	10	8	10	10	10	10	9	8/F	10
		2	10	6	10	10	10	10	8+	8/M	10
		3	10	6	10	10	10	10	8+	8/M	9
		4	10	6	10	10	10	10	8	6/M	9
		5	10–	6	10	10	9(E)	10	8	4/F	9
8	Kwajalein	1	8+	8	10	10	6(E)	8(E)	8–	2/D	8(E)
		2	8–	6	4/D(E)	10	2(E)	4(E)	7	2/D	4(E)
		3	8–	8	4/D(E)	10	0(E)	2(E)	–	–	–
		4	8–	8	2/D(E)	2(E)	0/E	0/E	–	–	–
		5	4	8	2/D(E)	0	0/E	0/E	–	–	–
	Ka[illegible]	1	9	8	2/F(E)	8(E)	8(E)	8(E)	8	2/H	6
		2	8–	6	2/MD(E)	6(E)	4(E)	6(E)	7	2/H	4
		3	7	6	2/MD(E)	6(E)	3(E)	4(E)	–	–	–
		4	7	6	2/MD(E)	4(E)	0(E)	0(E)	–	–	–
		5	–	–	–	–	–	–	–	–	–
	Port Hueneme	1	9+	6	10	10	8(E)	10	9	8/F	10
		2	9	6	10	10	8(E)	9(E)	8	8/F	10
		3	9–	6	10	10	8(E)	8(E)	8–	2/F	6
		4	8+	6	10	10	8(E)	8(E)	8–	2/M	6
		5	8	6	8/F(E)	9(E)	7(E)	8(E)	7	2/MD	4

(continued)

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting		Protection	Blistering	Undercutting
							I	II			
9	Kwajalein	1	9+	8	10	10	9(E)	10	8+	2/F	10
		2	9	6	10	10	9(E)	9(E)	8	2/M	9
		3	9	8	10	10	8(E)	9(E)	8–	2/MD	6
		4	9	8	10	10	8(E)	9(E)	8–	2/D	6
		5	8+	8	10	10	8(E)	8(E)	5	2/D	3
	Kaneohe	1	9	8	10	10	8(E)	10	9	6/MD	10
		2	8+	6	10	10	7(E)	9(E)	8	6/MD	10
		3	8+	6	10	10	7(E)	9(E)	8	4/MD	9
		4	8+	8	10	10	7(E)	8(E)	8	4/MD	9
		5	8+	8	10	10	6(E)	7(E)	8	4/MD	9
	Port Hueneme	1	10	6	10	10	10	10	9+	6/F	10
		2	10	6	10	10	10	10	8+	4/F	10
		3	10	6	10	10	10	10	8+	2/F	9
		4	10	6	10	10	9(E)	10	8	2/F	9
		5	10–	6	10	10	9(E)	10	8	2/F	9
10	Kwajalein	1	9+	8	10	10	9(E)	10	8+	2/F	10
		2	9	6	10	10	8(E)	9(E)	8	2/M	9
		3	9–	8	10	10	8(E)	9(E)	8	2/MD	7
		4	9	8	10	10	7(E)	9(E)	8	2/MD	7
		5	8+	8	10	8(E)	6(E)	9(E)	7	2/D	3
	Kaneohe	1	9+	8	10	10	10	10	9	6/MD	10
		2	9	6	10	10	9(E)	10	8	6/MD	10
		3	9	6	10	10	9(E)	10	8	6/MD	9
		4	9	6	10	10	8(E)	9(E)	8	6/MD	9
		5	9	8	10	10	8(E)	9(E)	8	6/MD	9
	Port Hueneme	1	10	6	10	10	10	10	10	8/MD	10
		2	10	6	10	10	10	10	8+	8/MD	10
		3	10	6	10	10	10	10	8	2/F	9(E)
		4	10	6	10	10	9(E)	10	8	2/F	8(E)
		5	10–	6	10	10	9(E)	10	8	2/F	8

(continued)

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting I	Rusting II	Protection	Blistering	Undercutting
11	Kwajalein	1	9+	8	10	10	9(E)	10	8+	2/F	10
		2	9	6	10	10	9(E)	9(E)	8	2/M	9
		3	9–	8	10	10	9(E)	9(E)	8–	2/MD	7
		4	9	8	10	10	9(E)	9(E)	—	—	—
		5	8+	8	10	10	9(E)	9(E)	—	—	—
	Kaneohe	1	9	8	10	10	9	10	9	8/MD	10
		2	9	8	10	10	9	10	8+	4/MD	9
		3	9	6	10	10	8(E)	9(E)	8	4/MD	8
		4	9	8	10	10	8(E)	9(E)	8	2/D	6
		5	9	8	10	10	7(E)	9(E)	8	2/D	6
	Port Hueneme	1	10	6	10	10	10	10	10	8/M	10
		2	10	6	10	10	10	10	8+	8/MD	10
		3	10	6	10	10	10	10	8+	2/F	9
		4	10–	6	10	10	10	10	8	2/F	9
		5	10–	6	10	10	9(E)	10	8	2/F	9
12	Kwajalein	1	9	8	10	10	9(E)	9(E)	8	2/F	8(E)
		2	8+	6	10	10	6(E)	8(E)	8	2/M	8(E)
		3	8+	8	10	10	6(E)	7(E)	8–	2/MD	7
		4	8+	8	10	10	4(E)	5(E)	7	2/MD	6
		5	8	8	10	8(E)	4(E)	5(E)	—	—	—
	Kaneohe	1	9+	8	10	10	9(E)	10	9	8/MD	10
		2	9	8	10	10	7(E)	9(E)	8	4/MD	9
		3	8+	6	10	10	6(E)	8(E)	8	4/MD	9
		4	8+	6	10	10	6(E)	8(E)	7	2/M	7
		5	8+	8	10	10	4(E)	5(E)	—	—	—
	Port Hueneme	1	10	6	10	10	10	10	9+	8/F	10
		2	9	6	10	10	9(E)	9(E)	8+	8/M	10
		3	9	6	10	10	8(E)	9(E)	8+	2/F	9
		4	9	6	10	10	8(E)	9(E)	8	2/F	9
		5	9–	6	9(E)	9(E)	8(E)	9(E)	8	2/F	9

(continued)

System No.	Exposure Site	Years Exposed	Unscribed Panels						Scribed Panels		
			Protection	Chalking	Blistering	Undercutting Edges	Rusting I	Rusting II	Protection	Blistering	Undercutting
13	Kwajalein	1	9	8	6/F(E)	10	9(E)	9(E)	8	4/D	10
		2	8	6	6/F(E)	10	6(E)	8(E)	7	4/D	8
		3	8	8	6/F(E)	9(E)	5(E)	6(E)	–	–	–
		4	8	6	6/D(E)	8(E)	4(E)	6(E)	–	–	–
		5	8–	6	6/D(E)	7(E)	3(E)	5(E)	–	–	–
	Kaneohe	1	9+	8	10	10	10	10	8	6/D	10
		2	9	6	10	10	9(E)	10	8	4/D	8
		3	9	6	10	10	8(E)	9(E)	8–	4/D	6
		4	9	6	10	10	8(E)	9(E)	8–	4/D	6
		5	9–	8	10	10	7(E)	8(E)	8–	4/D	4
	Port Hueneme	1	10	6	10	10	10	10	9	4/M	10
		2	9+	6	10	10	9(E)	9(E)	8	4/M	9
		3	9–	6	10	9(E)	8(E)	9(E)	8–	2/M	7
		4	9–	6	10	9(E)	8(E)	9(E)	8–	2/MD	6
		5	8+	6	6/F	9(E)	8(E)	9(E)	7	2/D	4
14	Kwajalein	1	9+	8	10	10	9(E)	10	8+	4/F	10
		2	9	6	10	10	9(E)	9(E)	8	4/M	10
		3	9	8	10	10	9(E)	9(E)	8	2/M	8
		4	9	6	10	10	8(E)	9(E)	8	2/M	8
		5	9–	8	10	10	8(E)	9(E)	7	2/MD	5
	Kaneohe	1	9+	8	10	10	9(E)	9(E)	8+	8/M	10
		2	9	6	10	10	8(E)	9(E)	9–	6/M	10
		3	9	6	10	10	8(E)	9(E)	8+	6/M	9
		4	9	6	10	10	6(E)	8(E)	8+	6/M	9
		5	9–	8	10	10	5(E)	8(E)	8+	6/M	8
	Port Hueneme	1	10	6	10	10	10	10	10	8/M	10
		2	10	6	10	10	10	10	8+	8/M	10
		3	10	6	10	10	10	10	8+	2/F	9
		4	10	6	10	10	10	10	8	2/M	9
		5	10	6	10	10	10	10	8	2/M	8

[a] f = filiform blistering.

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