research analyses consultation
EFEH & ASSOCIATES
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13 April 1995

Mr. Owen Jones
Royal Chemical Corporation
P.O. Box 342
Gretna, Louisiana 70054

Dear Mr. Jones:

EFEH & Associates has completed a study of the various coatings and thicknesses submitted to the laboratory on 9 December 1994. These coated plates were tested for corrosion resistance using ASTM methods as detailed in the reports for each sample.

If you have any questions, please do not hesitate to contact the laboratory.

Sincerely,

Edwin B. Smith, III
Quality Assurance Manager

Test Type	Coating Identification	Blister Size min/max/avg, cm.	Blister Density blisters/sq. cm.	Percent of coated area removed by exposure	Appearance of Rust Areas
Atlas Cell	10 mil Rust Kote	None Found	Not Applicable	3%	tight orange rust, no substrate flaking
2000 Hour Salt Fog ISO-D-4624	7 mil Rust Kote	0.1/0.1/0.1	2.0	5%	tight orange rust, no substrate flaking
2000 Hour Salt Fog ISO-D-4624	5 mil Easy Kote	0.1/1.1/0.3	1.4	5%	tight orange rust, no substrate flaking
2000 Hour Salt Fog	5 mil Easy Kote	0.1/0.9/0.2	0.9	1%	tight orange rust, no substrate flaking
2000 Hour Salt Fog ASTM D3359	12 mil Easy Kote	0.1/0.5/0.2	1.8	0%	no rust areas noted
Immersion Test	14 mil Easy Kote	None Found	Not Applicable	0%	no rust areas noted
2000 Hour Salt Fog	16 mil Easy Kote	None Found	Not Applicable	0%	no rust areas noted
Immersion Test	16 mil Easy Kote	None Found	Not Applicable	0%	no rust areas noted
Immersion Test	17 mil Easy Kote	0.1/0.5/0.2	2.5	0%	no rust areas noted
2000 Hour Salt Fog	12 mil Easy Kote	0.2/0.9/0.4	1.6	3%	no rust areas noted
2000 Hour Salt Fog	20 mil Easy Kote, 2 mil Zinc Primer	0.6/1.1/0.7	0.1	0%	no rust areas noted
Immersion Test	14 mil Easy Kote, 2 mil Zinc Primer	0.2/1.0/0.4	1.0	0%	no rust areas noted
Atlas Cell	4 mil Rust Kote, 2 mil Zinc Primer	1.0/1.6/1.3	0.6	0%	tight orange rust, no substrate flaking
Atlas Cell	18 mil Rust Kote, 2 mil Zinc Primer	1.0/1.6/1.1	0.4	0%	tight orange rust, no substrate flaking

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Laboratory Number J-3345
Sample Identification 10 mils Rust Kote
Test Procedure Atlas Cell

PROCEDURE

This panel was maintained in an Atlas Cell for 2000 hours. The test panel was examined at 1000 and 2000 hours. Test chamber temperature was held constant at 35 C on one side of the cell and 98 C on the other (non-tested) side of the cell for the duration of the test. Filtered and circulated artificial sea water was used as the corrosive medium.

The artificial sea water was prepared by using 42 grams per liter of "Sea Spray" brand sea salts. This is in accordance with ASTM D1141 "Specification for Substitute Ocean Water".

At the evaluation points of 1000 and 2000 hours, ASTM method D1654 "Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments" was used as a reference.

FINDINGS

At the 1000 hour point, the coating passed visual inspection with only minor amounts of blistering and no portion of the coated plate area showing signs of corrosion.

A simple test for coating attachment was also performed at 1000 hours. This test was performed by moving a glass rod over the coated surface while pushing against the coating with a moderate degree of force. No coating was removed.

The coated plate was then placed back into the Atlas cell for the remainder of the 2000 hours exposure.

The test specimen was evaluated at 2000 hours exposure, using the same method as discussed above for the 1000 hour evaluation. No corrosion was found to this exposure point. Using the glass rod test less than 5% of the coating surface area could be removed. This is considered by EFEH & Associates to be a passing test specimen.

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Explanation of Test Procedures:

I. The 2000 Hour Salt Fog is a commonly used corrosion resistance test governed by several ASTM Standards such as B117. In this test, the test specimen is exposed in an environmental test chamber to an atmosphere of ambient air with anatomized sea water mist. Various modifications of the test can include temperature cycling and acid additions to the sea water. For these tests, the temperature was held constant at 35°C (95°F) for the entire 2,000 hours of exposure.

II. An Atlas cell was used to simulate the effects on the test specimen of a high temperature material on the uncoated side of the test coupon while exposing the coated side to a sea water environment. These tests are ultimately to simulate conditions inside a marine ballast tank with a high temperature cargo in the adjacent hold.

A diagram of the Atlas cell is attached. Water at 95°C (200°F) was circulated on the uncoated side of the test specimen. This side of the Specimen was protected from corrosive attack by attaching a copper foil to it. The coated side of the test specimen was exposed to circulated artificial sea water at ambient temperature.

III. The immersion test is designed to simulate constant exposure to sea water. The test specimen is immersed in constantly circulated, filtered artificial sea water. The artificial sea water was held at 35°C (95°F) for the test exposure duration.

IV. After exposure to one of the three corrosive environments described above, many of the test specimens were tested using a coating adhesion test, either ASTM D3359 or ISO-4624. These tests endeavor to remove coating from the exposed test specimen by using adhesive tape. Pass/Fail criteria or a rating are then assigned to the test specimen by the percent area of coating removed versus the total area pulled on by the adhesive tape.

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Laboratory Number	J-3345
Sample Identification	7 mils Rust Kote
Test Procedure	2000 Hour Salt Fog followed by ISO-4624 Pull off test

PROCEDURE

This panel was maintained in a salt fog environment per ASTM B117 for 2000 hours. The test panel was examined at 1000 and 2000 hours. Test chamber temperature was held constant at 35 C for the duration of the test.

The artificial sea water was prepared by using 42 grams per liter of "Sea Spray" brand sea salts. This is in accordance with ASTM D1141 "Specification for Substitute Ocean Water".

At the evaluation points of 1000 and 2000 hours, ASTM method D1654 "Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments" was used as a reference.

FINDINGS

At the 1000 hour point, the coating passed visual inspection with only minor amounts of blistering and less than 5% of the coated plate area showing signs of corrosion. Said corrosion was a light rust coating. The base metal in the corroded areas was not significantly degraded; and coating did remain on these areas.

A simple test for coating attachment was also performed at 1000 hours. This test was performed by moving a glass rod over the coated surface while pushing against the coating with a moderate degree of force. No coating was removed.

The coated plate was then placed back into the test chamber for the remainder of the 2000 hours exposure.

The test specimen was evaluated at 2000 hours exposure, using the ISO-4624 coating attachment test. Areas near the edge of the test specimen pulled away, but it is likely this is from the coating process or edge corrosion causing disattachment. Away from any edges of the test specimen, approximately 5% of the coated area was removed by the pull off test.

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Laboratory Number	J-3345
Sample Identification	5 mils Easy Kote
Test Procedure	2000 Hour Salt Fog followed by ISO-4624 Pull off test

PROCEDURE

This panel was maintained in a salt fog environment per ASTM B117 for 2000 hours. The test panel was examined at 1000 and 2000 hours. Test chamber temperature was held constant at 35 C for the duration of the test.

The artificial sea water was prepared by using 42 grams per liter of "Sea Spray" brand sea salts. This is in accordance with ASTM D1141 "Specification for Substitute Ocean Water".

At the evaluation points of 1000 and 2000 hours, ASTM method D1654 "Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments" was used as a reference.

FINDINGS

At the 1000 hour point, the coating passed visual inspection with only minor amounts of blistering and less than 5% of the coated plate area showing signs of corrosion. Said corrosion was a light rust coating. The base metal in the corroded areas was not significantly degraded; and coating did remain on these areas.

A simple test for coating attachment was also performed at 1000 hours. This test was performed by moving a glass rod over the coated surface while pushing against the coating with a moderate degree of force. No coating was removed.

The coated plate was then placed back into the test chamber for the remainder of the 2000 hours exposure.

The test specimen was evaluated at 2000 hours exposure, using the ISO-4624 coating attachment test. The coating was removed in blistered areas only (30 areas total), with no removed area larger than 0.125 inches in diameter.

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Laboratory Number	J-3345
Sample Identification	5 mils Easy Kote
Test Procedure	2000 Hour Salt Fog

PROCEDURE

This panel was maintained in a salt fog environment per ASTM B117 for 2000 hours. The test panel was examined at 1000 and 2000 hours. Test chamber temperature was held constant at 35 C for the duration of the test.

The artificial sea water was prepared by using 42 grams per liter of "Sea Spray" brand sea salts. This is in accordance with ASTM D1141 "Specification for Substitute Ocean Water".

At the evaluation points of 1000 and 2000 hours, ASTM method D1654 "Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments" was used as a reference.

FINDINGS

At the 1000 hour point, the coating passed visual inspection with no blistering and none of the coated plate area showing signs of corrosion.

A simple test for coating attachment was also performed at 1000 hours. This test was performed by moving a glass rod over the coated surface while pushing against the coating with a moderate degree of force. No coating was removed.

The coated plate was then placed back into the test chamber for the remainder of the 2000 hours exposure.

The test specimen was evaluated at 2000 hours exposure, using the same method as discussed above for the 1000 hour evaluation. The test specimen still showed no corrosion, and only minor blistering. The glass rod test removed coating only in the blistered areas. This removal represented less than 1% of the coated surface; and no removed area was greater than 0.0625 inches in diameter.

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Laboratory Number	J-3345
Sample Identification	12 mils Easy Kote
Test Procedure	2000 Hour Salt Fog followed by ASTM D3359 tape pulloff test

PROCEDURE

This panel was maintained in a salt fog environment per ASTM B117 for 2000 hours. The test panel was examined at 1000 and 2000 hours. Test chamber temperature was held constant at 35 C for the duration of the test.

The artificial sea water was prepared by using 42 grams per liter of "Sea Spray" brand sea salts. This is in accordance with ASTM D1141 "Specification for Substitute Ocean Water".

At the 2000 hour point the coating was subjected to ASTM D3359 attachment testing.

FINDINGS

At the 1000 hour point, the coating passed visual inspection with only minor amounts of blistering and less than 5% of the coated plate area showing signs of corrosion. Said corrosion was a light rust coating. The base metal in the corroded areas was not significantly degraded; and coating did remain on these areas.

A simple test for coating attachment was also performed at 1000 hours. This test was performed by moving a glass rod over the coated surface while pushing against the coating with a moderate degree of force. No coating was removed.

The coated plate was then placed back into the test chamber for the remainder of the 2000 hours exposure.

The test specimen was evaluated at 2000 hours exposure, using the ASTM D3359 coating attachment test. No coating was removed, except in areas where edge corrosion had occurred. This test specimen is considered to have passed ASTM D3359.

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Laboratory Number	J-3345
Sample Identification	14 mils Easy Kote
Test Procedure	Immersion test as described below

PROCEDURE

This specimen was exposed for 2000 hours to continuously refreshed artificial sea water. The artificial sea water was prepared by using 42 grams per liter of "Sea Spray" brand sea salts. This is in accordance with ASTM D1141 "Specification for Substitute Ocean Water". The test chamber was held at 35 C for the duration of the test.

FINDINGS

This test specimen showed no coating removal or base metal corrosion during the test. At the 2000 hour point, the plate was removed and subjected to moderate coating removal attempts using a glass rod. Only minor flaking of the coating was observed using moderate force on the glass rod. This test specimen is considered to have passed.

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Laboratory Number	J-3345
Sample Identification	16 mils Easy Kote
Test Procedure	2000 Hour Salt Fog

PROCEDURE

This panel was maintained in a salt fog environment per ASTM B117 for 2000 hours. The test panel was examined at 1000 and 2000 hours. Test chamber temperature was held constant at 35 C for the duration of the test.

The artificial sea water was prepared by using 42 grams per liter of "Sea Spray" brand sea salts. This is in accordance with ASTM D1141 "Specification for Substitute Ocean Water".

At the evaluation points of 1000 and 2000 hours, ASTM method D1654 "Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments" was used as a reference.

FINDINGS

At the 1000 hour point, the coating passed visual inspection with no blistering and none of the coated plate area showing signs of corrosion.

A simple test for coating attachment was also performed at 1000 hours. This test was performed by moving a glass rod over the coated surface while pushing against the coating with a moderate degree of force. No coating was removed.

The coated plate was then placed back into the test chamber for the remainder of the 2000 hours exposure.

The test specimen was evaluated at 2000 hours exposure, using the same method as discussed above for the 1000 hour evaluation. The test specimen still showed no corrosion. The glass rod test removed coating only along the plate edge, where a slight degree of edge corrosion had begun. This removal represented less than 1% of the coated surface. This test specimen is considered to have passed.

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Laboratory Number	J-3345
Sample Identification	16 mils Easy Kote
Test Procedure	Immersion test as described below

PROCEDURE

This specimen was exposed for 2000 hours to continuously refreshed artificial sea water. The artificial sea water was prepared by using 42 grams per liter of "Sea Spray" brand sea salts. This is in accordance with ASTM D1141 "Specification for Substitute Ocean Water". The test chamber was held at 35 C for the duration of the test.

FINDINGS

This test specimen showed no coating removal or base metal corrosion during the test. At the 2000 hour point, the plate was removed and subjected to moderate coating removal attempts using a glass rod. Only minor flaking of the coating was observed using moderate force on the glass rod. Slight corrosion was found at the plate edge only. This test specimen is considered to have passed.

EFEH & ASSOCIATES

Laboratory Number	J-3345
Sample Identification	17 mils Easy Kote
Test Procedure	Immersion test as described below

PROCEDURE

This specimen was exposed for 2000 hours to continuously refreshed artificial sea water. The artificial sea water was prepared by using 42 grams per liter of "Sea Spray" brand sea salts. This is in accordance with ASTM D1141 "Specification for Substitute Ocean Water". The test chamber was held at 35 C for the duration of the test.

FINDINGS

This test specimen showed no coating removal or base metal corrosion during the test. At the 2000 hour point, the plate was removed and subjected to moderate coating removal attempts using a glass rod. Only minor flaking of the coating was observed using moderate force on the glass rod. This test specimen is considered to have passed.

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Laboratory Number	J-3345
Sample Identification	12 mils Easy Kote
Test Procedure	2000 Hour Salt Fog

PROCEDURE

This panel was maintained in a salt fog environment per ASTM B117 for 2000 hours. The test panel was examined at 1000 and 2000 hours. Test chamber temperature was held constant at 35 C for the duration of the test.

The artificial sea water was prepared by using 42 grams per liter of "Sea Spray" brand sea salts. This is in accordance with ASTM D1141 "Specification for Substitute Ocean Water".

At the evaluation points of 1000 and 2000 hours, ASTM method D1654 "Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments" was used as a reference.

FINDINGS

At the 1000 hour point, the coating passed visual inspection with slight blistering and less than 1% of the coated plate area showing signs of corrosion.

A simple test for coating attachment was also performed at 1000 hours. This test was performed by moving a glass rod over the coated surface while pushing against the coating with a moderate degree of force. No coating was removed.

The coated plate was then placed back into the test chamber for the remainder of the 2000 hours exposure.

The test specimen was evaluated at 2000 hours exposure, using the same method as discussed above for the 1000 hour evaluation. The test specimen still showed slight corrosion, although the coating was blistered significantly (greater than 20% of the surface disattached). The glass rod test removed coating along the plate edge, where a slight degree of edge corrosion had begun as well as several of the blistered areas. This removal represented 5% of the coated surface.

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Laboratory Number	J-3345
Sample Identification	20 mils Easy Kote + 2 mil Zinc Primer
Test Procedure	2000 Hour Salt Fog

PROCEDURE

This panel was maintained in a salt fog environment per ASTM B117 for 2000 hours. The test panel was examined at 1000 and 2000 hours. Test chamber temperature was held constant at 35 C for the duration of the test.

The artificial sea water was prepared by using 42 grams per liter of "Sea Spray" brand sea salts. This is in accordance with ASTM D1141 "Specification for Substitute Ocean Water".

At the evaluation points of 1000 and 2000 hours, ASTM method D1654 "Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments" was used as a reference.

FINDINGS

At the 1000 hour point, the coating passed visual inspection with slight blistering and no area of the coated plate showing signs of corrosion.

A simple test for coating attachment was also performed at 1000 hours. This test was performed by moving a glass rod over the coated surface while pushing against the coating with a moderate degree of force. No coating was removed.

The coated plate was then placed back into the test chamber for the remainder of the 2000 hours exposure.

The test specimen was evaluated at 2000 hours exposure, using the same method as discussed above for the 1000 hour evaluation. The test specimen showed slight edge corrosion, although the coating was blistered significantly (greater than 20% of the surface disattached). The glass rod test removed no coating.

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Laboratory Number	J-3345
Sample Identification	14 mils Easy Kote + 2 mil Zinc Primer
Test Procedure	Immersion test as described below

PROCEDURE

This specimen was exposed for 2000 hours to continuously refreshed artificial sea water. The artificial sea water was prepared by using 42 grams per liter of "Sea Spray" brand sea salts. This is in accordance with ASTM D1141 "Specification for Substitute Ocean Water". The test chamber was held at 35 C for the duration of the test.

FINDINGS

This test specimen showed no coating removal or base metal corrosion during the test. At the 2000 hour point, the plate was removed and subjected to moderate coating removal attempts using a glass rod. Only minor flaking of the coating was observed using moderate force on the glass rod. This test specimen is considered to have passed.

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Laboratory Number	J-3345
Sample Identification	18 mils Rust Kote + 2 mil Zinc Primer
Test Procedure	Atlas Cell

PROCEDURE

This panel was maintained in an Atlas Cell for 2000 hours. The test panel was examined at 1000 and 2000 hours. Test chamber temperature was held constant at 35 C on one side of the cell and 98 C on the other (non-tested) side of the cell for the duration of the test. Filtered and circulated artificial sea water was used as the corrosive medium.

The artificial sea water was prepared by using 42 grams per liter of "Sea Spray" brand sea salts. This is in accordance with ASTM D1141 "Specification for Substitute Ocean Water".

At the evaluation points of 1000 and 2000 hours, ASTM method D1654 "Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments" was used as a reference.

FINDINGS

At the 1000 hour point, the coating passed visual inspection with only minor amounts of blistering and no portion of the coated plate area showing signs of corrosion.

A simple test for coating attachment was also performed at 1000 hours. This test was performed by moving a glass rod over the coated surface while pushing against the coating with a moderate degree of force. No coating was removed.

The coated plate was then placed back into the Atlas cell for the remainder of the 2000 hours exposure.

The test specimen was evaluated at 2000 hours exposure, using the same method as discussed above for the 1000 hour evaluation. Slight corrosion was found to this exposure point. Using the glass rod test none of the coating surface area could be removed. This is considered by EFEH & Associates to be a passing test specimen.

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Laboratory Number	J-3345
Sample Identification	4 mils Rust Kote + 2 mil Zinc Primer
Test Procedure	Atlas Cell

PROCEDURE

This panel was maintained in an Atlas Cell for 2000 hours. The test panel was examined at 1000 and 2000 hours. Test chamber temperature was held constant at 35 C on one side of the cell and 98 C on the other (non-tested) side of the cell for the duration of the test. Filtered and circulated artificial sea water was used as the corrosive medium.

The artificial sea water was prepared by using 42 grams per liter of "Sea Spray" brand sea salts. This is in accordance with ASTM D1141 "Specification for Substitute Ocean Water".

At the evaluation points of 1000 and 2000 hours, ASTM method D1654 "Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments" was used as a reference.

FINDINGS

At the 1000 hour point, the coating passed visual inspection with only minor amounts of blistering and no portion of the coated plate area showing signs of corrosion.

A simple test for coating attachment was also performed at 1000 hours. This test was performed by moving a glass rod over the coated surface while pushing against the coating with a moderate degree of force. No coating was removed.

The coated plate was then placed back into the Atlas cell for the remainder of the 2000 hours exposure.

The test specimen was evaluated at 2000 hours exposure, using the same method as discussed above for the 1000 hour evaluation. Slight corrosion was found to this exposure point. Using the glass rod test none of the coating surface area could be removed. This is considered by EFEH & Associates to be a passing test specimen.