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Applicability of an Autodeposited Organic Coating as a Primer for Agricultural Tractor Hitch Assemblies to Improve Corrosion Resistance

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Applicability of an Autodeposited Organic Coating as a Primer for Agricultural Tractor Hitch Assemblies to Improve Corrosion Resistance

APPLICABILITY OF AN AUTODEPOSITED ORGANIC COATING AS A PRIMER FOR AGRICULTURAL TRACTOR HITCH ASSEMBLIES TO IMPROVE CORROSION RESISTANCE

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CHAPTER I

INTRODUCTION

Background of the Study

Agricultural tractor hitch assemblies presented a surface that was difficult to paint because:

1. The nodular iron surfaces had a rough texture. Dip, brush, and spray application of conventional water borne or solvent borne paint was somewhat ineffective because the coating had a tendency to flow away from the peaks of the surface and into the valleys.

2. Application of the coating to the unit parts was difficult and expensive. This was compounded by the fact that the nodular iron parts were tempered after machining requiring paint application after tempering. This would require much hand labor to mask mating surfaces from paint.

3. The assembly was quite massive and made the use of high temperature cure electrocoating and powder coating economically unattractive. Some parts would not cure completely in our current electrocoating systems due to the thickness of the castings. Coverage of inaccessible or recessed areas was also a problem.

4. Spray painting of the hitch as an assembly presented problems of rust bleedout from joints in the assembly and recessed or inaccessible areas due to poor or no coverage of the surface by the spray paint.

5. Additional pre-painting of unit parts and plating of some parts was required to counteract the coverage difficulties with spray painting of the assembly.

Autodeposition referred to an immersion coating process that applied a uniform thickness, latex coating on ferrous substrates. The process was patented by Parker Amchem and was also sometimes referred to as autophoresis. Autodeposited coating provided the following advantages over conventional painting methods:

1. The coating was capable of covering recessed areas or areas inaccessible by other application methods.

2. A low temperature cure was available.

3. The coating provided uniform coverage of all surfaces, including rough textures.

Problem Statement

The problem of this study was to evaluate corrosion resistance of, adhesion of, and visual defects in the following coatings on nodular cast iron.

1. An autodeposited coating as a primer used in conjunction with a topcoat of green alkyd enamel.

2. Wet-on-Wet green alkyd spray enamel.

Statement of Purpose

The purpose of this study included:

1. The compatibility of an autodeposited primer with a nodular iron substrate and topcoat paint was determined by adhesion testing and visual inspection.

2. Corrosion resistance of an autodeposited coating and current topcoat enamel on nodular cast iron was determined using the American Society of Tests and Measurements (ASTM) B117-86 Salt (Fog) Spray Test Method.

Statement of the Need

The need for this study was based on (a) corrosion complaints (b) poor paint coverage of the hitch assemblies, and (c) implementation of a more stringent corrosion resistance specification.

According to Hurley (1992, September 15), agricultural tractor hitch corrosion was a significant problem, and autodeposited coatings should have been investigated as a possible solution to the problem. Corrosion represented the second largest customer complaint problem on equipment manufactured by one large midwestern firm (Hurley, 1992, November 09).

The majority of the hitch assembly was nodular iron that had a rough texture. This texture made it difficult to ensure uniform coverage by the conventional spray painting methods. The sprayed enamel tends to fill the recessed areas of the rough surface and leave the peaks exposed (Kimberley, 1993). Recessed areas of the assembly were also difficult to paint properly by spray painting. These problems were overcome by the autodeposition method of paint application.

Improvements in the current coating technology were identified as necessary, and updated specifications with more stringent requirements had been written. These stricter requirements were being put on new part drawings (Hurley, 1992, September 15).

Research Questions

The research questions asked in this study were:

1. Would the autodeposited coating and topcoat combination provide superior salt spray performance in comparison to the old method of spray painting nodular iron hitches?

2. Would the development of a uniform coating on the rough textured surface provide an advantage to the autodeposited coating?

3. Would the level of adhesion to the base material and between the coating and topcoat meet the requirements of Class 3B when tested according to the ASTM D3359-87 test method?

Assumptions

The assumptions made in this study were:

1. ASTM Test Method B117-86 was an acceptable standard test to determine comparable corrosion resistance of the coatings and substrate in this study. This assumption was based on the fact that the ASTM test was part of our engineering standard for this coating.

2. Scrap parts cut up for test specimens were representative of normal production parts that would be assembled onto tractors.

3. A topcoat cure of 24 hours at 74 C (165 F) was assumed to provide full cure of the coating.

4. Test panel size was not critical since creepback was measured from a scribe, surface rust was evaluated as a percentage, and adhesion loss was checked in a small area.

Limitations

The limitations of this study were:

1. In this study, test evaluation was limited to a nodular iron substrate, an autodeposition coating, and the spray enamel used in our spray paint system.

2. This research is applicable to the types of coatings evaluated on the specific substrates used in the study.

3. Salt spray testing compared 15 test panels coated using the old painting method to 15 panels coated with autodeposited material followed by a topcoat of enamel from our paint line.

4. Machinability, chemical resistance, abrasion resistance, and field service of the coating combinations were not evaluated.

5. Filiform corrosion was not investigated.

6. Environmental advantages of the autodeposition process were not discussed in this study.

Definition of Terms

The definitions in this study were:

"American Society of Tests and Measurements (ASTM) was an organization that developed, evaluated, and certified testing and measurement procedures so that industry-wide standardized procedures were established." (Kramer, 1982, July)

Autodeposition was a generic term used to describe a method of applying a uniform organic film on a metal surface (Broadbent, 1986, March). This process was sometimes referred to as autophoresis.

Blistering resulted from hollow bubbles or water droplets in a paint film. These defects were usually caused by expansion of moisture trapped beneath the film.

Creepback was the perpendicular distance that a coating looses adhesion to a substrate as measured in one direction from a scribed area. This measurement was used as an evaluation tool for coatings that had been exposed to corrosion testing.

Electrocoating was an electrically deposited organic film typically applied as a corrosion resistant coating.

"Filiform Corrosion described a threadlike corrosion that occurred under coatings on steel substrates" (Roobol, 1992, December).

Fisheyes were paint defects that extended to the coating or bare metal underneath the paint film.

Induction hardening was the heat treatment process that used a magnetically induced field to heat a part and change the metallurgical properties of the material.

Mil was one thousandths of an inch. This was a term commonly used in description of paint or plating thickness.

Pinholes were small (normally less that 1 mm diameter) holes in the coating that extended to the substrate.

Scale was the iron oxide film left on the surface of iron castings or steel as a result of operations such as tempering.

Solvent Wash was the tendency of most of the coating in a recessed area to wash away as a result of solvent reflux into that location.

Tempering was the heating of a heat treated part to adjust the hardness to a certain selected range of values.

Throwing Power was the ability of a coating to cover internal surfaces as well as external surfaces.

Topcoat was defined as the final or finish coat of paint applied to a surface.

Chapter II

REVIEW OF LITERATURE

According to Riders (1992, June), one study estimated that 4% of the United States Gross National Product was consumed as a result of corrosion. Broadbent (1986, March p. 16) quoted Dr. George E. F. Brewer as saying "Probably the most promising new method for the application of paint is called autodeposition. It is endowed with 100 percent throwing power. Thus paint films are deposited in otherwise inaccessible areas." This is a definite advantage over spray or electrocoating materials when used for assemblies or parts that have inaccessible areas such as tubing.

Autodeposition is a waterborne process that had been in commercial use since 1973. The mildly acidic bath reacts with steel to dissolve iron and deposit a coating on the surface of the steel. Parker Amchem, a division of Henkel Corporation, holds the patent rights to this process (Henkel Corporation, 1991, September). Historically, the coating thickness was controlled in the range of 0.75 to 1.25 mils (Wagg, 1986, July). Automotive uses of autodeposition have increased due to the cost effectiveness of the coating, performance of the coating, and environmental advantages over other coating processes. There were more than 1.1 million square feet of part surfaces coated with autodeposited material for automotive use each week of 1991 (Roberto & Hart, 1991).

Agricultural tractor hitch assemblies consisted of a complex group of bare steel, electrocoated steel, zinc plated steel, chrome plated steel, phosphate and oil coated steel, and nodular iron. The vast majority of the surface was nodular iron. Some areas of these assemblies were not very amenable to painting with a spray or brush-on enamel paint or electrocoating due to accessibility. The nodular iron parts were shot blasted, machined, and then induction hardened and tempered. This did not allow for priming before machining due to the high temperature of the induction hardening and tempering operations. The surface finish was rough as a result of the casting process and the shot blasting operation. An advantage of the autodeposition process was the ability to provide a very uniform coating thus reducing the effects of surface texture (Henkel Corporation, 1991, September). Scale was left on the nodular iron hitch parts from the induction hardening and tempering operations. Nelson (1987) determined that autodeposited coatings provided a good coating on cold rolled steel and our cast iron, but coating on hot rolled steel was only fair. This difficulty with coating quality was confirmed by Jones's (1987) lab work on scaly parts from another facility. In either case nodular iron with or without scale was not evaluated. It was unknown whether the nature of the nodular iron scale was different from the hot rolled steel scale. Nelson (1987) showed that coating of zinc galvanized steel was poor. However more recent information shows good performance over zinc-nickel and zinc-cobalt alloy electroplated steel (Henkel Corporation 1992, March).

The spray painting application which was used, employed a minimum of two applications of paint but was still inadequate to provide complete coverage of the surfaces. Brush, pre-assembly painting of some areas was required to ensure complete paint coverage. Zinc electroplating was added to some parts in an attempt to compensate for the shortcomings of the spray and brush painting methods (Kimberley).

The assembly was well suited to a dip type of paint application method (Kimberley). However, Jones (1991) states that conventional dip coatings suffer from what was termed "solvent wash" which was the tendency of most of the coating in a recessed area to wash away as a result of solvent reflux into that location. One major advantage of autodeposition was the ability to coat subassemblies and fully assembled parts (Autodeposition at atwood automotive, 1991, June).

Chapter III

METHODOLOGY

Statement of Procedure

The testing followed a posttest only true experimental design. Subjects received coatings applied by the old or new method and were tested together.

Subjects

Test panels were made by cutting up sections of nodular iron castings after the annealing process to provide the surface conditions that would be present in assembly. Test panel size varied, based on the castings available. Sixty-three panels were made from the scrap castings that were available at the time. Each panel was stamped with a different number from one through 63 using a steel stamp and hammer.

Randomized selection of the test panels used for the old spray painting method (baseline) and experimental treatment was employed. The first 20 numbers randomly selected were sent to Parker Amchem, the second 20 panels selected were sent to another supplier (for a subsequent study), and the last twenty panels selected were retained for the baseline parts. Two of the remaining three panels were discarded. The third untreated panel was retained to calibrate the thickness tester on the machined surface of the casting. The results of the random selection are shown in Table 1. The random panel number is the number stamped on the test panel. The selection sequence number represents the order in which the panel numbers were selected. For example, panel number 43 was selected first and was sent to Parker Amchem for autodeposition.

Table 1: Random Panel Selection

Random Panel Number	Scaly Surfaces	Rusty Surfaces	Selection Sequence Number		Random Panel Number	Scaly Surfaces	Rusty Surfaces	Selection Sequence Number
43	n	n	1		11	n	n	35
3	n	y	2		25	y	y	36
7	n	n	3		41	n	n	37
62	n	y	4		40	n	n	38
14	y	n	5		19	y	y	39
38	n	n	6		61	heavy	n	40
33	y	n	7		28	n	n	41
23	n	n	8		30	y	n	42
47	n	n	9		8	n	n	43
4	n	y	10		39	n	n	44
49	heavy	n	11		54	y	y	45
46	n	n	12		22	y	y	46
36	n	n	13		48	n	n	47
2	y	y	14		16	y	y	48
45	n	n	15		51	y	n	49
42	n	y	16		15	y	n	50
50	heavy	n	17		59	heavy	n	51
26	n	n	18		18	n	n	52
34	y	n	19		17	n	n	53
63	n	y	20		10	n	y	54
55	n	n	21		9	n	y	55
6	n	n	22		20	n	y	56
32	y	y	23		37	n	n	57
58	heavy	n	24		52	n.	n	58
27	y	y	25		53	y	n	59
29	n	n	26		24	n	y	60
31	y	y	27		57	heavy	n	61
44	n	n	28		21	n	y	62
5	n	n	29		60	heavy	n	63
35	y	y	30					
1	y	y	31					
56	heavy	n	32					
12	n	y	33					
13	n	y	34					

The surface condition of the panels was recorded in case there appeared to be some effects on the results. The panels that received the autodeposited coating were acid cleaned by the supplier to remove any scale or rust, thus negating any further analysis of the effect of scale or rust on the treatment panel results. The panels receiving the wet-on-wet coating were processed in the same manner as the assembly would be processed. Acid cleaning was not employed in this case. The panel numbers and salt spray test results were listed in Table 2.

Table 2: Effects of Scale and Rust on Adhesion

Random			Selection	Creepback in	Per Cent
Panel	Scaly	Rusty	Sequence	Salt Spray	Rusty
Number	Surfaces	Surfaces	Number	mm	Surface
54	y	y	45	0.25	10
37	n	n	57	0.5	40
30	y	n	42	0.75	40
51	y	n	49	1	15
16	y	y	48	1.2	35
53	y	n	59	2	25
17	n	n	53	2.5	10
8	n	n	43	peeled	2
39	n	n	44	peeled	3
22	y	y	46	peeled	7
15	y	n	50	peeled	3
59	heavy	n	51	peeled	3
18	n	n	52	peeled	5
52	n	n	58	peeled	30
24	n	y	60	peeled	5

Seven of the fifteen wet-on-wet panels tested in the salt spray cabinet passed the 3 mm maximum creepback requirement. The remaining eight panels failed by peeling of the coating. There did not appear to be a relationship between the peeling failure and the presence of scale or rust. Two of the panels that passed the test were free of scale and rust while three of the panels that failed were rust and scale free. Three of eight panels that peeled had observable scale before the coating. Five of the seven panels that did not peel had visible scale before coating. Two panels in each case (peeled and not peeled) had some rust present before the coating process. It appears that factors other than scale and rust are responsible for adhesion of the baseline coating. Peeling of the coating was much more obvious on the machined surfaces than on the "as cast" surfaces. This was believed to be due to mechanical bonding of the coating to the rough, "as cast" surface. The cleaner-phosphater used before spray painting did not provide an adequate base to which the spray enamel could bond.

The baseline method of paint application used a two stage washer and a wet-on-wet airless spray process to apply two coats of the same green, alkyd, solventborne, topcoat enamel. The washer contained a cleaner-phosphater in the first stage and a tap water rinse in the second stage. The purpose of applying the paint wet-on-wet was to increase the thickness of the coating without requiring that the parts take two trips around the conveyor. The solventborne paint use was formulation 11-A140A alkyd enamel.

Application of the autodeposited coating was done at the chemical supplier's facility. Table 3 provided the process steps followed and their purpose. The order of the steps is from top to bottom of the table.

Table 3: Autodeposition Process Steps

Process Step	Purpose
Alkaline Clean	Remove oil and dirt
Tap Water Rinse	Remove cleaner from the previous step
Acid Clean	Remove scale and rust
Tap Water Rinse	Remove acid from the previous step
Alkaline Clean	Neutralize
Tap Water Rinse	Remove cleaner from the previous step
DI Water Rinse	Deionized water to prevent contamination of the coating bath
Coat with ACC 866	Coating of the substrate
Tap Water Rinse	Remove unreacted coating
Reaction Rinse	Improve corrosion resistance of the coating

Upon completion of the process steps outlined in Table 3 the supplier cured the parts in a gas-fired oven at 109 C (230 F) for 30 minutes to ensure full cure of the coating and to enhance corrosion resistance. The process steps, application methods, concentrations, times, and temperatures were provided in Appendix A.

Application of the topcoat was done in-house using the same two stage washer and airless spray paint application of the same alkyd enamel as used for the baseline parts. A single coating of the topcoat material was used on these panels. Both sets of panels were processed through the system at the same time.

All coated test panels were then submitted to a 24 hour cure at 74 C (165 F) to simulate full cure of the coating prior to testing.

The coating thickness was checked on the panels that had machined surfaces. The thickness of the autodeposited coating, the autodeposited coating and topcoat applied to it, and the wet-on-wet coatings were checked.

Thirty samples, 15 with each treatment, were scribed with two lines at 90 degrees. These panels were then randomly placed in the salt spray cabinet for test.

Instruments

Thickness of the coatings was checked using a CMI International Minitest 1000S and an F1(10) probe which is for non magnetic coatings on ferrous substrates. The machined surface of panel number 21 and the 1.93 mil thick plastic shim provided with the instrument were used to calibrate the tester. The panels were checked at room temperature.

A Harshaw Model 21 salt spray cabinet was used to run the salt spray test. The procedure was run according to ASTM B117-86. Test panels were scribed and hung using plastic clips. Test panels were evaluated after completion of 168 and 255 hours.

Crosscut adhesion was run with a knife and a metal straight edge. Tape used for the coating removal was according to the ASTM

D3359-87 test method specification. Adhesion was checked after the salt spray test was performed.

Visual inspection was done by the unaided eye to determine if any obvious defects were present. The defects could include blistering, loss of gloss of the topcoat, color change, fisheyes, lifting of the coating, or pinholes.

Test Procedure

A single variable true experimental design was used in this study. A posttest-only group design was employed. The coating combination used was the independent variable. The resulting creepback and spot rusting in the salt spray test, adhesion level attained, and visual defects were the dependent variables. Salt spray testing and visual inspection were performed on the cast and machined surfaces. Adhesion testing was performed only on the machined surfaces because of the difficulty with scribing an as-cast surface.

The procedures followed in this analysis were listed below:

1. Corrosion resistance was performed using the accelerated salt (fog) spray corrosion test specified in ASTM B117-86. Test panels were evaluated for creepback (loss of adhesion) from a scribed area and the percentage of the surface that was rusty. Monitoring of the salt spray cabinet was performed daily during the regular work week. The items monitored included the salt solution collection rate, solution pH, wet bulb temperature and dry bulb

temperature. The data collected was provided in Appendix B. Ratings were in accordance with ASTM D1654-79a.

2. Cross-cut adhesion was performed in accordance with the test method outlined in ASTM D3359-87.

3. The coating thickness test was performed in accordance with ASTM D1186-87, Method B.

CHAPTER IV

RESULTS

Testing

Thickness Testing

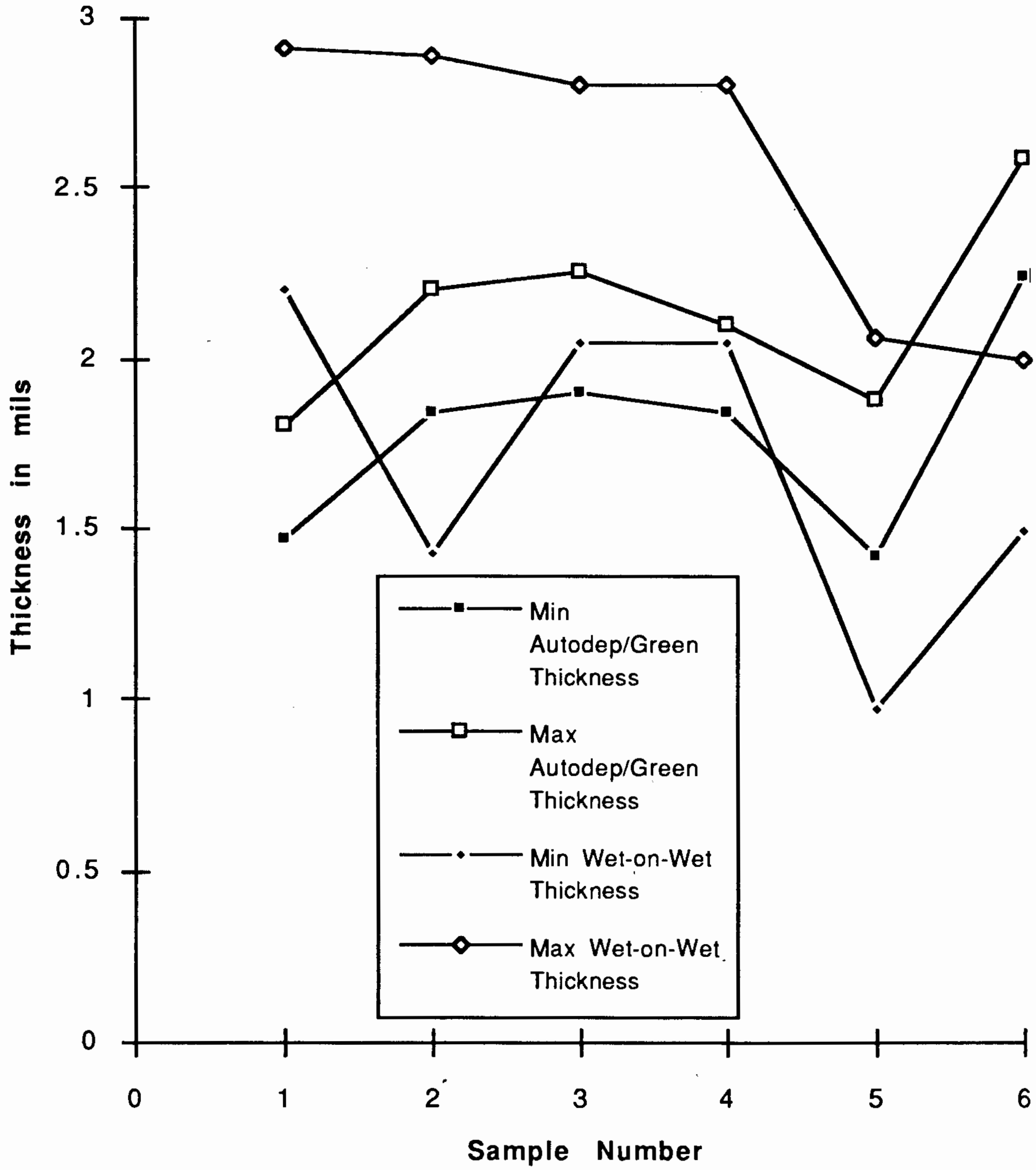
Test panels were checked to determine if there was a significant difference in total coating thickness between the two treatments. Six panels receiving each treatment were checked, The panels checked were chosen because they had machined surfaces that were smooth enough to get accurate readings with the thickness testing instrument. An Excel spreadsheet was used to determine the mean thickness of the two coatings applied to each panel. The actual thickness check data and mean thicknesses were provided in Appendix D.

Figure 1 was used to show that the ranges of thickness for the two treatments were similar. The maximum and minimum checks on the twelve panels (six receiving each treatment) mentioned earlier were provided in the figure. The two treatments had similar thickness ranges. The baseline method displayed more variability as would be expected of this process since it was more operator dependent than the autodeposition portion of the other method.

Salt Spray

The test was run according to ASTM B117-86. The pH and collection rate fell outside the specified range in a couple of instances. This was not felt to be a significant problem since all panels were tested concurrently.

Figure 1: Coating Thickness Information



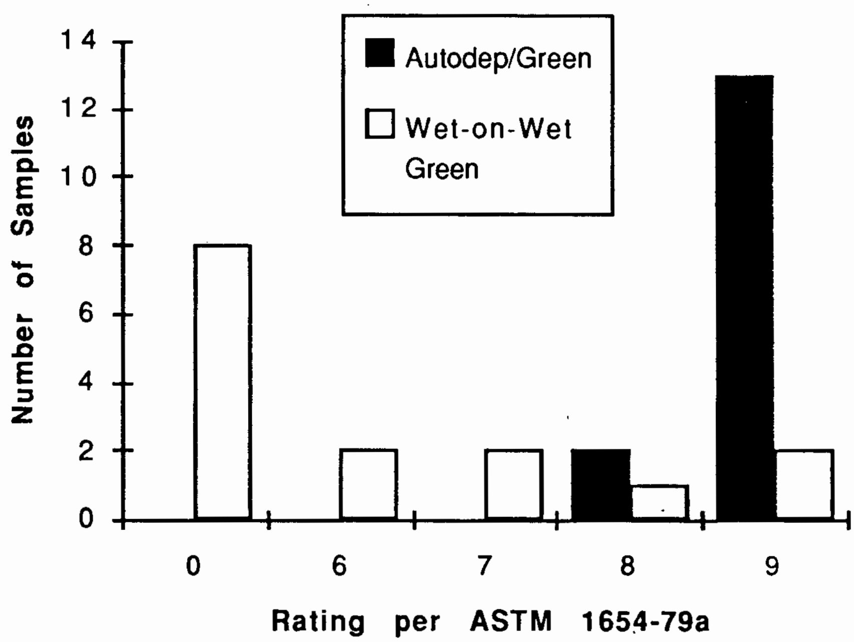
Readings were taken at 168 hours (without scraping) of testing and 255 hours. The test data from the 168 hour check is provided in Appendix B. Upon completion of the 255 hours of salt spray testing the panels were scraped according to Method 2 of ASTM D1654-79a. Thirty samples, fifteen from each group, were then evaluated for creepback (loss of adhesion) from the scribed area. Panels that exhibited large areas of adhesion loss were not measured because of the catastrophic nature of the failure. These panels were reported as peeled rather than by a creepback distance. The distance across the creepback area, perpendicular to the scribe, was measured in six locations on each scribed line of the remaining panels. The mean of the twelve measurements per panel was calculated on an Excel worksheet and then divided by two to arrive at the arithmetic average creepback distance per ASTM D1654-79a. A rating was then applied to each sample according to ASTM D1654-79a. The 255 hour creepback test ratings are summarized in Tables 4 and 5 and Figure 2.

The test data in figure 2 showed the creepback results of the salt spray test. The higher the rating number the better the coatings performed. The rating scale was from 10 for no removal to zero for over 16 mm removal. A rating of 5 to zero was a failure. In this chart the autodeposition panels were represented by the black bars, while the wet-on-wet panels were represented by the white bars.

The autodeposition and green panels performed better and with less variation from panel to panel. Thirteen of the fifteen autodeposition and green samples received a rating of nine. The other two panels received a rating of eight. All panels passed the salt spray test. The highest creepback on any autodeposition and green panel was 0.56 millimeters on panel number 47.

Eight panels from the baseline (wet-on-wet) process displayed peeling of the coating after completion of the test and thus received a zero rating. Two panels each received a rating of six, seven, and nine while one panel received a rating of eight. Therefore eight of the baseline panels failed the test, and seven panels passed.

Figure 2: Salt Spray Test Creepback Results



The data collected on the autodeposition and green enamel panels was provided in Table 4. The data collected on the wet-on-wet green enamel panels was provided in Table 5.

Table 4: Autodeposition and Green Enamel Salt Spray Test Results

Random Number	Creepback in mm	Rating	% Rust	Rating	Selection Number
45	0.42	9	4	7	15
47	0.56	8	3	8	9
43	0.27	9	2	8	1
4	0.27	9	2	8	10
26	0.12	9	3	8	18
62	0.31	9	3	8	4
2	0.48	9	2	8	14
46	0.54	8	1	9	12
50	0.38	9	1	9	17
63	0.33	9	1	9	20
14	0.12	9	1	9	5
23	0.47	9	1	9	8
49	0.42	9	1	9	11
36	0.42	9	1	9	13
33	0.25	9	0	10	7

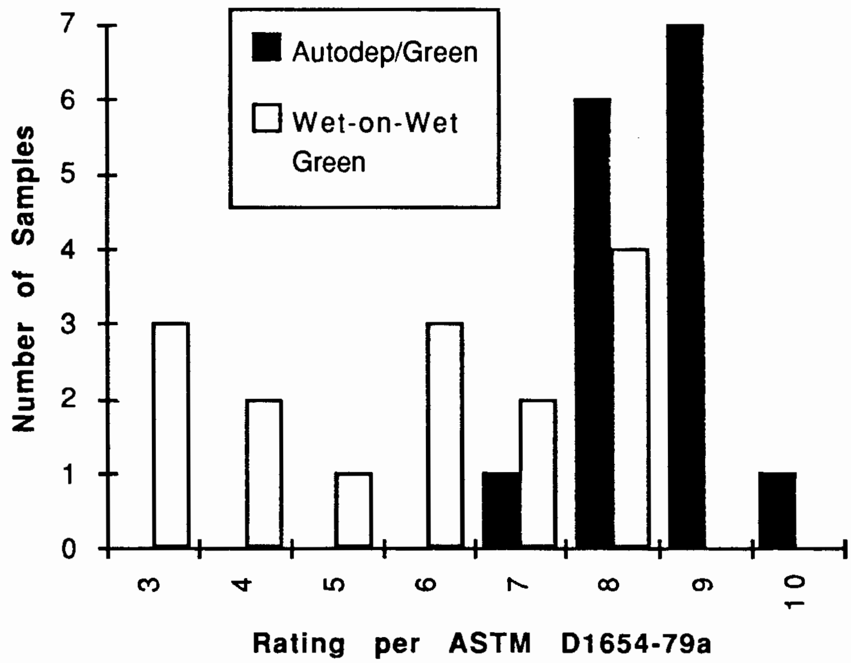
Per cent of the surface that was rusty was evaluated on the scribed surface of the panel. A rating per ASTM D1654-79a was then applied to each sample. Areas where peeling of the coating

Table 5: Wet-on-Wet Green Enamel Salt Spray Test Results

Random Number	Creepback in mm	Rating	% Rust	Rating	Selection Number
16	1.2	7	35	3	48
30	0.75	8	40	3	42
37	0.5	9	40	3	57
52	peeled	0	30	4	58
53	2	6	25	4	59
51	1	7	15	5	49
22	peeled	0	7	6	46
17	2.5	6	10	6	53
54	0.25	9	10	6	45
18	peeled	0	5	7	52
24	peeled	0	5	7	60
8	peeled	0	2	8	43
39	peeled	0	3	8	44
59	peeled	0	3	8	51
15	peeled	0	3	8	50

from the scribe occurred were not considered as part of this evaluation. The ratings were summarized in Tables 4 and 5 and Figure 3. Here, again, the black bars represented the autodeposition and the white bars the wet-on-wet green. A higher rating number indicated the coating performed better in the test. The per cent rust was not used as one of the criteria to determine if the coatings passed or failed the test but was shown for informational purposes.

Figure 3: Salt Spray Test Rust Rating Results



The autodeposition and green panels performed better and with less variation from panel to panel. One panel each received a rating of seven and ten, while six and seven panels received ratings of eight and nine respectively.

Three Wet-on-Wet panels were rated three and six. Two panels were rated four and seven. One panel was rated five, and four panels were rated eight. The most rusting was generally observed on the panels with the roughest surface finish. Evaluation of only the areas unaffected by the peeling of the coating resulted in high ratings for seven of the eight panels that peeled. The peeled panels included four rated as eight, two rated as seven, and one rated as six. Although the paint peeled from the baseline panels they were not rusty in the areas that peeled. The baseline panels would have been rated much worse if the peeled areas were included in the evaluation of the rusty surface.

Adhesion

It should be noted that four autodeposition samples and one wet-on-wet sample were cross-cut for the adhesion test. There are two reasons for this: (a) the cast surfaces of some panels were not scribed because of the difficulty ensuring a cut through the coatings and (b) eight of the wet-on-wet coatings peeled from the substrate as a result of the salt spray test. Ratings for the test were in the range from 5B to 0B. A rating of 5B represented zero removal while a 0B represented greater than 65% removal. Ratings of 2B, 1B, or 0B indicated greater than 15% removal of the coating which was considered a failure. The results of the test were given in Table 6.

Table 6: Adhesion Results

	255 Hours
Autodep & Green	3B to 4B
Wet-on-Wet Green	0B to 3B

The table indicates that adhesion of the wet-on-wet parts was in the range of 0B to 3B. Eight of nine machined samples had catastrophic failure (peeling) of the coating in the salt spray test resulting in a rating of 0B. The one remaining sample was cross-cut and received a 3B rating. The baseline panels failed the adhesion test.

The initial adhesion check on panel number 33 (autodep and green) gave a 2B rating. However, the scribing was done in several passes that resulted in multiple scribe lines. For this reason the result was disregarded and the test was redone on this panel. This panel was rechecked in two locations resulting in 4B and 3B ratings. The loss of adhesion is more prevalent between the autodeposited coating and the topcoat than the autodeposit and the substrate. The autodeposition and green coated panels passed the cross-cut adhesion test. Some blistering of the green enamel topcoat was noted. This adhesion problem was between the green enamel and the autodeposition coating. This problem was not prevalent in the area where adhesion was checked. If it had been, it is expected that this coating combination would have failed by a loss of intercoat adhesion.

Visual Inspection

Some blistering of the topcoat was observed on ten of the autodeposition panels after salt spray testing, during the scraping operation. The problem appeared to be one of intercoat adhesion (failure of the topcoat to stick to the primer). This blistering was obvious only on the machined surfaces but was not obvious after the panels were allowed to stand at room temperature for two days. For this reason the blistering was not evaluated. Black spots as seen in Figures 4 and 5 were evidence of the topcoat adhesion loss. Two autodeposition panels had a grainy appearance that is believed to be dirt in the paint.

Eight baseline panels exhibited severe peeling of the paint during the scraping of the panels after completion of the salt spray test. Figure 4, panel 15, shows the peeling problem. Four panels showed some blistering of the coating in areas not adjacent to the scribe.

Figure 4: Salt Spray Test Creepback Examples
Left panel autodeposition, Right panel baseline

In Figure 5 the loss of adhesion on the baseline panel (number 17) was not as severe as in the case of the baseline panel (number 15) shown in Figure 4. This was, in part, believed to be due to the rough texture of panel 17 providing some mechanical bonding of the coating.

Figure 5: Salt Spray Test Creepback Examples
Left panel baseline, Right panel autodeposition

Five wet-on-wet panels showed a visual discoloration of the paint on the surface being evaluated. Some areas of the panels exhibited a blue color. This color change was unexplained. The color change did not show through on the picture in Figure 6 but was evident on panel 37. The color change was limited to the baseline panels. The paint formulation used did not contain any iron blue pigment so the color change is not simply the leaching of the yellow pigment (Horton, 1993, March 16).

Figure 6: Salt Spray Test Per Cent Rust Examples
Left panel baseline, Right panel autodeposition

The per cent of rust on the surface of the panels was believed to be related to the roughness of the nodular iron surface. The visually rougher surfaces generally displayed the higher per cent of rust. If peeling of the coating was from the scribe, this area was ignored in the evaluation of per cent rusty surface. This may have provided a better rating for some panels due to the large peeled area that was not considered in the evaluation.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

Poor corrosion resistance of nodular iron hitch parts prompted a study to evaluate the acceptability of an autodeposition coating as a primer for this type of part or assembly.

Standardized tests were used to evaluate corrosion resistance and adhesion of a production coating method used on cast nodular iron to an experimental treatment. The two coating schemes evaluated were autodeposition with an alkyd enamel topcoat (experimental treatment) and a wet-on-wet application of the same alkyd enamel topcoat. Testing included: salt spray testing according to ASTM B117-86 and adhesion according to ASTM D3359-87. Results are reported as a creepback rating and a percentage rusty surface rating according to ASTM D1654-79a and adhesion class according to ASTM D3359-87.

Test panels, made from actual parts, were used in the tests.

Comments on the visual observations are included along with pictures of some of the test specimens.

Conclusions

Total thickness of the coating combinations appeared to be comparable based on a limited number of sample parts. The wet-on-wet process showed more variability in coating thickness.

The collection rate and pH of the salt solution fell outside the specified range for the salt spray test. This is not believed to be significant, since the panels were randomly placed in the cabinet and were all run at the same time. The pH being out of range could have caused the color change exhibited by the baseline panel coating, but this did not explain the absence of the color change in the panels with the autodeposition coating.

Autodeposition and green panels passed the 3 mm creepback criteria of the salt spray test. Adhesion test results were in the acceptable range of 3B to 4B. A small number of samples were evaluated, so statistical significance was not determined. It should be noted that the adhesion test was performed after the salt spray test that may have had some deleterious effects on the results. This is, however, the normal procedure for this type of evaluation. This coating also performed well with regard to the per cent rust on the surface. This was believed to be due to the ability of the autodeposition coating to cover rough surfaces evenly. Blistering of the topcoat was not explained. The blistering did subside after the panels were allowed to stand over the weekend.

The baseline process failed the creepback and the adhesion tests. This indicated that the production process used to coat these panels was unacceptable. Some mechanical bonding appeared to have helped the creepback results on the "as cast" surfaces of some parts. The per cent rusting was higher on the rougher baseline parts. This was believed to be due to the inability of the spray process to cover the peaks of the surface and that the areas where the coating peeled where not included in the evaluation.

Recommendations

Autodeposition and green enamel provided a significant improvement in corrosion resistance when it was compared to wet-on-wet spray painting. Further study recommendations included:

1. A determination of the economic viability of autodeposition on hitch assemblies should be done.

2. The cause of the blistering of the green enamel topcoat should be determined.

3. Parker Amchem should be used to coat a complete assembly for field test.

4. Autodeposition should be evaluated with lead and chrome free paints.

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Appendix A:- Autodeposition Process Steps

Process Step	Application Method	Concentration	Time in minutes	Temperature in degrees F
Alkaline Clean	Spray	5% v/v	1	180
Tap Water Rinse	Spray		0.5	Ambient
Acid Clean	Dip	20% v/v	2	Ambient
Tap Water Rinse	Dip		0.5	Ambient
Alkaline Clean	Dip	5% v/v	2	180
Tap Water Rinse	Dip		0.5	100
DI Water Rinse	Dip		0.5	Ambient
Coat with ACC 866	Dip	6% v/v	1.5	70
Tap Water Rinse	Dip		1	Ambient
Reaction Rinse	Dip	0.85% v/v	1	Ambient

Appendix B: 168 Hours Salt Spray Test Results

Autodeposition and Green Enamel					
Random Number	Creepback in mm	Rating	% Rust	Rating	Selection Number
4	0.25	9	2	8	10
62	0.5	9	2	8	4
46	1	8	1	9	12
26	0.25	9	1	9	18
23	0.5	9	1	9	8
45	0.5	9	1	9	15
33	0.25	9	0	10	7
50	0.25	9	0	10	17
63	0.25	9	0	10	20
14	0.5	9	0	10	5
47	0.5	9	0	10	9
49	0.5	9	0	10	11
36	0.5	9	0	10	13
2	0.5	9	0	10	14
43	0	10	0	10	1

Appendix B: 168 Hours Salt Spray Test Results

Wet-on-Wet Green Enamel					
Random Number	Creepback in mm	Rating	% Rust	Rating	Selection Number
16	0.5	9	30	4	48
37	1	8	15	5	57
30	0.5	9	20	5	42
17	0.5	9	15	5	53
54	1	8	10	6	45
51	0.5	9	10	6	49
52	0.5	9	10	6	58
53	0	10	10	6	59
59	0.5	9	5	7	51
18	0.5	9	5	7	52
15	2	7	2	8	50
22	1	8	1	9	46
8	0.5	9	1	9	43
39	0.5	9	1	9	44
24	0.5	9	1	9	60

Appendix C: Salt Spray Test Data Collected

Date	Time	Wet Bulb Temperature °F	Dry Bulb Temperature °F	Humidity Tower Temperature °F
16-Feb-93	9:55 AM	96	96.6	118.3
16-Feb-93	4:00 PM	96.1	97	117.6
17-Feb-93	10:00 AM	96	97	117.8
17-Feb-93	3:30 PM	93.9	94.7	118.8
18-Feb-93	7:40 AM	95.7	96.7	118.1
18-Feb-93	4:10 PM	94.4	94.7	117.7
19-Feb-93	7:05 AM	95.3	95.6	119.5
19-Feb-93	2:40 PM	95.5	96.5	118.5
22-Feb-93	7:15 AM	93.9	94.5	119.5
22-Feb-93	3:40 PM	96	97	117
23-Feb-93	6:45 AM	93.8	94.5	119.2
23-Feb-93	3:30 PM	96.1	96.9	119.6
24-Feb-93	6:55 AM	96.1	96.9	119.1
24-Feb-93	3:45 PM	94.6	95.3	119.4
25-Feb-93	6:55 AM	95.8	97	119.5
26-Feb-93	7:00 AM	94.8	96.2	119.8
Date	Collection Rate Close, ml	Collection Rate, Far ml	Condensate pH	Condensate Specific Gravity
16-Feb-93	40	20	7.8	1.0255
16-Feb-93	-	-	-	-
17-Feb-93	50	26	6.14	1.03
17-Feb-93	-	-	-	-
18-Feb-93	45	20	6.08	1.03
18-Feb-93	-	-	-	-
19-Feb-93	48	23	6.14	1.0255
19-Feb-93	-	-	-	-
22-Feb-93	107	32	7.54	1.035
22-Feb-93	-	-	-	-
23-Feb-93	50	10	6.65	1.035
23-Feb-93	-	-	-	-
24-Feb-93	43	13	6.72	1.035
24-Feb-93	-	-	-	-
25-Feb-93	37.5	18	6.58	1.03
26-Feb-93	36	15.5	-	1.03

Appendix C: - Salt Spray Test Data Collected

Date	Interruption Time, minutes	Humidity Tower Air Pressure psig	Exhaust Water Press. psig	Humidity Supply
16-Feb-93	none	18.5	5	full
16-Feb-93	none	18.5	4.5	full
17-Feb-93	none	18.5	4.5	full
17-Feb-93	2	18.5	4.5	full
18-Feb-93	none	18.5	4.5	3/4 full
18-Feb-93	none	18.5	4.5	3/4 full
19-Feb-93	none	18.5	4.5	2/3 full
19-Feb-93	30	18.5	4.75	filled
22-Feb-93	none	18.25	4.4	full
22-Feb-93	60	18.4	4.5	full
23-Feb-93	none	18.5	4.5	full
23-Feb-93	none	18.4	4.5	full
24-Feb-93	none	18.5	4.3	3/4 full
24-Feb-93	none	18.4	4.6	3/4 full
25-Feb-93	none	18.4	4.5	2/3 full
26-Feb-93	none	19	4.5	2/3 full

Date	Salt Supply	Humidity Tower Level	Salt Solution Mixing Tank	Wet bottom
16-Feb-93	1/2 full	normal	ok	ok
16-Feb-93	1/2 full	normal	ok	ok
17-Feb-93	1/2 full	normal	ok	-
17-Feb-93	1/2 full	normal	ok	ok
18-Feb-93	1/3 full	normal	ok	ok
18-Feb-93	1/3 full	normal	ok	-
19-Feb-93	1/3 full	normal	ok	-
19-Feb-93	filled	normal	made new	ok
22-Feb-93	full	normal	ok	-
22-Feb-93	full	normal	ok	-
23-Feb-93	full	normal	ok	ok
23-Feb-93	full	normal	ok	ok
24-Feb-93	3/4 full	normal	ok	-
24-Feb-93	3/4 full	normal	ok	-
25-Feb-93	2/3 full	normal	ok	-
26-Feb-93	2/3 full	normal	ok	ok

Appendix C: Salt Spray Test Data Collected

Date	Comments
16-Feb-93	
16-Feb-93	
17-Feb-93	
17-Feb-93	
18-Feb-93	
18-Feb-93	
19-Feb-93	
19-Feb-93	
22-Feb-93	adjusted humidity tower pressure
22-Feb-93	interrupted for 168 hour check
23-Feb-93	
23-Feb-93	adjusted humidity tower opening
24-Feb-93	
24-Feb-93	
25-Feb-93	adjusted humidity tower pressure
26-Feb-93	test completed

Appendix D: -. Coating Thickness Test Results

Autodeposition and green enamel						
Panel Number	2	14	33	23	47	43
1st Primer reading	0.65	0.65	0.38	0.59	0.35	0.52
2nd Primer reading	0.9	0.75	0.46	0.65	0.35	0.62
3rd Primer reading	1.11	0.79	0.51	0.63	0.32	0.62
4th Primer reading		0.89	0.46	0.71	0.41	0.64
5th Primer reading		0.68	0.44	0.68	0.44	0.65
6th Primer reading			0.45	0.51	0.34	
7th Primer reading			0.45	0.63	0.28	
8th Primer reading				0.72		
1st Topcoat Reading	1.73	2.2	1.9	1.93	1.57	2.35
2nd Topcoat Reading	1.72	1.93	2.13	2.10	1.65	2.37
3rd Topcoat Reading	1.47	1.84	2.14	2.07	1.42	2.35
4th Topcoat Reading	1.6	2.06	2.19	1.94	1.45	2.24
5th Topcoat Reading	1.81	2.1	2.25	1.84	1.88	2.58
6th Topcoat Reading		1.94	2.16	1.86	1.56	
	Panel 2 Total Thickness		*Panel 33 Total Thickness*		*Panel 47 Total Thickness*	
	Mean	1.666	Mean	2.128333	Mean	1.588333
	Standard Deviation	0.132778	Standard Deviation	0.119903	Standard Deviation	0.165821
	Range	0.34	Range	0.35	Range	0.46
	Minimum	1.47	Minimum	1.9	Minimum	1.42
	Maximum	1.81	Maximum	2.25	Maximum	1.88
	Count	5	Count	6	Count	6
	Panel 14 Total Thickness		*Panel 23 Total Thickness*		*Panel 43*	
	Mean	2.011667	Mean	1.956667	Mean	2.378
	Standard Deviation	0.131821	Standard Deviation	0.107083	Standard Deviation	0.123976
	Range	0.36	Range	0.26	Range	0.34
	Minimum	1.84	Minimum	1.84	Minimum	2.24
	Maximum	2.2	Maximum	2.1	Maximum	2.58
	Sum	12.07	Sum	11.74	Sum	11.89
	Count	6	Count	6	Count	5

Appendix D: Coating Thickness Test Results

Wet-on-Wet Green Enamel						
Panel Number	8	54	15	22	18	24
1st Topcoat Reading	2.31	1.84	2.53	2.33	1.23	1.81
2nd Topcoat Reading	2.59	1.84	2.62	2.63	2.06	1.57
3rd Topcoat Reading	2.89	1.43	2.05	2.05	0.97	1.85
4th Topcoat Reading	2.2	2.26	2.49	2.49	1.34	1.83
5th Topcoat Reading	2.91	2.89	2.8	2.8	1.36	1.49
6th Topcoat Reading	2.53		2.28	2.28	1.43	2
	Panel 8 Total Thickness		*Panel 15 Total Thickness*		*Panel 18 Total Thickness*	
	Mean	2.571667	Mean	2.461667	Mean	1.398333
	Standard Deviation	0.29137	Standard Deviation	0.263622	Standard Deviation	0.362073
	Range	0.71	Range	0.75	Range	1.09
	Minimum	2.2	Minimum	2.05	Minimum	0.97
	Maximum	2.91	Maximum	2.8	Maximum	2.06
	Sum	15.43	Sum	14.77	Sum	8.39
	Count	6	Count	6	Count	6
	Panel 54 Total Thickness		*Panel 22 Total Thickness*		*Panel 24 Total Thickness*	
	Mean	2.052	Mean	2.43	Mean	1.758333
	Standard Deviation	0.552784	Standard Deviation	0.267357	Standard Deviation	0.190832
	Range	1.46	Range	0.75	Range	0.51
	Minimum	1.43	Minimum	2.05	Minimum	1.49
	Maximum	2.89	Maximum	2.8	Maximum	2
	Sum	10.26	Sum	14.58	Sum	10.55
	Count	5	Count	6	Count	6

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