

Feature

The Effect of Oil, Grease, and Salts on Coating Performance - A Laboratory Evaluation

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The years since World War II have seen a tremendous growth in both the number and sophistication of coating systems intended for the protection of structural steel. This is not surprising, since estimates of annual corrosion damage are in the billions of dollars. However, despite the improvement in coatings, their performance is still limited by the quality of their application, especially with many of the new high performance coatings, which require greater sophistication on the part of the applicator to perform to their maximum potential.

One of the most crucial aspects of application is surface preparation. Thus, organizations such as the Steel Structures Painting Council (SSPC), National Association of Corrosion Engineers (NACE), and the Swedish Standards Institute have spent considerable time and effort in developing effective visual criteria for judging the quality of blast cleaning of steel surfaces. Relatively little work has been done, however, on the effect of so-called non-visible contaminants such as salts, grease, and oil, other than to recognize them as potential troublemakers.

While the opinion has long been held that even traces of grease or oil will lead to adhesion failure if they are painted,^{1,2} little, if any, quantitative work on this subject has been published. Of somewhat more recent concern is the effect of soluble salts, particularly chlorides and sulfates, on coating performance. These salts, if painted, are known to induce such failures as osmotic blistering upon immersion or exposure to condensing humidity.^{3,4,5,6}

The most common sources of chlorides are deicing salts and marine exposure. Perhaps the most common sulfate is ferrous sulfate, produced by the reaction of atmospheric sulfuric acid (from sulfur dioxide emissions) with the steel surface.⁶ The purpose of this paper is to report about a laboratory investigation of the effects of these various contaminants on coating performance.

Materials and Equipment

Test panels used in these experiments were 4 in. by 6 in. commercial grade, hot rolled carbon steel panels. They were prepared to SSPC-SP 5, white metal blast, using either aluminum oxide or steel grit abrasives.

Solutions of chloride and sulfate at concentrations of 1000 parts per million (ppm) were prepared by using reagent grade sodium chloride and ferrous sulfate heptahydrate (hydrated iron sulfate) and deionized water. Other contaminants included light machine oil, motor oil (SAE-30), and grease (Kendall Superblu Multi Purpose Grease L-427), which were prepared as chloroform solutions.

The contaminants were applied using disposable 1 cc tuberculine syringes manufactured by Becton, Dickenson and Company.

The coatings used in the study were all commercially available products of major American coatings suppliers. They consisted of a two-component polyamide epoxy, an alkyd primer, a two-component, ethyl silicate-based inorganic zinc-rich primer, and a three-coat vinyl system consisting of a primer, intermediate, and topcoat. For some experiments, the vinyl primer was tested without the application of the intermediate or topcoat.

The test chambers consisted of a condensing humidity cabinet manufactured by the Q-Panel Company of Cleveland, OH, and an ASTM B117 Salt Fog Cabinet produced by Industrial Filter and Pump Manufacturing Company of Cicero, IL.

Procedure

The procedure involved contaminating freshly blast-cleaned panels with known levels of chloride, sulfate, light oil, motor oil, and grease. In the case of the salts, this was done by using 1 ml disposable syringes to apply the appropriate volume of solution in a bead across the top edge of the panel. Immediately after applying the solution, it was spread down the length of the panel using a soft plastic straight edge. Attempts were made to produce as uniform a film as possible. For example, in order to deposit 10 micrograms/cm² of chloride on a 4 in. by 6 in. panel, 1.60 ml of 1000 ppm chloride solution was applied and spread evenly over the panel face. (Note that 1 microgram is a mere 35 billionths of an ounce.)

Chloride levels ranged from 2.5 to 50 micrograms/cm², while sulfate levels ranged from 10 to 100 micrograms/cm². For the higher levels, several applications of the solutions were used, since it was not feasible to apply large volumes in one application.

Since one purpose of the study was to investigate the effects which soluble salts have on blistering, a control series of panels was also prepared wherein the corresponding volumes of pure deionized water were applied. This was necessary to ensure that any ensuing blistering was due to the

presence of the salt, and not simply to the effects of the water that had been applied.

Once the desired level of salts had been deposited upon the panels, they were allowed to thoroughly air dry. The top half of each panel was then blast cleaned once again, while the bottom half was shielded from the blasting abrasive either by heavy layers of paper taped to the panel, or by using a piece of heavy rubber.

The procedure used for applying the oil and grease contaminants was similar to that described above. Various chloroform solutions were prepared so that the application of 0.5 ml to 4.0 ml of solution resulted in the desired level of contamination. Chloroform was chosen since it wet the steel surface evenly and evaporated quickly. The levels used varied for the different coatings, but fell between 40 to 2400 micrograms/cm². At approximately the 600 micrograms/cm² level, the contaminants were visually apparent on the freshly blasted steel surfaces.

The various coatings (epoxy, vinyl, alkyd, and inorganic zinc) were then applied to the contaminated panels using conventional (pressure pot) spray technique. All coatings were thoroughly mixed and applied according to manufacturers' recommendations. The salt-contaminated panels were coated with epoxy at approximately 5.0 mils dry film thickness (DFT) and the three-coat vinyl system at approximately 7.0 mils total DFT. The oil- and grease-contaminated panels were coated with the epoxy, the vinyl primer, the alkyd, and the inorganic zinc, at approximately 2 mils to 4 mils DFT, depending on coating type.

Testing

The testing performed on the panels varied somewhat depending on the type of contamination. After air drying for at least one week, the salt-contaminated panels were exposed to condensing humidity (ASTM D2247) for two to eight weeks, and evaluated for blistering by ASTM D714. According to this method, blisters are given a numerical rating ranging from 8 (very small, approximately 1/32 in.) to 2 (large, approximately 1/4 in.), and a frequency rating varying from dense (D) to few (F).

After a few days of cure time, the oil and grease panels were evaluated for tape adhesion by ASTM D3359, Method B. This involves making a cross-hatch pattern of parallel knife cuts and applying a special adhesive tape. The tape is then removed, and the adhesion evaluated. Panels that did not fail the adhesion testing were cured an additional week and then subjected to ten freeze/thaw/immersion cycles in order to stress the coatings, after which they were retested for adhesion. Each cycle consisted of placing the panels in a 140 F (60 C) oven for 7 hours, followed by immersion for one hour in tap water, and then 16 hours in a freezer at approximately 0 F (-18 C).

In addition to adhesion and freeze/thaw/immersion testing, non-failing grease and oil panels coated with epoxy were subjected to two weeks of

condensing humidity, and non-failing epoxy and zinc panels were also exposed to 1000 hours of salt fog (ASTM B117).

Results - Oil and Grease Contamination

Table 1 shows the results of the adhesion testing of the alkyd primer applied over panels contaminated with light oil, motor oil, and grease. As the results show, extremely high levels of oil and grease were painted over without any detrimental effect on adhesion. Indeed, up to 1200 micrograms/cm² of motor oil and grease were tested, and up to 2400 micrograms/cm² of light oil. At levels of 600 or higher, the oil and grease could actually be seen with the unaided eye, and the panels had an oil smell. Nevertheless, the adhesion of the alkyd did not suffer.

One interesting observation was that the alkyd became somewhat soft and tacky when applied over 1200 micrograms/cm² of grease. This would indicate that the coating actually solubilized at least a portion of the grease, which then acted as a plasticizer. Indeed, visual defects such as fish eyeing and tackiness became apparent even though the adhesion was still excellent.

Table 2 shows the epoxy adhesion results. Once again, the coating displayed excellent adhesion, even when applied over high levels of oil and grease. However, whereas no failures were observed with the alkyd coating, the epoxy failed at 1200 micrograms/cm² of grease, disbonding from the entire cross-hatch area.

It is interesting to note that while disbondment occurred at 1200 micrograms/cm² of grease, adhesion was still very good at this same level of light oil and motor oil (Fig. 1). This indicates that the solubility of the contaminant plays an important role in adhesion failure. The solubility in chloroform decreased going from light oil to motor oil to grease. Apparently, the solvents or resins in the epoxy were able to dissolve the light oil and motor oil and essentially lift it from the steel surface, incorporating it into the body of the coating. Evidence for this can be seen from the panel contaminated with 2400 micrograms/cm² of light oil. Here, the test tape would not adhere at all to the surface of the epoxy, most likely due to oil that had solubilized and exuded to the surface.

Table 3 shows the adhesion results of the vinyl coating. Here, adhesion remained good up to 1200 micrograms/cm² of motor oil and 600 micrograms/cm² of grease. However, at 1200 micrograms/cm² of grease, the vinyl cleanly delaminated from the steel (Fig. 2). Once again, this is evidence of the importance of the solubility of the contaminant.

Table 4 shows the results of the inorganic zinc-rich primer applied over motor oil and grease. Here, adhesion failure was noted at 600 micrograms/cm² of motor oil (Fig. 3) and 320 micrograms/cm² of grease. Once again, the effect of solubility on adhesion is demonstrated.

While the above results show that substantial amounts of oil- or grease-like contaminants can be present without affecting adhesion, it was thought that perhaps a latent flaw had been introduced and would manifest itself as the coating was aged or stressed. Therefore, several panels that did not fail the initial adhesion testing were subjected to various accelerated tests.

One such test consisted of freeze/thaw/immersion cycles, which were meant to stress the coating through expansion and contraction caused by rapid temperature changes. As the tests (Table 5) indicate, the adhesion did not suffer as a result of this stress. Only in one instance did adhesion decrease, and that was with the vinyl applied over 600 micrograms/cm² of grease. Here, the initial adhesion was rated good (4), and the final adhesion fair (3). In one instance, adhesion was actually seen to improve. This was with the inorganic zinc and 320 micrograms/cm² of grease. The initial poor (1) adhesion improved to good (4) after exposure. Although this may simply have been an anomaly, it might be that the one hour immersion period of the cycle further cured the untopcoated zinc, resulting in improved adhesion.

Table 6 shows the results of two weeks of condensing humidity exposure on the epoxy panels. A slight decrease in adhesion was noted, but no blistering developed.

Table 7 shows the effect of 1000 hours of ASTM B117 salt fog exposure on contaminated epoxy and inorganic zinc panels. While adhesion was not assessed after this prolonged exposure, the panels were evaluated for rusting and blistering. The motor oil and grease had little or no effect on the corrosion resistance of the two coatings, and did not result in any blistering of the inorganic zinc. Although the epoxy panels did blister after 1000 hours, this was not due to the effect of oil or grease, since the uncontaminated control panels also blistered.

Results - Salt Contamination

The results of the condensing humidity testing of the salt contaminated panels are shown in Table 8 , Table 9 , Table 10 and Table 11 (the control panels contaminated with deionized water showed no blistering). After two weeks of condensing humidity, blistering was evident on the epoxy-coated panels that had received 10 micrograms/cm² of chloride or higher. At this early stage, there was little difference between the frequency or size of blisters between the 10 and 20 microgram levels, but at 50 micrograms, No. 4 medium dense blisters developed. No blistering was evident on the top half of the panels (which had been re-blast cleaned after contamination), except at the 50 micrograms/cm² level. Here, the blisters on the blast cleaned upper half were rated as No. 8 medium as opposed to No. 4 medium dense on the uncleaned half.

After four weeks of exposure, the 2.5 and 5.0 microgram panels still displayed no blistering on either the top or bottom half, whereas the 20 microgram panels had advanced to even larger blisters (No. 6 medium) on

the uncleaned halves. Even after four weeks, no blistering was observed on the recleaned upper half of the 2.5 through 20 microgram panels.

The same epoxy coating performed much better when the contaminant was sulfate rather than chloride. As [Table 9](#) shows, after six weeks the only panels that had blistered were the 50 and 100 micrograms/cm² levels, and even here, blistering was confined to the uncleaned bottom half.

Apparently, sulfate contamination is not as detrimental to the epoxy's performance as chloride contamination.

The performance of the three-coat vinyl system panels are illustrated in [Table 10](#) and [Table 11](#). After four weeks of condensing humidity, all of the 20 and 50 microgram chloride panels showed considerable blistering confined to the lower, uncleaned halves. Some of the 5 and 10 microgram panels also showed extremely small blistering (No. 8 medium).

With one exception, sulfate contamination resulted in no blistering on any of the vinyl panels after four weeks of exposure. The exception was one of the 20 microgram panels, which showed a few very small blisters (No. 8 few). Apparently, the effect of sulfate on the vinyl system is much less than that of chloride, as was the case with the epoxy panels.

Discussion

As the above results show, surprisingly high levels of oil and grease can be painted over without any adverse effect on adhesion. Indeed, all four of the coating types tested displayed very good adhesion over oil and grease levels as high as 320 micrograms/cm², and adhesion of some of the coatings remained very good even at levels as high as 1200 and 2400 micrograms/cm². At these high levels, the presence of the contaminant is easily seen by the unaided eye, and the panels possess an "oily" odor. Under close inspection, contamination is even detectable at the 600 micrograms/cm² level. The excellent adhesion of the coatings over such high levels of contamination is in direct contradiction to the common assumption that even minute levels of oil or grease will lead to gross adhesion failures.

A commonly held theory is that there are three factors contributing to coating adhesion. The first effect is a purely mechanical one, wherein the blast profile provides a jagged surface of high area, contributing to a mechanical "tooth" or bond. Therefore, all other conditions being equal, a coating should have better adhesion over a rough surface than a smooth one. Since the dimensions of profile are usually expressed in units of mils, it is felt that surface roughness is a macro-phenomenon, and would not be affected appreciably by thin layers of contaminant.

The other two factors affecting adhesion are thought to be covalent bonding of the polymeric material to the substrate, and electrostatic, or van der Waals, effects. Since molecules must come into intimate contact in order for covalent bonds to be formed, and since the electrostatic effect of van der Waals forces is extremely dependent on distance (decreasing in

proportion to the inverse sixth power of distance), it has been thought that any layer of interfering contaminant, no matter how thin, would seriously affect these two modes of adhesion.

If the above theory of adhesion is correct, then the results of this paper can be explained in one of two ways. The first possibility is that the mechanical aspect of adhesion far outweighs the covalent and electrostatic aspects. The reasoning behind this hypothesis is that the oil and grease, at the levels used in this experiment, would certainly be expected to provide an insulating layer over the substrate far in excess of the thickness required for covalent bonding to occur or for electrostatic forces to exert themselves. Therefore, the excellent adhesion observed would have to be due only to the mechanical tooth provided by the blast cleaning operation.

The second possibility is that the solvents present in the coatings, or perhaps even the resins themselves, are sufficient to solubilize the oil and grease and essentially lift it from the surface.

This second hypothesis is believed to be most likely, due to a number of observations. The first observation is the relationship between coating adhesion and solubility of the contaminant. This can be seen in [Table 2](#), where epoxy adhesion remained very good at 1200 micrograms of light oil and motor oil, but was very poor at the same level of grease. [Table 3](#) and [Table 4](#) display similar results. The grease used was much more viscous than either of the two oils, and was dissolved in chloroform only with difficulty. The fact that equivalent levels of grease resulted in poorer adhesion than the oils indicates that the adhesion is a function of the coating's ability to solubilize the contaminant.

That the primer coats at least partially solubilized the contaminants can be seen by the results in [Table 1](#) and [Table 2](#). In [Table 1](#), the alkyd was found to be tacky when applied over 1200 micrograms/cm² of grease, indicating that it had solubilized a portion of the grease and in essence became plasticized. In [Table 2](#), the adhesive tape would not stick when the coating was applied over 2400 micrograms/cm² of light oil. This is almost certainly because at least a portion of the oil had been solubilized by the coating and subsequently exuded to the surface during cure.

Regardless of the explanation, the results indicate that substantial amounts of oil can be present on blast cleaned steel surfaces without producing a detrimental effect on coating adhesion. Furthermore, results of freeze/thaw/immersion testing and condensing humidity testing indicate that the adhesion does not diminish upon stress. The performance of the coating systems in salt fog exposure was also not diminished by the presence of oil or grease.

Another common belief in the paint industry is that the more sophisticated coatings are less tolerant to surface contamination. The results of these experiments support this belief. Whereas the alkyd coating, with its oil modification, high solvent content, and relatively low surface tension could not be made to fail even at contamination levels of 1200 micrograms/cm², the high solids, high surface tension, inorganic zinc primer failed at 600

micrograms/cm² of motor oil and at only 320 micrograms/cm² of grease (Fig. 4). Indeed, the results tabulated in [Table 1](#) , [Table 2](#) , [Table 3](#) and [Table 4](#) indicate the inorganic zinc-rich coating is most sensitive to oil and grease contamination, followed by the vinyl, epoxy, and alkyd, in that order.

While oil-like contamination has long been identified, rightly or wrongly, as a culprit in coating performance, the role of soluble salts has been of concern only recently. The results of the humidity testing of the epoxy and vinyl applied over salt-contaminated panels is shown in [Table 8](#) , [Table 9](#) , [Table 10](#) and [Table 11](#) . While hundreds of micrograms/cm² of oil-like contaminants could be present without affecting humidity resistance, a mere 10 micrograms/cm² of chloride was sufficient to cause substantial blistering after two weeks of exposure to condensing humidity. This would be roughly equivalent to spreading a single dash of salt from a salt shaker over a 5 sq ft desk top. Higher levels of sulfate also caused blistering, but only after a longer exposure.

The results of this testing clearly show that even small amounts of soluble salts trapped beneath a coating can induce blistering upon exposure to condensing humidity, and presumably also upon immersion. The mechanism of such blistering has been described by Funke,³ and is a result of an osmotic process. Basically, when a water-soluble or hydrophilic material is trapped within or behind a semi-permeable membrane such as a coating, water will permeate the film in order to dilute or lower the concentration of salt behind it. The blisters thus produced are described as osmotic blisters. The fact that only a few micrograms of chloride were necessary to cause blistering, whereas over 1000 micrograms of oil did not, is due simply to the fact that chloride is water soluble and oil is not. Therefore, oil or grease cannot produce an osmotic cell.

The above results also indicate that at least in some circumstances of very high concentration, blast cleaning the steel surface to a white metal blast may not be sufficient to remove all of the soluble salts. This is indicated by the fact that the epoxy applied over 50 micrograms/cm² of chloride still blistered on the re-cleaned half.

It should also be pointed out that there is some concern within the industry about salt contamination of abrasive blasting material. The fear is that blasting material containing too high a level of soluble salts may actually deposit them on the freshly cleaned steel, resulting in a later failure of the coating system.

The series of experiments described in this paper utilized only a few types of contaminants and only four coatings, and certainly cannot be used to establish universal criteria for allowable contamination. In addition, the means used to produce soluble salt contamination (i.e., syringes) and to evaluate performance (i.e., adhesion, salt fog, condensing humidity) were artificial laboratory procedures and are not representative of actual field conditions.

Nevertheless, the results clearly indicate that even fairly low levels of soluble salts on steel surfaces can result in blistering problems, and that it is possible for very high levels of grease and oil to be present on steel surfaces without affecting the adhesion of subsequently applied coatings.

References

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Table 1
Alkyd Adhesion^a Results

Amount (micrograms/cm ²)	Light Oil	Motor Oil	Grease
40	very good (5)	—	—
80	very good (5)	very good (5)	very good (5)
160	very good (5)	—	—
320	very good (5)	very good (5)	very good (5)
600	very good (5) oil visually apparent	—	—
1200	very good (5) oil apparent: coating fisheyed	good (4) oil visually apparent	very good (5) grease visually apparent: topcoat tacky
2400	very good (5) oil apparent: coating fisheyed	—	—

^aNumerical rating refers to ASTM D3359, Method B: (5) corresponds to no loss of adhesion, while (0) corresponds to adhesion loss of 65 percent or greater.

Table 2
Epoxy Adhesion^a Results

Amount (micrograms/cm ²)	Light Oil	Motor Oil	Grease
40	very good (5)	—	—
80	very good (5)	very good (5)	very good (5)
160	very good (5)	—	—
320	very good (5)	very good (5)	very good (5)
640	very good (5) oil visually apparent	—	very good (5) grease visually apparent
1280	very good (5) oil visually apparent	very good (5) oil visually apparent	very poor (0) grease visually apparent
2560	tape would not adhere to epoxy	—	—

^aNumerical rating refers to ASTM D3359, Method B: (5) corresponds to no loss of adhesion, while (0) corresponds to adhesion loss of 65 percent or greater.

Table 3
Vinyl Adhesion^a Results

Amount (micrograms/cm ²)	Motor Oil	Grease
80	very good (5)	very good (5)
320	very good (5)	good (4)
600	very good (5) oil visually apparent	good (4) grease visually apparent
1200	good (4) oil visually apparent	very poor (0) grease visually apparent

^aNumerical rating refers to ASTM D3359, Method B. (5) corresponds to no loss of adhesion, while (0) corresponds to adhesion loss of 65 percent or greater.

Table 4
Inorganic Zinc Adhesion^a Results

Amount (micrograms/cm ²)	Motor Oil	Grease
80	very good (5)	very good (5)
320	very good (5)	poor (1)
600	very poor (0) oil visually apparent	very poor (0) grease visually apparent
1200	very poor (0) oil visually apparent	very poor (0) grease visually apparent

^aNumerical rating refers to ASTM D3359, Method B. (5) corresponds to no loss of adhesion, while (0) corresponds to adhesion loss of 65 percent or greater.

Table 5
Effect of 10 Freeze/Thaw/Immersion Cycles
on Contaminated Panels

Coating	Contaminant	Amount (micrograms/cm ²)	Adhesion ^a Before	Adhesion ^a After
Alkyd	motor oil	80	very good (5)	very good (5)
Alkyd	motor oil	320	very good (5)	very good (5)
Alkyd	motor oil	1200	very good (5)	very good (5)
Alkyd	grease	80	very good (5)	very good (5)
Alkyd	grease	320	very good (5)	very good (5)
Epoxy	motor oil	80	very good (5)	very good (5)
Epoxy	motor oil	320	very good (5)	very good (5)
Epoxy	motor oil	1200	very good (5)	very good (5)
Epoxy	grease	80	very good (5)	very good (5)
Epoxy	grease	320	very good (5)	very good (5)
Vinyl	motor oil	80	very good (5)	very good (5)
Vinyl	motor oil	320	very good (5)	very good (5)
Vinyl	motor oil	600	very good (5)	very good (5)
Vinyl	motor oil	1200	good (4)	good (4)
Vinyl	grease	80	very good (5)	very good (5)
Vinyl	grease	320	good (4)	very good (5)
Vinyl	grease	600	good (4)	fair (3)
Zinc	motor oil	80	very good (5)	very good (5)
Zinc	motor oil	320	very good (5)	very good (5)
Zinc	grease	80	very good (5)	very good (5)
Zinc	grease	320	poor (1)	good (4)

^aNumerical rating refers to ASTM D3359, Method B: (5) corresponds to no loss of adhesion, while (0) corresponds to adhesion loss of 65 percent or greater.

Table 6
Effect of Two Weeks Condensing Humidity on Epoxy

Contaminant	Amount (micrograms/cm²)	Adhesion^a Before	Adhesion^a After	Blistering
Motor Oil	80	very good (5)	very good (5)	none
Motor Oil	320	very good (5)	very good (5)	none
Motor Oil	1200	very good (5)	good (4)	none
Grease	80	very good (5)	good (4)	none
Grease	320	very good (5)	good (4)	none

^aNumerical rating refers to ASTM D3359, Method B: (5) corresponds to no loss of adhesion, while (0) corresponds to adhesion loss of 65 percent or greater.

Table 7
Effect of Salt Fog on Oil- and Grease-Contaminated Epoxy and Zinc Panels

Coating	Contaminant	Amount (micrograms/cm ²)	Rusting, 500 hrs	Blistering, 500 hrs	Rusting, 1000 hrs	Blistering, 1000 hrs
Epoxy	none	0 (control)	slight at scribe	isolated # 8	moderate at scribe	# 4 few
Eopxy	motor oil	80	slight at scribe	none	moderate at scribe	# 4 few
Epoxy	motor oil	320	slight at scribe	none	moderate at scribe	# 4 few
Epoxy	motor oil	1200	slight at scribe	none	moderate at scribe	# 4/# 2 few
Epoxy	grease	80	slight at scribe	none	moderate at scribe	# 4 few
Epoxy	grease	320	slight at scribe	none	moderate at scribe	# 4 few
Epoxy	grease	600	slight at scribe	isolated # 8	moderate at scribe	# 4 few
Epoxy	grease	1200	slight at scribe	none	moderate at scribe	# 4 few
Zinc	none	0 (control)	very slight at scribe	none	slight at scribe	none
Zinc	motor oil	80	none	none	none	none
Zinc	motor oil	320	none	none	very slight at scribe	none
Zinc	motor oil	600	slight at scribe	none	slight at scribe	none
Zinc	grease	80	none	none	none	none
Zinc	grease	320	none	none	very slight at scribe	none
Zinc	grease	1200	slight at scribe	none	slight at scribe	none

Table 8
Effect of Condensing Humidity on
Chloride-Contaminated Epoxy Coating

Chloride Level (micrograms/cm ²)	Blistering. 2 Weeks		Blistering. 4 Weeks	
	Blasted Half	Non-Blasted Half	Blasted Half	Non-Blasted Half
2.5	none	none	none	none
2.5	none	none	none	none
5.0	none	none ^a	none	none
5.0	none	none	none	none
5.0	none	none	none	none
10.0	none	# 6 medium	none	none
10.0	none	# 8 medium dense	none	# 8 medium dense
10.0	none	# 8 medium dense	none	# 8 medium dense
20.0	none	# 4 medium	none	none
20.0	none	# 8 medium	none	# 6 medium
20.0	none	# 8 medium	none	# 6 medium
50.0	# 8 medium	# 4 medium dense	none	none

All panels initially blast cleaned prior to contamination; one half then re-blast cleaned prior to paint application.

^aExcept a few # 8 blisters in two small localized areas.

Table 9
Effect of Condensing Humidity on
Sulfate-Contaminated Epoxy Coating

Sulfate Level (micrograms/cm ²)	Blistering, 4 Weeks		Blistering, 8 Weeks	
	Blasted Half	Non-Blasted Half	Blasted Half	Non-Blasted Half
5.0	none	none		
5.0	none	none	none	none
5.0	none	none	none	none
10.0	none	none		
10.0	none	none	none	none
10.0	none	none	none	none
20.0	none	none		
20.0	none	none	none	# 6 few
20.0	none	none	none	none
50.0	none	none		
50.0	none	# 4 few	none	# 4 few
50.0	none	# 4 few	none	# 4 few
100.0	none	# 4 few	none	# 4 medium
100.0	none	# 4 few	none	# 4 medium

All panels initially blast cleaned prior to contamination; one half then re-blast cleaned prior to paint application.

Table 10
Effect of Condensing Humidity on
Chloride-Contaminated Vinyl System

Chloride Level (micrograms/cm ²)	Blistering, 4 Weeks	
	Blasted Half	Non-Blasted Half
5.0	none	# 8 medium
5.0	none	none
10.0	none	# 8 medium
10.0	none	none
20.0	none	# 6 medium dense
20.0	none	# 8 medium dense
50.0	none	# 6 medium
50.0	none	# 6 medium

All panels initially blast cleaned prior to contamination; one half then re-blast cleaned prior to paint application.

Table 11
Effect of Condensing Humidity on
Sulfate-Contaminated Vinyl System

Sulfate Level (micrograms/cm ²)	Blistering - 4 Weeks	
	Blasted Half	Non-Blasted Half
10.0	none	none
10.0	none	none
20.0	none	none
20.0	none	# 8 few
50.0	none	none
50.0	none	none
100.0	none	none
100.0	none	none (some pinholes)

All panels initially blast cleaned prior to contamination; one half then re-blast cleaned prior to paint application.