DL LABORATORIES

116 East 16th Street, New York, N.Y. 10003
Telephone: 212-777-4410 TWX: 710-581-6132

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EVALUATION OF PROPERTIES OF INDUSTRIAL COATINGS

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Jerry H. Willner
Jerry H. Willner
Chief Chemist

Saul Spindel
Saul Spindel
Technical Director

Sidney B. Levinson
Sidney B. Levinson
President

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50 copies

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DISCLAIMER

The statements and conclusions in this report are those of the contractor and not necessarily those of the California Air Resources Board. The mention of any commercial products, their source or use in connection with material reported herein, is not to be construed as either an actual or implied endorsement of such products.

ABSTRACT

The properties of commercially available powder, water-borne and high-solids industrial coatings and their use in production were evaluated relative to conventional high solvent coatings.

A comprehensive survey of the industry was conducted in order to obtain test samples of both low VOC and equivalent conventional industrial coatings for metal parts and products. A total of 105 coatings were received and evaluated, including 71 coatings with VOC concentrations varying from 0 to 360 grams per liter of paint, less water, (g/l), and 34 equivalent conventional coatings.

The results of the tests demonstrate that, among the low VOC coatings, 13 water base, 17 high solids and 4 powder coatings can be considered to be acceptable. 24 are baked coatings, 4 are force dried coatings and 6 are air dried coatings. Their VOC levels compare as follows:

	VOC (g/l) Range	VOC (g/l) Average
Baked Coatings (except powder and inorganic)	136 to 360	274
Force Dry Coatings	216 to 340	280
Air Dry Coatings	284 to 354	316

High solids baked topcoats exhibit the best overall performance among the low VOC coatings tested. As a group, they exhibit superior overall resistance to both impact and abrasion as compared with the conventional topcoats with no significant deficiencies overall. VOC for the acceptable coatings varies from 206 to 360 g/l with an average VOC of 278 g/l. The same superiority holds true even when the three best solids baked topcoats are compared with the three best equivalent conventional coatings. VOC concentrations for these low VOC coatings varies from 248 to 284 g/l with an average of 265 g/l.

A literature search and survey were conducted to determine the experience of metal fabricators who are using low VOC coatings. As a result, information was obtained from 43 companies (53 plants) using water-borne coatings, 24 companies (25 plants) using powder coatings and 10 companies (10 plants) using high-solids coatings. Plant locations covered a total of 25 states with the largest number (10) in Califonia.

Powder coatings have proved to be most successful in spite of their limitations of 1 coat application, difficulties of changing colors and the requirement of cure by baking. Although the initial investment is much higher than either water-borne or high-solids coatings, this is offset by reduced operating, maintenance and energy costs. Also, air pollution is lowest of all three since practically no solvent is used.

Water-borne coatings allow the most rapid change over at minimum expense. They also can be applied on large manufactured items since they can be air or force dried. However, water-borne coatings exhibit the greatest number of problems in production due to the slow evaporation of water and the sensitivity of the coating to water and high humidity. Furthermore, installation or modification of electrostatic spray equipment is difficult because of the conductivity of water-borne coatings.

High-solids coatings have the shortest history of use because of their relatively recent development. They require some changes in equipment because of their high viscosity and the caveat that no solvent can be added to improve spray application. Although they air dry, they do not produce high quality finishes when air dried. On the other hand, when baked, they produce coatings with equal and even superior performance to conventional coatings.

The successful users of water-borne and high-solids coatings have found that close cooperation between them and both the equipment and coating suppliers is very helpful in developing a replacement coating in the shortest time.

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SYMBOLS AND ABBREVIATIONS

ARB - Air Resources Board

VOC - Volatile organic compounds (primarily solvents) expressed as grams per liter of paint, less water (g/l).

Products Tested

T	- Topcoat		2 Comp	-	Two component
Pr	- Primer				
C	- Conventional		WB	-	Water base
HS	- High solids		In	-	Inorganic
Wht	- White		Gry	-	Grey
Blk	- Black		Bge	-	Beige
Clr	- Clear		Yel	-	Yellow
Grn	- Green		Org	-	Orange
B	- Baked		AD	-	Air dry
FD	- Force dry				
			SIC	-	Standard Industrial Classification
Zn	- Zinc phosphated steel				
Fe	- Iron phosphated steel				
St	- Clean steel				
Pr	- Primed steel				

* Raw material supplier

Tables

Acc.	- Accelerated		Int	-	Acceptable for Interior use
H	- High				
L	- Low				
V	- Very				

Test Results

ASTM - ASTM description. See Test Procedure
°F - Degrees Fahrenheit
Hrs - Hours
In. lbs - Inch pounds
KU - Krebs units
L/mil - Liters per mil
Mins - Minutes
mm - Millimeters

Score - <u>ASTM Scoring Scheme</u>

Score	Performance	or	Effect
10	Perfect		None
9	Excellent		Trace
8	Very good		Very slight
6	Good		Slight
4	Fair		Moderate
2	Poor		Considerable
1	Very poor		Severe
0	No value		Failed

Conv - Conventional
MEK - Methyl ethyl ketone solvent
Acc. - Accelerated
2 - Two component
Sol - Solidified
X - Not applicable

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I INTRODUCTION

In 1978, the Air Resources Board adopted a suggested control measure to limit volatile organic compound (VOC) emissions resulting from industrial coating operations for manufactured metal parts and products. This measure is applicable to all metal objects that are painted during a manufacturing process except: automobiles, cans, coils, marine vessels, aircraft and aerospace vehicles, and related components. (Each of these exempted products is regulated by a source-specified rule). Under the suggested control measure for metal parts, VOC emissions would be reduced by the substitution of low-polluting and more energy-efficient low-solvent (waterborne and high-solids) and powder coatings, for conventional industrial coatings that contain relatively higher amounts of organic solvents.

As originally adopted, the suggested rule limited VOC emissions from existing coating operations to 275 and 340 grams per liter (g/l) of coating applied, excluding water, for baked and air-dried or force-dried coatings, respectively. New or modified sources using baked coatings were subject to a more stringent limit of 180 g/l. (The latter provision was subsequently deleted from district regulations). The original rule was adopted essentially unchanged by all local air pollution control districts with nonattainment status and it was scheduled to be implemented in January 1982. Implementation of the rule was later postponed to January 1984 in the South Coast Air Basin and to January 1985 in other areas of the state. Instead, the solvent limitations suggested by the Federal EPA of 360 g/l for baked coatings and 420 g/l for air dried and higher performance coatings were adopted as interim limits effective January 1983.

In recent years, partly in response to the model rule, coating manufacturers have improved substantially the quality and availability of low-solvent industrial coatings. The purpose of this study was to monitor progress by evaluating the performance of newly developed low-solvent and powder industrial coatings relative to their conventional counterparts, based upon laboratory evaluations and the experiences of manufacturers using low-solvent or powder coatings in production.

II SUMMARY AND CONCLUSIONS

A comprehensive survey was made of the coatings industry, both by publicity and by direct mail, in order to obtain samples of both low VOC and equivalent conventional industrial coatings for use on metal parts and products. The result was the receipt of 145 products from 30 suppliers.

After the initial determination of the VOC of the low VOC coatings, all low VOC products containing VOC concentrations above 360 g/l were eliminated. In addition, others were eliminated either because of excessive baking temperatures, end uses other than those specified in the contract or instability during initial tests. The result was a final test group of 105 coatings - 71 low VOC and 34 conventional.

The samples that were tested can be categorized as follows:

	Bake		Force Dry		Air Dry		Total	
	Low VOC	Conv	Low VOC	Conv	Low VOC	Conv	Low VOC	Conv
Primers		1		1		2		4
Water Base	3		1		5		9	
Topcoats		18		4		8		30
Water Base	10		5		9		24	
High Solids	20				3		23	
Powder	15	—	—	—	—	—	15	—
TOTAL	48	19	6	5	17	10	71	34

The test results demonstrate that many of the low VOC industrial coatings can be considered to be Acceptable and capable of competing with the equivalent conventional coatings. Acceptability is based on the following criteria:

At least Good in the following properties of major importance:

Pot life - 2 component coatings
Speed of dry - Air dry coatings
Opacity - Topcoats
Adhesion
Flexibility
Water resistance

At least Poor in properties which are considered to be of minor importance:

Viscosity and package stability
Abrasion resistance - Primers
Whiteness - many are not sold as whites

At least Fair in all other properties.

As a result, the following coatings were determined to be Acceptable. Those limited to interior use are designated by a ( ).

	Bake		Force Dry		Air Dry		Total	
	Low VOC	Conv	Low VOC	Conv	Low VOC	Conv	Low VOC	Conv
Primers		1		(1)		2		3,(1)
Water Base	1		1		3,(1)		5,(1)	
Topcoats		13,(1)		1		4		18,(1)
Water Base	2,(2)		3		3,(1)		8,(3)	
High Solids	17				0		17	
Powder	4,(1)						4,(1)	
TOTAL	24	14	4	1	6	6	34,(5)	21,(2)

The following conclusions may be drawn from the results of this evaluation of low VOC industrial coatings vs the equivalent conventional coatings. Note that at least two low VOC coatings in any category must be Acceptable in order to draw a definite conclusion.

Primers

Baked - Only one of the three water base primers tested is Acceptable. Therefore no definite conclusion drawn regarding this product category.

Force Dry - The same statement holds true for this group since only one water base primer is Acceptable.

Air Dry - Three of the five water base primers tested are Acceptable. As a group, they tend to exhibit superior Package Stability, Opacity and Abrasion Resistance but inferior Water Resistance, Salt Fog Resistance and Weathering. VOC averages 326 g/l. One primer is limited to interior use.

Topcoats - Baked

Water Base - Two of the ten products tested are Acceptable. They tend to exhibit superior Opacity, Impact Resistance, Abrasion Resistance and Weathering but inferior Resistance to Water and Salt Fog. VOC averages 236 g/l. Two more are limited to interior use.

High Solids - 17 of the 20 products tested are Acceptable. As a group, they are competitive to conventional topcoats exhibiting superior Resistance to Impact and Abrasion with no significant deficiencies. VOC averages 278 g/l.

Powder - Four of the 15 products tested are Acceptable. As a group, they exhibit superior Hardness and Abrasion Resistance but somewhat less gloss retention. VOC is essentially 0. These products are based on epoxy resins which tend to lose gloss when exposed to the weather. One product is limited to interior use.

Topcoats - Force Dry

Three of the five water base coatings tested are Acceptable. As a group, they exhibit superior Color Retention and Resistance to Impact, Abrasion and Water. On the other hand, they are inferior in Viscosity Stability, Gloss Retention, Salt Fog Resistance and Weathering. VOC averages 280 g/l.

Topcoats - Air Dry

Water Base - Three of the nine products tested are Acceptable. As a group, they are superior in Viscosity Stability, Package Stability and Weathering but at a sacrifice in Opacity, Gloss Retention, Color Retention, and Resistance to Water and Salt Fog. VOC averages 306 g/l.

High Solids - None of the three products tested are Acceptable.

A survey and literature search were made to determine the results obtained by metal fabricators when using low VOC coatings, i.e., powder, water-borne and high-solids. The results are based on information obtained from a total of 77 companies with 88 plants located in 25 states, as follows:

	Companies	Plants	States
Powder coatings	24	25	19
Water-borne coatings	43	53	20
High-solids coatings	10	10	8
	77	88	

The information obtained was reviewed and analyzed considering the following parameters:

A. Metal products on which applied

B. Coating and substrate

C. Application and cure

D. Production

E. Coating performance

F. Economics

It is evident that all three types of low VOC coatings are being used with some degree of success. Most changes have been made as a result of air quality regulations but the result in some cases has been better coating performance, savings in production, maintenance and/or energy costs, or both.

The classes of metal products which account for the highest percentage of use of each type of coating are as follows. The percentages given are based on total end uses for that type of coating.

Powder	–	Furniture and fixtures (21%)
Water-borne	–	Transportation equipment (26%)
High-solids	–	Furniture and fixtures (30%) Architectural fabricated metal (20%)

Each other end use among the total of 12 classes of metal products covered among to less than 15%.

The major polymers used in their coatings are as follows:

Powder	–	Epoxy (47%) Polyester (33%)
Water-borne	–	Alkyd (43%) Acrylic (39%)
High-solids	–	Polyester (45%)

The major substrate for all low VOC coatings is steel, as would be anticipated, with aluminum second in importance. The most common metal treatment is phosphate, either zinc or iron.

The most common method of coating application is by spray. All powder coatings must be applied electrostatically as are most high solids coatings. Water-borne coatings, however, are most commonly applied by conventional spray because of the difficulty of controlling electrostatic spray due to the greater conductivity of these coatings.

All electrostatic coatings must be applied in one coat. However, most water-borne and high-solids coatings are also applied in one coat.

Total dry film thickness of powder coatings is above 1 mil because of the difficulty of obtaining a thickness of 1 mil or less. Most water-borne coatings are also applied above 1 mil in an effort to improve water and corrosion resistance. On the other hand, high solids coatings can readily be applied at 1 mil or even less and still exhibit good performance.

All powder coatings must be baked. Both water-borne and high-solids coatings can be air dried or force dried but most are baked to speed up production and to improve coating performance.

All low VOC coatings reduce air pollution and waste to some extent. Water-borne paints also are less flammable and less toxic. However, powder coatings are best of the three in all these characteristics since they contain essentially no solvent and they develop almost no waste inasmuch as most of the overspray is reused.

Powder coatings require the greatest capital expense since a major installation is required. However, once installed, economics in production, maintenance and energy costs will help recover this initial cost. Water-borne paints require a minimum capital investment since the same equipment can be used. The exception is electrostatic spraying, in which case the equipment must be completely insulated to prevent loss of the charge due to the conductivity of the coating. High-solids coatings require the installation of either high speed electrostatic dics or the use of heaters to handle their high viscosity.

Powder coatings exhibit the best coating performance of the three types with outstanding corrosion resistance, durability and resistance to wear. Water-borne coatings are marginal, especially when air dried, because of their initial water sensitivity. High-solids coatings are marginal when air dried but equal or superior to conventional coatings when baked.

The following conclusions may be drawn from the results of the survey:

1. Commercial powder, water-borne and high-solids industrial coatings for metal parts and products, which apparently meet the CARB model rule for the control of VOC emissions, are available and are being used with some success. At least 77 companies with 88 plants located in 25 states are doing so.

2. Powder coatings release the lowest emissions of the three types and result in definitely superior coating performance. Although they require a major investment, this cost can be reclaimed due to the savings in production, maintenance and energy costs. However, they result in more expensive (although superior) coatings because of their initial cost and difficulty of obtaining films of 1 mil or less. They also require baking and color changes are relatively difficult and time consuming.

3. Water-borne coatings require minimum changes in production and therefore can readily replace conventional coatings in production. They also can be both air dried and force dried, as well as baked. Therefore, they can be used for large items such as construction or farm equipment. However, the poor wetting of unclean surfaces by water, its slow evaporation and the sensitivity of these coatings to water and high humidity requires the installation of flash-off tunnels and careful control of substrate cleanliness and of application. If electrostatic equipment is used, it must be well insulated to prevent loss of the charge due to the conductivity of the coating. Coating performance is marginal, especially when air dried.

4. High-solids coatings are the newest products on the market. The high viscosity of many high-solids coatings requires the use of high speed electrostatic discs or heaters in order to achieve the desired application. Furthermore, waste disposal is more of a problem because of the sticky overspray produced. Although they will air dry, they are much more effective in coating performance when baked, surpassing the water-borne coatings and being essentially equivalent to powder coatings.

III RECOMMENDATIONS

1. It is evident that the VOC specification for new facilities is too low at 180 g/l. Therefore, it should be increased to at least 275 g/l, at least for the time being.

2. The high solids baked coatings appear to have excellent potential to replace conventional baked coatings. However, many of these coatings may require heated equipment or high speed discs for proper spray application.

3. It is evident that the technology continues to advance and that low VOC products available at the present time most likely will be superior to those obtained over a year ago. Therefore it would be beneficial to repeat an evaluation of low VOC industrial coatings in the near future. It is anticipated that many coatings, both water base, as well as high solids, and both air dry and force dry, as well as baked, will be as good or perhaps even superior to the conventional coatings they replace.

IV PART A LABORATORY EVALUATION

A OBJECTIVE

The purpose of this investigation was to locate and evaluate commercially available low VOC industrial coatings which are recommended for in-plant application on metal parts and products. The evaluation was to be conducted in comparison with equivalent commercially available conventional (solvent-thinned) industrial coatings.

The types of low VOC coatings investigated included the following:

Water base or water-borne

High solids

Powder

The methods of cure included were:

Baked - From 195°F to 550°F

Force dry - From 165°F to 194°F

Air dry

Coatings specifically recommended for the following metal parts and products were excluded from this study:

Cans
Coil and wire
Marine vessels
Aircraft and aerospace
Autos and light trucks

The following types of coatings were also excluded:

Touch up and repair
Industrial maintenance for structures in service

B. PROCEDURE

Survey

It was realized that the development of low VOC coatings was still in its infancy. Therefore it was necessary to publicize the program and to cover a broad spectrum of both coating manufacturers and raw material suppliers in order to make contact with any who might have coatings to offer.

Consequently the following steps were taken:

1. Publicity Releases were sent to all industry publications and industry associations. See Appendix IA to ID.

2. Letters and Data Forms were sent to all major coating manufacturers. See Appendix IE and F.

3. Letters and Data Forms were sent to all major suppliers of polymers and resins. See Appendix IG and H.

Submitted Coatings

A total of 145 products were received from both coating manufacturers and raw material suppliers. However, some had to be rejected for the following reasons:

1. Baking temperature was excessive - above 550°F. These products appear to be ceramic type (inorganic) coatings.

2. Some were determined to be maintenance paints recommended for use on sand blasted steel only.

VOC Determination

All low VOC coatings were analyzed for actual VOC concentration. All low VOC coatings above 360 g/l were rejected.

Test Samples

Some coatings were rejected early in the program because of poor stability. Consequently, a total of 71 low VOC coatings and 34 conventional coatings were completely tested.

Test Procedure

The 105 candidate products were submitted to the following tests, as appropriate:

1. Viscosity

2. Viscosity stability

3. Package stability

4. Pot life - two component coatings

5. Speed of dry - air dry coatings

6. Overcure - baked coatings
   a) Twice the normal bake time
   b) 50°F above the normal bake temperature

7. Gloss

8. Whiteness

9. Opacity

10. Exposure to ultraviolet light
    a) Gloss change
    b) Color change

11. Hardness

12. Adhesion

13. Flexibility

14. Impact resistance

15. Abrasion resistance

16. Water resistance

17. Acid resistance

18. Alkali resistance

19. Xylol resistance

20. Resistance to methyl ethyl ketone (MEK)

21. Resistance to salt fog (corrosion)

22. Accelerated weathering

The test methods are described in Appendix III.

C. PRODUCTS TESTED

A total of 105 coatings from 25 suppliers were tested. 19 coating manufacturers submitted from 1 to 16 products and six raw material suppliers submitted from 3 to 11 products.

The coatings tested are listed in Table 1 below. The table also includes the following information:

1. Product tested, i.e., primer or topcoat

2. Type of coating, i.e., water base, high solids or conventional.

3. Polymer type, e.g., acrylic, alkyd, polyester, etc.

4. VOC - actual determination for low VOC coatings and submitted for conventional coatings.

5. Color of coating.

6. Recommended cure, e.g., bake, force dry or air dry.

7. Recommended substrate, on which the coating was tested, e.g., zinc phosphated steel, iron phosphated steel, clean steel or primed steel.

8. Supplier code.

Table 1

Products Tested

Liquid Coatings

No.	Prod	Type	Polymer	VOC g/l	Color	Cure	Substrate	Supplier
1	T	C	P	471	Wht	B	Zn	8
2	T	HS	Ac	264	"	B	Zn	8
4	T	C	Al	547	"	FD	Zn	8
5	T	WB	P	346	Wht	B	St	17
6	T	HS	P	277	"	B	Fe	17
7	T	WB	Ac/Al	346	"	AD	Zn	17
8	T	WB	Ac	136	Blk	B	Zn	17
9	T	C	P	415	"	B	Zn	17
10	T	C	StAl	473	Wht	AD	Zn	17
12	T	C	Al	458	Wht	AD	Zn	24
13	T	WB	Al	300	"	AD	Zn	24
14	T	WB	AcL	329	Wht	B	Zn	27
16	T	C	Al	-	"	B	Zn	27
17	T	HS	P	286	Wht	B	Fe	30
18	T	C	P	479	"	B	Fe	30
19	T	C	P	433	Clr	B	Fe	30
20	T	HS	P	288	"	B	Fe	30
23	T	HS	P	332	Wht	B	Fe	13
24	T	C	Ac	465	"	B	Fe	13
25	T	WB	AcL	283	Wht	FD	Fe	22**
26	T	WB	AcL	216	"	FD	Fe	22**
27	T	C	Ac	625*	"	FD	St	22**
28	T	HS	P	223	Wht	B	Pr	21
29	Pr	C	StEE	-	Grn	FD	St	29
30	T	C	Al	-	Gry	FD	Pr	29
32	T	HS	P	360	Blu	B	St	29
36	T	HS	Al	327	Wht	B	Zn	16
37	T	C	Al	571	"	B	Fe	16

* Reduced to spray viscosity
** Raw material supplier

Table 1 (Cont)

Products Tested

Liquid Coatings

No.	Prod	Type	Polymer	VOC g/l	Color	Cure	Substrate	Supplier
38	T	C	P	463	Wht	B	Fe	25**
39	T	HS	P	301	"	B	Fe	25**
40	T	HS	P	284	"	B	Fe	25**
41	T	HS	Al	262	"	B	Fe	25**
42	T	C	Al	516	"	B	Fe	25**
43	T	WB	Al	355	Wht	FD	St	15**
44	T	HS	Al	180	"	AD	St	15**
45	T	C	Al	519	"	FD	St	15**
46	T	C	Al	467	"	AD	St	15**
47	T	HS	P	289	Wht	B	St	9**
48	T	HS	P	303	"	B	Zn	9**
49	T	WB	Al	327	Wht	AD	Fe	5
51	T	HS	P	342	"	B	Fe	5
52	T	C	A	ND	"	AD	Fe	5
53	T	C	A	607	"	B	Fe	5
54	T	C	P	624**	"	B	Fe	5
55	T	C	Al	541	Wht	AD	St	25**
56	T	C	Al	564	"	AD	St	25**
57	T	WB	Al	260	"	AD	St	25**
58	T	WB	Al	303	"	AD	St	25**
59	T	WB	Al	278	"	AD	St	25**
61	T	WB	AcL	283	"	AD	St	25**
62	T	C	Al/Ur	382	"	AD	St	25**
64	T	WB	Ac	313	Wht	B	Zn	22**
69	T	C	Ac	627	"	B	Fe	22**
70	T	HS	Ac/P	237	"	B	Zn	22**
74	T	C	Al	532	Wht	B	St	4
75	T	WB	P	336	"	B	St	4
79	Pr	WB	Ep***	354	Grn	AD	St	6
80	Pr	WB	Ep***	281	"	AD	St	6
81	Pr	C	Ep***	650	Yel	AD	St	6
82	Pr	WB	Ep***	267	Grn	AD	St	6
83	Pr	C	Ep***	650	"	AD	St	6
84	Pr	WB	Ep***	341	Red	AD	St	6
85	Pr	WB	Ep***	284	"	AD	St	6
87	T	WB	Ep***	348	Wht	AD	Pr	6

*** Two component

Table 1 (Cont)

Products Tested

Liquid Coatings

No.	Prod	Type	Polymer	VOC g/l	Color	Cure	Substrate	Supplier
95	T	WB	AcL	224	Wht	AD	Zn	28
98	T	WB	Al	247	Blk	FD	Zn	28
99	T	HS	Ur***	262	Wht	AD	Zn	18**
100	T	HS	Ur***	300	"	AD	Zn	18**
101	T	C	Ur***	419	"	AD	Zn	18**
103	T	WB	Ac	250	Clr	B	St	12**
104	Pr	WB	Ac***	270	Yel	B	St	12**
105	T	WB	Ac	220	Wht	B	St	12**
106	T	WB	Ac	136	Wht	B	St	26
107	T	C	Ac	500	"	B	St	26
110	T	WB	In	5	Gry	B	St	23
111	Pr	WB	In	5	Org	B	St	23
117	T	C	Ac	606*	Wht	B	Zn	19
118	T	C	Al	608*	Bwn	B	Fe	19
119	T	HS	P	262	"	B	Zn	19
120	T	HS	P	240	Bge	B	Zn	19
121	T	WB	Al	340	Grn	FD	Fe	11
122	Pr	WB	AcL	289	Org	FD	Fe	11
123	T	WB	P	302	Yel	B	Fe	11
124	Pr	WB	Ac	340	Gry	B	Zn	11
125	Pr	C	Al/Ac	ND	"	B	Zn	11
126	T	HS	P	237	Wht	B	Zn	11
127	T	C	Al	ND	"	B	Zn	11
128	T	HS	P	206	"	B	Zn	11
129	T	HS	P	248	"	B	Zn	11
130	T	C	Ac	0	"	B	Zn	11

Table 1 (Cont)

Products Tested

Powder Coatings

No.	Prod	Polymer	Color	Cure	Substrate	Supplier
P1	T	P	Grn	B	Zn	7
P2	T	P	Bwn	B	Zn	7
P3	T	Ep	Blk	B	Zn	7
P4	T	Ep	Wht	B	St	5
P5	T	Ep	"	B	St	5
P6	T	Ep	"	B	St	5
P7	T	P/Ur	Wht	B	Zn	9**
P8	T	P	Wht	B	Zn	2
P9	T	Ep	"	B	Zn	2
P10	T	Ep	Wht	B	Zn	11
P11	T	Ep/P	Gry	B	Zn	11
P12	T	Ac	Wht	B	Zn	11
P13	T	P	"	B	Zn	11
P14	T	P	"	B	Zn	11
P15	T	Ep	Clr	B	Zn	11

Product - Product

T - Topcoat
Pr - Primer

Type

C - Conventional
HS - High solids
WB - Water base

Polymer

Ac - Acrylic
Al - Alkyd
Ep - Epoxy
EE - Epoxy Ester
In - Inorganic
L - Latex
P - Polyester
St - Styrenated
Ur - Urethane
*** - 2 Component

Color

Wht - White
Blk - Black
Clr - Clear
Grn - Green
Gry - Grey
Bge - Beige
Yel - Yellow
Org - Orange

Substrate

Zn - Zinc phosphated steel
Fe - Iron phosphated steel
St - Clean steel
Pr - Primed steel

Cure

B - Baked
FD - Force dry
AD - Air dry

VOC

ND - No data
* - Reduced to spray viscosity

Supplier

** - Raw material supplier

D. TEST RESULTS

Results of paint tests are expressed in two ways depending on whether the test involves a quantitive measurement or subjective observation. In the latter case, the results are scored using the following ASTM Scoring Scheme in order to avoid the necessity of using lengthy descriptions:

Score	Performance	or	Effect
10	Perfect		None
9	Excellent		Trace
8	Very good		Very slight
6	Good		Slight
4	Fair		Moderate
2	Poor		Considerable
1	Very poor		Severe
0	No value		Failed

Test results involving quantitive measurement are expressed in a variety of units which cannot be readily interpreted by those outside the paint industry. Therefore, in order to facilitate interpretation, the quantitive test results have been converted to the following simplified version of the ASTM Scoring Scheme:

Rating	Performance
10	Excellent
8	Very good
6	Good
4	Fair
2	Poor
0	No value

The rating scale for each of the quantitive tests are based on the experience and judgement of the authors and are provided in Appendix IV. Performance ratings for all of the coatings tested are presented in Tables 2 through 13. Actual quantitive test results are provided in Appendix II.

Table 2

Primers - Baked

	Water Base		Conv
	111	124	125
VOC (g/l) ------	5	340	ND
Color ------	Orange	Grey	Grey
Viscosity	L	VH	M
Viscosity Stability	10	1	9
Package Stability	6	6	9
Overcure	4	9	8
Gloss	H	MH	H
Opacity	*	10	10
Hardness	9	8	10
Adhesion	10	10	10
Flexibility	10	6	8
Resistance To -			
- Impact	10	4	4
- Abrasion	10	6	6
- Water	10	10	10
Salt Fog Exposure	9	9	10
Acc. Weathering	10	4	4
ACCEPTABLE	Yes	No	Yes
End Uses - SIC No.	331 335	363	

* Unable to determine

St - Steel Zn - Zinc Phosphate Conv. - Conventional

In - Inorganic SIC No. - Standard Industrial Classification Number

ND - No data

Table 3

Primers - Force Dry

	Water Base	Conv
VOC (g/l) ------	122 / 289	29 / 456
Color ------	Orange	Green
Viscosity	M	M
Viscosity Stability	10	9
Package Stability	9	9
Pot Life	X	X
Overcure	8	10
Gloss	ML	H
Opacity	10	10
Hardness	4	4
Adhesion	10	10
Flexibility	10	10
Resistance To		
Impact	8	10
- Abrasion	4	2
- Water	9	10
Salt Fog Exposure	6	8
Acc. Weathering	9	1
ACCEPTABLE	Yes	Int
End Uses - SIC No.	331 335 352	

Int - Acceptable for interior use.

Table 4

Primers - Air Dry

	Water Base					Conv	
	79	80	82	84	85	81	83
VOC -------	354	281	267	341	284	650	650
Color -------	Grn	Grn	Grn	Red	Red	Yel	Grn
Viscosity - Mixed	LM	H	LM	H	MH	L	VL
Viscosity Stability	10	10	9	10	10	8	10
Package Stability	8	10	2	10	8	4	4
Pot Life	10	8	4	10	10	10	10
Speed of Dry	8	6	8	8	8	8	10
Gloss	VL	VL	VL	VL	VL	VL	ML
Opacity	4	4	2	10	10	4	9
Hardness	6	6	6	6	6	8	6
Adhesion	10	10	10	10	10	10	10
Flexibility	10	10	10	10	10	10	10
Resistance To -							
- Impact	10	10	10	10	10	10	8
- Abrasion	6	4	4	4	4	4	2
- Water	9	4	10	6	9	10	10
Salt Fog Exposure	6	2	2	4	4	9	9
Acc. Weathering	4	4	8	4	4	4	8
ACCEPTABLE	Yes	Int	No	Yes	Yes	Yes	Yes
End Use - SIC No.	335 Ext	335 Ext	335 Ext	335 Ext	335 Ext		

Note: All are 2 component

Grn - Green   Yel - Yellow   Ext - Exterior Use

Ext - Recommended for exterior use

Table 5

Water Base Topcoats - Baked

	5	8	14	64	75	103	105	106	110	123
VOC (g/l)----	346	136	329	313	336	250	220	136	*	302
Color ----	Wht	Blk	Wht	Wht	Wht	Clr	Wht	Wht	Gry	Yel
Viscosity	MH	M	M	L	LM	LM	L	H	LM	M
Viscosity Stability	9	6	10	10	10	0	10	0	8	9
Package Stability	9	10	4	2	2	0	10	0	6	8
Overcure	10	10	10	9	8	8	10	9	10	10
Gloss	VH	ML	VH	H	MH	H	MH	H	VL	M
Whiteness	8	X	8	8	6	X	8	6	X	X
Opacity	9	10	8	10	10	X	9	9	**	8
UV Exposure										
Gloss retention	8	9	9	10	9	8	6	6	10	8
Color retention	8	10	10	10	9	6	10	10	10	10
Hardness	6	8	6	9	6	8	8	6	9	10
Adhesion	10	10	10	10	10	10	10	10	10	10
Flexibility	10	10	10	0	10	10	10	10	0	2
Resistance To -										
- Impact	10	6	6	2	10	4	4	4	4	6
- Abrasion	6	6	4	4	8	8	6	9	10	8
- Water	4	4	8	4	4	10	2	4	6	2
Salt Fog Exposure	6	4	2	8	4	4	2	6	6	4
Acc. Weathering	2	10	0	8	9	8	10	4	6	0
ACCEPTABLE	Int	Yes	Int	No	Yes	No	No	No	No	No
End Use - SIC No.	331 335	331 335	331 335	331 335	331 335	331 335	331 335	363	342	252 331 335

* Inorganic
** Unable to determine

Blk - Black
Clr - Clear

Gry - Grey

Table 6

High Solids Topcoats - Baked

	2	6	17	20	23	28	32	36	39	40
VOC (g/l)----	264	277	286	288	332	223	360	327	301	284
Color ----	Wht	Wht	Wht	Clr	Wht	Wht	Blu	Wht	Wht	Wht
Viscosity	H	MH	M	MH	M	M	LM	M	M	LM
Viscosity Stability	9	10	9	6	10	6	9	6	1	8
Package Stability	10	9	8	10	8	9	6	9	9	9
Overcure	10	10	10	10	10	8	9	10	10	10
Gloss	VH	VH	H	VH	VH	H	H	VH	VH	VH
Whiteness	8	8	10	X	8	8	X	8	8	8
Opacity	10	9	9	X	10	9	10	9	9	9
UV Exposure										
Gloss retention	10	8	9	10	8	10	8	9	10	9
Color retention	10	10	10	9	8	6	4	9	10	10
Hardness	8	6	6	8	8	6	8	8	0	8
Adhesion	10	10	10	10	10	10	10	10	10	10
Flexibility	10	10	10	10	10	10	10	10	10	10
Resistance To -										
- Impact	6	10	10	10	6	10	10	10	4	10
- Abrasion	8	10	9	8	6	10	9	10	6	10
- Water	10	10	10	10	10	10	10	10	9	10
Salt Fog Exposure	9	9	10	9	9	9	9	9	4	9
Acc. Weathering	10	4	6	4	4	4	4	8	2	8
ACCEPTABLE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
End Use - SIC No.	252 331 335 363	335	331 335	331 Ext	331 335 363	331 335	361	363	252 352 Ext	363 Ext

Table 6 (Cont)

High Solids Topcoats - Baked

	41	47	48	51	70	119	120	126	128	129
VOC (g/l)-----	262	289	303	342	237	262	240	237	206	248
Color -----	Wht	Wht	Wht	Wht	Wht	Brn	Bge	Wht	Wht	Wht
Viscosity	LM	LM	M	M	LM	MH	MH	H	H	M
Viscosity Stability	6	9	6	6	9	9	9	6	9	8
Package Stability	8	8	8	4	8	9	9	10	10	9
Overcure	10	9	10	10	6	8	6	10	6	9
Gloss	VH	VH	VH	H	MH	M	H	VH	MH	VH
Whiteness	8	8	8	8	6	X	X	8	6	8
Opacity	9	9	9	9	9	10	10	9	10	9
UV Exposure										
Gloss retention	10	9	8	6	9	9	10	10	9	9
Color retention	10	6	9	10	10	8	10	10	9	10
Hardness	4	8	8	6	6	8	9	8	8	10
Adhesion	10	10	10	10	10	10	10	10	10	10
Flexibility	10	10	4	10	0	10	10	10	10	10
Resistance To -										
- Impact	10	10	4	10	2	6	4	10	10	9
- Abrasion	10	8	8	10	4	6	8	10	9	9
- Water	10	10	10	10	10	10	10	10	10	10
Salt Fog Exposure	9	9	10	10	9	9	9	6	4	9
Acc. Weathering	4	10	8	8	4	6	4	10	4	8
ACCEPTABLE	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes
End Use - SIC No.	331 335	331 335 363	363	252 363	331 335	331 335 358	331 335 358	331 335	331 335	331 335 358

Bwn - Brown Bge - Beige

Table 7

Powder Coatings - Baked

	P-1	P-2	P-3	P-4	P-5	P-6	P-7	P-8
Color -----	Grn	Bwn	Blk	Wht	Wht	Wht	Wht	Wht
Overcure	10	10	10	10	10	10	10	10
Gloss	MH	MH	MH	H	H	MH	VH	H
Whiteness	X	X	X	8	8	8	8	8
UV Exposure								
Gloss Retention	10	9	4	4	10	9	9	10
Color Retention	10	9	4	6	10	9	8	10
Hardness	9	8	9	8	8	8	8	10
Adhesion	10	10	10	10	10	10	10	10
Flexibility	0	10	2	8	10	4	0	0
Resistance To -								
- Impact	4	2	4	4	4	4	6	4
- Abrasion	9	10	10	10	10	8	9	6
- Water	10	10	10	10	10	10	10	10
Salt Fog Exposure	10	10	10	10	10	10	10	10
Acc. Weathering	2	6	2	4	6	8	6	4
ACCEPTABLE	No	No	No	Yes	Yes	No	No	No
End Use - SIC No.	331 335 352 363 371	331 335 352 363 364 371	331 335 371	331	331 335 Ext	331 Ext	252 331 335 353 371 394 Ext	252 352 371

Table 7 (Cont)

Powder Coatings - Baked

Color-----	P-9 Wht	P-10 Wht	P-11 Gry	P-12 Wht	P-13 Wht	P-14 Wht	P-15 Clr
Overcure	10	10	10	10	10	10	8
Gloss	VH	VH	MH	MH	MH	H	VH
Whiteness	9	9	X	8	10	10	X
UV Exposure Gloss Retention	6	2	4	9	10	9	8
Color retention	6	4	6	10	10	10	4
Hardness	10	10	9	10	9	9	6
Adhesion	10	10	10	10	10	10	6
Flexibility	8	10	10	0	0	10	0
Resistance To -							
- Impact	6	9	4	2	4	6	10
- Abrasion	10	10	10	4	8	8	4
- Water	10	10	10	10	10	10	9
Salt Fog Exposure	10	10	10	10	10	10	10
Acc. Weathering	4	4	1	9	6	8	4
ACCEPTABLE	Yes	No	Int	No	No	Yes	No
End Use - SIC No.	252 352 353 371 394	331 335 364	331 335 364	364	331 335 364	331 335	331 335
				Ext	Ext	Ext	

Table 8

Conventional Topcoats - Baked

	1	9	16	18	19	24	37	38	42
VOC (g/l) --	471	415	488	479	433	465	571	463	516
Color ------	Wht	Blk	Wht	Wht	Clr	Wht	Wht	Wht	Wht
Viscosity	LM	LM	LM	M	LM	M	L	LM	LM
Viscosity Stability	9	6	9	8	9	9	10	9	10
Package Stability	9	4	8	9	4	6	2	8	8
Overcure	10	9	10	9	9	10	9	9	8
Gloss	H	ML	VH	VH	H	VH	VH	VH	VH
Whiteness	8	X	8	8	X	8	8	8	8
Opacity	9	10	8	9	X	10	8	9	8
UV Exposure									
Gloss retention	10	10	9	8	9	9	9	9	9
Color retention	8	6	10	10	10	9	9	10	8
Hardness	8	6	6	6	6	8	6	8	0
Adhesion	10	10	10	10	10	10	10	10	10
Flexibility	10	10	10	10	10	10	10	8	10
Resistance To -									
- Impact	6	6	8	10	4	4	4	4	6
- Abrasion	8	4	4	6	10	8	4	8	8
- Water	10	10	10	10	10	10	9	10	9
Salt Fog Exposure	9	9	9	10	9	10	8	9	9
Acc. Weathering	4	10	4	2	1	8	2	2	2
ACCEPTABLE	Yes	Yes	Yes	Yes	Int	Yes	Yes	Yes	No

Table 8

Conventional Topcoats - Baked

	53	54	69	74	107	117	118	127	130
VOC (g/l)---	607	624	627	532	500	606	608	ND	ND
Color ------	Wht	Wht	Wht	Wht	Wht	Wht	Bwn	Wht	Wht
Viscosity	LM	LM	L	LM	MH	M	LM	LM	M
Viscosity Stability	2	4	10	9	6	9	8	9	9
Package Stability	8	8	8	8	10	9	9	10	10
Overcure	9	10	10	6	10	10	8	10	10
Gloss	H	VH	VH	H	H	VH	H	H	VH
Whiteness	6	8	8	8	8	8	X	8	8
Opacity	9	9	8	8	8	9	10	8	9
UV Exposure									
Gloss retention	9	9	9	9	9	9	8	9	8
Color retention	10	10	10	9	9	8	6	10	10
Hardness	6	8	8	6	6	6	6	6	9
Adhesion	10	10	10	10	10	10	10	10	10
Flexibility	10	10	4	10	0	0	10	10	8
Resistance To -									
- Impact	4	6	6	6	4	2	4	8	4
- Abrasion	4	6	6	4	4	2	4	4	6
- Water	10	10	10	9	10	10	10	10	10
Salt Fog Exposure	9	9	9	9	9	10	9	10	10
Acc. Weathering	2	8	9	4	4	4	4	4	10
ACCEPTABLE	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes

Table 9

Water Base Topcoats - Force Dry

	25	26	43	98	121
VOC (g/l) ------	283	216	355	247	340
Color ------	Wht	Wht	Wht	Blk	Grn
Viscosity	M	L	LM	VL	H
Viscosity Stability	9	10	10	1	2
Package Stability	9	10	10	1	2
Overcure	10	10	10	9	10
Gloss	H	H	VH	VL	VH
Whiteness	8	9	1	X	X
Opacity	8	8	9	10	10
UV Exposure					
Gloss retention	10	9	10	10	6
Color retention	10	9	4	9	9
Hardness	6	6	4	6	4
Adhesion	10	10	10	10	10
Flexibility	10	10	10	8	10
Resistance To -					
- Impact	4	6	6	6	10
- Abrasion	6	4	6	6	6
- Water	4	4	4	9	9
Salt Fog Exposure	4	4	2	2	9
Acc. Weathering	10	10	4	6	4
ACCEPTABLE	Yes	Yes	No	No	Yes
End Use - SIC No.	331 335	331 335	331 335	254 371	331 335 352 Ext

Table 10

Conventional Topcoats - Force Dry

	4	27	30	45
VOC (g/l) ---	547	625	362	519
Color -------	White	White	Grey	White
Viscosity	L	M	M	MH
Viscosity Stability	10	9	10	8
Package Stability	2	10	4	6
Overcure	10	10	9	10
Gloss	VH	H	H	VH
Whiteness	2	9	X	8
Opacity	8	8	10	8
UV Exposure				
Gloss retention	10	9	4	9
Color retention	8	10	6	8
Hardness	6	6	0	2
Adhesion	10	10	10	2
Flexibility	10	0	10	10
Resistance To -				
- Impact	4	4	4	2
- Abrasion	4	4	6	6
- Water	4	10	8	9
Salt Fog Exposure	9	6	9	8
Acc. Weathering	10	9	4	4
ACCEPTABLE	Yes	No	No	No

Table 11

Water Base Topcoats - Air Dry

	7	13	49	57	58	59	61	87[2]	95
VOC (g/l) ----	346	300	327	260	303	278	283	348	224
Color ----	Wht	Wht	Wht	Wht	Wht	Wht	Wht	Wht	Wht
Viscosity	LM	MH	MH	M	H	H	L	M	LM
Viscosity Stability	10	6	10	1	2	6	10	8	10
Package Stability	8	6	6	6	6	2	6	8	10
Pot Life	X	X	X	X	X	X	X	10	X
Speed of Dry	10	2	9	8	8	0	8	6	10
Gloss	MH	H	H	H	H	VH	MH	M	MH
Whiteness	4	2	1	2	2	4	6	8	8
Opacity	8	9	8	9	8	8	8	6	8
UV Exposure									
Gloss retention	10	10	9	8	9	8	6	4	9
Color retention	6	6	9	4	6	6	10	6	10
Hardness	6	6	6	6	6	4	6	8	6
Adhesion	10	10	10	10	10	10	6	10	10
Flexibility	10	10	10	10	10	10	0	8	10
Resistance To -									
- Impact	4	10	6	4	4	10	4	4	4
- Abrasion	4	6	6	6	4	4	6	8	4
- Water	4	9	9	9	9	9	4	8	4
Salt Fog Exposure	8	9	9	8	2	8	2	9	4
Acc. Weathering	8	6	4	4	4	10	9	6	6
ACCEPTABLE	Yes	No	No	No	Int	No	No	Yes	Yes
End Use - SIC No.	331 335	331 335	331 335 352 Ext	331 335 352 374 Ext	331 335	331 335	331 335 352	331 335	254 364

2 - Two component

Table 12

High Solids Topcoats - Air Dry

VOC (g/l) ------	$\frac{44}{180}$	$\frac{99^2}{262}$	$\frac{100^2}{300}$
Color ------	White	White	White
Viscosity	M	LM	LM
Viscosity Stability	8	8	8
Package Stability	8	8	8
Pot Life	X	2	10
Speed of Dry	0	6	2
Gloss	MH	H	VH
Whiteness	2	8	8
Opacity	10	8	9
UV Exposure			
Gloss retention	6	9	10
Color retention	6	10	9
Hardness	6	10	10
Adhesion	8	10	10
Flexibility	10	10	9
Resistance To -			
- Impact	6	10	6
- Abrasion	10	9	8
- Water	8	10	10
Salt Fog Exposure	9	9	9
Acc. Weathering	4	9	9
ACCEPTABLE	No	No	No
End Use - SIC No.	331 335	335	371 Ext

2 - Two component

Table 13

Conventional Topcoats - Air Dry

	10	12	46	52	55	56	62	101*
VOC (g/l) --	473	458	467	ND	541	564	382	419
Color -----	Wht	Wht	Wht	Wht	Wht	Wht	Wht	Wht
Viscosity	LM	M	M	LM	LM	LM	MH	LM
Viscosity Stability	9	4	9	6	6	8	6	9
Package Stability	2	4	6	6	9	6	4	10
Pot Life	X	X	X	X	X	X	X	8
Speed of Dry	9	0	2	9	9	9	8	6
Gloss	VH	H	H	H	VH	VH	MH	VH
Whiteness	4	6	8	6	6	8	4	8
Opacity	9	10	9	8	8	9	9	8
UV Exposure								
Gloss retention	9	10	9	10	9	9	6	10
Color retention	10	8	8	10	9	9	6	10
Hardness	6	4	6	6	4	4	4	10
Adhesion	10	10	10	10	6	0	8	10
Flexibility	10	10	10	10	0	0	10	10
Resistance To -								
- Impact	6	10	8	4	0	0	4	6
- Abrasion	4	6	4	4	6	4	6	10
- Water	10	9	6	10	9	6	4	10
Salt Fog Exposure	9	9	6	9	6	8	6	9
Acc. Weathering	6	4	6	4	4	2	4	8
ACCEPTABLE	Yes	No	No	Yes	No	No	Yes	Yes

E. DISCUSSION OF RESULTS

The results of Rating the properties tested enable the determination of the acceptability or unacceptability of each product tested, based on a practical consideration of the relative importance of the properties tested.

This can be done by assigning minimum criteria for Acceptability as follows:

1. A minimum rating of 6 (Good) for the following properties considered to be of major importance for all industrial coatings.

   Pot life - 2 component coatings

   Speed of dry - Air dry coatings

   Opacity - Topcoats (except clears)

   Adhesion

   Flexibility

2. A minimum rating of 2 for properties which are relatively minor, as explained below:

   a) Viscosity and Package Stability

      Industrial coatings are rarely stored for long periods of time so that accelerated storage is of less significance than it is for architectural paints which may be stored for 12 months or longer.

   b) Whiteness

      Many white coatings are sold as Off-Whites so that their whiteness is of minor importance.

   c) Abrasion resistance - Primers

      Primers are intended primarily to prevent corrosion and/or improve adhesion. Topcoats are used to protect the primer against degradation from, e.g., water, abrasion, weathering, etc.

   d) Salt fog - Primers

      See (c) above

   e) Weathering - Primers

      See (c) above

3. A minimum rating of 4 (Fair) for all other properties.

Using these criteria, the Ratings of the Acceptable low VOC coatings, as well as the equivalent conventional coatings, have been averaged in order to determine the relative importance of each group of coatings tested. The results are summarized in Tables 14 and 15.

Note that the comparison was considered to be valid only when at least two low VOC coatings in the group were found to be Acceptable. Also note that coatings limited to interior use have not been included in averaging the Ratings.

Table 14

Average Properties of Acceptable Primers

	Baked WB	Baked C	Force Dry WB	Force Dry C	Air Dry WB	Air Dry C
Total Tested --------	3	1	1	1	5	2
Acceptable ----------	1	1	1		3	2
Interior Use Only ---				1	1	
Viscosity Stability	Insufficient number				10	9
Package Stability	of Acceptable low				8.7	4
Pot Life (2 Comp)	VOC coatings. Should				10	10
Speed of Dry	have at least two.				8	9
Opacity					8	6.5
Hardness					6	7
Adhesion					10	10
Flexibility					10	10
Resistance To -						
- Impact					10	9
- Abrasion					4.7	3
- Water					8	10
- Salt Fog					4.7	9
Weathering					4	6
Average VOC (g/l)					326	-

WB - Water base
C - Conventional
2 Comp - Two component samples only

NOTE - Average ratings and VOC concentrations of coatings limited to interior use are not included.

Table 15

Average Properties of Acceptable Topcoats

	Baked				Force Dry		Air Dry		
	WB	HS	P	C	WB	C	WB	HS	C
Total Tested -------	9	20	15	18	5	4	9	3	8
Acceptable ---------	2	17	4	13	3	1	3	0	4
Interior Use Only --	2		1	1			1		
Viscosity Stability	8	7.9	X	7.8	7	10	9.3	None Are Acceptable	7.5
Package Stability	6	8.5	X	7.6	Minor		8.7		5.5
Speed of Dry	-	-	-	-	-	-	8.7		8
Overcure	9	9.1	10	9.2	10	10	-		-
Whiteness	6	7.2*	8.8	7.8*	Minor		6.7		5.5
Opacity	10	9.4**	X	8.9	8.7	8	7.3		8.5
UV Exposure									
Gloss retention	9	9	7.3	8.9	8.3	10	7.7		8.8
Color retention	9.5	8.8	8	9	9.3	8	7.3		9
Hardness	7	7.5	8.8	6.8	5.3	6	6.7		6.5
Adhesion	10	10	10	10	10	10	10		9.5
Flexibility	10	10	9	9.8	10	10	9.3		10
Resistance To -									
- Impact	8	8.9	5	5.7	6.7	4	4		5
- Abrasion	7	8.8	9.5	5.4	6.7	4	5.3		6
- Water	4	9.9	10	9.8	5.7	4	5.3		8.5
- Salt Fog	4	8.6	10	9.2	5.7	9	7		8.3
Weathering	9.5	6.2	5.5	6	8	10	6.7		5.5
Average VOC (g/l)	236	278	-	-	280	-	306		-

X - Unable to test
* - Whites only

** Disregarding clears

NOTE - Average ratings and VOC concentrations of coatings limited to interior use are not included.

The Acceptable low VOC coatings exhibited the following significant differences (over one unit) vs the equivalent conventional coatings. Note that no statements have been made regarding minor properties such as Whiteness, also regarding products for which no more than one coating was considered to be Acceptable.

	Superior	Inferior
Primers - Air Dry (Water base)	Package stability Opacity Abrasion resistance	Resistance to - Water Salt Fog Weathering
Topcoats - Baked		
Water Base	Opacity Resistance to - Impact Abrasion Weathering	Resistance to - Water Salt Fog
High Solids	Resistance to - Impact Abrasion	None
Powder	Hardness Abrasion resistance	Gloss retention
Topcoats - Force Dry (Water base)	Color retention Resistance to - Impact Abrasion Water	Viscosity stability Gloss retention Salt Fog resistance Weathering
Topcoats - Air Dry (Water base)	Viscosity stability Package stability Weathering	Opacity Gloss retention Color retention Resistance to - Water Salt Fog

Inasmuch as so many high solids and conventional baked coatings were evaluated, it is possible to compare the best three (3) coatings of each group. Their average values are shown in Table 16.

Note that the best high solids baked coatings are generally superior to the best equivalent conventional baked coatings exhibiting superior Resistance to Impact and Abrasion with no significant deficiencies.

Table 16

Average Properties of Best Topcoats - Baked

Coatings	High Solids 3	Conventional 3
Viscosity Stability	8.3	8.7
Package Stability	9.3	8.3
Overcure	9.7	9.7
Whiteness	8	8
Opacity	9.3	9.3
UV Exposure		
Gloss retention	9.3	8.3
Color retention	10	9.7
Hardness	8.7	7.7
Adhesion	10	10
Flexibility	10	9.3
Resistance To -		
- Impact	8.3	6
- Abrasion	9	6.7
- Water	10	10
- Salt Fog	9	10
- Acc. Weather	8.7	8.7
Coating Nos.	2,40,129	18,24,130
Average VOC (g/l)	265	-

The acceptability of the low VOC coatings should also be considered from the point of view of their intended use or uses. Their recommended uses are shown in Tables 2 through 12 above, listed in accordance with the following SIC codes for metal products:

SIC	
252	Office furniture
254	Cabinets and shelving
331	Fabricated steel
335	Fabricated aluminum
342	Hardware
352	Farm and garden machinery and equipment
353	Construction machinery and equipment
358	Refrigeration equipment
361	Electric transmission equipment
363	Household appliances
364	Electric lighting fixtures
371	Truck and bus bodies
374	Railroad equipment
394	Toys and sporting goods

18 of the low VOC coatings tested are recommended for exterior use.

Note that, although many of the low VOC coatings are recommended for specific end uses, the gread majority are recommended for general use, i.e., for use on fabricated metal, e.g., steel and aluminum. Of the low VOC coatings tested, only from 1 to 11 coatings, overall, are recommended for specific end uses, whereas 45 are recommended for general use. Therefore, it is difficult to express definite opinions for the more limited end uses. However, an attempt has been made to do so where at least two low VOC coatings for the same end use within a group were found to be either acceptable or unacceptable.

Table 2 Water Base Primers - Baked

SIC Nos.* 331, 335, 363

There are an insufficient number of primers tested for any end use to express an opinion.

Table 3 Water Base Primers - Force Dry

SIC Nos.* 331, 335, 352

Same as above.

Table 4 Water Base Primers - Air Dry

SIC No.* 335 Fabricated Aluminum

Three primers tested are acceptable and one is limited to interior use. Only one product is unacceptable because of poor opacity.

* Standard Industrial Classification Number

Table 5 Water Base Topcoats - Baked

SIC Nos. 331, 335 Fabricated Metals

Two products tested are acceptable, two more are limited to interior use and four are unacceptable. Two of the latter exhibit poor to very poor flexibility, a property which cannot be tolerated on sheet metals that may be flexed during manufacture and/or use. On the other hand, this property would be less critical for metal castings. One product exhibits very poor storage stability which cannot be tolerated for any coating. The fourth product has poor resistance to both water and salt fog. Salt fog resistance may be overlooked for interior use but any protective coating should have at least fair water resistance.

SIC 252, 342, 363

There are an insufficient number of products tested for any end use to express an opinion.

Table 6 High Solids Topcoats - Baked

SIC No. 252 Furniture

Two products tested are acceptable whereas one is not because of its extremely soft film which would be subject to damage.

SIC Nos. 331, 335 Fabricated Metal

Twelve products tested are acceptable whereas one is not because of very poor flexibility which cannot be tolerated on flexible metals.

SIC No. 358 Refrigeration Equipment

All three products tested are acceptable.

SIC No. 363 Appliances

Six products are acceptable whereas one is not because of insufficient flexibility, an important requirement on the sheet metal usually used in the manufacture of appliances.

SIC Nos. 352, 361

There are an insufficient number of products tested for each end use to express an opinion.

Table 7 Powder Coatings - Baked

SIC No. 252 Furniture

One product tested is acceptable but two are not because of extremely poor flexibility which cannot be tolerated on the sheet metal, of which furniture is normally constructed.

SIC No. 331 Fabricated Steel

Three products are acceptable and one is limited to interior use. On the other hand, eight products are unacceptable. Of these, five have poor to very poor flexibility and should not be used on sheet metal. One (P-2) has low impact resistance but excellent flexibility and another (P-6) has only fair flexibility and impact resistance. Both might be used on steel castings. Another (P-10) has poor gloss retention which might not be too significant in some applications.

SIC No. 335 Fabricated Aluminum

Only two products tested are acceptable and one is limited to interior use. On the other hand, seven products are unacceptable. Of these, five have poor to very poor flexibility. See above for comments about the other two, P-2 and P-10.

SIC No. 352 Farm Equipment

Only one product tested is acceptable but three are not. Two of the latter exhibit very poor flexibility but one is marginal. See above for comments about P-2.

SIC No. 353 Construction Machinery and Equipment

One product tested is acceptable but one is not because of very poor flexibility.

SIC No. 363 Appliances

Only two products tested are recommended for this use and both are unacceptable. One has very poor flexibility but P-2 is marginal, as discussed above. However castings are of limited use in the manufacture of appliances.

SIC No. 364 Light Fixtures

Five products tested are recommended for this end use. One is limited to interior use and four are unacceptable. One of the latter has very poor flexibility but three are marginal. See comments re P-2, P-6 and P-10 above.

SIC No. 371 Truck and Bus Bodies

One product tested is acceptable whereas five are not. Four of the latter have poor to very poor flexibility but P-2 might be used on castings. See comments above.

SIC No. 394 Toys and Sporting Goods

There are an insufficient number of products to express an opinion.

Table 9 Water Base Topcoats - Force Dry

SIC Nos. 331, 335 Fabricated Metal

Three products tested are acceptable. On the other hand, one product is unacceptable because of very poor color and poor resistance to salt fog (No. 43). It might be acceptable for interior use where color is not important.

SIC Nos. 254, 352, 371

There are an insufficient number of products tested for each end use to express an opinion.

Table 11 Water Base Topcoats - Air Dry

SIC Nos. 331, 335 Fabricated Metal

Three products tested are acceptable and one is limited to interior use. Four products are unacceptable; two because of slow to very slow dry, which cannot be tolerated in any industrial coating, one because of very poor flexibility and one because of poor color. The latter (No. 49) is marginal and might be acceptable where color is not important.

SIC No. 352 Farm Equipment

Only three products tested are recommended and none are acceptable. One exhibits very poor flexibility; another marginal storage stability and poor color; the third exhibits very poor color. The latter (No.49) might be acceptable if color is not important.

SIC Nos. 254, 364, 374

There are an insufficient number of samples tested for each end use to express an opinion.

Table 12 High Solids Topcoats - Air Dry

SIC No. 335 Fabricated Aluminum

Two products tested are recommended and both are unacceptable; one for too long a drying time, the other for too short a pot life which can ruin equipment in the plant if the mixed coating gels during use.

SIC Nos. 331, 371

There are an insufficient number of samples tested for each end use to express an opinion.

Exterior Coatings

Of the 18 low VOC coatings recommended for exterior use, five are primers and 13 are topcoats.

Among the primers (Table 2), three are acceptable for SIC No. 331 and 335 "Fabricated Metals"; one is limited to interior use because of poor corrosion resistance and one is not acceptable because of both low opacity and poor corrosion resistance.

Among the 13 topcoats, five are acceptable for their end use but 8 are not. Of these, only one, No. 39 in Table 6 "High Solids Topcoats - Baked, is unacceptable for exterior use because of poor resistance to weathering.

V PART B PLANT SURVEY

A. OBJECTIVE

The purpose of this survey was to determine the availability of commercial powder, water-borne and high-solids industrial coatings which comply with the CARB model rule for the control of VOC emissions from the surface coating of manufactured metal parts and products.

B. PROCEDURE

A survey was conducted by submitting a questionnaire or data form (See Appendix VA) to 201 metal fabricators. A total of 17 replied, of which only 4 submitted any data on low VOC coatings.

A literature search was then conducted to locate articles by or about metal fabricators who are using low VOC coatings. The search was limited to the last five years. The result was a total of 37 articles by or about metal fabricators using low VOC coatings plus abstracts of comments by 29 companies who are successfully using water-borne coatings.

The final phase of the survey was the direct telephone communication with a total of 40 metal fabricators who were believed to be using low VOC coatings. The data form used is shown in Appendix VB. As a result, data was submitted on 30 low VOC coatings presently being used.

C. RESULTS

The survey and literature search located 48 metal fabricators who are using low VOC coatings successfully. Some of them are among the largest manufacturers of their particular products in the United States with a number of plants throughout the country.

The number of companies for each type of coating are as follows overall:

Powder coatings	-	24
Water-borne coatings	-	14
High-solids coatings	-	10
		48

The surveys and articles were reviewed to obtain data on the following:

A. Metal products on which the coatings are applied.

B. Coating and substrate

1. Polymer or resin type
2. Substrate coated
3. Treatment of the substrate
4. Number of colors used
5. Cost of the coating

C. Application and cure

6. Method of application
7. Number of coats
8. Total dry film thickness
9. Cure schedule

D. Production

10. Advantages
11. Problems
12. Use limitations

E. Coating Performance

13. Advantages
14. Limitations

F. Economics

15. Equipment changes
16. Production changes
17. Capital costs
18. Operation costs
19. Maintenance costs
20. Energy costs
21. Effect on sales

The location and number of the plants covered in this report are shown in Table 1. Also included are the 29 plants about whom only limited data was obtained.

The data covering the 21 points listed above are shown in Tables 17 through 23. The numbers given may not add up to the total of companies reviewed because of the absence of data for some of the points listed.

Note that no significant data on VOC was obtained. Most metal fabricators did not know the VOC of their coatings and appear to rely on their suppliers to meet the current air quality regulations.

Table 17

Plant Locations

	Powder	Water Borne	High Solids	Total
Alabama	1	2		3
Arizona		1		1
California	4	3	3	10
Connecticut	1	4	1	6
Florida		2		2
Georgia	1	1		2
Illinois	1	6		7
Indiana	2	2	1	5
Iowa			1	1
Louisiana	1			1
Maryland	1	2	1	4
Massachusetts	1	1		2
Michigan		5	1	6
Minnesota	2	2		4
Missouri	1	2		3
New Jersey	1	4		5
New York		4		4
North Carolina	1	2	1	4
Ohio	1	2	1	4
Oklahoma	1			1
Oregon	1			1
Pennsylvania	2	5		7
Texas		2		2
Virginia	1			1
Wisconsin	1	1		2
TOTAL PLANTS	25	53	10	88
TOTAL STATES	19	20	8	25

Note: Includes 29 plants for whom only limited data was obtained. All of these use water-borne coatings.

Table 18

A. Metal Products

(No. of Companies)

	Powder	Water	Hi-Solids
Furniture and fixtures	5		3
Transportation equipment	3	6	
Heating and cooling equipment	3	1	1
Farm and garden equipment	3		
Lighting fixtures	2		1
Appliances	2		1
Electrical equipment	2		
Pipe and tubing	2	2	
Architectural fabricated metal	1		2
Construction equipment	1	1	1
Hardware and housewares		2	
Materials handling equipment		1	
Miscellaneous	—	1	1
Total	24	14	10

Table 19

B. Coating and Substrate

(No. of Companies)

	Powder	Water Borne	High Solids
1. Polymer	*		
Epoxy	14	2	1
Polyester	10		4
Urethane	3		
Acrylic		5	
Alkyd		4	1
Phenolic			1
Blends of above	3		2
2. Substrate		*	
Steel	12	12	5
Aluminum	6	4	3
Galvanized	3	3	2
Plated steel	2		
3. Treatment of Substrate			
Phosphate	18	10	2
Chromate	2		3
Wash clean		2	
Miscellaneous	2	2	2
4. Colors			
1	5	2	1
2	6	3	2
3		3	
4	4	1	1
5	3	3	
6-8	3	1	1
30+		1	2
5. Cost			
Powder coatings, $/lb.	1.75-3.00		
Liquid coatings, $/gal.		8-11	11-18

* Some companies use more than one.

Table 20

C. Application and Cure

(No. of Companies)

		Powder	Water Borne	High Solids
6. Application			*	
Electrostatic		24	4	6
Spray-Air			6	3
-Airless			6	1
Dip and flow coat			3	
7. Number of Coats				
1		24	5	6
2			4	2
8. Total Dry Film Thickness				
Below 1 mil			3	
Nominal-1 mil				5
1.1 to 3 mils		13	5	2
3.1 to 6 mils		7	2	
Above 6 mils		2		
9. Cure Schedule				
Air dry	(No.)		(4)	(2)
Force dry	Mins (No.)			
140°F			10-20 (2)	
Bake	Mins (No.)			
200°F-250°F			6-33 (3)	
275°F-300°F		5 (1)	10-15 (2)	15 (2)
320°F-350°F		5-23 (4)	12-20 (3)	15-30 (2)
360°F-375°F		12-15 (6)		12-20 (2)
390°F-400°F		3-20 (7)		
420°F-450°F		20-22 (2)		

* Some companies use more than one.

Table 21

D. Production

(No. of Companies)

	Powder	Water Borne	High Solids
10. Advantages			
No pollution (solvent)	18	2	2
Can reuse overspray	9		
Faster production	7		
Cleaner plant	6	2	
Makeup air is reduced	6		
Tough - no damage during assembly	5		
Fewer rejects	4		
Lower labor cost	4		
Safety (fire hazard)	2	4	
Less floor space	2		
Shorter bake cycle	2		
Better coverage			2
Fewer drums			2
11. Problems			
None	8		
Color change	5		
Control film thickness	2		
Slow dry		5	
Blistering		5	
Viscosity control		3	
Foaming		3	
Cure at high humidity		3	
Inconsistent quality		2	
Storage stability		2	
Careful metal treatment is necessary		2	3
Clogs spray guns		2	
Difficult application			5
Wet or sticky overspray			3
Housekeeping is difficult			3
Viscosity control			2
12. Use Limitations			
None		3	2
Small runs	2		
Sharp edges and corners	2		

Table 22

E. Coating Performance

(No. of Companies)

	Powder	Water Borne	High Solids
13. Advantages			
Corrosion resistance	11		
Durability	9		
Impact resistance	5		
Mar resistance	4		
Gloss	3		2
Appearance	3		
Hardness	3		
Flexibility	3		
None		3	3
14. Limitations			
None	10		5
Water resistance (Blistering)		5	
Adhesion		2	

Table 23

F. Economics

(No. of Companies)

	Powder	Water Borne	High Solids
15. Equipment Changes			
Major	5		
None		5	3
16. Production Changes			
Major	5		
None		2	2
17. Capital Costs			
$50,000-$1.5MM	10		
Higher		10-25% (3)	3
Same		2	4
18. Operating Costs			
Lower	5-80% (12)	3*	5*
Same	2	2	2
Higher		3	
19. Maintenance Costs			
Lower	15-80% (8)		2
Same		7	4
20. Energy Costs			
Lower	10-50% (11)		
Same		2	4
Higher		2	
21. Effect on Sales			
Increase	3		2
None	5	7	4

* Saving in cost of solvent.

A search of the literature also revealed statements by 29 metal fabricators who are using water-borne coatings successfully. Their comments can be summarized as follows:

1. Metal Products Being Coated

Furniture and fixtures	-	6
Transportation equipment	-	5
Heating and cooling equipment	-	2
Farm and garden equipment	-	1
Lighting fixtures	-	2
Appliances	-	1
Electrical and electronic equipment	-	3
Architectural fabricated metals	-	1
Hardware and housewares	-	2
Materials handling equipment	-	2
Miscellaneous	-	4
		29

2. Polymer

Alkyd	-	8
Acrylic	-	6
Polyester	-	3

3. Substrate

Steel	-	16
Aluminum	-	2
Galvanize	-	1

4. Application

Electrostatic	-	12
Spray	-	1
Dip and low coat	-	8

5. Comments

Lower energy costs	-	6
Lower cure temperatures	-	5
Cost saving (solvent)	-	3

The information obtained from all sources is summarized in

Table 24

Overall Summary (%)

	Powder	Water Borne	High Solids
Total Companies -----	24	43	10
Total Plants --------	25	53	10
1. Metal Products			
Furniture and fixtures	21	14	30
Transportation equipment	13	26	
Heating and cooling equipment	13	7	10
Farm and garden equipment	13	2	
Lighting fixtures	8	5	10
Appliances	8	2	
Electrical equipment	8	7	10
Pipe and tubing	8	5	
Architectural fabricated metal	4	2	20
Construction equipment	4	2	10
Hardware and housewares		9	
Materials handling equipment		7	
Miscellaneous		12	10
2. Polymer			
Epoxy	47	7	11
Polyester	33	11	45
Alkyd		43	11
Acrylic		39	
Urethane	10		
Phenolic			11
Hybrids of above	10		22
3. Substrate			
Steel	52	74	50
Aluminum	26	16	30
Galvanize	13	10	20
Plated steel	9		

D. DISCUSSION OF RESULTS

A review of Table 24 points up the major differences between powder, water-borne and high-solids coatings.

Major Metal Products (Highest Percentages)

Powder - Furniture and fixtures (21%)

Water-borne - Transportation equipment (26%)

High-solids - Furniture and fixtures (30%)

- Architectural fabricated metal (20%)

Note: All other percentages are below 15%

Major Polymers

Powder - Epoxy (47%)

- Polyester (33%)

Water-borne - Alkyd (43%)

- Acrylic (39%)

High-solids - Polyester (45%)

Note: All other percentages are below 12% or are based on hybrids (combinations) of these polymers

Substrate

Steel is the major substrate, as would be anticipated, with percentages of 50 to 74% of all substrates used. Aluminum is second with percentages of 16 to 30% of all substrates used. Galvanize is third with 10 to 20% of all substrates.

Considering all sources of information utilized to develop this analysis, it is evident that powder, water-borne and high-solids coatings all demonstrate some advantages as well as some limitations in both production and coating performance when compared with equivalent conventional coatings. The overall advantages for all three are shown in Table 25 and their overall limitations are shown in Table 26.

Note that all three improve ecology and safety, as would be anticipated, with powder coatings exhibiting the greatest advantage since VOC emissions and waste are minimal.

Powder coatings require a major expenditure for installation. Furthermore, they are restricted to use on metal products which can be heated to baking temperatures and therefore cannot be used on large equipment. They also produce coatings which tend to be in excess of 1 mil in thickness thus increasing the cost per square foot. Color change is difficult so that only a limited number of colors are usually handled in the plant. However, their advantages in both production and coating performance, as well as savings in production, maintenance and energy costs, offset these limitations to a great degree.

Table 25

Advantages

	Powder	Water Borne	High Solids
Ecology and Safety			
Less air pollution	Best	X	X
Less flammable	X	X	
Less toxic	X	X	
Less waste disposal	Best	X	X
Production			
Minimal equipment changes		X	
Less storage space	X		X
Increase conveyor load	X		
Shorter oven - no flash-off	X		
Lower exhaust rates	Best		X
High efficiency - re-use overspray	X		
Less makeup air	X		
No drip or sag	X		
Cover surface defects	X		
Fewer rejects	X		
Better coverage	X		X
Faster production	X		
Less cleanup	Best	X	
No damage when packed or shipped	X		
Coating Performance			
Gloss	X		Best
Corrosion resistance	X		
Mar resistance	X		
Durability	X		X
Economics			
Saving on solvent	Best	X	X
Lower operating costs	X		
Lower maintenance costs	X		
Lower energy costs	X		

Table 26

Limitations

	Powder	Water Borne	High Solids
Economics			
More expensive	X	X	X
Equipment installation or modification	Major	X	X
Production			
Critical modification of electrostatic spray		X	
Humidity control	X	X	
Temperature control	X	X	
pH control		X	
Storage stability		X	
High viscosity			X
Viscosity control		X	X
Difficult application			X
Sensitivity to substrate cleanliness		X	X
Flash-off time		X	
Limited to baking only	X		
Difficult to achieve 1 mil thickness	X		
Slow dry - dirt pickup and recoat		X	
Foaming		X	
Blistering during cure		X	
Color change	X		
Coat corners and edges	X		
Flow and leveling (orange peel)	X		X
Cleanup of spray booth		X	Major
Pump maintenance		X	
Strip conveyor racks	X		
Handling 800 lb drums			X
Coating Performance			
Initial water resistance		X	

Water-borne coatings require the smallest expenditure in equipment changes and can be both air dried and force dried, as well as baked. Therefore, they can be used to coat large items, such as construction and farm equipment, as well as small items. However, production problems are greatest with water-borne coatings primarily because of the inherent problems with a coating employing water as a solvent. These includes poor wetting of other than very clean surfaces, foaming, slow evaporation of water as compared with organic solvents and initial water sensitivity of the cured coating. Furthermore, the performance of the cured coating is marginal with respect to replacement of conventional coatings.

High-solids coatings are difficult to apply because of their relatively high viscosity. Therefore, some capital expenditure is required to install either high speed electrostatic discs or heaters to enable their application. They can be air dried or force dried but exhibit their best performance properties when baked. When cured by baking, their performance is superior to water-borne coatings and essentially equal to powder coatings.

General

Essentially, all of the changes to the use of powder and especially water-borne and high-solids coatings within the last five years have been made to meet actual or anticipated regulations on air quality.

Powder coatings have been in use for about 15 years so that the technology had been developed and coatings were available. However, further development work on powder coatings had to be carried out to expand their use in applications where relatively thin films were desired, i.e., in the range of 1 mil.

Water-borne coatings for application by electrodeposition (electrocoating) have been in use for nearly 20 years. They are used primarily as primers for automobile bodies. Furthermore, they were not included in the laboratory evaluation (Part A of this report). Therefore they are outside of the scope of this report.

On the other hand, the technology for spray or flow coat applied water-borne and high-solids coatings, especially the latter, still is in its infancy. Consequently, companies who wished to change their products to meet air quality regulations have had to work very closely with both the suppliers of their equipment as well as of their coatings in order to develop a viable, cost effective operation. As a result of this necessity to review their entire operation, many have actually upgraded their operation with favorable results.

VI GLOSSARY LABORATORY EVALUATION

A simple description of the properties tested will aid in understanding the test results.

1. Viscosity - Thickness or consistency

2. Viscosity Stability - Retention of viscosity after 4 weeks of accelerated storage. This is considered to be as severe as six months of storage at ambient temperatures.

3. Package Stability - Absence of liquid separation, skin formation on the surface of the coating and pigment settling or caking during accelerated storage. Ease of remixing after storage.

4. Pot Life - Two component coatings tend to react as soon as mixed. However, this reaction should be controlled so that the mixed paint is useable for at least a working day, i.e., 6 or 8 hours.

5. Ease of Application - The ability to spray the paint and produce a uniform paint film.

6. Speed of Dry -

   Set to touch - the length of time the paint remains wet to touch

   Tack free - free of any tackiness or stickiness

   Dry hard - coating can be handled carefully with no damage.

   Dry thru - coating is hard and can be handled readily.

7. Overcure - This is a measure of the ability of the coating to withstand unanticipated variations in the curing time or temperature without a significant change in gloss or damage to its appearance. The undesirable variations are an excessive temperature or an excessive time in the oven.

8. Gloss - Lustre or shininess

9. Whiteness - Purity of whiteness

10. Opacity - Ability of the coating to hide or obscure the surface on which it is applied.

11. Hardness - Ability of the coating to withstand scratching, e.g., by a pencil lead.

12. Adhesion - Ability of the coating to adhere to the surface on which it is applied. If its adhesion is poor, performance will deteriorate rapidly.

13. Flexibility - Ability of the coating to be flexible when the metal is formed or expands and contracts with temperature during use.

14. Impact Resistance - Ability of the coating to withstand deformation when struck with a hard object.

15. Abrasion Resistance - Ability of the coating to withstand wear from an abrasive medium.

16. UV Exposure - Ability of the coating to retain its color and gloss when exposed indoors. Ultraviolet light accelerates the exposure.

17. Resistance Tests - Ability fo the coating to withstand exposure to water, dilute acid, dilute alkali and strong solvents with minimum effect on color, gloss, hardness and with minimum damage as evidenced by blistering.

    All coatings should be water resistant to prevent damage when wet. The acid, alkali and solvents are typical of what might be encountered in industrial applications.

18. Salt Fog Exposure - This simulates an exposure to a marine or seashore environments and is the most popular test for corrosion , an "X" is scored through the coating to expose the steel and simulate damage to the coating.

19. Accelerated Weathering - The apparatus combines artificial sunlight lamps and moisture condensation to simulate but accelerate exposure condiions and thus determine relative durability outdoors.

IX GLOSSARY PLANT SURVEY

Air spray - The coating is atomized by the use of air under pressure.

Airless spray - The coating is atomized by forcing it through a small orifice under very high pressure.

Chromate - Chemical treatment of aluminum surfaces which is empolyed to improve adhesion of applied coatings.

Conventional Coatings - Solvent-thinned coatings which do not meet the VOC requirements.

Conventional Spray - Air or airless, not electrostatic.

Dip - The process in which the metal is immersed in the liquid coating and then withdrawn.

Electrocoating - A dip process in which an electric current is passed through the liquid paint to deposit the coating on the metal.

Electrodeposition - The process of electrocoating.

Electrostatic Spray - Application process in which an electrostatic charge is placed on the atomized spray particles causing the coating droplets to be attracted to the grounded metal substrate.

Flow Coat - The process in which the paint is allowed to flow over the metal substrate and the excess is drained off.

Foaming - Formation of air bubbles.

High-Solids - Higher non-volatile content (less solvent) than conventional coatings.

Makeup Air - Air drawn from outdoors which is required to replace the internal air removed by spray booth exhaust fans. This air may have to be heated in winter and cooled in summer.

Metal Fabricators - Companies who manufacture metal objects from sheet metal or castings.

Overspray - The paint particles which do not coat the substrate but are pulled up the exhaust stack or fall onto the floor or walls of the spray booth.

Phosphate - Chemical treatment of steel surfaces which is employed to improve the adhesion of applied coatings. The most common are iron and zinc phosphate.

Polymer - The binder portion of the coating.

Powder coatings - A coating supplied as a fusible powder. It is applied by electrostatic spray which causes the powder to adhere to the metal substrate in a uniform layer. Subsequent baking fuses the powder to form a continuous coating.

Resin - See Polymer.

Spray Booth - An enclosed area used for spray painting of fabricated items. It may be equipped with a source of filtered air to keep the atmosphere dust free, a waterfall backdrop to trap overspray and an exhaust system to vent the evaporating solvents.

Substrate - The metal surface on which the coating is applied.

Viscosity - The flow properties of a coating in its liquid state.

Water-Borne - A coating in which the major portion of the solvent is water.

X ABBREVIATIONS

CARB - California Air Resources Board

VOC - Volatile Organic Compounds

Appendix I

Publicity, Letters & Data Forms

Appendix IA

D/L LABORATORIES

(FORMERLY DAVID LITTER LABORATORIES)

116 East 16th Street, New York, N.Y. 10003
Telephone: 212-777-4410

Publicity Release - Covering Letter to Publications

As you probably know, the California Air Resources Board (CARB) has been in the forefront in developing regulations which reduce air pollution by limiting the concentration of volatile organic compounds (VOC) in applied coatings.

CARB, as part of its continuing research effort, wishes to determine whether low VOC coatings for the industrial finishing of metal parts and products are available which demonstrate competitive performance properties vs their conventional (solvent-thinned) counterparts. Consequently, CARB has contracted with the D/L Laboratories to assist in this program.

The first approach is to publicize CARB's interest as widely as possible in order to alert paint manufacturers, raw material suppliers and metal fabricators as to the proposed plan. We will then obtain commercial, prototype or formulated samples of these products and evaluate them vs equivalent commercial products.

We would, therefore, appreciate your inserting the enclosed Publicity Release in an early issue of your publication. Please send us two copies of the printed release.

Thank you for your cooperation.

Sincerely,

Sidney B. Levinson
President

SBL/df
cc: S. Spindel

enc.

D/L LABORATORIES

(FORMERLY DAVID LITTER LABORATORIES)

116 East 16th Street, New York, N.Y. 10003
Telephone: 212-777-4410

Appendix IB

Publicity Release - Covering Letter to Associations

As you probably know, the California Air Resources Board (CARB) has been in the forefront in developing regulations which reduce air pollution by limiting the concentration of volatile organic compounds (VOC) in applied coatings.

CARB, as part of its continuing research effort, wishes to determine whether low VOC coatings for the industrial finishing of metal parts and products are available which demonstrate competitive performance properties vs their conventional (solvent-thinned) counterparts. Consequently, CARB has contracted with the D/L Laboratories to assist in this program.

The first approach is to publicize CARB's interest as widely as possible in order to alert paint manufacturers, raw material suppliers and metal fabricators as to the proposed plan. We will then obtain commercial, prototype or formulated samples of these products and evaluate them vs equivalent commercial products.

We would, therefore, appreciate your advising your membership of this program. If you have a newsletter, the enclosed Publicity Release should serve to do so. Please send us two copies of the printed release. We also would appreciate receiving a copy of your membership directory for which we will be pleased to pay if there is a charge.

Thank you for your cooperation.

Sincerely,

Sidney B. Levinson
President

SBL/df
cc: S. Spindel

enc.

Appendix IC

D/L LABORATORIES

(FORMERLY DAVID LITTER LABORATORIES)

116 East 16th Street, New York, N.Y. 10003
Telephone: 212-777-4410

Publicity Release

CARB SEEKS LOW VOC INDUSTRIAL FINISHES

The California Air Resources Board (CARB), as part of its research program to investigate the current status of coating technology, is seeking industrial finishes for metal parts and products which meet its solvent limitation requirements. Consequently, CARB has contracted with the D/L Laboratories to locate and evaluate the relative performance, vs conventional industrial finishes, of commercial or developmental coatings (or formulations from raw material suppliers), which contain no more than 340 grams of volatile organic compounds (VOC) per liter of coating, less water.

These coatings may be either water-based, high solids or powder. Any organic solvents may be used within the VOC limits. It is not necessary to meet Rule 66 or any of its variations.

The coatings should be intended for use on metal parts or products and can be cured by bake, air dry or force dry.

Selected submitted coatings will be evaluated vs equivalent conventional solvent-thinned products. All products will be coded, no names will be used in the report and all cooperators will receive a copy of the report with their code numbers.

Your cooperation is solicited. If you wish to have your products (or formulations) included in this program, please call or write.

Sidney B. Levinson
President
D/L Laboratories
116 East 16th Street
New York, N.Y. 10003

212/777-4410

Appendix ID

D/L LABORATORIES

(FORMERLY DAVID LITTER LABORATORIES)

116 East 16th Street, New York, N.Y. 10003
Telephone: 212-777-4410

Letter to Associations

As you probably know, the California Air Resources Board (CARB) has been in the forefront in developing regulations which reduce air pollution by limiting the concentration of volatile organic compounds (VOC) in applied coatings.

CARB, as part of its continuing research effort, wishes to determine whether low VOC coatings for the industrial finishing of metal parts and products are available which demonstrate competitive performance properties vs their conventional (solvent-thinned) counterparts. Consequently, CARB has contracted with the D/L Laboratories to assist in this program.

The first approach is to publicize CARB's interest as widely as possible in order to alert paint manufacturers, raw material suppliers and metal fabricators as to the proposed plan. We will then obtain commercial, prototype or formulated samples of these products and evaluate them vs equivalent commercial products.

We would, therefore, appreciate your reading the enclosed Publicity Release at your next meeting.

Thank you for your cooperation.

Sincerely,

Sidney B. Levinson
President

SBL/df
cc: S. Spindel

enc.

Appendix IE

LABORATORIES

(FORMERLY DAVID LITTER LABORATORIES)

116 East 16th Street, New York, N.Y. 10003
Telephone: 212-777-4410

Letter to Paint Manufacturers

The California Air Resources Board (CARB), as part of its research program to investigate the current status of coating technology, is seeking industrial coatings for metal parts and products which meet its solvent limitation requirements. Consequently, CARB has contracted with the D/L Laboratories to locate and evaluate the relative performance, vs conventional industrial finishes, of commercial or developmental coatings which contain no more than 340 grams of volatile organic compounds (VOC) per liter of coating, less water.

These coatings may be either water-based, high solids or powder. Any organic solvents may be used within the VOC limits. It is not necessary to meet Rule 66 or any of its variations.

The coatings should be intended for use on metal parts or products <u>except</u> can, coil, wire, auto, aircraft and marine substrates. They can be cured by bake, air dry or forced dry.

Selected submitted coatings will be evaluated vs equivalent conventional products, preferably from the same source. All samples will be coded, no names will be used in the report and all cooperators will receive a copy of the report with their code numbers.

If you wish to have any of your products included in this test program, please send us quart samples of both the low solvent and equivalent conventional products (if available). White and/or metallic finishes are preferred, but send us what you have. Also please send us whatever literature and data you can supply on your products and fill in whatever data you can on the enclosed form. The form is important for comparison purposes.

We solicit your cooperation in what should be a very interesting project.

Sincerely,

ENCLOSURE - Data Form

Sidney B. Levinson
President

SBL/df

P.S. If this letter should be addressed to someone else in your company, please forward it or advise us and we will write directly.

LABORATORIES
116 East 16th Street, New York, N.Y. 10003

Appendix IF

Paint Mfrs.

DATA FORM

LOW SOLVENT VS CONVENTIONAL METAL FINISHES

Provide Whatever Information is Available

Company: ______________________

Address: ______________________

Submitted By: ______________________ Date: ______________________

	LOW SOLVENT	CONVENTIONAL	
Product: -			
Name:			
Code No:			
Polymer Type:			
Weight per Gallon:			Lbs
Total Solids: -			
Weight:			%
Volume:			%
VOC (less water): -			
By Weight:			gm/l
By Volume:			%
Flash Point:			°F
Method			
Viscosity:			KU
Shelf Life:			Mos.
Recommended Substrates: (Check)	Steel: ____ Alum: ____ Galv: ____ Other: ____	Steel: ____ Alum: ____ Galv: ____ Other: ____	
Metal Preparation:			
Dry or Cure: -			
Bake:	____ Mins. ____ °F	____ Mins. ____ °F	
Force Dry:	____ Mins. ____ °F	____ Mins. ____ °F	
Air Dry:	____ Hrs	____ Hrs	

(OVER)

	LOW SOLVENT	CONVENTIONAL
Application Instructions Including Thinning and Equipment: -		
Spray:		
Flow Coat:		
Roller Coat:		
Dip:		
Major End Uses:		
Outstanding Properties:		
Limitations:		
Selling Prices (Approximate or Anticipated): -		
5 gal. cans:		$/Gal
Drums:		$/Gal
Annual Sales (Approximate or Anticipated) in $:		
	Under 50M ____ 50-100M ____	Under 50M ____ 50-100M ____
	100-200M ____ Over 200M ____	100-200M ____ Over 200M ____

Can you recommend any Major Users whom we might contact? ________________

Samples For Test:

Please submit one or two quarts of each product. White is the preferred color though other colors are acceptable. There is no limit as to the number of products which can be submitted, but only one color of each. Also send any available data and literature.

Send samples and data to:

Sidney B. Levinson
President
D/L Laboratories
116 East 16th Street
New York, N.Y. 10003

Appendix IG

LABORATORIES

(FORMERLY DAVID LITTER LABORATORIES)

116 East 16th Street, New York, N.Y. 10003
Telephone: 212-777-4410

Letter to Raw Material Suppliers

The California Air Resources Board (CARB), as part of its research program to investigate the current status of coating technology, is seeking industrial coatings for metal parts and products which meet its solvent limitation requirements. Consequently, CARB has contracted with the D/L Laboratories to locate and evaluate the relative performance, vs conventional industrial finishes, of commercial or developmental coatings which contain no more than 340 grams of volatile organic compounds (VOC) per liter of coating, less water.

These coatings may be either water-based, high solids or powder. Any organic solvents may be used within the VOC limits. It is not necessary to meet Rule 66 or any of its variations.

The coatings should be intended for use on metal parts or products <u>except</u> can, coil, wire, auto, aircraft or marine substrates. They can be cured by bake, air dry or forced dry.

Selected submitted coatings will be evaluated vs equivalent conventional products, preferably from the same source. All samples will be coded, no names will be used in the report and all cooperators will receive a copy of the report with their code numbers.

If you wish to have any of your recommended formulations included in this test program, please send quart samples of both the low solvent and equivalent conventional formulations. We must request samples since the program precludes the preparation of samples by us. Also please send whatever literature and data you have, including your recommended formulations on the products submitted, and fill in whatever data you can on the enclosed form.

We solicit your cooperation in what should be a very interesting project.

Sincerely,

ENCLOSURE - Data Form

Sidney B. Levinson
President

SBL/df

P.S. If this letter should be addressed to someone else in your company, please forward it or advise us and we will write directly.

LABORATORIES
116 East 16th Street, New York, N.Y. 10003

Appendix IH

DATA FORM

LOW SOLVENT VS CONVENTIONAL METAL FINISHES

Provide Whatever Information is Available

Company: ______________________________

Address: ______________________________

Submitted By: ______________________ Date: ______________

	LOW SOLVENT	CONVENTIONAL
Product: -		
Name:	______	______
Code No:	______	______
Generic Type:	______	______
Weight per Gallon:	______	______ Lbs
Total Solids: -		
Weight:	______	______ %
Volume:	______	______ %
VOC (less water): -		
By Weight:	______ gm/l	______
By Volume:	______ %	______
Flash Point:	______	______ °F
Method:	______	______
Viscosity	______	______ KU
Shelf Life:	______	______ Mos
Recommended Substrates:	Steel: ______ Alum: ______	Steel: ______ Alum: ______
(Check)	Galv: ______ Other: ______	Galv: ______ Other: ______
Metal Preparation:	______	______
	______	______
Dry or Cure: -		
Bake:	______ Mins. ______ °F	______ Mins. ______ °F
Force Dry:	______ Mins. ______ °F	______ Mins. ______ °F
Air Dry:	______ Hrs	______ Hrs

(OVER)

	LOW SOLVENT	CONVENTIONAL
Application Instructions Including Thinning and Equipment: -		
Spray:		
Flow Coat:		
Roller Coat:		
Dip:		
Major End Uses:		
Outstanding Properties:		
Limitations:		
Can you recommend any paint manufacturers whom we might contact?	Name: Co.: Add.:	Name: Co.: Add.:

Samples and Formulations

Please submit your formulation and a one quart sample of each product. White is the preferred color, though other colors are acceptable. There is no limit as to the number of products which can be submitted.

Send samples, formulations and data to:

Sidney B. Levinson
President
D/L Laboratories
116 East 16th Street
New York, NY 10003

Appendix IJ

DL LABORATORIES

(FORMERLY DAVID LITTER LABORATORIES)

116 East 16th Street, New York, N.Y. 10003
Telephone: 212-777-4410

Follow-up Letter to Cooperators

Re: CARB Industrial Coatings

We have received the following product(s) from you which will be tested in this project.

However, we need more information, to the extent that it can be supplied in order to classify these products in logical groups and to run the proper tests which will demonstrate their service capabilities. Therefore we request that you give us as much information as possible on the enclosed form.

Thank you for your cooperation.

Sincerely,

Sidney B. Levinson
President

SBL/df
cc: S. Spindel

enc.

Appendix II

Test Data

Appendix II

TEST DATA

Application for all samples was Excellent when thinned down to spray viscosity.

It should be understood that a broad variety of tests were conducted in order to determine whether low VOC coatings are available which are competitive with equivalent conventional coatings. Some tests might be too severe for the type of coating tested, e.g., air dry, regardless whether low VOC or conventional, and therefore can be disregarded in rating the relative performance of that group of coatings.

Appendix IIA

Test Results

Primers - Baked

		Water Base			Conv.
		104	111*	124	125
Substrate --------		St.	St.	Zn.	Zn.
Color ------------		Yellow	Orange	Grey	Grey
Viscosity	KU				
Initial		60	53	140	72
4 wks at 125°F		56	53	63	83
Package Stability	Score				
Liq. separation		10	6	6	8
Skinning		10	10	10	10
Pigment settling		8	6	6	10
Ease of remixing		9	6	6	8
Pot Life	Hrs	0.5*	X	X	X
Cure - Time	Mins	15	30	15	20
- Temperature	°F	212	550	400	390
Overcure -					
50°F above normal					
Appearance	Score	10	8	8	8
Gloss change	%	22	20	4	5
Adhesion	%	100	100	100	100
2X normal					
Appearance	Score	10	6	8	6
Gloss change	%	26	38	1	5
Adhesion	%	100	100	100	100
Gloss	Units	23	81	76	81
Opacity	%	75.8	***	100	100
Hardness (Pencil) - Pass		2H	3H	2H	6H
Adhesion	%	100	100	100	100
Flexibility	Inch	1/8	1/8	3/8	1/4
Impact	In. lbs	28	160+	24	20
Abrasion Resistance	L/mil	32	60+	24	31

* - When mixed with catalyst
** - Inorganic
*** - Temp. too high to determine
Conv. - Conventional

St - Steel
Zn - Zinc phosphate
X - Not applicable

Appendix IIA (Cont)

Test Results

Primers - Baked

		Water Base			Conv.
		104	111*	124	125
	Substrate -----	St.	St.	Zn.	Zn.
	Color ---------	Yellow	Orange	Grey	Grey
Water Resistance	Hrs	188	500	500	500
Blistering	ASTM		10	10	10
Color change	Score		10	10	10
Gloss change	"		10	10	10
Hardness	"		10	10	10
Recovery	"		10	10	10
Acid Resistance	Hrs	96	500	168	500
Blistering	ASTM		10		10
Color change	Score		10		10
Gloss change	"		10		10
Hardness	"		10		10
Recovery	"		10		10
Alkali Resistance	Hrs	-1	500	168	288
Blistering	ASTM		10		
Color change	Score		10		
Gloss change	"		10		
Hardness	"		10		
Recovery	"		10		
Xylol Resistance - 500 Hours					
Blistering	ASTM	10	10	10	10
Color change	Score	9	8	10	9
Gloss change	"	10	10	10	10
Hardness	"	1	10	10	10
Recovery	"	10	10	10	10
MEK Resistance	Hrs		500	500	500
Blistering	ASTM	20	10	10	10
Color change	Score		10	9	10
Gloss change	"		10	10	10
Hardness	"		10	10	6
Recovery	"		10	10	10

MEK - Methyl Ethyl Ketone

Test Results

Appendix IIA (Cont)

Primers - Baked

		Water Base			Conv.
		104	111*	124	125
Substrate -------		St.	St.	Zn.	Zn.
Color -----------		Yellow	Orange	Grey	Grey
Salt Fog Exposure	Hrs	200	500	500	500
Blistering at X	ASTM		8F	10	10
" - overall	"		8F	10	10
Creep at X	mm		2	2	2
Corrosion	Score		6	9	10
Acc. Weathering - 500 Hours					
Color change	Score	10	8	8	10
Gloss change	"	6	10	2	2
Chalking	ASTM	10	10	6	8
Checking	"	10	10	10	10
Blistering	"	10	10	10	10
Rusting	Score	10	8	10	10

Appendix IIB

Test Results

Primers - Forced Dry

		Water Base 122	Conv. 29
Substrate --------		Fe.	St.
Color ------------		Orange	Green
Viscosity	KU		
Initial		84	83
4 wks @ 125°F		84	93
Package Stability	Score		
Liq. separation		8	8
Skinning		8	10
Pigment settling		8	10
Ease of remixing		8	9
Pot Life	Hrs	X	X
Cure - Time	Mins	15	30
- Temperature	°F	180	175
Overcure			
50°F above normal			
Appearance	Score	10	10
Gloss change	%	33	0
Adhesion	%	100	100
2X normal			
Appearance	Score	10	10
Gloss change	%	33	0
Adhesion	%	100	100
Gloss	Units	33	87
Opacity	%	100	100
Hardness (Pencil) - Pass		3B	3B
Adhesion	%	100	100
Flexibility	Inch	1/8	1/8
Impact	In. lbs	108	160+
Abrasion Resistance	L/mil	12	9

X - Not applicable
* - When mixed with catalyst

Test Results

Appendix IIB (Cont)

Primers - Forced Dry

		Water Base	Conv.
		122	29
Substrate --------		Fe.	St.
Color ------------		Orange	Green
Water Resistance	Hrs	500	500
Blistering	ASTM	10	10
Color change	Score	9	9
Gloss change	"	8	10
Hardness	"	1	10
Recovery	"	10	10
Acid Resistance	Hrs	16	2
Blistering	ASTM		
Color change	Score		
Gloss change	"		
Hardness	"		
Recovery	"		
Alkali Resistance	Hrs	-1	-1
Blistering	ASTM		
Color change	Score		
Gloss change	"		
Hardness	"		
Recovery	"		
Xylol Resistance	Hrs	-1	-1
Blistering	ASTM		
Color change	Score		
Gloss change	"		
Hardness	"		
Recovery	"		
MEK Resistance	Hrs	-1	-1
Blistering	ASTM		
Color change	Score		
Gloss change	"		
Hardness	"		
Recovery	"		

Test Results

Appendix IIB (Cont)

Primers - Forced Dry

		Water Base	Conv.
		122	29
Substrate --------		Fe.	St.
Color ------------		Orange	Green
Salt Fog Exposure	Hrs	230	336
Blistering at X	ASTM		
" - overall	"		
Creep at X	mm		
Corrosion	Score		
Acc. Weathering - 500 Hours			
Color change	Score	8	0*
Gloss change	"	8	0*
Chalking	ASTM	10	4
Checking	"	10	10
Blistering	"	10	10
Rusting	Score	10	10

* Due to heavy chalking

Appendix IIC

Test Results

Primers - Air Dry

		Water Base					Conventional	
		79[2]	80[2]	82[2]	84[2]	85[2]	81[2]	83[2]
Substrate ----		St.	St.	St.	St.	St.	St.	St.
Color --------		Grn	Grn	Grn	Red	Red	Yel	Grn
Viscosity (Mixed)	KU	63	105	64*	105	97	58	42
Initial		141/57	141/69	96/141	141/57	141/58	128/42	63/42
4 wks @ 125°F		141/57	141/70	104/141	141/61	141/61	141/42	63/42
Package Stability	Score							
Liq. separation		9/10	10	6/10	10	9/10	6/10	6/10
Skinning		10/10	10	10/10	10	10/10	10/10	10/10
Pigment settling		6/10	10	4/10	10	6/10	6/10	4/10
Ease of remixing		6/10	10	2/10	10	6/10	4/10	4/10
Pot Life	Hrs	16	6	2.5	16	16	48	48
Speed of Dry	Hrs							
Set to touch		0.6	1.0	0.6	0.6	0.6	0.2	0.2
Tack free		1.5	3.0	2.3	1.5	2.3	1.3	0.6
Dry hard		2.3	3.5	3.0	4.0	3.5	2.3	1.0
Dry thru		2.3	3.5	3.0	4.0	3.5	2.3	1.0
Gloss	Units	5	5	5	3	5	5	30
Opacity	%	74.9	80.6	66.3	100	100	79.3	96.6
Hardness (Pencil)	Pass	HB	F	F	F	F	H	F
Adhesion	%	100	100	100	100	100	100	100

* Water added to mix as per directions
2 - Two component
Grn - Green
Yel - Yellow

Appendix IIC (Cont)

Test Results

Primers - Air Dry

		Water Base					Conventional	
		79[2]	80[2]	82[2]	84[2]	85[2]	81[2]	83[2]
	Substrate -------	St.	St.	St.	St.	St.	St.	St.
	Color -----------	Grn	Grn	Grn	Red	Red	Yel	Grn
Flexibility	Inch	1/8	1/8	1/8	1/8	1/8	1/8	1/8
Impact	In. lbs	160+	160+	160+	160+	160+	160+	128
Abrasion Resistance	L/mil	23	21	15	11	13	15	9
Water Resistance	Hrs	500	116	500	188	500	500	500
Blistering	ASTM	10		10		8M	10	10
Color change	Score	8		10		9	10	10
Gloss change	"	10		10		10	10	10
Hardness	"	4		10		1	10	10
Recovery	"	10		10		8	10	10
Acid Resistance	Hrs	1	1	1	1	20	20	20
Blistering	ASTM							
Color change	Score							
Gloss change	"							
Hardness	"							
Recovery	"							
Alkali Resistance	Hrs	500	20	20	20	1	44	1
Blistering	ASTM	10						
Color change	Score	9						
Gloss change	"	10						
Hardness	"	10						
Recovery	"	10						

Appendix IIC (Cont)

Test Results

Primers - Air Dry

		Water Base					Conventional	
		79[2]	80[2]	82[2]	84[2]	85[2]	81[2]	83[2]
Substrate ------		St.	St.	St.	St.	St.	St.	St.
Color ----------		Grn	Grn	Grn	Red	Red	Yel	Grn
Xylol Resistance - 500 Hours								
Blistering	ASTM	10	10	10	10	10	8F	10
Color change	Score	6	8	9	9	9	8	10
Gloss change	"	6	10	10	10	10	10	10
Hardness	"	6	10	10	10	10	10	10
Recovery	"	6	10	10	10	10	10	10
MEK Resistance - 500 Hours								
Blistering	ASTM	10	10	10	10	10	10	10
Color change	Score	9	10	10	10	10	10	10
Gloss change	"	10	10	10	10	10	10	10
Hardness	"	0	10	10	10	10	10	10
Recovery	"	8	10	10	10	10	10	10
Salt Fog Exposure - Hrs		200	68	68	116	116	500	500
Blistering at X	ASTM						2F	4F
" - overall	"						2F	10
Creep at X	mm						4	2
Corrosion	Score						6	10
Acc. Weathering - 500 Hours								
Color change	Score	2	4	6	6	4	4	6
Gloss change	"	6	6	8	8	6	8	8
Chalking	ASTM	2	2	6	2	2	6	6
Checking	"	10	10	10	10	10	10	10
Blistering	"	10	10	10	10	10	10	10
Rusting	Score	10	10	10	10	10	10	10

Appendix IID

Test Results

Water Base Topcoats - Baked

		5	8	14	64	75	103	105	106	110*	123
Substrate ---------		St.	Zn.	Zn.	Zn.	St.	St.	St.	St.	St.	Fe.
Color -------------		Wht	Blk	Wht	Wht	Wht	Clr	Wht	Wht	Gry	Yel
Viscosity	KU										
Initial		89	72	72	55	64	60	58	116	65	74
2 wks @ 125°F		96	93	69	53	67	Sol	54	Sol	82	81
Package Stability	Score										
Liq. separation		10	9	2	2	2	Sol	8	Sol	6	6
Skinning		10	10	10	10	10		10		10	10
Pigment settling		8	10	9	6	6		8		6	10
Ease of remixing		8	10	9	2	8		8		6	8
Cure - Time	Mins	20	12	15	20	15	15	15	30	60	15
- Temperature	°F	300	350	300	275	300	350	212	300	500	350
Overcure											
50°F above normal											
Appearance	Score	10	10	10	10	10	10	10	10	10	10
Gloss change	%	3	0	2	1	18	12	3	7	0	4
Adhesion	%	100	100	100	100	100	100	100	100	100	100
2X normal											
Appearance	Score	100	10	10	8	10	6	10	10	10	10
Gloss change	%	1	0	2	1	15	6	5	0	0	2
Adhesion	%	100	100	100	100	100	100	100	100	100	100
Gloss	Units	94	20	90	86	78	85	77	83	2	56
Whiteness Index	Units	83.5	X	88.2	87.1	77.3	X	83.3	74.2	X	X
Opacity	%	99.2	100	95.2	100	100	X	89.8	99.0	**	96.1
Hardness (Pencil) - Pass		HB	H	F	3H	HB	H	2H	F	3H	6H
Adhesion	%	100	100	100	100	100	100	100	100	100	100

* - Inorganic
** - Temperature too high to determine

Wht - White
Blk - Black

Clr - Clear
Gry - Grey

Sol - Solid

Appendix IID (Cont)

Test Results

Water Base Topcoats - Baked

		5	8	14	64	75	103	105	106	110*	123
Substrate -------		St.	Zn.	Zn.	Zn.	St.	St.	St.	St.	St.	Fe.
Color ----------		Wht	Blk	Wht	Wht	Wht	Clr	Wht	Wht	Gry	Yel
Flexibility	Inch	1/8	1/8	1/8	1+	1/8	1/8	1/8	1/8	1+	3/4
Impact - Direct	In.lbs	160+	80	80	12	160+	48	40	36	36	68
Abrasion Resistance	L/mil	31	27	21	20	37	45	30	49	60+	36
UV Exposure											
Gloss change	%	16	10	7	0	3	16	35	33	0	16
Color change	Score	8	10	10	10	9	6	10	10	10	10
Water Resistance	Hrs	100	168	336	96	144	500	20	116	240	40
Blistering	ASTM						8M				
Color change	Score						10				
Gloss change	"						10				
Hardness	"						10				
Recovery	"						10				
Acid Resistance	Hrs	144	1	16	16	20	500	20	500	144	16
Blistering	ASTM						10		10		
Color change	Score						9		9		
Gloss change	"						10		10		
Hardness	"						10		10		
Recovery	"						10		10		
Alkali Resistance	Hrs	20	16	-1	-1	-1	20	1	116	24	16
Blistering	ASTM										
Color change	Score										
Gloss change	"										
Hardness	"										
Recovery	"										

Appendix IID (Cont)

Test Results

Water Base Topcoats - Baked

		5	8	14	64	75	103	105	106	110*	123
Substrate -------		St.	Zn.	Zn.	Zn.	St.	St.	St.	St.	St.	Fe.
Color -----------		Wht	Blk	Wht	Wht	Wht	Clr	Wht	Wht	Gry	Yel
Xylol Resistance	Hrs	-1	500	-1	120	1	500	500	500	500	500
Blistering	ASTM		10				10	2D	10	10	10
Color change	Score		10				9	8	10	10	9
Gloss change	"		10				10	10	10	10	
Hardness	"		1				1	1	10	10	
Recovery	"		10				10	10	10	10	
MEK Resistance	Hrs	-1	500	-1	20	-1	20	-1	20	500	500
Blistering	ASTM		10							10	10
Color change	Score		10							10	10
Gloss change	"		10							10	10
Hardness	"		1							10	10
Recovery	"		10							10	10
Salt Fog Exposure	Hrs	270	117	20	410	100	92	24	250	200	96
Blistering at X	ASTM										
" - overall	"										
Creep at X	mm										
Corrosion	Score										
Acc. Weathering	Hrs	500	500	20	500	500	500	500	500	500	20
Color change	Score	6	9		10	8	6	10	6	10	
Gloss change	"	2	10		6	8	6	10	2	10	
Chalking	ASTM	10	10		10	10	10	10	10	10	
Checking	"	10	10		10	10	10	10	10	10	
Blistering	"	8D	10		10	10	10	10	10	10	
Rusting	"	10	10		10	10	10	10	10	4	

Appendix IIE

Test Results

High Solids Topcoats - Baked

		2	6	17	20	23	28	32	36	39	40
Substrate -------		Zn	Fe	Fe	Fe	Fe	Pr	St	Zn	Fe	Fe
Color -----------		Wht	Wht	Wht	Clr	Wht	Wht	Blu	Wht	Wht	Wht
Viscosity	KU										
Initial		108	95	79	91	74	77	69	82	75	69
2 wks @ 125°F		120	95	90	111	78	102	74	106	141+	85
Package Stability	Score										
Liq. separation		10	8	9	10	6	8	4	10	10	9
Skinning		10	10	10	10	10	10	10	10	10	10
Pigment settling		10	10	8	10	10	10	10	8	8	8
Ease of remixing		10	9	6	9	9	9	9	8	8	8
Cure - Time	Mins	20	15	10	10	20	15	12	14	10	20
- Temperature	°F	325	300	350	350	350	360	300	360	250	350
Overcure											
50°F above normal											
Appearance	Score	10	10	10	10	10	10	10	10	10	10
Gloss change	%	1	0	1	4	0	18	12	0	9	2
Adhesion	%	100	100	100	100	100	100	100	100	100	100
2X normal											
Appearance	Score	10	10	10	10	10	10	10	10	10	10
Gloss change	%	0	0	3	5	1	2	15	0	0	4
Adhesion	%	100	100	100	100	100	100	100	100	100	100
Gloss	Units	94	93	88	100	95	88	86	90	95	94
Whiteness Index	Units	82.7	83.6	95.2	X	88.1	83.2	X	84.3	81.7	85.5
Opacity	%	100	98.7	99.4	X	100	99.1	100	99.2	99.0	98.3
Hardness (Pencil) - Pass		H	F	F	H	2H	F	2H	H	6B	2H
Adhesion	%	100	100	100	100	100	100	100	100	100	100

Pr - Primed Blu. - Blue

Test Results

High Solids Topcoats - Baked

		2	6	17	20	23	28	32	36	39	40
	Substrate--	Zn	Fe	Fe	Fe	Fe	Pr	St	Zn	Fe	Fe
	Color------	Wht	Wht	Wht	Clr	Wht	Wht	Blu	Wht	Wht	Wht
Flexibility	Inch	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8
Impact	In.lbs	56	160+	160+	160+	56	160+	160+	160+	36	160+
Abrasion Resistance	L/mil	42	60+	58	43	33	60+	55	60+	31	60+
UV Exposure											
Gloss change	%	0	16	10	0	20	0	19	6	2	10
Color change	Score	10	10	10	9	8	6	4	9	10	10
Water Resistance - 500	Hours										
Blistering	ASTM	10	10	10	10	10	10	10	10	10	10
Color change	Score	10	10	10	10	10	9	10	10	9	10
Gloss change	"	10	10	10	10	10	10	10	10	10	10
Hardness	"	10	10	10	10	10	10	10	10	1	10
Recovery	"	10	10	10	10	10	10	10	10	8	10
Acid Resistance	Hrs	120	96	500	500	336	500	20	192	20	96
Blistering	ASTM			10	10		4F				
Color change	Score			6	9		10				
Gloss change	"			8	10		0				
Hardness	"			10	10		1				
Recovery	"			10	10		4				
Alkali Resistance	Hrs	120	450	188	500	120	336	-1	288	188	500
Blistering	ASTM				10						10
Color change	Score				10						10
Gloss change	"				10						10
Hardness	"				10						10
Recovery	"				10						10

Appendix IIE (Cont)

Test Results

High Solids Topcoats - Baked

		2	6	17	20	23	28	32	36	39	40
Substrate --		Zn	Fe	Fe	Fe	Fe	Pr	St	Zn	Fe	Fe
Color ------		Wht	Wht	Wht	Clr	Wht	Wht	Blu	Wht	Wht	Wht
Xylol Resistance	Hrs	288	-1	500	500	192	500	1	500	-1	500
Blistering	ASTM			10	10		10		10		10
Color change	Score			9	10		9		8		10
Gloss change	"			10	10		10		10		10
Hardness	"			10	10		10		1		10
Recovery	"			10	10		10		10		10
MEK Resistance	Hrs	1	116	500	500	20	500	72	500	-1	500
Blistering	ASTM			10	8F		10		10		2D
Color change	Score			10	10		10		10		10
Gloss change	"			10	10		10		10		10
Hardness	"			1	1		1		1		1
Recovery	"			10	10		10		10		10
Salt Fog Exposure	Hrs	500	500	500	500	500	500	500	500	92	500
Blistering at X	ASTM	10	8F	10	2M	6F	6F	2M	2F		10
" - overall	"	10	9	10	9	8F	9	9	9		10
Creep at X	mm	2	1	2	4	2	2	1	1		3
Corrosion	Score	9	10	10	6	9	10	10	10		10
Acc. Weathering - 500 Hours											
Color change	Score	10	8	8	2	9	8	6	9	8	10
Gloss change	"	9	2	4	2	2	2	2	6	0	6
Chalking	ASTM	10	10	8	10	8	10	10	10	10	10
Checking	"	10	10	10	10	10	10	10	10	2	10
Blistering	"	10	10	10	10	10	10	10	10	10	10
Rusting	Score	10	10	10	10	10	10	10	10	10	10

Appendix IIF

Test Results

High Solids Topcoats - Baked

		41	47	48	51	70	119	120	126	128	129
Substrate ----		Fe	St	Zn	Fe	Zn	Zn	Zn	Zn	Zn	Zn
Color --------		Wht	Wht	Wht	Wht	Wht	Bwn	Bge	Wht	Wht	Wht
Viscosity	KU										
Initial		67	63	77	83	63	89	89	108	120	84
2 wks @ 125°F		95	69	102	112	68	100	98	134	125	98
Package Stability	Score										
Liq. separation		9	8	9	9	9	8	8	10	9	8
Skinning		10	10	10	2	10	10	10	10	10	10
Pigment settling		8	6	6	10	8	8	10	10	10	8
Ease of remixing		6	6	6	10	6	8	8	10	9	8
Cure - Time	Mins	15	20	20	15	15	20	20	20	20	20
- Temperature	°F	300	350	300	325	275	350	350	300	300	350
Overcure											
50°F above normal											
Appearance	Score	10	8	10	10	6	10	4	10	10	8
Gloss change	%	9	2	15	0	21	28	11	4	40	1
Adhesion	%	100	100	100	100	100	100	100	100	100	100
2X normal											
Appearance	Score	10	8	10	10	8	6	6	10	10	8
Gloss change	%	10	2	10	5	38	9	4	9	27	1
Adhesion	%	100	100	100	100	100	100	100	100	100	100
Gloss	Units	91	90	94	85	73	57	82	93	73	92
Whiteness Index	Units	82.3	86.3	87.0	83.2	77.1	X	X	83.9	75.3	82.4
Opacity	%	98.2	97.7	97.5	98.2	98.2	100	100	98.2	100	97.4
Hardness (Pencil) - Pass		2B	H	2H	HB	F	2H	4H	H	H	6H
Adhesion	%	100	100	100	100	100	100	100	100	100	100

Bwn - Brown Bge - Beige

Test Results

High Solids Topcoats - Baked

		41	47	48	51	70	119	120	126	128	129
Substrate-----		Fe	St	Zn	Fe	Zn	Zn	Zn	Zn	Zn	Zn
Color---------		Wht	Wht	Wht	Wht	Wht	Bwn	Bge	Wht	Wht	Wht
Flexibility	Inch	1/8	1/8	1/2	1/8	1+	1/8	1/8	1/8	1/8	1/8
Impact	In.lbs	160+	160+	44	160+	12	60	36	160+	160+	152
Abrasion Resistance	L/mil	60+	35	41	60+	18	33	41	60+	49	50
UV Exposure											
Gloss change	%	5	13	18	26	8	12	2	1	7	8
Color change	Score	10	6	9	10	10	8	10	10	9	10
Water Resistance - 500	Hours										
Blistering	ASTM	10	10	10	10	10	10	10	10	10	8F
Color change	Score	10	10	10	10	10	10	10	9	8	10
Gloss change	"	10	10	10	10	10	10	10	10	10	10
Hardness	"	10	10	10	10	10	10	10	10	10	10
Recovery	"	10	10	10	10	10	10	10	10	10	10
Acid Resistance	Hrs	500	500	500	500	500	336	336	16	16	336
Blistering	ASTM	10	10	10	2D	10					
Color change	Score	9	10	6	2	9					
Gloss change	"	2	10	4	4	10					
Hardness	"	10	10	10	0	10					
Recovery	"	10	10	10	0	10					
Alkali Resistance		500	500	500	500	24	96	168	-1	16	500
Blistering	ASTM	10	6M	6F	10						10
Color change	Score	4	9	9	8						4
Gloss change	"	2	8	10	10						2
Hardness	"	2	10	10	10						0
Recovery	"	2	10	10	10						0

Appendix IIF (Cont)

Test Results

High Solids Topcoats - Baked

		41	47	48	51	70	119	120	126	128	129
Substrate -----		Fe	St	Zn	Fe	Zn	Zn	Zn	Zn	Zn	Zn
Color ---------		Wht	Wht	Wht	Wht	Wht	Bwn	Bge	Wht	Wht	Wht
Xylol Resistance	Hrs	500	-1	500	500	24	500	16	500	500	500
Blistering	ASTM	10		10	10		10		10	10	10
Color change	Score	9		8	10		9		10	10	10
Gloss change	"	10		10	10		9		10	6	10
Hardness	"	10		10	10		1		8	1	10
Recovery	"	10		10	10		8		10	10	10
MEK Resistance	Hrs	500	1	500	500	24	500	16	500	500	500
Blistering	ASTM	10		10	2D		10		10	6F	10
Color change	Score	10		10	10		10		8	6	8
Gloss change	"	10		10	10		10		10	8	9
Hardness	"	4		1	1		1		1	1	1
Recovery	"	10		10	10		10		10	9	9
Salt Fog Exposure	Hrs	500	500	500	500	500	500	500	230	140	500
Blistering at X	ASTM	10	2F	10	10	6F	8F	10			10
" - overall	"	10	6F	10	10	9	8F	10			4F
Creep at X	mm	5	2	1	2	3	2	3			3
Corrosion	Score	6	10	10	10	9	8	8			10
Acc. Weathering - 500 Hours											
Color change	Score	8	9	9	10	9	8	8	10	10	10
Gloss change	"	2	9	6	6	6	4	6	10	0	6
Chalking	ASTM	4	10	10	10	4	10	10	10	10	10
Checking	"	10	10	10	10	10	10	4	10	10	10
Blistering	"	10	10	10	10	10	10	10	10	10	10
Rusting	Score	10	10	10	10	10	10	10	10	10	10

Test Results

Appendix IIG

Powder Coatings - Baked

		P-1	P-2	P-3	P-4	P-5	P-6	P-7	P-8
Substrate ---		Zn	Zn	Zn	St	St	St	Fe	Zn
Color -------		Grn	Bwn	Blk	Wht	Wht	Wht	Wht	Wht
Cure - Time	Mins	10	10	15	10	10	10	20	10
- Temperature	°F	400	400	350	350	400	400	360	400
Overcure									
50°F above normal									
Appearance	Score	10	10	10	10	10	10	10	10
Gloss change	%	14	4	11	9	2	4	1	5
Adhesion	%	100	100	100	100	100	100	100	100
2X normal time									
Appearance	Score	10	10	10	10	10	10	10	10
Gloss change	%	1	3	2	9	2	3	1	2
Adhesion	%	100	100	100	100	100	100	100	100
Gloss	Units	70	68	64	85	86	77	93	87
Whiteness Index	Units	X	X	X	87.4	84.9	86.4	84.2	87.5
Hardness (Pencil) - Pass		3H	2H	4H	2H	2H	2H	2H	5H
Adhesion	%	100	100	100	100	100	100	100	100
Flexibility	Inch	1+	1/8	3/4	1/4	1/8	1/2	1+	1+
Impact	In.lbs	24	16	32	32	32	20	40	36
Abrasion Resistance	L/mil	49	60+	60+	60+	60+	40	57	33
UV Exposure									
Gloss change	%	4	6	41	48	2	12	8	0
Color change	Score	10	9	4	6	10	9	8	10
Water Resistance - 500 Hours		10	10	10	10	10	10	10	10

Test Results

Appendix IIG (Cont)

Powder Coatings - Baked

		P-1	P-2	P-3	P-4	P-5	P-6	P-7	P-8
Substrate ---		Zn	Zn	Zn	St	St	St	Fe	Zn
Color -------		Grn	Bwn	Blk	Wht	Wht	Wht	Wht	Wht
Acid Resistance - 500 Hours		10	10	10	10	10	10	10	10
Alkali Resistance - 500 Hours									
Blistering	ASTM	10	10	10	10	10	10	10	10
Color change	Score	6	8	10	4	8	6	9	10
Gloss change	"	0	0	10	10	0	0	6	10
Hardness	"	10	10	10	10	10	10	10	10
Recovery	"	10	10	10	10	10	10	10	10
Xylol Resistance	Hours	500	-1	500	500	500	500	-1	500
Blistering	ASTM	10		10	10	10	10		10
Color change	Score	10		10	6	8	8		8
Gloss change	"	8		10	4	4	10		10
Hardness	"	1		10	1	1	1		1
Recovery	"	10		10	8	8	10		10
MEK Resistance	Hours	500	-1	500	500	500	144	-1	500
Blistering	ASTM	10		10	8F	8F			10
Color change	Score	10		10	6	8			8
Gloss change	"	8		10	10	10			10
Hardness	"	1		1	1	1			1
Recovery	"	10		10	8	8			10
Salt Fog Exposure - 500 Hours									
Blistering at X	ASTM	10	10	10	10	10	10	10	10
" - overall	"	10	10	10	10	10	10	10	10
Creep at X	mm	1	0	0	2	2	2	1	2
Corrosion	Score	10	10	10	10	10	10	10	10
Acc. Weathering - 500 Hours									
Color change	Score	6	8	6	6	8	8	8	10
Gloss change	"	0	4	0	4	4	6	4	2
Chalking	ASTM	6	10	10	6	10	10	10	10
Checking	"	10	10	10	10	10	10	10	10
Blistering	"	10	10	10	10	10	10	10	10
Rusting	Score	10	10	10	10	10	10	10	10

Appendix IIH

Test Results

Powder Coatings - Baked

		P-9	P-10	P-11	P-12	P-13	P-14	P-15
Substrate --		Zn	Zn	Zn	Zn	Zn	Zn	Zn
Color ------		Wht	Wht	Gry	Wht	Wht	Wht	Clr
Cure - Time	Mins	5	20	20	20	20	20	10
- Temperature	°F	400	340	340	360	360	360	300
Overcure								
50°F above normal								
Appearance	Score	10	10	10	10	10	10	10
Gloss change	%	3	2	7	5	1	3	33
Adhesion	%	100	100	100	100	100	100	100
2X normal time								
Appearance	Score	10	10	10	10	10	10	10
Gloss change	%	3	1	4	8	3	0	24
Adhesion	%	100	100	100	100	100	100	100
Gloss	Units	97	91	70	73	76	80	98
Whiteness Index	Units	92.4	92.4	X	87.1	95.4	98.7	X
Hardness (Pencil) - Pass		5H	7H	4H	6H	4H	4H	F
Adhesion	%	100	100	100	100	100	100	50
Flexibility	Inch	1/4	1/8	1/8	1+	1+	1/8	1+
Impact	In.lbs	60	136	44	12	32	56	-4
Abrasion Resistance	L/mil	60+	60+	60+	17	35	45	19
UV Exposure								
Gloss change	%	28	65	40	8	3	14	22
Color change	Score	6	4	6	10	10	10	4
Water Resistance - 500 Hours								
Blistering	ASTM	10	10	10	10	10	10	10
Color change	Score	10	10	10	10	10	10	10
Gloss change	"	10	10	10	10	10	10	6
Hardness	"	10	10	10	10	10	10	10
Recovery	"	10	10	10	10	10	10	10

Appendix IIH (Cont)

Test Results

Powder Coatings - Baked

		P-9	P-10	P-11	P-12	P-13	P-14	P-15
	Substrate --	Zn	Zn	Zn	Zn	Zn	Zn	Zn
	Color ------	Wht	Wht	Gry	Wht	Wht	Wht	Clr
Acid Resistance - 500 Hours		10	10	10	10	10	10	10
Alkali Resistance	Hours	500	500	500	500	500	500	240
Blistering	ASTM	10	10	10	10	10	10	
Color change	Score	9	10	8	10	8	8	
Gloss change	"	10	10	6	10	0	0	
Hardness	"	10	10	10	10	10	10	
Recovery	"	10	10	10	10	10	10	
Xylol Resistance	Hours	500	500	500	-1	500	500	144
Blistering	ASTM	10	10	10		10	10	
Color change	Score	8	10	8		6	4	
Gloss change	"	10	10	2		4	2	
Hardness	"	10	10	1		1	1	
Recovery	"	10	10	10		10	8	
MEK Resistance	Hours	500	500	500	-1	500	500	-1
Blistering	ASTM	10	10	10		10	10	
Color change	Score	10	8	10		8	6	
Gloss change	"	10	6	10		10	10	
Hardness	"	1	1	1		1	1	
Recovery	"	10	10	10		10	8	
Salt Fog Exposure - 500 Hours								
Blistering at X	ASTM	10	10	10	10	10	10	10
" - overall	"	10	10	10	10	10	10	10
Creep at X	mm	2	1	1	1	1	1	2
Corrosion	Score	10	10	10	10	10	10	10
Acc. Weathering - 500 Hours								
Color change	Score	6	4	4	8	8	8	4
Gloss change	"	2	2	0	10	4	6	4
Chalking	ASTM	2	4	4	10	10	10	10
Checking	"	10	10	10	10	10	10	10
Blistering	"	10	10	10	10	10	10	10
Rusting	Score	10	10	10	10	10	10	10

Appendix IIJ

Test Results

Conventional Topcoats - Baked

		1	9	16	18	19	24	37	38	42
Substrate		Zn	Zn	Zn	Fe	Fe	Fe	Fe	Fe	Fe
Color		Wht	Blk	Wht	Wht	Clr	Wht	Wht	Wht	Wht
Viscosity	KU									
Initial		64	64	69	72	67	82	57	63	67
2 wks @ 125°F		69	94	75	90	72	92	53	73	70
Package Stability	Score									
Liq. separation		8	10	9	10	2	4	2	10	9
Skinning		10	2	10	10	10	10	10	10	10
Pigment settling		8	10	8	8	10	9	6	8	8
Ease of remixing		8	10	6	8	9	9	8	6	6
Cure - Time	Mins	30	12	15	15	10	20	10	20	15
- Temperature	°F	350	350	300	350	350	350	250	350	300
Overcure										
50°F above normal										
Appearance	Score	10	10	10	10	10	10	8	10	10
Gloss change	%	0	19	0	1	22	3	14	9	2
Adhesion	%	100	100	100	100	100	100	100	100	100
2X normal										
Appearance	Score	10	10	10	8	10	10	8	8	6
Gloss change	%	0	6	0	2	23	3	0	9	2
Adhesion	%	100	100	100	100	100	100	100	100	100
Gloss	Untis	82	31	98	95	82	92	98	91	95
Whiteness Index	Units	86.4	X	85.0	85.4	X	86.2	80.5	85.3	80.2
Opacity	%	99.2	100	95.0	96.5	X	99.6	92.9	96.6	95.8
Hardness (Pencil) - Pass		H	F	HB	F	HB	2H	HB	H	6B
Adhesion	%	100	100	100	100	100	100	100	100	100

Test Results

Conventional Topcoats - Baked

		1	9	16	18	19	24	37	38	42
Substrate------		Zn	Zn	Zn	Fe	Fe	Fe	Fe	Fe	Fe
Color----------		Wht	Blk	Wht	Wht	Clr	Wht	Wht	Wht	Wht
Flexibility	Inch	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/4	1/8
Impact	In.lbs	52	52	108	160+	28	40	32	28	80
Abrasion Resistance	L/mil	45	13	15	33	60+	35	19	42	43
UV Exposure										
Gloss change	%	0	3	11	20	9	8	12	11	8
Color change	Score	8	6	10	10	10	9	9	10	8
Water Resistance - 500 Hours										
Blistering	ASTM	10	8F	10	10	10	10	10	10	10
Color change	Score	10	10	9	10	10	10	10	10	10
Gloss change	"	10	10	10	10	10	10	10	10	10
Hardness	"	10	10	10	10	10	10	4	10	1
Recovery	"	10	10	10	10	10	10	10	10	8
Acid Resistance	Hours	500	192	500	500	500	500	96	500	500
Blistering	ASTM	10		2M	8M	10	2D		10	6F
Color change	Score	9		4	6	6	6		8	9
Gloss change	"	10		2	8	4	10		8	0
Hardness	"	10		4	10	10	1		10	8
Recovery	"	10		10	10	10	10		10	8
Alkali Resistance	Hours	288	16	120	500	500	500	288	1	20
Blistering	ASTM				10	2D	10			
Color change	Score				10	2	10			
Gloss change	"				10	4	10			
Hardness	"				10	10	10			
Recovery	"				10	10	10			

Appendix IIJ (Cont)

Test Results

Conventional Topcoats - Baked

		1	9	16	18	19	24	37	38	42
Substrate ----		Zn	Zn	Zn	Fe	Fe	Fe	Fe	Fe	Fe
Color --------		Wht	Blk	Wht	Wht	Clr	Wht	Wht	Wht	Wht
Xylol Resistance	Hrs	500	500	500	20	500	500	-1	2	500
Blistering	ASTM	10	10	8F		10	10			10
Color change	Score	9	10	6		10	10			8
Gloss change	"	10	10	10		10	10			10
Hardness	"	4	1	1		1	6			1
Recovery	"	10	10	10		8	10			10
MEK Resistance	Hrs	500	500	-1	2	500	500	500	-1	500
Blistering	ASTM	10	10			10	10	10		10
Color change	Score	9	10			10	10	9		10
Gloss change	"	10	10			10	10	10		10
Hardness	"	1	1			1	1	1		1
Recovery	"	10	10			10	10	10		10
Salt Fog Exposure	Hrs	500	500	500	500	500	500	350	500	500
Blistering at X	ASTM	10	6F	6F	10	2M	10		10	2D
" - overall	"	10	8F	9	10	9	10		10	9
Creep at X	mm	2	2	2	2	4	2		3	2
Corrosion	Score	9	10	8	10	6	10		10	8
Acc. Weathering - 500 Hours										
Color change	Score	8	9	8	8	2	9	6	9	6
Gloss change	"	2	9	2	4	0	6	2	6	4
Chalking	ASTM	10	10	10	8	10	8	6	8	4
Checking	"	10	10	10	10	2	10	10	10	10
Blistering	"	10	10	10	10	10	10	10	10	10
Rusting	Score	10		0	10	10	10	10	10	10

Appendix IIK

Test Results

Conventional Topcoats - Baked

		53	54	69	74	107	117	118	127	130
Substrate --------		Fe	Fe	Fe	St	St	Zn	Fe	Zn	Zn
Color -----------		Wht	Wht	Wht	Wht	Wht	Wht	Bwn	Wht	Wht
Viscosity	KU									
Initial		63	69	57	61	92	86	61	63	72
2 wks @ 125°F		115	112	54	68	122	92	76	70	81
Package Stability	Score									
Liq. separation		10	10	9	10	10	8	10	10	10
Skinning		6	8	10	10	10	10	10	10	10
Pigment settling		9	8	8	8	10	8	8	9	10
Ease of remixing		9	6	6	6	10	8	8	10	10
Cure - Time	Mins	10	15	30	15	30	10	10	20	25
- Temperature	°F	300	325	300	300	300	350	350	300	335
Overcure										
50°F above normal										
Appearance	Score	10	10	10	4	10	10	8	9	10
Gloss change	%	8	3	3	2	10	13	21	1	3
Adhesion	%	100	100	100	100	100	100	100	100	100
2X normal										
Appearance	Score	8	10	10	10	10	10	6	10	10
Gloss change	%	19	3	1	2	6	8	18	1	1
Adhesion	%	100	100	100	100	100	95	100	100	100
Gloss	Units	85	96	98	85	83	95	85	83	90
Whiteness Index	Units	77.2	80.6	87.7	83.5	82.8	84.6	X	84.5	82.4
Opacity	%	96.9	97.5	94.8	94.0	95.0	98.0	100	93.8	96.6
Hardness (Pencil) - Pass		F	H	2H	F	F	F	F	F	4H
Adhesion	%	100	100	100	100	100	100	100	100	100

Appendix IIK (Cont)

Test Results

Conventional Topcoats - Baked

		53	54	69	74	107	117	118	127	130
Substrate-------		Fe	Fe	Fe	St	St	Zn	Fe	Zn	Zn
Color----------		Wht	Wht	Wht	Wht	Wht	Wht	Bwn	Wht	Wht
Flexibility	Inch	1/8	1/8	1/2	1/8	1+	1+	1/8	1/8	1/4
Impact	In.lbs	44	80	60	64	40	12	44	112	20
Abrasion Resistance	L/mil	19	25	29	19	13	10	15	16	25
UV Exposure										
Gloss change	%	6	8	9	6	6	5	20	10	24
Color change	Score	10	10	10	9	9	8	6	10	10
Water Resistance - 500 Hours										
Blistering	ASTM	10	10	10	8MD	10	10	10	10	10
Color change	Score	10	10	10	10	10	10	10	9	10
Gloss change	"	10	10	10	8	10	10	10	10	10
Hardness	"	10	10	10	1	10	10	10	10	10
Recovery	"	10	10	10	10	10	10	10	10	10
Acid Resistance	Hrs	500	500	500	500	500	336	336	192	500
Blistering	ASTM	10	10	10	10	10				10
Color change	Score	8	9	9	10	9				6
Gloss change	"	10	10	10	10	10				2
Hardness	"	10	10	10	10	10				10
Recovery	"	10	10	10	10	10				10
Alkali Resistance	Hrs	20	500	500	500	188	192	500	16	500
Blistering	ASTM		10	10	2D			10		10
Color change	Score		9	10	6			9		10
Gloss change	"		10	10	6			6		10
Hardness	"		10	10	1			0		10
Recovery	"		10	10	6			0		10

Test Results

Conventional Topcoats - Baked

		53	54	69	74	107	117	118	127	130
Substrate ------		Fe	Fe	Fe	St	St	Zn	Fe	Zn	Zn
Color ----------		Wht	Wht	Wht	Wht	Wht	Wht	Bwn	Wht	Wht
Xylol Resistance	Hrs	500	500	500	-1	-1	288	500	192	288
Blistering	ASTM	8F	10	10				10		
Color change	Score	6	9	10				10		
Gloss change	"	10	10	10				10		
Hardness	"	10	10	10				1		
Recovery	"	10	10	10				10		
MEK Resistance	Hrs	-1	500	500	-1	-1	20	120	-1	20
Blistering	ASTM		10	10						
Color change	Score		10	10						
Gloss change	"		10	10						
Hardness	"		10	10						
Recovery	"		10	10						
Salt Fog Exposure - 500 Hours										
Blistering at X	ASTM	2D	6F	10	2D	8D	10	4M	10	10
" - overall	Score	10	10	10	10	9	10	4M	10	10
Creep at X	mm	3	2	3	3	5	2	4	2	1
Corrosion	Score	8	10	8	8	8	10	6	10	10
Acc. Weathering - 500 Hours										
Color change	Score	6	10	9	8	6	8	6	8	10
Gloss change	"	6	6	8	2	2	2	2	4	10
Chalking	ASTM	4	10	10	4	10	4	4	2	10
Checking	"	10	10	10	10	10	10	10	10	10
Blistering	"	10	10	10	10	10	10	10	10	10
Rusting	Score	10	10	10	10	10	10	10	10	10

Appendix IIL

Test Results

Water Base Topcoats - Force Dry

		25	26	43	98	121
Substrate -----		Fe	Fe	St	Zn	Fe
Color ---------		Wht	Wht	Wht	Blk	Grn
Viscosity	Ku					
Initial		73	57	69	50	106
4 wks @ 125°F		65	60	65	130	141+
Package Stability	Score					
Liq. separation		10	10	4	8	8
Skinning		6	8	10	10	10
Pigment settling		10	8	6	6	8
Ease of remixing		10	8	6	8	8
Cure - Time	Mins	30	30	15	40	20
- Temperature	°F	165	165	180	180	165
Overcure						
50°F above normal						
Appearance	Score	10	10	10	10	10
Gloss change	%	1	2	4	0	3
Adhesion	%	100	100	100	100	100
2X normal						
Appearance	Score	10	10	10	10	10
Gloss change	%	1	2	2	20	2
Adhesion	%	100	100	100	100	100
Gloss	Units	80	86	90	5	95
Whiteness Index	Units	84.3	89.0	40.9	X	X
Opacity	%	93.1	95.7	96.8	100	100
Hardness (Pencil) - Pass		F	F	2B	F	2B
Adhesion	%	100	100	100	100	100
Flexibility	Inch	1/8	1/8	1/8	1/4	1/8
Impact	In.lbs	48	60	56	72	160+
Abrasion Resistance	L/mil	25	16	32	25	27

Appendix IIL (Cont)

Test Results

Water Base Topcoats - Force Dry

		25	26	43	98	121
Substrate ------		Fe	Fe	St	Zn	Fe
Color ----------		Wht	Wht	Wht	Blk	Grn
UV Exposure						
Gloss change	%	4	6	0	0	26
Color change	Score	10	9	4	9	9
Water Resistance	Hrs	96	96	96	500	500
Blistering	ASTM				8M	8M
Color change	Score				9	6
Gloss change	"				9	10
Hardness	"				4	1
Recovery	"				10	10
Acid Resistance	Hrs	120	500	192	20	500
Blistering	ASTM		2D			10
Color change	Score		4			2
Gloss change	"		8			2
Hardness	"		10			10
Recovery	"		10			10
Alkali Resistance	Hrs	16	16	-1	20	-1
Xylol Resistance	Hrs	500	1	-1	500	500
Blistering	ASTM	8F			10	10
Color change	Score	4			8	8
Gloss change	"	10			6	8
Hardness	"	1			10	1
Recovery	"	10			10	4
MEK Resistance	Hrs	20	500	1	500	500
Blistering	ASTM		10		10	10
Color change	Score		8		9	9
Gloss change	"		10		10	9
Hardness	"		1		1	1
Recovery	"		10		10	10
Salt Fog Exposure	Hrs	116	116	68	68	500
Blistering at X	ASTM					4F
" - overall	"					8M
Creep at X	mm					3
Corrosion	Score					8
Acc. Weathering - 500 Hours						
Color change	Score	10	10	6	6	8
Gloss change	"	10	10	4	6	2
Chalking	ASTM	10	10	4	6	10
Checking	"	10	10	10	10	10
Blistering	"	10	10	10	10	10
Rusting	Score	10	10	10	10	10

Appendix IIM

Test Results

Conventional Topcoats - Force Dry

		4	27	30	45
Substrate -----		Zn	St	Pr	St
Color ---------		Wht	Wht	Gry	Wht
Viscosity	KU				
Initial		54	72	72	89
4 wks @ 125°F		52	84	76	106
Package Stability	Score				
Liq. separation		2	10	4	9
Skinning		10	10	4	4
Pigment settling		8	10	9	10
Ease of remixing		8	10	9	9
Cure - Time	Mins	30	30	30	15
- Temperature	°F	180	165	175	180
Overcure					
50°F above normal					
Appearance	Score	10	10	10	10
Gloss change	%	3	2	8	1
Adhesion	%	100	100	100	100
2X Adhesion					
Appearance	Score	10	10	10	10
Gloss change	%	3	4	17	1
Adhesion	%	100	100	100	100
Gloss	Units	97	82	87	92
Whiteness Index	Units	51.8	89.1	X	80.9
Opacity	%	96.2	96.0	100	95.7
Hardness (Pencil) - Pass		F	F	6B	4B
Adhesion	%	100	100	100	15
Flexibility	Inch	1/8	1+	1/8	1/8
Impact	In.Lbs	48	28	48	8
Abrasion Resistance	L/mil	20	18	23	25

Appendix IIM (Cont)

Test Results

Conventional Topcoats - Force Dry

		4	27	30	45
	Substrate -----	Zn	St	Pr	St
	Color ---------	Wht	Wht	Gry	Wht
UV Exposure	Hrs				
Gloss change	%	2	12	48	14
Color change	Score	8	10	6	8
Water Resistance	Hrs	168	500	336	500
Blistering	ASTM		10		8D
Color change	Score		10		8
Gloss change	"		10		6
Hardness	"		10		1
Recovery	"		10		2
Acid Resistance	Hrs	16	500	500	500
Blistering	ASTM		10	8M	8M
Color change	Score		10	10	8
Gloss change	"		10	6	4
Hardness	"		10	6	1
Recovery	"		10	10	2
Alkali Resistance	Hrs	1	500	1	-1
Blistering	ASTM		6M		
Color change	Score		8		
Gloss change	"		8		
Hardness			10		
Recovery	"		10		
Xylol Resistance	Hrs	500	-1	-1	-1
Blistering	ASTM	10			
Color change	Score	2			
Gloss change	"	10			
Hardness	"	1			
Recovery	"	10			
MEK Resistance	Hrs	-1	-1	-1	-1
Salt Fog Exposure	Hrs	500	270	500	336
Blistering at X	ASTM	4M		2M	
" - overall	"	8F		8F	
Creep at X	mm	2		2	
Corrosion	Score	9		10	
Acc. Weathering - 500 Hours					
Color change	Score	9	9	6	6
Gloss change	"	9	9	2	2
Chalking	ASTM	10	10	6	6
Checking	"	10	10	10	10
Blistering	"	10	8M	10	10
Rusting	"	10	10	10	10

Appendix IIN

Test Results

Water Base Topcoats - Air Dry

		7	13	49	57	58	59	61	87[2]	95
Substrate-------		Zn	Zn	Fe	St	St	St	St	Pr	Zn
Color-----------		Wht	Wht	Wht	Wht	Wht	Wht	Wht	Wht	Wht
Viscosity (Mixed)	KU								72	
Initial		63	100	90	82	108	108	58	127/82	61
4 wks @ 125°F		65	129	92	141+	141+	128	54	141/89	61
Package Stability	Score									
Liq. separation		6	9	4	4	4	2	4	8/10	10
Skinning		9	4	10	8	8	8	10	10/10	10
Pigment settling		8	10	9	10	10	6	8	8/10	10
Ease of remixing		8	10	8	9	9	8	8	6/10	10
Pot Life	Hrs	X	X	X	X	X	X	X	16	X
Speed of Dry	Hrs									
Set to touch		0.2	0.1	0.4	0.2	0.1	0.3	0.2	1.3	0.2
Tack free		0.4	6.0	1.0	1.5	2.0	24	0.9	4.0	0.4
Dry hard		0.8	16	1.5	3.0	3.0	24	3.0	4.5	0.8
Dry thru		0.8	16	1.5	3.0	3.0	24	3.0	4.5	0.8
Gloss	Units	76	83	82	88	87	91	68	50	74
Whiteness Index	Units	64.9	54.9	35.3	56.0	52.1	61.3	79.1	80.8	85.4
Opacity	%	95.8	98.7	94.1	96.5	94.1	94.2	93.7	89.1	96.0
Hardness (Pencil) - Pass		F	F	HB	HB	HB	2B	HB	2H	HB
Adhesion	%	100	100	100	100	100	100	70	100	100

2 - Two component

Appendix IIN (Cont)

Test Results

Water Base Topcoats - Air Dry

		7	13	49	57	58	59	61	87[2]	95
	Substrate -------	Zn	Zn	Fe	St	St	St	St	Pr	Zn
	Color -----------	Wht	Wht	Wht	Wht	Wht	Wht	Wht	Wht	Wht
Flexibility	Inch	1/8	1/8	1/8	1/8	1/8	1/8	1+	1/4	1/8
Impact	In.Lbs	40	160+	84	48	36	160+	32	48	28
Abrasion Resistance	L/mil	16	29	24	27	17	16	29	37	18
UV Exposure										
Gloss change	%	0	0	10	16	14	20	26	40	12
Color change	Score	6	6	9	4	6	6	10	6	10
Water Resistance	Hrs	168	500	500	500	500	500	100	336	168
Blistering	ASTM		8MD	10	10	8MD	8F			
Color change	Score		6	10	10	8	10			
Gloss change	"		4	10	10	4	9			
Hardness	"		6	2	1	1	1			
Recovery	"		10	10	10	10	10			
Acid Resistance	Hrs	24	500	96	500	500	500	20	24	24
Blistering	ASTM		4MD		6F	8F	8F			
Color change	Score		8		8	10	10			
Gloss change	"		6		8	10	10			
Hardness	"		4		10	10	10			
Recovery	"		10		10	10	10			
Alkali Resistance	Hrs	-1	1	1	-1	-1	20	20	96	-1

Appendix IIN (Cont)

Test Results

Water Base Topcoats - Air Dry

		7	13	49	57	58	59	61	87[2]	95
Substrate-------		Zn	Zn	Fe	St	St	St	St	Pr	Zn
Color-----------		Wht	Wht	Wht	Wht	Wht	Wht	Wht	Wht	Wht
Xylol Resistance	Hrs	-1	500	500	-1	-1	-1	-1	500	-1
Blistering	ASTM		8MD	10					10	
Color change	Score		6	2					4	
Gloss change	"		4	2					10	
Hardness	"		6	10					10	
Recovery	"		10	10					10	
MEK Resistance	Hrs	1	500	-1	-1	1	-1	-1	500	-1
Blistering	ASTM		10						10	
Color change	Score		6						9	
Gloss change	"		10						10	
Hardness	"		1						1	
Recovery	"		10						10	
Salt Fog Exposure	Hrs	410	500	500	336	72	336	72	500	100
Blistering at X	ASTM		8M	4M					2F	
" - overall	"		8F	4M					9	
Creep at X	mm		2	4					2	
Corrosion	Score		6	8					10	
Acc. Weathering - 500 Hours										
Color change	Score	8	10	6	4	4	9	9	4	6
Gloss change	"	6	4	2	2	2	9	9	10	4
Chalking	ASTM	10	8	6	8	10	10	8	6	10
Checking	"	10	10	10	10	10	10	10	10	10
Blistering	"	10	10	10	10	10	10	10	10	10
Rusting	Score	10	10	10	10	10	10	10	10	10

Appendix II0

Test Results

High Solids Topcoats - Air Dry

		44	99^2	100^2
Substrate ------		St	Zn	Zn
Color-----------		Wht	Wht	Wht
Viscosity (mixed)	KU		68*	61*
Initial		80	101/123	84/104
4 wks @ 125°F		84	87/114	70/95
Package Stability	Score			
Liq. separation		6	6/10	6/10
Skinning		10	10/10	10/10
Pigment settling		10	10/10	8/10
Ease of remixing		9	8/10	6/10
Pot Life	Hrs	X	1.5	16
Speed of Dry	Hrs			
Set to touch		5.0	0.5	2.0
Tack free		16	3.0	6.0
Dry hard		16	4.0	16
Dry thru		16	4.0	16
Gloss	Units	78	80	98
Whiteness Index	Units	56.4	82.4	83.5
Opacity	%	99.6	95.4	96.5
Hardness (Pencil) - Pass		HB	5H	7H
Adhesion	%	90	100	100
Flexibility	Inch	1/8	1/8	3/16
Impact	In.Lbs	56	160	56
Abrasion Resistance	L/mil	60+	54	39

2 - Two component

* - Thinner added as directed

Appendix II0 (Cont)

Test Results

High Solids Topcoats - Air Dry

		44	99[2]	100[2]
Substrate ------		St	Zn	Zn
Color ----------		Wht	Wht	Wht
UV Exposure				
Gloss change	%	33	13	3
Color change	Score	6	10	9
Water Resistance	Hrs	336	500	500
Blistering	ASTM		10	10
Color change	Score		10	10
Gloss change	"		10	10
Hardness	"		10	10
Recovery	"		10	10
Acid Resistance	Hrs	24	500	500
Blistering	ASTM		8M	10
Color change	Score		10	10
Gloss change	"		10	10
Hardness	"		4	10
Recovery	"		10	10
Alkali Resistance	Hrs	-1	500	96
Blistering	ASTM		2F	
Color change	Score		8	
Gloss change	"		6	
Hardness	"		10	
Recovery	"		10	
Xylol Resistance	Hrs	1	500	500
Blistering	ASTM		10	10
Color change	Score		10	9
Gloss change	"		10	10
Hardness	"		10	10
Recovery	"		10	10
MEK Resistance	Hrs	-1	500	500
Blistering	ASTM		10	10
Color change	Score		10	8
Gloss change	"		10	10
Hardness	"		10	10
Recovery	"		10	10

2 - Two component

Appendix IIO (Cont)

Test Results

High Solids Topcoats - Air Dry

		44	99[2]	100[2]
Substrate-------		St	Zn	Zn
Color-----------		Wht	Wht	Wht
Salt Fog Exposure - 500 Hours				
Blistering	ASTM	6MD	2F	6F
" - overall	"	6M	9	9
Creep at X	mm	2	2	2
Corrosion	Score	10	10	10
Acc. Weathering - 500 Hours				
Color change	Score	4	8	8
Gloss change	"	2	8	6
Chalking	ASTM	4	10	10
Checking	"	10	10	10
Blistering	"	10	10	10
Rusting	Score	10	10	10

Appendix IIP

Test Results

Conventional Topcoats - Air Dry

		10	12	46	52	55	56	62	101[2]
Substrate		Zn	Zn	St	Fe	St	St	St	Zn
Color		Wht	Wht	Wht	Wht	Wht	Wht	Wht	Wht
Viscosity (mixed)	KU								68
Initial		61	79	74	69	65	67	92	95/62
4 wks @ 125°F		70	113	83	90	86	86	121	100/62
Package Stability	Score								
Liq. separation		9	10	9	9	8	10	9	10
Skinning		2	2	4	6	10	4	4	10
Pigment settling		8	10	10	6	10	8	6	10
Ease of remixing		8	10	9	6	8	8	9	10
Pot Life	Hrs	X	X	X	X	X	X	X	6
Speed of Dry	Hrs								
Set to touch		0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.5
Tack free		0.8	16	16	1.0	0.5	0.5	2.0	4.0
Dry hard		1.3	24	16	1.3	2.0	2.0	3.0	5.0
Dry thru		1.3	24	16	1.3	2.0	2.0	3.0	5.0
Gloss	Units	90	86	86	85	90	90	72	100
Whiteness Index	Units	69.1	71.5	84.6	77.2	78.0	79.9	60.6	86.5
Opacity	%	96.8	100	96.9	96.0	96.1	99.3	97.2	95.4
Hardness (Pencil) - Pass		F	3B	HB	F	2B	3B	2B	7H
Adhesion	%	100	100	100	100	50	0	90	100

2 - Two component

Test Results

Conventional Topcoats - Air Dry

		10	12	46	52	55	56	62	101[2]
	Substrate	Zn	Zn	St	Fe	St	St	St	Zn
	Color	Wht	Wht	Wht	Wht	Wht	Wht	Wht	Wht
Flexibility	Inch	1/8	1/8	1/8	1/8	1+	1+	1/8	1/8
Impact	In.Lbs	60	160+	108	44	-4	-4	40	96
Abrasion Resistance	L/mil	14	30	19	18	23	17	23	60+
UV Exposure									
Gloss change	%	11	2	13	1	11	13	28	3
Color change	Score	10	8	8	10	9	9	6	10
Water Resistance	Hrs	500	500	200	500	500	264	144	500
Blistering	ASTM	10	10		10	8D			10
Color change	Score	9	6		10	10			10
Gloss change	"	10	10		10	6			10
Hardness	"	10	10		10	1			10
Recovery	"	10	10		10	10			10
Acid Resistance	Hrs	500	500	240	450	500	500	500	500
Blistering	ASTM	10	4M			8F	10	8F	10
Color change	Score	9	10			8	8	9	10
Gloss change	"	10	8			4	4	6	10
Hardness	"	10	6			1	10	10	10
Recovery	"	10	10			10	10	10	10
Alkali Resistance	Hrs	-1	1	-1	20	-1	-1	-1	500
Blistering	ASTM								6F
Color change	Score								10
Gloss change	"								10
Hardness	"								10
Recovery	"								10

Appendix IIP (Cont)

Test Results

Conventional Topcoats - Air Dry

		10	12	46	52	55	56	62	101[2]
Substrate ------		Zn	Zn	St	Fe	St	St	St	Zn
Color ----------		Wht	Wht	Wht	Wht	Wht	Wht	Wht	Wht
Xylol Resistance	Hrs	1	500	-1	500	-1	-1	-1	500
Blistering	ASTM		10		10				10
Color change	Score		6		2				10
Gloss change	"		10		4				10
Hardness	"		10		1				10
Recovery	"		10		8				10
MEK Resistance	Hrs	-1	-1	-1	-1	-1	-1	-1	500
Blistering	ASTM								10
Color change	Score								9
Gloss change	"								10
Hardness	"								10
Recovery	"								10
Salt Fog Exposure	Hrs	500	500	200	500	270	336	270	500
Blistering at X	ASTM	8MD	4M		10				2F
" - overall	Score	8MD	4F		10				9
Creep at X	mm	3	6		2				3
Corrosion	Score	6	6		8				10
Acc. Weathering - 500 Hours									
Color change	Score	8	10	8	6	8	6	6	8
Gloss change	F"	4	2	4	6	4	2	4	6
Chalking	ASTM	10	6	4	4	6	8	8	10
Checking	"	10	10	10	10	10	10	10	10
Blistering	"	10	10	10	10	10	10	10	10
Rusting	Score	10	10	10	10	10	10	10	10

Appendix III

Test Procedures

Appendix III

TEST PROCEDURE

Except as noted, tests were conducted in accordance with ASTM methods as described in Part 27 - "Tests for Formulated Products and Applied Coatings" issued by the American Society for Testing and Materials, Philadelphia, PA.

1. Viscosity — KU

ASTM D-562 "Consistency of Paints Using the Stormer Viscometer"

2. Viscosity Stability — KU

Viscosity was redetermined after storage for 4 weeks at 125°F.

3. Package Stability — Score*

The following changes were scored (see Scoring Scheme below) after storage for 4 weeks at 125°F.

a) Liquid separation
b) Skinning
c) Pigment settling
d) Ease of remixing to a homogeneous condition

4. Pot Life — Hrs

Eight ounces (8 oz) of the two component products were mixed in accordance with the supplier's instructions. The time was recorded when viscosity increased beyond a useable value.

5. Ease of Application — Score*

Water or the specified thinner (except for Powder Coatings) was added to spray viscosity. The thinned sample was then tested for sprayability. Powder Coatings were sprayed as received.

6. Speed of Dry — Hrs

ASTM D-1640 "Drying, Curing or Film Formation of Organic Coatings at Room Temperature".

7. Overcure

The applied coatings were baked at two schedules in accordance with ASTM D-2454 "Determining the Effect of Overbaking on Organic Coatings:

a) Normal time but 50°F above normal temperature.

b) Normal temperature but twice the normal time.

The cured coatings were then examined for -

1) Change in Appearance	Score*
2) Change in Gloss - See No. 9 below	% of Initial
3) Adhesion - See No. 13 below	%

8. Gloss — Units

ASTM D-523 "Specular Gloss"

9. Whiteness Index — Units

ASTM E-313 "Index of Whiteness of Near-White Opaque Materials"

10. Opacity — %

The coatings were applied on Black and White Leneta charts, then cured as scheduled.

$$\text{Opacity} = \frac{\text{Reflectance on Black}}{\text{Reflectance on White}} \times 100$$

11. Hardness — Pencil No.

ASTM D-3363 "Film Hardness by Pencil Test"

12. Adhesion — %

ASTM D-3359 "Measuring Adhesion by Tape Test"

13. Flexibility — Inch

ASTM D-1737 "Elongation of Coatings With Cylindrical Mandrel Apparatus".

14. Impact Resistance — In.lbs

ASTM D-2794 "Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)"

15. Abrasion Resistance — L/mil

ASTM D-968 "Abrasion Resistance of Coatings of Paint, Varnish Lacquer and Related Products by the Falling Sand Method".

16. UV Exposure

The cured coatings were exposed to ultraviolet light for two weeks. They were then evaluated vs the unexposed coatings for -

a) Change in Gloss - See No. 9 above — % of Initial

b) Change in Color — Score*

17. The following tests were conducted in accordance with ASTM D-1308 "Test for Effect of Household Chemicals on Clear and Pigmented Organic Finishes" even though some reagents are industrial products:

a) Water Resistance - Immersion

b) Acid Resistance (5% HCl) - Spot test

c) Alkali Resistance (5% NaOH) - Immersion

d) Xylol Resistance - Immersion

e) MEK (Methyl Ethyl Ketone) Resistance - Immersion

The following changes were recorded after an exposure of 500 hours:

1) Blistering - ASTM D-714 "Evaluating Degree of Blistering of Paints"

2) Color Change — Score*

3) Gloss Change — Score*

4) Hardness - When removed and after 24 hour recovery — Score*

Coatings which failed before 500 hours were removed and the exposure time recorded.

18. Salt Fog Exposure

ASTM B-117 "Salt Spray (Fog) Testing". After 500 hours of exposure, the coatings were evaluated for the following properties:

a) Blistering at X Score	ASTM D-714
b) Blistering overall	Ditto
c) Creep from the X	mm
d) Corrosion on the stripped panel	Score*

Coatings which failed before 500 hours were removed and the time recorded.

19. Accelerated Weathering

ASTM G-53 "Operating Light-and Water- Exposure Apparatus (Fluorescent UV - Condensation Type) for Exposure of Nonmetallic Materials".

After 500 hours of exposure, the coatings were evaluated for the following properties:

a) Color Change	Score*
b) Gloss Change	Score*
c) Chalking	ASTM D-659
d) Checking	ASTM D-660
e) Blistering	ASTM D-714
f) Rusting	Score*

Coatings which failed before 500 hours were removed and the time recorded.

* Scoring Scheme

The following ASTM scoring system was used to describe subjective observations:

Score	Performance	or	Effect
10	Perfect		None
9	Excellent		Trace
8	Very good		Very slight
6	Good		Slight
4	Fair		Moderate
2	Poor		Severe
1	Very poor		Extreme
0	No value		Failed

Appendix IV

Rating Scheme

Appendix IV

RATING SCHEME

The following ratings or designations are used to evaluate or describe the data developed. They are numbered in accordance with the tests described in Appendix III, Test Procedure.

1. Viscosity (KU)

VL	-	42	to	50
L	-	53	to	58
LM	-	60	to	69
M	-	72	to	86
MH	-	89	to	100
H	-	105	to	120
VH	-	140+		

2. Viscosity Stability (Change)

Rating	KU	KU to 141+
10	0 to 4	
9	5 to 12	
8	13 to 19	
6	20 to 30	
4	34 to 43	
2	52	33 to 35
1	77 to 80	59 to 66
0	Solid	

Two component products - based on least stable component.

3. Package Stability

Total Score		Rating				
	Lowest Score ----	9	8	6	4	2
40 to 38		10				
37 to 30			9	8	6	4
28 to 20				6	4	2

Two component products - based on least stable component.

4. Pot Life (Hrs)

10	-	16+
8	-	6
4	-	2.5
2	-	1.5
0	-	0.5

5. Ease of Application

Not rated since all were Excellent

6. Speed of Dry (Hrs)

Total of all values

10	-	2.2 to 2.8
9	-	3.6 to 4.6
8	-	6.1 to 10.1
6	-	11.0 to 14.5
2	-	38.1 to 48.2
0	-	53+

7. Overcure

	Rating				
Lowest Score -----	9	8	6	4	2
Total Score					
60 to 54	10	9	8	6	
52 to 47		8	8	6	
46 to 42			6	4	4
30 to 34					2

Scores	Gloss Change (%)	Adhesion (%)
10	0 to 5	100
9	6 to 15	95
8	17 to 24	
6	26 to 33	
4	38 to 40	
2		20

8. Gloss (Units)

VH	-	90+
H	-	89 to 80
MH	-	78 to 64
M	-	57 to 50
ML	-	33 to 20
L	-	10
VL	-	5-

9. Whiteness (Round Units)

10	-	95+
9	-	92 to 89
8	-	88 to 80
6	-	79 to 71
4	-	69 to 60
2	-	56 to 51
1	-	50-

10. Opacity (Round %)

10	-	100
9	-	99 to 97
8	-	96 to 93
6	-	90 to 89
4	-	81 to 75
2	-	66

11. Hardness (Pencil)

10	-	6H to 5H
9	-	4H to 3H
8	-	2H to H
6	-	F to HB
4	-	2B to 3B
2	-	4B to 5B
0	-	Below 5B

12. Adhesion (%)

10	-	100
8	-	90
6	-	70 - 50
2	-	15 - 5
0	-	0

13. Flexibility (Inch)

10	-	1/8
9	-	3/16
8	-	1/4
6	-	3/8
4	-	1/2
2	-	3/4
0	-	1+

14. Impact (Inch Lbs)

10	-	160+
9	-	152 to 136
8	-	128 to 108
6	-	98 to 52
4	-	48 to 20
2	-	19 to 8
0	-	4-

15. Abrasion Resistance (L/Mil)

10	-	60+
9	-	58 to 49
8	-	45 to 35
6	-	33 to 23
4	-	21 to 11
2	-	10 to 9

16. UV Exposure

Color Retention - Same as Score for Color Change

Gloss Retention (Change - %

10	-	0 to 5
9	-	6 to 14
8	-	16 to 24
6	-	26 to 35
4	-	40 to 48
2	-	65

17. Water Resistance

Rating	Hours	Total Score
10	500	50 - 48
9	500	46 - 16
8	500	6
	450 - 336	
6	288 - 188	
4	168 - 96	
2	72 - 16	
0	Below 16	

18. Salt Fog Exposure

Rating	Hours	Total Score
10	500	40 - 38
9	500	37 - 20
8	410 - 336	
6	270 - 200	
4	140 - 92	
2	72 - 20	
0	Below 20	

19. Accelerated Weathering (500 hours)

	Rating				
Lowest Score ----	8	6	4	2	0
Total Score					
60 - 57	10				
56 - 50	9	8	6	4	4
49 - 40	8	6	4	4	2
38 - 30				2	1

20 hours = 0

Re: Nos. 17, 18, 19

Blistering (ASTM)

Size	Score F	M	MD	D
8	9	8	6	4
6	8	6	4	2
4	6	4	2	1
2	4	2	1	0

Creep at X (Salt Fog)

mm	Score
0	10
1	9
2	8
3,4	6
5	4
9	2

DL LABORATORIES
116 East 16th Street, New York, N.Y. 10003

Appendix VA

DATA FORM

LOW SOLVENT VS CONVENTIONAL METAL FINISHES

Provide whatever information you can comparing the low solvent finish vs the conventional product. If you want a copy of the report, please fill in your name and company. Otherwise, inclusion of your name is optional:

Name: ______________________ Position: ______________________

Co.: ______________________ Address: ______________________

____

	LOW SOLVENT	CONVENTIONAL
Product: - Name:	______	______
- Code:	______	______
Type: (Check)	Hi Solids: ____ Powder: ____ Water-Base: ____	
Generic (Resin) Type:	______	______
For Use On:	Steel: ____ Galv: ____	Alum: ____ Other: ____
Special Metal Treatment:	______	______
Method of Application:	______	______
No. of Coats:	______	______
Total Thickness:	______ mils	______ mils
Cure:	____ mins. at ____ °F	____ mins. at ____ °F
No. of Colors:	______	______
Color Change Frequency:	______	______
Coating Cost:	____ ¢/sq.ft. ____ $/gal	____ ¢/sq.ft. ____ $/gal

Please fill in the following information for the Low Solvent Coatings:

Equipment Changes Required: ______________________________

Production Changes Required: ______________________________

(OVER)

Effect on Cost (Estimated $ change and/or % change vs Conventional Coating):

	$	%	Increase (Check)	Decrease
Capital Cost:	$______	______%	______	______
Operating Cost:	$______	______%	______	______
Maintenance Cost:	$______	______%	______	______
Energy Cost:	$______	______%	______	______

Advantages - Production: ______________________________

____

-Performance: ______________________________

____

Problems - Production: ______________________________

____

- Performance: ______________________________

____

Effect on Sales: $______ ______% Increase:______ Decrease:______

Where Can It Not Be Used: ______________________________

Can you tell us whom to contact for product information?

Name: ______________	Name: ______________
Company: ______________	Company: ______________
Address: ______________	Address: ______________
______________	______________

Please send to:

Sidney B. Levinson
President
D/L Laboratories
116 East 16th Street
New York, NY 10003

Appendix VB

DATA FORM

Name: ______________________________ Co.: ______________________________

Address: ____

Phone No.: ________________________

1. Do you use water base, high solids or powder coatings on metal products?:

   Yes ______________________ No ______________________

2. Product Name: ____________________ Code: ________________________

3. Type: - Water Base: ______ Hi Solids: ______ Powder: ________

4. VOC: ________________________g/l ________________________lbs/gal

5. Resin Type: ___________________________

6. What conventional coating does it replace:

   ____

7. On what product is it used?: ____________________________________

8. On what substrate?: Steel ______ Alum ______ Galv. ________

9. Metal treatment: ____

10. Application Method: ____

11. No. of coats: __________________ Total dft: ____________________

12. Cure: ________________________mins. at _____________°F

13. No. of colors: ___________________________

14. Color change frequency: _____________________________________

15. Coating cost: ____________________¢/sq.ft _________________$/gal

16. Advantages:
    Production: ____

    Performance: ____

17. Problems:
 Production: ______________________________

____

 Performance: ______________________________

____

18. Equipment Changes Required: ______________________________

____

19. Production Changes Required: ______________________________

____

20. Effect on Cost vs Conventional:

	$	%	Increase	Decrease
Capital Cost:	____	____	____	____
Operating Cost:	____	____	____	____
Maintenance:	____	____	____	____
Energy Cost:	____	____	____	____

21. Effect on Sales ____ ____ ____ ____

22. Where Can It Not Be Used: ______________________________

____

23. Is it possible to get a copy of your specifications?: ____________

24. Can you suggest anyone whom I can talk to about this survey?:

 Name ____________________

 Company ____________________

 Tel. No. ____________________