TECHNICAL REPORT **PROJECT NUMBER 21901.01**

DEBOURGH MFG. CO.

JWB COUNSULTING SERVICES

SALT SPRAY TESTING PER ASTM B---117

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INTRODUCTION:

In an effort to provide their customers with world class paint finishes, combined with outstanding durability and corrosion protection, and at the most competitive price, DeBourgh Manufacturing contracted JWB Consulting Services to perform an independent analysis of their painting processes in the area of salt spray analysis.

ANALYSIS:

The analysis included comprehensive Salt Spray testing of Cardinal Industrial Finishes Liquid and Electrostatic Powder Coatings applied over various pretreated substrates for analysis of the corrosion protection and the benefits associated with each process. All testing was performed in accordance with American Society for Testing and Materials (ASTM) Method B 117[1].

PROCEDURE:

The painted test panels were evaluated in the un-scored condition, (ref: Table 1) as well as the scored condition, (ref. Table 2 & 3), by scoring through the paint film with a metal scribe to expose the substrate. The panels were then exposed to intervals of 214; 398.5; 700; 1019.6 and 1908 hours of Salt Spray (Fog) Testing in a Salt Spray Chamber prepared with laboratory grade NaCl (Sodium Chloride). To acquire a 5% solution, 5 ± 0.5 parts of NaCL was added to 95 ± 0.5 parts by weight of deionized water and thoroughly mixed. The solution was then tested for 5% NaCl by weight with a Fisher Scientific hydrometer. The pH of the solution was maintained in a range of 6.5 -7.2, with a laboratory pH meter. The operating range of the chamber was set to 96° Fahrenheit, and the flow rate maintained between 1.0 to 2.0 milliliters/hour. At the specified intervals, the chamber was shut down to check the parameters of pH, flow rate, and chamber operating temperature. The panels were then gently washed in clean running water to remove any salt deposit and dried immediately with a soft (Kaydry) tissue. The panels were then visually analyzed for visual degradation, i.e. corrosion of the paint film beyond 1/16 inch of the scribe and blistering.

Prepared by: JWB Consulting Services **Date:** December 19, 2001

SUBSTRATES and PRETREATMENT PARAMETERS:

The following substrates are currently used in the manufacturing processes at DeBourgh Manufacturing, and were all processed through DeBourgh's five stage automated iron phosphate system for this evaluation:

Expanded Metal: Expanded metal is currently used for the front panels of certain lockers.

Angle Iron: Angle Iron is used as the framework of lockers where durability is a prime consideration.

Electro-Galvanized: Electro-Galvanized or (EG) is used as a zinc pretreatment for promoting paint adhesion and corrosion protection.

G-90: G-90 is a factory pre-plated zinc substrate.

Cold Rolled Steel: Cold Rolled steel is used for the locker cabinetry.

Perforated Cold Rolled Steel: Perforated Cold Rolled steel is used for the front panels of certain lockers.

A-60: A-60 is a factory pre-plated zinc substrate.

Note: (The referenced tests on Electro Galvanized, G-90 and A-60, were provided for comparative purposes only)

Salt spray testing on painted zinc and galvanized substrates is not typically recommended, due to the fact that the results may appear visually worse than on painted steel even though the painted zinc provides far superior corrosion resistance in field service[2]. Reference Dr. Norman Roobol "Industrial Painting Principles and Practices", 1991 Edition (pgs 268 – 269) Hitchcock Publishing Company.

* Coating weight was tested and certified by Fremont Industries at 35 to 45 mg per ft/sq.

*Fremont Industries is the chemical supplier for DeBourgh's automated iron phosphate system. All of the referenced samples for this evaluation were processed in the automated five stage system under the following operational parameters:

First stage: Alkaline Cleaner with 60 – 90 second dwell time.
Second stage: Fresh Water ambient rinse with 30 – 45 second dwell times.
Third stage: Iron Phosphate with 60 – 90 second dwell time.

Fourth stage: Fresh Water ambient rinse with 30 – 45 second dwell times.
Fifth stage: Non-Chrome seal rinse with reverse osmosis water, with 30 – 45 second dwell times.

- **Liquid High Solids Polyester Paint:**

Cardinal High Solids Baking Enamel, 9000 Series, was applied at the recommended film thickness in accordance with Cardinal Industrial Finishes' Technical Data Sheet. The primary attributes of this paint are excellent edge coverage and low curing temperatures (Reference Figure 1.1)

High Solids Polyester Paint:

Property:	Range:
Hardness (Pencil)	**H – 2H**
Impact Resistance (in. lbs.)	**60 (F) – 160 (R)**
Salt Spray	**500 + Hours**
Condensing Humidity	**500 + Hours**
Cure Range	**10 minutes @ 375° F** **15 minutes @ 350° F**

(Figure 1.1): Properties of High Solids Baking Enamel

- **T.G. I.C Electrostatic Powder:**

Cardinal Polyester Triglycidyl Isocyanurate (T.G.I.C.) powder, T-Series, was applied at the recommended film thickness in accordance with Cardinal Industrial Finishes' Technical Data Sheet. The primary attributes of this powder are its excellent mechanical properties at high film thicknesses and good edge coverage. This powder also provides excellent over-bake color stability. (Reference Figure 1.2)

T.G. I.C Electrostatic Powder:

Property:	Range:
Hardness (Pencil)	**H – 2H**
Impact Resistance (in. lbs.)	**60 (F) – 160 (R)**
Salt Spray	**1,000 + Hours**
Condensing Humidity	**1,000 + Hours**
Cure Range	**10 minutes @ 400° F** **30 minutes @ 300° F**

(Figure 1.2): Properties of Polyester T.G.I.C Powders

LIQUID AND ELECTROSTATIC POWDER PAINT DESCRIPTIONS (Continued):

- **Epoxy Primer:**

Cardinal Powder Epoxy Primer, product number: E305 – GR533, was applied at the recommended film thickness in accordance with Cardinal Industrial Finishes' Technical Data Sheet. The primary attributes of this powder are its excellent corrosion and adhesion properties to various substrates. (Reference Figure 1.3)

Epoxy Primer:

Property:	Range:
Hardness (Pencil)	**2H**
Impact Resistance (in. lbs.)	**60 (F) – 60 (R)**
Salt Spray	**1,000 Hours**
Condensing Humidity	**1,000 Hours**
Cure Range	**10 min. @ 400°F**

(Figure 1.3): Properties of Powder Epoxy Primers

- **Epoxy Powder:**

Cardinal Epoxy Powder, product number: E305 – GR533, was applied at the recommended film thickness in accordance with Cardinal Industrial Finishes' Technical Data Sheet. The primary attributes of this powder are its excellent durability and chemical resistance.
(Reference Figure 1.4)

Epoxy Powder:

Property:	Range:
Hardness (Pencil)	**2H**
Impact Resistance (in. lbs.)	**60 (F) – 60 (R)**
Salt Spray	**1,000 Hours**
Condensing Humidity	**1,000 Hours**
Cure Range	**10 min. @ 400°F**

(Figure 1.4): Properties of Epoxy Powder

TABLE 1:
Film Thickness / Hours of Exposure Results
(Un-Scored)

	A Series	B Series	C Series	D Series
	POLYESTER LIQUID **1.1 to 3.**	**T.G.I.C. POWDER** **3.0 to 3.7 mils**	**EPOXY PRIMER WITH T.G.I.C. POWDER**	**EPOXY POWDER**
Expanded Metal (Mesh)	398 hours @ 2.2 mils	1019 hours @ 3.5 mils	1019 hours @ 6.5 mils	686 hours @ 3.6 mils
Angle Iron	***Sample 1A:*** 214 hours @ 1.1 mils	***Sample 1B:*** 1019 hours @ 1.5 mils	***Sample 1C:*** 1908 hours @ 5.0 mils	***Sample 1D:*** 1019 hours @ 1.5 mils
Electro-Galvanized	***Sample 2A:*** 686 hours @ 1.4mils	***Sample 2B:*** 1908 hours @ 3.5 mils	***Sample 2C:*** 1908 hours @ 5.6 mils	***Sample 2D:*** 1908 hours @ 3.8 mils
G-90	***Sample 3A:*** 686 hours @ 3.1 mils	***Sample 3B:*** 1908 hours @ 3.0 mils	***Sample 3C:*** 1908 hours @ 4.4 mils	***Sample 3D:*** 1908 hours @ 1.4 mils
Cold Rolled Steel	***Sample 4A:*** 686 hours @ 1.2 mils	***Sample 4B:*** 1908 hours @ 3.0 mils	***Sample 4C:*** 1908 hours @ 4.6 mils	***Sample 4D:*** 1908 hours @ 3.1 mils
Perforated Cold Rolled Steel	***Sample 5A:*** 686 hours @ 1.5 mils	***Sample 5B:*** 1019 hours @ 3.7 mils	***Sample 5C:*** 1908 hours @ 6.4 mils	***Sample 5D:*** 1019 hours @ 4.0 mils
A-60	***Sample 6A:*** 686 hours @ 1.5 mils	***Sample 6B:*** 1908 hours @ 3.6 mils	***Sample 6C:*** 1908 hours @ 4.6 mils	***Sample 6D:*** 1908 hours @ 3.4 mils

Table 1: Defines the applicable substrate tested and the paint type used in this evaluation. Film thickness measurements and hours of exposure are provided to demonstrate the performance characteristics and the benefits associated with each process.

Un-Scored Results Summary:

(A Series) Polyester Liquid:

Sample#:	Blistering:	Rusting:	Hours:	Mils:	Status:
Mesh	Entire piece	Edges	398	2.2	Pulled
1A (Angle)	Over all edges	Edges	214	1.1	Pulled
2A (EG)	slight blistering	None	686	1.4	Pulled
3A (G-90)	some blistering	None	686	3.1	Pulled
4A (CRS)	Blisters on edges	None	686	1.2	Pulled
5A (Perf)	On edges of mesh	Edges	686	1.5	Pulled
6A (A-60)	Very slight	Edges	686	1.5	Pulled

(B Series) T.G.I.C Powder:

Sample#:	Blistering:	Rusting:	Hours:	Mils:
Mesh	None	Entire Piece	1019	3.5
1B (Angle)	Small	Along Edges	1019	1.5
2B (EG)	None	None	1908	3.5
3B (G-90)	One Blister	None	1019	3.0
4B (CRS)	None	None	1908	3.0
5B (Perf)	On edge	Along Edges	1019	3.7
6B (A-60)	None	None	1908	3.6

(C Series) Epoxy Primer with T.G.I.C Powder:

Sample#:	Blistering:	Rusting:	Hours:	Mils:
Mesh	None	Slight in Corners	1019	6.5
1C (Angle)	None	None	1908	5.0
2C (EG)	None	None	1908	5.6
3C (G-90)	None	None	1908	4.4
4C (CRS)	None	None	1908	4.6
5C (Perf)	None	None	1908	6.4
6C (A-60)	None	None	1908	4.6

(D Series) Epoxy Powder:

Sample#:	Blistering:	Rusting:	Hours:	Mils:
Mesh	None	On front side	686	3.6
1D (Angle)	Few	Spots on Coating	1019	1.5

2D (EG)	None	None	1908	3.8
3D (G-90)	None	None	1908	1.4
4D (CRS)	None	Slight on edge	1908	3.1
5D (Perf)	None	On front side	1019	3.1
6D (A-60)	None	Slight on edge	1908	3.4

TABLE 2:
Film Thickness / Hours of Exposure Results
Scored

	A Series	B Series	C Series	D Series
	HIGH SOLIDS BAKING ENAMEL	**T.G.I.C. POWDER**	***EPOXY PRIMER WITH T.G.I.C. POWDER**	**EPOXY POWDER**
Electro-Galvanized	***Sample 2A:*** 686 hours @ 1.0 mils	***Sample 2B:*** 1019 hours @ 3.1 mils	***Sample 2C:*** 1908 hours @ 5.5 mils	***Sample 2D:*** 1908 hours @ 2.3 mils
G-90	***Sample 3A:*** 686 hours @ 2.5 mils	***Sample 3B:*** 1019 hours @ 3.8 mils	***Sample 3C:*** 1908 hours @ 5.5 mils	***Sample 3D:*** 1908 hours @ 1.6 mils
Cold Rolled Steel	***Sample 4A:*** 686 hours @ 2.0 mils	***Sample 4B:*** 1019 hours @ 3.6 mils	***Sample 4C:*** 1908 hours @ 5.1 mils	***Sample 4D:*** 1908 hours @ 1.5 mils
Perforated Cold Rolled Steel	***Sample 5A:*** N/A	***Sample 5B:*** N/A	***Sample 5C:*** N/A	***Sample 5D:*** N/A
A-60	***Sample 6A:*** 686 hours @ 1.5 mils	***Sample 6B:*** 1019 hours @ 3.4 mils	***Sample 6C:*** 1908 hours @ 4.4 mils	***Sample 6D:*** 1908 hours @ 2.5 mils

NOTE: Angle Iron and Mesh do not appear in the scored testing due to insufficient surface area.

Table 2: Defines the applicable substrate tested and the paint type used in this evaluation. Film thickness measurements and hours of exposure are provided to demonstrate the performance characteristics and the benefits associated with each process.

Scored Results Summary:

(A Series) Polyester Liquid:

Sample#:	Blistering:	Rusting:	Hours:	Mils:	Undercut:	Status:
2A (EG)	All over sample	along scribe	686	0.7	5/16"	Pulled
3A (G-90)	All over sample	along scribe	686	2.5	1/2 "	Pulled
4A (CRS)	Slight all over	along scribe	686	2.0	1/2"	Pulled
6A (A-60)	Along scribe	along scribe	686	1.5	1/4"	Pulled

(B Series) T.G.I.C Powder:

Sample#:	Blistering:	Rusting:	Hours:	Mils:	Undercut:
2B (EG)	Medium on scribe	along scribe	1019	3.1	1/8"
3B (G-90)	Few on scribe	along scribe	1019	3.8	3/16"
4B (CRS)	Few on scribe	none	1019	3.6	1/8"
6B (A-60)	Small on scribe	along scribe	1019	3.4	3/16"

(C Series) Epoxy Primer with T.G.I.C Powder:

Sample#:	Blistering:	Rusting:	Hours:	Mils:	Undercut:
2C (EG	2 on scribe	none	1908	5.5	none
3C (G-90)	None	Very slight	1908	5.5	none
4C (CRS)	None	On scribe	1908	5.1	1/16"
6C (A-60)	None	Along scribe	1908	4.4	1/16"

(D Series) Epoxy Powder:

Sample#:	Blistering:	Rusting:	Hours:	Mils:	Undercut:
2D (EG)	Few	Along scribe	1908	2.3	on blisters
3D (G-90)	None	Along scribe	1908	1.6	none
4D (CRS)	None	Severe	1908	1.5	1/8"
6D (A-60)	None	Along scribe	1908	2.5	none

TABLE 3:
T.G.I.C. Powder Coating
1.0 –1.5 Mil Film Thickness / Hours of Exposure Results
Versus 3.0 –4.5 or greater Mil Film Thickness /Hours of Exposure Results

B-Series	T.G.I.C. POWDER	1.0 – 1.5 Mils	3.0 – 4.5 Mils
Electro - Galvanized	Pulled after 185 hours	Pass	Pass
G-90	Pulled after 185 hours	Fail	Fail
Cold Rolled Steel	**Pulled after 41 hours**	**Fail**	**Pass**
A-60	Pulled after 185 hours	Fail	Fail

Table 3: Defines the applicable substrate tested and hours of exposure results when coated with only 1.0 – 1.5 mil of T.G.I.C. Powder Coating vs.: 3.0 – 4.5 mil of T.G.I.C. Powder Coating. This table demonstrates the adverse corrosive affects that can occur if a supplier paints the same substrates as demonstrated for Series B, in Table 2, at a film thickness which is less than the recommended thickness specified in Cardinal's Technical Data Sheets.

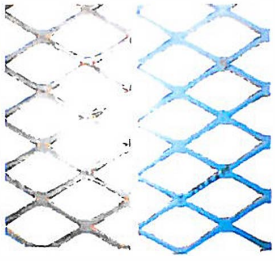

Figure 1

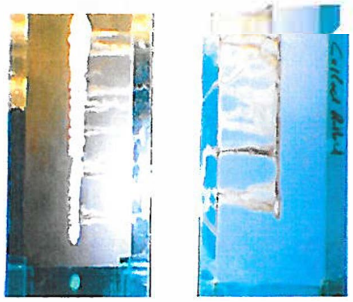

Figure 2

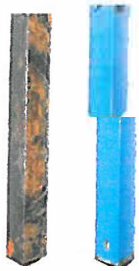

Figure 3

Figure 1: The black mesh represents 1 mil thickness of T.G.I.C powder coat. Note the significant corrosion along the edges. The blue mesh represents 3.0 mil thickness T.G.I.C. powder. There is no apparent corrosion anywhere on the substrate.

Figure 2: The panel on the left is a 1 mil thickness of T.G.I.C. powder coat. The creepage from the scribe exceeds 1/16 inch. This signifies failure of the part. The panel on the right is 3 mil powder coat. The creepage is minimal. The rust that you see on this panel is from the scribe itself.

Figure 3: The black angle is 1 mil thickness of T.G.I.C. powder coat. Note the total failure of corrosion protection. The sample on the right is 3 mil thickness of T.G.I.C.

Figure 3: The black angle is 1 mil thickness of T.G.I.C. powder coat. Note the total failure of corrosion protection. The sample on the right is 3 mil thickness of T.G.I.C. powder coat. Note the signs of minimal failure on the edges of the part.

RESULTS AND DISCUSSIONS

Series A: High Solids Baking Enamel

The results indicated that the High Solids Baking Enamel was unable to meet the 1000 hours minimum requirement established for powder, failing at 686 hours. (All samples were pulled at 686 hours due to extensive blistering and failing beyond 1/16" of the scribe, with the exception of the expanded metal, which failed at 214 hours).

Series B: T.G.I.C. Powder

The results indicated that the T.G.I.C Powder, applied in accordance with Cardinal Technical data sheet recommendations, met the 1000 hours minimum requirement, by passing 1019 hours.

The results indicated that the T.G.I.C. Powder, (*applied at approximately 1.0 mil*), demonstrated extreme corrosion at only 41 to 339 hours of exposure. This test was used to demonstrate the corrosive effects which would result, if a competitor were to extol the benefits of T.G.I.C. Powder but failed to meet the recommended film thickness requirements.

Series C: Epoxy Primer with T.G.I.C. Powder

The results indicated that the Epoxy Primer with T.G.I.C Powder exceeded the minimum 1000 hour requirement by passing 1908 hours with the exception of the perforated cold-rolled steel, expanded metal and angle iron which only passed 1019 hours.

Series D: Epoxy Powder

The results indicated that the Epoxy Powder exceeded the minimum 1000 requirement by passing 1908 hours with the exception of the perforated cold-rolled steel and angle iron, which only passed 1019 hours, and the expanded metal, which only passed 686 hours.

CONCLUSIONS

Locker manufacturers rely primarily on liquid paint application as the industry standard for painting lockers. The results from the liquid Series A, (High Solids Baking Enamel), indicated extreme corrosion failure at just 686 hours of exposure. When tested at 1.0 – 1.5 mil thickness, T.G.I.C. powder has results very similar to the liquid.

The B Series, (T.G.I.C. Powder), as a stand-alone finish, (without the added benefit of an Epoxy Primer), exceeded the corrosion results of their competitor's liquid by 314 hours, surpassing 1019 hours on all substrates tested. This test result shows than when applied in accordance with the guidelines set forth in the Powder Coat manufacturers Technical Data Sheet, T.G.I.C. Powder offers a superior finish. This finish is a very durable, high quality finish that is recommended for all but the most corrosive environments. When applied at a thickness of 1 mil, T.G.I.C. Powder no longer provides the corrosion protection benefit of the thicknesses provided in the B Series testing.

The C Series, (which utilizes the benefits of a T.G.I.C. top-coat, with an epoxy primer), surpassed the minimum 1000 hour requirement by passing 1908 hours on all substrates with the exception of mesh. The far superior results achieved over many substrates and the decreased incidence of blistering, indicates that the C Series, is the preferred finish for highly corrosive environments such as swimming pools and Habiterra.

The D Series (Epoxy Powder), although providing comparable results is not recommended due to low QUV and over-bake resistance results.

RECOMMENDATIONS

Due to the outstanding performance achieved by the B Series as a stand alone finish on cold rolled steel, all future production should utilize the benefits associated with Cardinals T.G.I.C. Powder Coat. This process will provide DeBourghs' customers, with outstanding durability and un-surpassed corrosion protection in non – corrosive environments. When the environment is highly corrosive, the T.G. I.C top – coat.with the Epoxy primer is recommended,

REFERENCES

1. ASTM B 117 "Standard Method of Salt Spray (Fog) Testing".
2. "Industrial Painting Principles and Practices", by: Dr. Norman Roobol, 1991 Edition (pgs 268 – 269) Hitchcock Publishing Company