Charter Coating SERVICE LTD.

"Failure Avoidance Through Laboratory Testing"

Coating Testing Laboratory
Consulting Services
Field Inspection

SPECIALTY POLYMER COATINGS, INC.

LABORATORY EVALUATION
OF
SP8888® SPRAY GRADE COATING

0154-02-04-T

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report details the findings of a study conducted at Charter Coating Service (2000) Ltd. for Specialty Polymer Coatings, Inc.. The objective of this study was to evaluate the performance and related characteristics of SP8888® Spray Grade Coating for high temperature pipeline applications.

This study included the following:

- Physical Tests: Bend/Flex of Substrate; Direct Impact
- Wet Adhesion
- Resistance to Cathodic Disbondment

Results obtained from this test program are summarized in Table 1 and given in the data sheets at the end of each test section.

Table 1. Summary of Test Results - SP8888 ® Spray Grade Coating

TEST & CONDITIONS	STANDARD METHOD	SUMMARY OF TEST RESULTS
Flexibility @ 21°C/70°F	CSA Z245.20-98, Section 12.11	The coating passed 1.74°/PDL.**
Flexibility @ 0°C/32°F	CSA Z245.20-98, Section 12.11	The coating passed 1.03°/PDL.
Flexibility @ -30°C/-22°F	CSA Z245.20-98, Section 12.11	66% of the tested samples passed 1.02°/PDL.
Impact Resistance @ 21°C/70°F with 1.5J	CSA Z245.20-98, Section 12.12	The coating passed the test.
Impact Resistance @ 0°C/32°F with 1.5J	CSA Z245.20-98, Section 12.12	The coating passed the test.
Impact Resistance @ -30°C/-22°F with 1.5J	CSA Z245.20-98, Section 12.12	The coating passed the test.
Wet Adhesion by knife, as received.	CSA Z245.20-21-98	The coating maintained excellent adhesion as a result of testing.
Wet Adhesion by knife, after immersion in tap water @ 95°C/203°F for 1 day.	CSA Z245.20-21-98	The coating maintained excellent adhesion as a result of testing.
Wet Adhesion by knife, after immersion in tap water @ 95°C/203°F for 7 days.	CSA Z245.20-21-98	The coating maintained excellent adhesion as a result of testing.
Wet Adhesion by knife, after immersion in tap water @ 95°C/203°F for 14 days.	CSA Z245.20-21-98	The coating maintained excellent adhesion as a result of testing.
Wet Adhesion by knife, after immersion in tap water @ 95°C/203°F for 28 days.	CSA Z245.20-21-98	The coating maintained excellent adhesion as a result of testing.
Cathodic Disbondment, 1.5V, 14 days @ 95°C/203°F	CSA Z245.20-21, Modified*	The average radius of disbondment was 2.70 mm.
Cathodic Disbondment, 1.5V, 28 days @ 95°C/203°F	CSA Z245.20-21, Modified*	The average radius of disbondment was 4.30 mm.
Cathodic Disbondment, 1.5V, 28 days @ 120°C/248°F	CSA Z245.20-21, Modified*	The average radius of disbondment was 4.7 mm.
Cathodic Disbondment, 1.5V, 28 days @ 150°C/302°F	CSA Z245.20-21, Modified*	The average radius of disbondment was 9.17 mm.

*No industry acceptance criteria exist for the twenty-eight (28) days high temperature Cathodic Disbondment Test.
**PDL: Pipe Diameter Length

INTRODUCTION

Charter Coating Service (2000) Ltd. conducted a test program for Specialty Polymer Coatings, Inc.. This was done in order to evaluate the performance and related characteristics of SP8888® Spray Grade Coating. The report is divided into sections, with each test constituting a different section.

OBJECTIVE

The objective of this study was to evaluate the performance and related characteristics of Specialty Polymer's SP8888® Spray Grade.

SCOPE

The scope of this project was as follows:

1. Specialty Polymer Coatings, Inc. selected the candidate coating.

2. The client did the selection of the different parts of the project. This included:

    - Testing to be performed by Charter Coating Service (2000) Ltd.
    - Testing conditions
    - Testing procedure for high temperature Cathodic Disbondment (120°C/248°F and 150°C/302°F)

Coated samples were supplied and numbered by Specialty Polymer Coatings, Inc., Langley B.C..

FLEXIBILITY TEST

INTRODUCTION

In the field, coatings are subject to bending forces. The coating's ability to 'bend' or 'flex' with the substrate it is applied to and remain adhered, is an important property.

The objective of this test was to determine the ability of SP8888® Spray Grade Coating to bend without cracking or breaking.

CONCLUSIONS

The following can be concluded as a result of this test:

- At 21°C/70°F, the Flexibility Test for SP8888® Spray Grade Coating resulted in no cracking or breaking when bent over and above 280 mm radius mandrel size. This radius corresponds to an average value of 1.74°/PDL.

- At 0°C/32°F, the Flexibility Test for the same coating showed no cracking or breaking when bent over and above 414 mm radius mandrel size. This radius corresponds to an average value of 1.03°/PDL.

- At –30°C/-22°F, 66% of the tested samples of SP8888® Spray Grade Coating exhibited no cracking or breaking when bent over and above 414 mm radius mandrel size. This radius corresponds to an average value of 1.02°/PDL.

METHODOLOGY

The Flexibility Test was conducted according to CSA Z245.20-98 Section 12.11. The test was modified by using fixed radius mandrels to determine failure point. Test specimens (1" wide x 8" length x 1/4" thick) were prepared from the coated samples. Tests were conducted at 21°C/70°F, 0°C/32°F, and -30°C/-22°F using the received coated samples. Six (6) coated samples were tested at each test condition. The Flexibility Test was conducted by placing the specimen in the test apparatus. The samples were clamped at one end of the bar, half an inch from the sample end, and a force was applied to the other end of the sample, and each sample was bent over the mandrel for a 10 second time period. The bent specimens were visually inspected for cracks and disbondment.

RESULTS

The results are shown in Figures 1 to 3 and given in the attached data sheet at the end of this section.

Figure 1. Post-Test Overview – Flexibility Test, 21°C/70°F

The above photograph is the post-test overview of the Bend Test samples at 21°C/70°F. The coating showed no cracks as a result of being bent to an average value of 1.74°/PDL. Cracks occurred as a result of bending to an average value of 2.29°/PDL (blue arrows). All samples were taken to their failure point and the degree of bending was calculated for each one.

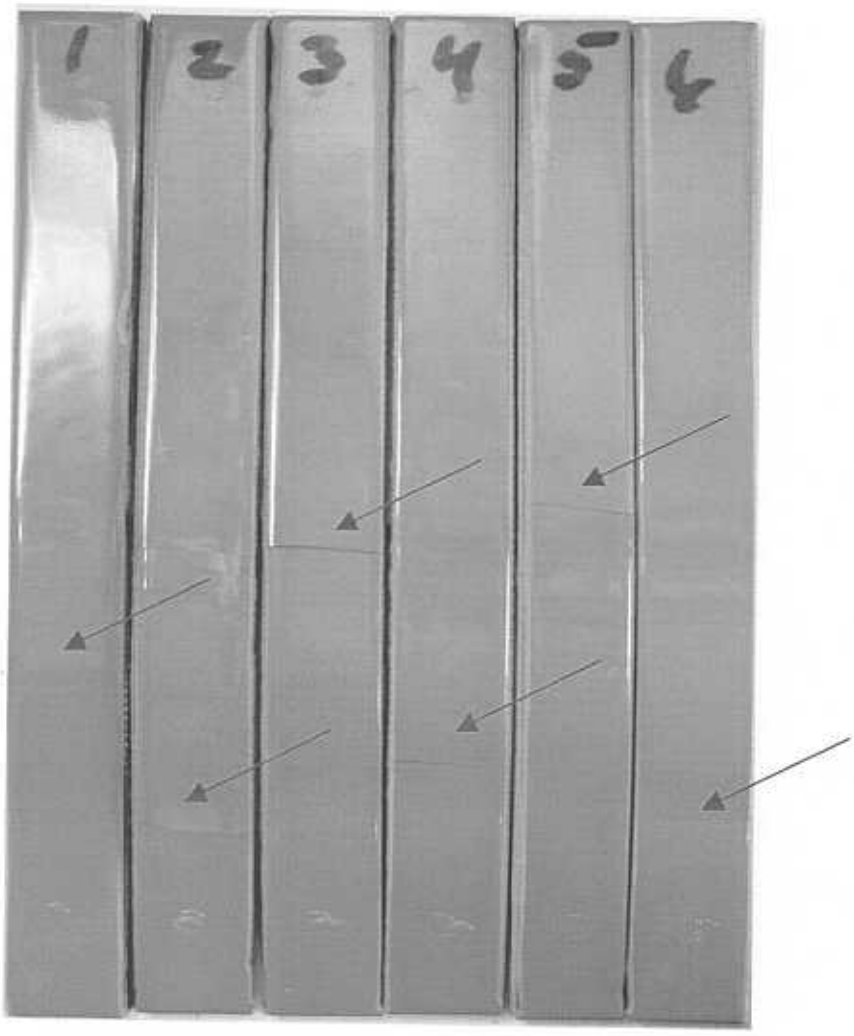


Figure 2. Post-Test Overview – Flexibility Test, 0°C/32°F

The above photograph is the post-test overview of the Bend Test samples at 0°C/32°F. The coating showed no cracks as a result of being bent to an average value of 1.03°/PDL. Cracks occurred as a result of bending to an average value of 1.52°/PDL (blue arrows). All samples were taken to their failure point and the degree of bending was calculated for each one.

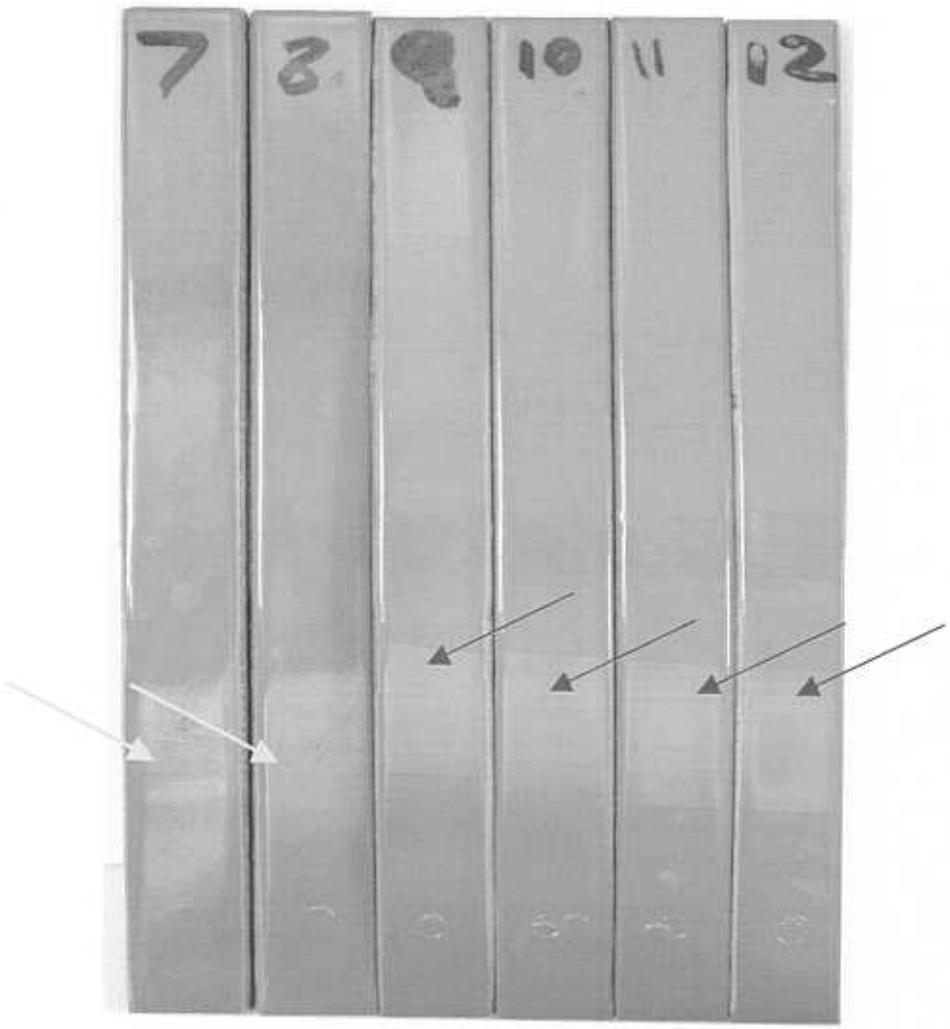


Figure 3. Post-Test Overview – Flexibility Test, -30°C/-22°F

The above photograph is the post-test overview of the Bend Test samples at -30°C/-22°F. Samples 7 and 8 showed cracking as a result of being bent to an average of 1.03°/PDL (yellow arrows). The other coated samples showed no cracks as a result of being bent to an average value of 1.02°/PDL. Samples 9 to 12 showed cracks as a result of bending to an average value of 1.52°/PDL (blue arrows). All samples were taken to their failure point and the degree of bending was calculated for each one.

CHARTER COATING SERVICE (2000) LTD
FLEXIBILITY TEST DATA SHEET
(CAN/CSA Z245.20-98, Clause 12.11)

WORK ORDER NO: 0154-02-04 **TEMPERATURE:** 21°C/70°F

TECHNICIAN: J. Hartt **COATING:** SP8888® Spray Grade

DATE: May 23, 2002

Sample #	Film Thickness (mils)	Mandrel Size (Radius in mm)	Cracks/ Holidays	Pass/Fail	Degree of Bend (°/PDL)*	%Elongation
1	46 –50	414	No	Pass	1.19	1.18
		280	No	Pass	1.76	1.73
		210	Yes	Fail	2.35	2.30
2	44 – 45	414	No	Pass	1.15	1.14
		280	No	Pass	1.70	1.67
		210	Yes	Fail	2.26	2.22
3	52 – 56	414	No	Pass	1.20	1.21
		280	No	Pass	1.78	1.78
4	38 – 42	414	No	Pass	1.16	1.13
		280	No	Pass	1.72	1.66
		210	Yes	Fail	2.29	2.20
5	38 – 44	414	No	Pass	1.16	1.13
		280	No	Pass	1.72	1.16
		210	Yes	Fail	2.29	2.21

*PDL: Pipe Diameter Length

CHARTER COATING SERVICE (2000) LTD
FLEXIBILITY TEST DATA SHEET
(CAN/CSA Z245.20-98, Clause 12.11)

WORK ORDER NO: 0154-02-04 **TEMPERATURE:** 0°C/32°F

TECHNICIAN: J. Hartt **COATING:** SP8888® Spray Grade

DATE: May 23, 2002

Sample #	Film Thickness (mils)	Mandrel Size (Radius in mm)	Cracks/ Holidays	Pass/Fail	Degree of Bend (°/PDL)*	%Elongation
1	35 – 40	840	No	Pass	0.51	0.52
		414	Yes	Fail	1.05	1.03
2	36 – 41	840	No	Pass	0.51	0.50
		414	No	Pass	1.03	1.01
		280	Yes	Fail	1.52	1.49
3	40 – 42	840	No	Pass	0.52	0.52
		414	No	Pass	1.06	1.04
		280	Yes	Fail	1.57	1.53
4	42 – 45	840	No	Pass	0.50	0.50
		414	No	Pass	1.02	1.01
		280	Yes	Fail	1.50	1.49
5	41 – 43	840	No	Pass	0.51	0.48
		414	No	Pass	1.03	0.98
		280	Yes	Fail	1.52	1.44
6	34 - 36	840	No	Pass	0.51	0.49
		414	No	Pass	1.03	0.98
		280	Yes	Fail	1.52	1.45

*PDL: Pipe Diameter Length

CHARTER COATING SERVICE (2000) LTD.
FLEXIBILITY TEST DATA SHEET
(CAN/CSA Z245.20-98 Section 12.11)

WORK ORDER NO: 0154-02-04 **TEMPERATURE:** -30°C/-22°F

TECHNICIAN: J. Hartt **COATING:** SP8888® Spray Grade

DATE: May 23, 2002

Sample #	Film Thickness (mils)	Mandrel Size (Radius in mm)	Cracks/ Holidays	Pass/Fail	Degree of Bend (°/PDL)*	%Elongation
1	33 – 35	840	No	Pass	0.51	0.50
		414	Yes	Fail	1.04	1.00
2	33 – 35	840	No	Pass	0.50	0.49
		414	Yes	Fail	1.02	0.98
3	34 – 36	840	No	Pass	0.49	0.48
		414	No	Pass	1.00	0.98
		280	Yes	Fail	1.48	1.44
4	36 – 40	840	No	Pass	0.50	0.49
		414	No	Pass	1.01	0.99
		280	Yes	Fail	1.49	1.46
5	35 – 37	840	No	Pass	0.51	0.50
		414	No	Pass	1.04	1.01
		280	Yes	Fail	1.53	1.49
6	36 - 38	840	No	Pass	0.51	0.49
		414	No	Pass	1.04	1.00
		280	Yes	Fail	1.53	1.47

*PDL: Pipe Diameter Length

IMPACT RESISTANCE

INTRODUCTION

To protect steel from corrosion, a coating film must be continuous. Breaks in the coating will allow the environment to permeate to the steel substrate and initiate corrosive degradation.

The objective of this test is to evaluate the resistance of the coating, to damage from impact by a blunt ended object at 21°C/70°F, 0°C/32°F, and -30°C/-22°F.

CONCLUSIONS

The following can be concluded as a result of this testing:

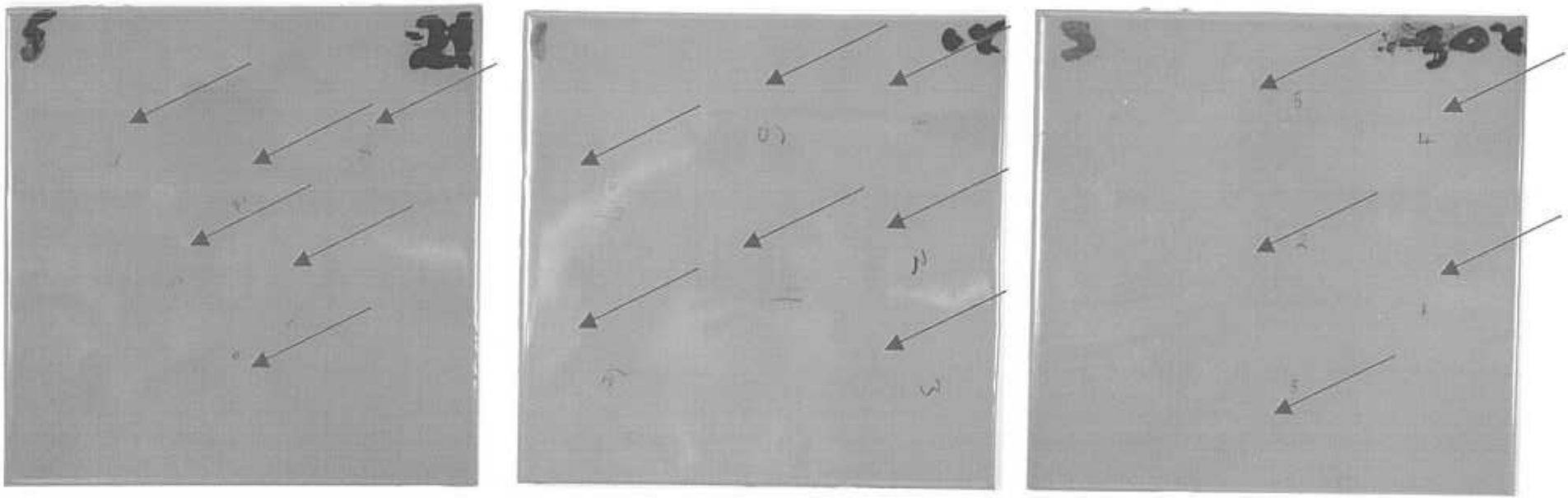
- SP8888® Spray Grade Coating passed the 1.5 Joules impact test at 21°C/70°F, 0°C/32°F, and -30°C/-22°F. No cracking, breaking, or adhesion loss was observed as a result of testing.

METHODOLOGY

The Impact Test was conducted according to CSA Z245.20-98, Section 12.12. Samples were pre-conditioned at the required temperature for one (1) hour. The drop height, in order to give 1.5 Joules of force, was determined by calculation. Each sample was impacted one (1) to three (3) times within 30 seconds and with each impact point greater than 50 mm apart. Damage assessment of the impacted areas was carried out at room temperature, using a Hot Spark Holiday Detector.

RESULTS

Results obtained are shown in Figure 4, and given in the attached data sheet.



21°C/70°F 0°C/32°F -30°C/-22°F

Figure 4. Post-Test Overview - Impact Testing

The above photographs are the post-test overviews of the test panels. The blue arrows indicate the approximate location of where the sample was impacted. No cracks or holidays were observed or detected as a result of testing.

CHARTER COATING SERVICE (2000) LTD.
RESISTANCE TO IMPACT OF THE COATING
(CAN/CSA Z245.20-98, Clause 12.12)

WORK ORDER NO.: 0154-02-04-T
TECHNICIAN: J. Hartt
DATE: May 28, 2001
COATING: SP8888® Spray Grade
IMPACT ENERGY: 1.5 Joules
HOLIDAY VOLTAGE: 3000 VDC

Sample Number	Temperature	Film Thickness (mils)	No. of Test Impacts	Holiday (Yes/No)	Pass/Fail*
1	21°C/70°F	34 - 39	6	No	Pass
2		42 – 48	6	No	
1	0°C/32°F	40 - 44	7	No	Pass
2		37 - 42	5	No	
1	-30°C/-22°F	42 – 46	5	No	Pass
2		39 – 42	6	No	

* Pass/Fail criteria: No Holidays is a pass.

WET ADHESION – KNIFE

INTRODUCTION

Water can be the most detrimental environment to a coating system, especially at elevated temperatures. Water molecules can penetrate through the coating to the substrate, which would cause blistering and loss of adhesion. If the bond between the coating and the substrate were weakened, the danger of the coating letting go and falling off would leave the substrate unprotected. The Hot Water Soak Test examines a coating's ability to adequately protect the steel in immersion conditions.

The objective of the test was to determine the adhesion of SP8888® Spray Grade Coating after immersion in an aqueous environment.

CONCLUSIONS

As a result of this test, the following can be concluded:

- SP8888® Spray Grade Coating showed excellent adhesion before and after the Immersion Test with a rating of one (1).
- No blistering, change in colour or gloss were observed as a result of testing at 95°C/203°F.

METHODOLOGY

The Wet Adhesion-Knife Test was conducted according to the CAN/CSA Z245.20-98 (Section 12.14). In this test, the coated panels were immersed in water at 95°C/203°F for twenty-four (24) hours, seven (7), fourteen (14), and twenty-eight (28) days. Adhesion rating was conducted by cutting a rectangle approximately 30 mm x 15 mm in the center of each sample. Using a levering action, a knife blade was inserted under the coating and was used to remove the coating from the substrate. This was continued until all of the coating within the rectangle was removed, or until the coating exhibited a definite resistance to the levering action.

RESULTS

Results obtained are shown in Figure 5 and given in the attached data sheet at the end of this section.

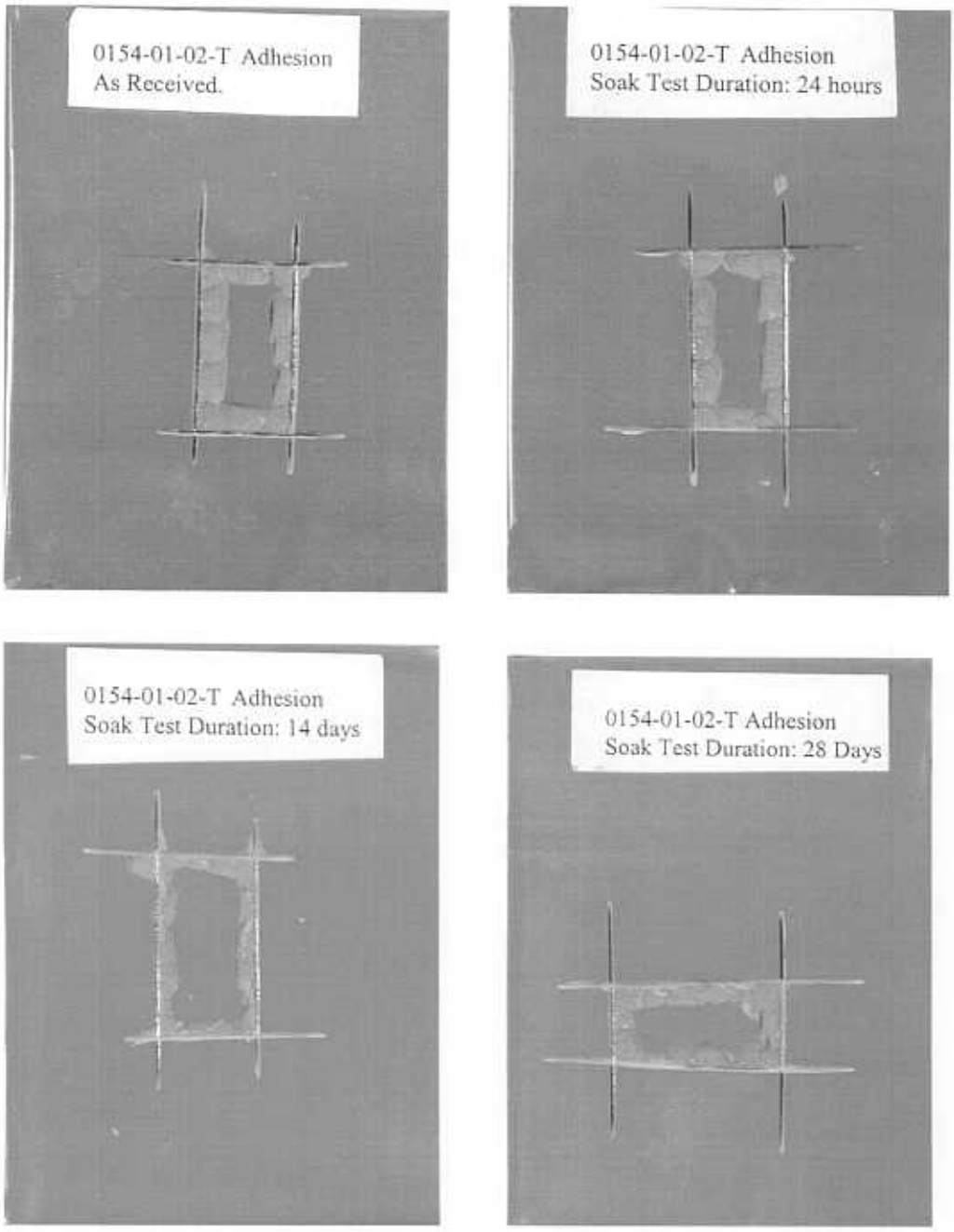


Figure 5. Post-Test Overview - Adhesion Knife Test

The above photographs are the adhesion results before and after the immersion of the tested panels at 95°C/203°F. The coating exhibited a definite resistance to the applied levering action and maintained excellent adhesion. No blistering, changing of colour or gloss was observed as a result of testing.

CHARTER COATING SERVICE (2000) LTD.
ADHESION OF COATING TEST DATA SHEET
(CAN/CSA Z245.20-98, Clause 12.14)

WORK ORDER NO.: 0154-01-02-T

COATING: SP8888® Spray Grade

TECHNICIAN: R. Taggart

TEMPERATURE: 95°C/203°F

Duration	Film Thickness (mils)	Adhesion Rating	Pass/Fail*
As Received	34 – 40	1	Pass
24 hours	32 – 35	1	Pass
7 Days	38 – 42	1	Pass
14 Days	27 – 33	1	Pass
28 Days	32 – 40	1	Pass

* Pass/Fail criteria: Pass is a rating of 1 to 3

Rating Key
1. Coating cannot be removed cleanly.
2. Less than 50% of the coating can be removed.
3. More than 50% of the coating can be removed but the coating demonstrates a definite resistance to the levering action.
4. The coating can be easily removed in strips or large chips.
5. The coating can be completely removed as a single piece.

CATHODIC DISBONDMENT

INTRODUCTION

Cathodic Protection is a technique used to reduce the corrosion of a metal surface, by providing sufficient current to make the anodic dissolution rate become negligible. While preserving the steel, this technique can be detrimental to the performance of the coating applied. Anodes develop at breaks and defects in the coating film (holidays). An aggressive, caustic environment at the substrate/coating interface develops on the edge of the holiday (the cathode) by the electrical stress impressed. Coating disbondment is initiated and propagates around the holiday due to the increase in pH in the immediate environment. The phenomenon is commonly referred to as Cathodic Disbondment.

The objective of this test was to determine the coating's ability to withstand cathodic protection conducted at high temperatures of 95°C/203°F, 120°C/248°F, and 150°C/302°F.

CONCLUSIONS

As a result of testing, the following can be concluded:
(Note that no industry acceptance criteria currently exist for the twenty-eight (28) days, high temperature Cathodic Disbondment Test).

- SP8888® Spray Grade Coating was tested at 95°C/203°F and showed an average radius of disbondment of 2.70 mm for fourteen (14) days and 4.30 mm for twenty-eight (28) days. Some loss of sheen and chalking was observed as a result of testing.

- The same coating showed an average radius of disbondment of 4.7 mm radius after twenty-eight (28) days of testing at 120°C/248°F. Some loss of sheen and chalking was observed as a result of testing.

- The same coating showed an average radius of disbondment of 9.17 mm after twenty-eight (28) days of testing at 150°C/302°F. Loss of sheen and chalking was observed as a result of testing.

METHODOLOGY

In this study, the Cathodic Disbondment Test was conducted according to CSA Z245.20-M98, "Cathodic Disbondment of External Fusion Bond Epoxy Coating, Modified." An external holiday of 3.2-mm/0.125 inch diameter was drilled through the coating to the steel surface. The experimental set-up consists of making a seal between a cylinder and coated sample, using silicone sealant centred on the initial holiday. The cylinder was filled with 3.0% NaCl solution and the samples were polarized cathodically, by impressing an electrical potential of -1.50V (with respect to $Cu|CuSO_4$ reference electrode at 21°C/70°F). The test was modified by running the samples at high temperatures of 95°C/203°F, 120°C/248°F, and 150°C/302°F. For test temperatures above 100°C/212°F, the test was further modified using an autoclave. The tested pressure was 50 psi for the 120°C/248°F test and 100 psi for the 150°C/302°F test. The autoclave was depressurised at low temperature and the cell solution was replaced every week to compensate for any change in the solution chemistry as a result of testing.

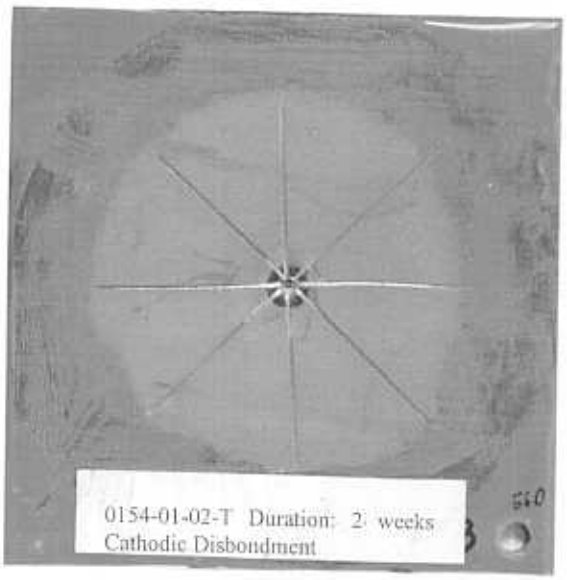
The test conditions were as follows:

Temperature(s):	95°C/203°F, 120°C/248°F, and 150°C/302°F
Electrolyte:	3% NaCl in Distilled Water
Impressed Voltage:	-1.50VDC
Test Duration(s):	14-28 days

After testing, the samples were examined for blisters and radial cuts were made through the coating to the substrate. The coating was lifted from the substrate adjacent to the initial holiday to measure the extent of any disbondment.

RESULTS

The results are shown in Figures 6 to 8 and given in the attached data sheet at the end of this section.



Test Panel after 14 Days

Test Panel after 28 Days

Figure 6. Post-Test Overview - Cathodic Disbondment Test
Magnification 5X for 14 and 28 days

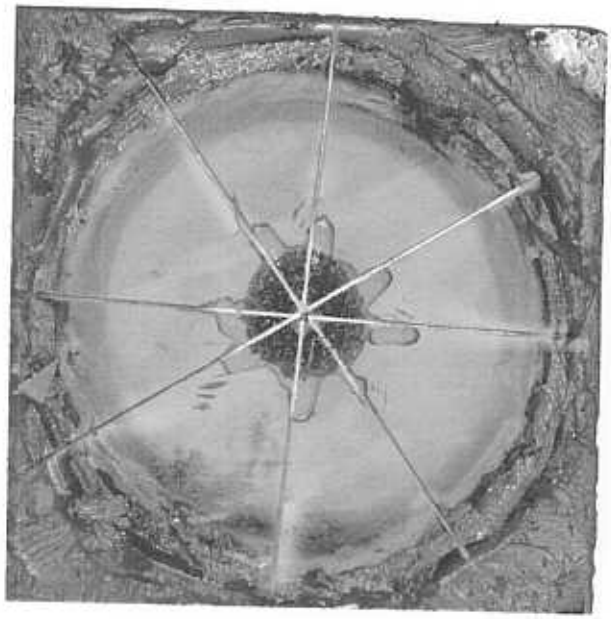
The above photographs are a representative sample of the Cathodic Disbondment Test samples. The radial cuts intersect the initial holiday. SP8888® Spray Grade Coating showed radius of disbondment of 2.70 and 4.30 mm after fourteen (14) and twenty-eight (28) days of testing at 95°C/203°F.

Test Panel No. 1 after 28 Days

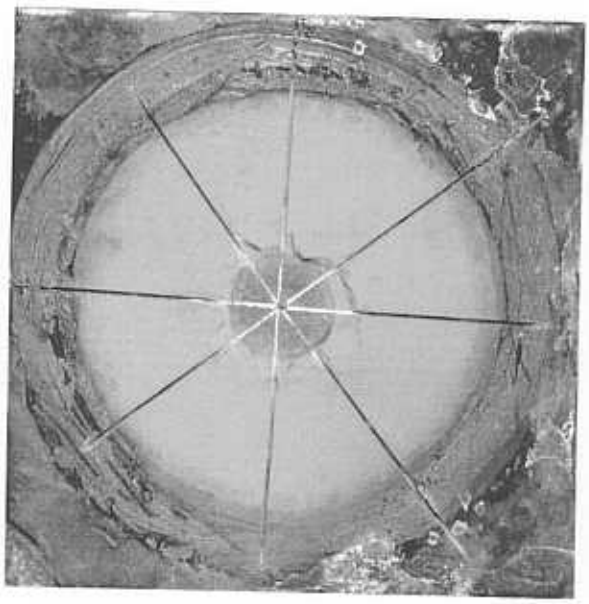
Test Panel No. 2 after 28 Days

Figure 7. Post-Test Overview - Cathodic Disbondment Test

The above photographs are samples of the Cathodic Disbondment Test after twenty-eight (28) days of testing at 120°C/248°F. The radial cuts intersect the initial holiday. The average radius of disbondment is 4.7 mm, excluding the initial holiday radius. Loss of sheen and chalking was observed as a result of testing.



Test Panel No. 1 after 28 Days



Test Panel No. 2 after 28 Days

Figure 8. Post-Test Overview - Cathodic Disbondment Test

The above photographs are samples of the Cathodic Disbondment Test after twenty-eight (28) days of testing at 150°C/302°F. The radial cuts intersect the initial holiday. The average radius of disbondment for the coating is 9.17 mm, excluding the initial holiday. Loss of sheen and chalking was observed as a result of testing.

CHARTER COATING SERVICE (2000) LTD.
CATHODIC DISBONDMENT OF THE COATING
(CAN/CSA Z245.20 -98, Clause 12.8)

WORK ORDER NO (S).: 0154-01-02, 0154-02-04

COATING: SP8888® Spray Grade

TECHNICIAN: J. Hartt

VOLTAGE: -1.5 VDC

DATE: May 04, 2002

TEMPERATURE: 95°C/203°F

Test Panel No.	Duration (Days)	Film Thickness (mils)	Average Radius Disbondment (mm)*	Pass/Fail
2	14	33 – 36	2.70	Pass
5	28	40 – 42	4.30	Pass

* Excludes the initial holiday measurement (1.6 mm radius)

TEMPERATURE: 120°C/248°F

Test Panel No.	Duration (Days)	Film Thickness (mils)	Average Radius Disbondment (mm)*	Pass/Fail
1	28	33 – 45	3.0	Pass
2		36 – 40	6.36	Pass

* Excludes the initial holiday measurement (1.6 mm radius)

TEMPERATURE: 150°C/302°F

Test Panel No.	Duration (Days)	Film Thickness (mils)	Average Radius Disbondment (mm)*	Pass/Fail
1	28	36 – 40	9.51	Pass
2		37 – 42	8.83	Pass

* Excludes the initial holiday measurement (1.6 mm radius)