Charter Coating
SERVICES LTD.

"Failure Avoidance Through Laboratory Testing"

Coating Testing Laboratory
Consulting Services
Field Inspection

ENDURANCE
TECHNOLOGIES INC.
Boronized Coatings for Corrosion & Erosion Protection

Pressurized Atlas Cell Testing of BC1100 Boron Coating

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0174-98-01-T

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INTRODUCTION

At the request of Endurance Technologies, Charter Coating Service conducted pressurized atlas cell testing on BC 1100 boron coating. This coating was a participant in a blind study conducted for PanCanadian Petroleum. This report will cover the test results from the blind study as well as further testing conducted for Endurance Technologies.

The pressurized atlas cell test was designed to simulate corrosive oilfield service environments. This test measures the ability of a protective coating to withstand a temperature gradient between the internal and external surfaces under the influence of pressure, temperature, and the effect of the testing environment. Coatings which demonstrate the least reaction to the test are considered the most suitable for use as a corrosion mitigation barrier.

OBJECTIVE

The objective of this project was to determine the effects of simulated oil field service on the coating, utilising produced fluids and gas mixtures the coating would be exposed to in field service conditions.

SCOPE

This project is limited to:

- The test methods, conditions, and samples specified by PanCanadian Petroleum
- Applied sample supplied by Endurance Technologies
- Produced fluids supplied by PanCanadian Petroleum

TEST SAMPLE

An 8½" x 8½" A-36 grade steel panel, with a 1⅞" piece of steel welded perpendicular to the centre of the panel, was coated with BC 1100 boron coating. A ⅜" punch was used to create an artificial holiday in the coating. These "holidays" were located in the centre of each test phase, and were used to measure the undercreep at the edge of the "holiday".

TEST METHOD

The pressurized atlas cell test was conducted in accordance to a modification of NACE TM0174-91, "Laboratory Methods for the Evaluation of Protective Coatings Used as Lining Materials in Immersion Service", Method A. The procedure was modified by applying pressure to the test environments with specific gaseous components.

Test panels were centred on both ends of the central cylindrical cell with the coating facing the cell. Flanges were placed against the back of the panels. The cell was uniformly tightened and the test solutions were added. The gas mixture was loaded into the cell to the specified pressure, and heat was applied. The temperature and pressure were monitored daily to ensure compliance to the specified requirements.

The panels were exposed to the following environment:

Temperature:	70°C / 158°F
Pressure:	3.4 MPa / 500 psi
Gas Phase:	7% H_2S, 80% CO_2, 13% CH_4
Hydrocarbon Phase:	Produced Crude
Water Phase:	Produced Water
Duration:	120 days, with 14 and 64 day interim ratings

At the 14 day, 64 day, and final ratings, the test panel was downloaded from the cell and visually examined for coating film deterioration, and corrosion of the substrate at the artificial holiday.

RESULTS

The following table outlines the performance of the test sample at the three rating periods.

Table 1
Pressurized Atlas Cell Test Results

Sample	Rating	Blisters			Corrosion			Cracks
		Gas	Hydrocarbon	Water	Gas	Hydrocarbon	Water	
BC 1100	14 Days	None	None	None	None	None	Slight	None
	64 Days	None	None	None	None	None	Yes*	None
	120 Days	None	None	None	None	None	Yes*	None

* 2.0mm deep pit found in the steel substrate under the artificial holiday; BC 1100 coating was unaffected

CONCLUSIONS

BC 1100 showed excellent resistance to the test environment. This coating would likely perform well in the field service represented by this testing.

The coating provided excellent protection to both the weld and the edges of the welded piece of steel. No corrosion was noted, indicating complete coverage of the irregular shapes and sharp edges. This conclusion is based on the evaluation of the protection afforded the substrate adjacent to the weld. No evidence of coating deterioration or corrosion of the substrate was detectable at any of the rating intervals.

The coating must be holiday free when placed into service with water. This conclusion is based on observations that corrosion of the steel substrate occurred under the artificially induced holiday in the water phase after 64 days.

Submitted By:
CHARTER COATING SERVICE LTD.

Jennifer Morse

Jennifer Morse
Laboratory Supervisor

CHARTER COATING SERVICE LTD.
PRESSURIZED ATLAS CELL DATA SHEET

DATE:	January 12, 1998			TEMPERATURE:	70°C/158°F
WORK ORDER NO.:	0036-97-04-T			PRESSURE:	3.4MPa / 500psi
TEST NO.:	10			LIQUID #1:	Produced Water
RATED BY:	J. Morse			LIQUID #2:	Produced Crude
PANEL #:	97-513/BC 1100			GAS:	7% H_2S, 80% CO_2, 13% CH_4
14 DAY RATING:	X	DATE:	Nov 12,1997	DURATION:	64 Days
FINAL RATING:	X	DATE:	Jan. 12, 1998	REL. TEMP.:	38°C / 100°F
				REL. PRESSURE:	8.3MPa / 120psi
				REL. TIME:	18 Minutes

COMMENTS:

Static 14 Day Interim Rating:

- No blistering, corrosion, cracking, or coating deterioration noted
- No visible corrosion at base of weld
- Indications of a pit forming under the artificial holiday in the water phase

Static 64 Day Final Rating:

- No blistering, corrosion, cracking, or coating deterioration noted
- A 2.0mm deep pit in the steel substrate found under the holiday in the water phase.

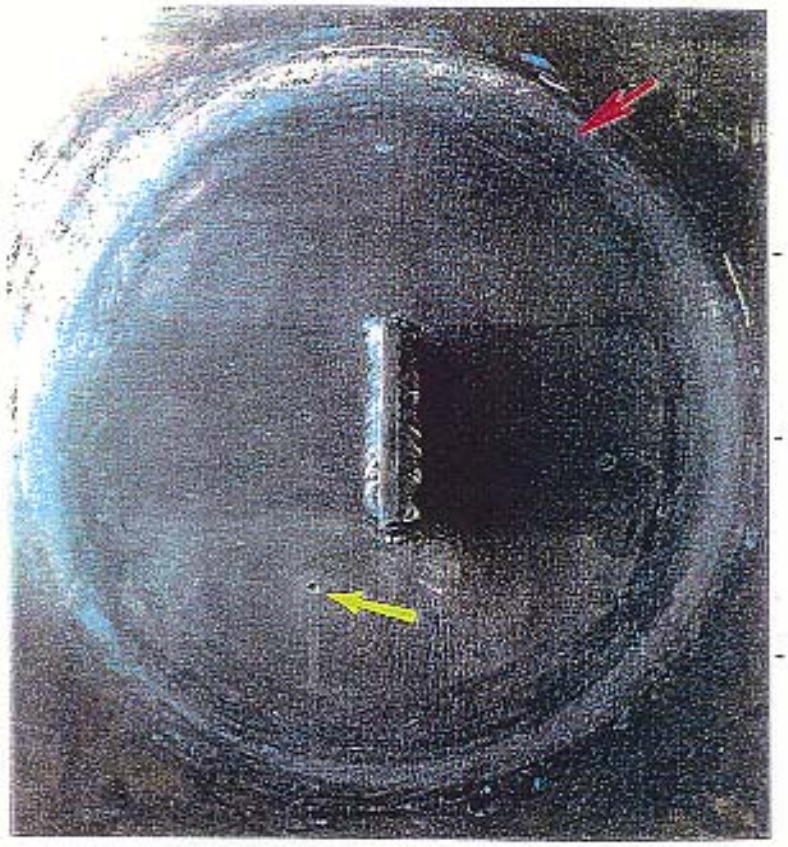

Figure 1
Overview of BC 1100

The coating film showed no deterioration as a result of the test. The only negative reaction noted was a 2.0mm deep pit that developed under the holiday of the water phase (yellow arrow).

The pressurized atlas cell test was composed of three phases: gas, hydrocarbon, and water. These phases were contained within a cylindrical cell, the inside of which defined the total test area. The test area is within the circular discolouration (red arrow). A square piece of steel was welded to the centre of the panel to determine the coatings ability to adequately protect sharp edges and irregular surfaces. The three artificial holidays in the centre of each test phase were created to measure undercreep of the test environment.

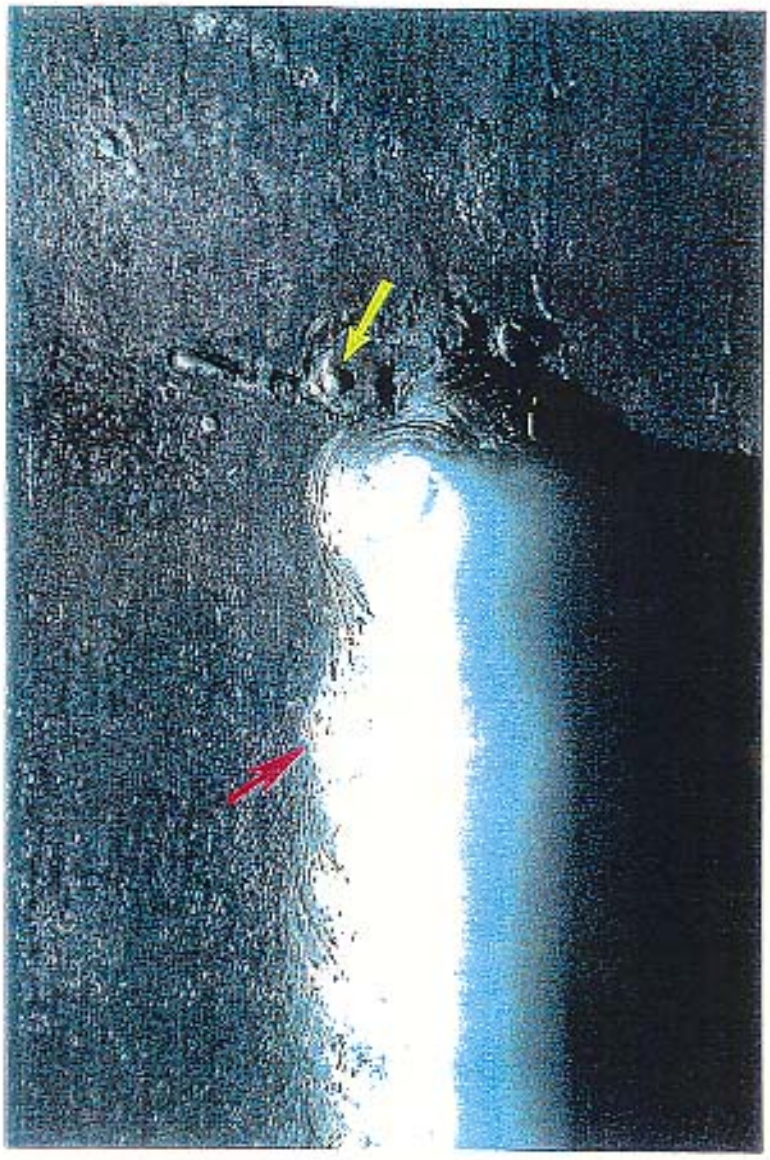

Figure 2
Closeup of Weld Seam

This photograph is a closeup of the weld seam around the piece of steel in the centre of the panel. Note the narrow grooves in the weld seam (red arrow). Liquid coatings often do not penetrate into narrow crevices and grooves, but rather coat over them, leaving the steel surfaces uncoated and subject to ingress of the environment. No corrosion was noted in this area, indicating that BC 1100 penetrated into the crevices. Also note that no corrosion can be seen around the weld splatter adjacent to the weld seam (yellow arrow), indicating that all surfaces of the weld splatter were adequately coated.

Figure 3
Closeup of Pit Under Holiday in Water Phase
Magnification: 30X

The holidays were made in the coating film to determine the coatings ability to resist undercreep. At the 14 day rating, a pit was noted in the substrate at the holiday in the water phase. No exploration or measurements were conducted at this time. At the 64 day interim rating, close examination of the holiday revealed a 2.0mm deep pit that had developed in the substrate under the holiday. Re-evaluation at the final 120 day final rating showed that the pit remained the same depth measured at 64 days.

A portion of the coating film was removed during evaluation of the pit. The bright area (red arrow) above the pit is the clean boron coating film. Note that there are no detrimental anomalies, such as foam, or evidence of permeation of the test environment within the coating film. Though corrosion of the substrate occurred where there was a break in the coating, the coating film has not been affected by the test environment. There was no evidence that debonding of the coating occurred as a result of undercreep.

CHARTER COATING SERVICE LTD.
PRESSURIZED ATLAS CELL DATA SHEET

DATE:	March 23, 1998			TEMPERATURE:	70°C / 158°F
WORK ORDER NO.:	0174-98-01-T			PRESSURE:	3.4MPa / 500psi
TEST NO.:	2			LIQUID #1:	Produced Water
RATED BY:	D. Switzer			LIQUID #2:	Produced Crude
PANEL #:	BC-1100			GAS:	7% H_2S, 80% CO_2, 13% CH_4
120 DAY RATING:	X	DATE:	Mar. 23 / 98	DURATION:	120 Days
				REL. TEMP.:	38°C/ 100°F
				REL. PRESSURE:	1.2MPa / 180psi
				REL. TIME:	15 Minutes

COMMENTS:

Static 120 Day Final Rating:

- No blistering, corrosion, cracking, or coating deterioration noted
- Indications of a pit forming under the artificial holiday in the water phase

PARALLEL SCRIBE

METHOD FOR RATING ADHESION

OF COATING TO SUBSTRATE

The following method with slight variations is used throughout the internal pipe coating industry by manufacturers, applicators and consumers.

The coating is cut to the metal in two parallel scribes approximately 1/8" (5mm) apart. A knife blade is then inserted in one of the scribes so as to lift the coating from the substrate. The adhesion is rated as follows:

'A' The coating may shear within itself but does not release from the substrate. The only bare metal visible is in the scribes.

'B' Less than 50% of bare metal is visible between the scribes.

'C' More than 50% of bare metal is visible between the scribes.

'D' All coating releases between scribes when probed with blade, but remains adhered adjacent to cuts.

'F' No bond exists between coating and substrate. Once the film has been scribed, the coating releases.

Designations of '+' and '-' are used to differentiate subtle variations in the adhesion that are not defined by the above ratings.