ENBRIDGE

Coating Repairs Work Plan
Line 5 Dual Pipelines

United States v. Enbridge Energy et al Case 1:16 –cv-914

Consent Decree	VII. Injunctive Measures, E. Measures To Prevent Spills In The Straits Of Mackinac, Paragraph 69c., Biota Investigation		
Version	3.0	Version date	September 13, 2017

ENBRIDGE

TABLE OF CONTENTS

ENBRIDGE

Introduction

Paragraph 69 of the Consent Decree entered in Case 1:16-cv-00914 (ECF No. 14, 05/23/17) requires the Enbridge defendants (collectively referred to as "Enbridge") to create and complete a Biota Investigation Work Plan ("BI Work Plan") on the Dual Pipelines that cross the Straits of Mackinac. On or about August 14, 2017, Enbridge initiated the field activities of the BI Work Plan at the Straits and as of September 13, 2017 the BI Work Plan field work has been completed.

Through the BI Work Plan activities there have been several locations identified as areas with bare or potentially bare metal.

Per Paragraph 69c. Enbridge is required to submit a final report to the EPA within 60 days of completion of the BI Work Plan investigation. In particular, in the event that evidence is developed that zebra mussels and other biota have impaired, or threaten to impair, the Dual Pipelines Enbridge shall supplement the final report with a proposed work plan to address such impairments. Enbridge however, is currently unaware of any evidence linking zebra mussels or other biota to the coating repairs identified above.

Enbridge is submitting this Coating Repairs Work Plan ("CR Work Plan") in advance of the final BI Work Plan Report with the intent of receiving EPA approval for implementing coating repairs in time to allow Enbridge to complete the work in 2017.

Objective

The objective of the CR Work Plan is to ensure that all repairs are completed safely and in accordance with the Enbridge's coating procedure and in compliance with federal regulations.

Background

On June 13, 2017 the EPA approved Enbridge's BI Work Plan. This plan included detailed steps to complete biota sampling at various locations along the Dual Pipelines. The BI Work Plan also highlighted 18 areas of interest that would be investigated by divers as per the BI Work Plan definition (partial) included below:

Area(s) of Interest: An Area of Interest is a part of the pipeline where, based on visual inspection, (i) the normal (local) Biota is unexpectedly absent or (ii) there is evidence of possible coating damage (e.g., Dislodged Coating and/or potential Holiday).

In addition to the 18 Areas of Interest, three (3) Additional Sites were identified by the Enbridge marine contractor as being appropriate to investigate further. These Additional Sites were identified on Figures 2 and 3 of the BI Work Plan.

Coating Repair Scope Of Work And Schedule

The following locations have been identified as areas with bare or potentially bare metal:

• Additional Site #1 (EAS-1): One area proposed for coating repair (bare metal). • Additional Site #2 (EAS-2): One area proposed for coating repair (potential bare metal). • Additional Site #3 (WAS-1): Four areas proposed for coating repair (bare metal).	Known at the time for inclusion in CR Work Plan - Version 1.0
• East Additional Sites (August Supplement): Three areas proposed for coating repair (bare metal) (North and South). Please refer to coating inspection reports titled EAS-3 and EAS-4.	Known at the time for inclusion in CR Work Plan - Version 2.0
• Area of Interest #1 (EAOI-1): Three areas proposed for coating repair (potential	Known at the time for inclusion

bare metal). • Area of Interest #5 (EAOI-5): One area proposed for coating repair (potential bare metal). • Area of Interest #7 (EAOI-7): One area proposed for coating repair (potential bare metal).	in CR Work Plan - Version 3.0 (current version)

Note: EAS and WAS represents East Additional Site and West Additional Site respectively. EAOI represents East Area of Interest.

The coating inspection reports are included in Appendix A. Thus far, there is no visual evidence or inspection data that suggests any material corrosion or impact on the integrity of the pipe at these locations as the redundant systems – external coating and the cathodic protection – continues to protect the pipelines.

Enbridge will be ready to begin the coating repair work as soon as September 14, 2017 pending approvals from the EPA and the State of Michigan. It is intended to complete the currently known coating repair scope of work in an expeditious manner however, the actual time required to complete the work is highly dependent upon the weather conditions at the Straits.

Coating Repair and Coating Application Procedure

Prior to implementing the coating repairs the following actions will be completed by the Diver:

- Visually inspect the exposed bare steel for corrosion. If deposits are present they will be removed and the underlying metal surface inspected for corrosion related impacts. Any bare metal exposed by the surface preparation (i.e. By removal of loose coating material) shall also be visually inspected for corrosion by the Diver.
- Measure the wall thickness of the pipe using a Cygnus Instruments, Dive-Underwater ultrasonic thickness gage. The Diver will be OQ trained for taking these measurements. At least five (5) pipe wall thickness measurements will be collected per area that is less than 0.25 square feet, while a total of at least eight (8) pipe wall thickness measurements taken at areas 0.25 square feet and greater.

Enbridge has determined an appropriate system and application procedure for the coating repairs on the Line 5 Straits. This procedure is based on the Manufacturer's history with underwater coating installation that dates back to 1989 and the successful full-scale application and testing of the coating repair technology at a third party laboratory (Stress Engineering Services (SES) in Waller, Texas). SES performed a series of tests in which repairs were applied to laboratory samples and a representative 20" diameter pipe from Line 5 that was supplied by Enbridge. Both patch and full 360° circumferential repairs were conducted on the samples, while they were submerged in 40°F water with a composition similar to that found in the Straits. The results of SES's testing program indicate that the coating repair system is an effective repair system. The report is included in Appendix B.

The proposed coating system for the coating repairs is as follows:

- BIO-DUR 563 epoxy filler followed by E-glass fabric impregnated with X-100 UW epoxy manufactured by Piping Repair Technology Incorporated (PRTI).

Coating repairs consist of two approved methods that include:

- Method 1 – Epoxy Filler/ X-100 Epoxy/Full Circumferential Composite Wrap Repair/Stricture Banding®
- Method 2 – Epoxy Filler/ X-100 Epoxy/Composite Patch Repair/Stricture Banding®

Both Method 1 (full circumferential wrap application of the epoxy impregnated fiber) and Method 2 (patch application of the epoxy impregnated fiber) are Enbridge approved methods when using the Stricture Banding® to seal the repair while it cures. SES testing showed that Method 2 without the Stricture Bandings is not acceptable.

Method 1 is more likely to be chosen when the repair is located on the side of the pipe and the repair area is larger and runs axially along the pipe. Method 2 is more likely to be chosen in situations where dive time is limited, the repair area is smaller, and the repair is located on top of the pipe.

Enbridge is currently working with the coating manufacturer to investigate the suitability of using Method 2 with a pre-cast sleeve in place of the Stricture Bandings ("Modified Method 2"). Enbridge will approach the EPA for approval of Modified Method 2 if the investigation shows the approach is effective. The table below shows the coating repair locations and the currently proposed coating repair method.

Location	Identification	Coating Repair Method
Additional Site #1	EAS-1	Method 1
Additional Site #2	EAS-2	Method 1
Additional Site #3	WAS-1	Method 1
East Additional Site (August Supplement)	EAS-3	Method 1
	EAS-4	Method 1 or Modified Method 2 - if deemed acceptable through testing and subsequently approved by the EPA
Area of Interest #1	EAOI-1	Method 1
Area of Interest #5	EAOI-5	Method 1
Area of Interest #7	EAOI-7	Method 1

It is anticipated that permit(s) for lake floor excavation will be required for EAS-4 unless Modified Method 2 is acceptable and approved. Enbridge will provide the state of Michigan with the plan detailing the materials, methods, and procedures it will use to repair the coating areas.

The product data sheets for the BIO-DUR 563 epoxy filler and the X-100 UW epoxy are included in Appendix C. In addition, Appendix D includes a letter from the Manufacturer confirming that the materials comply with 49CFR195.559 and highlighting underwater installations that have been performed using their products since 1989.

Based on the full scale application and testing at SES, Enbridge has also developed a procedure for the application of the coating repair to the Dual Pipelines. The Enbridge procedure "Application Of Underwater Repair Coatings For Line 5 Straits" – Version 2.0 is found in Appendix E. The procedure was developed in consultation with PRTI.

The cure time for the coating system will be verified using a field trial to confirm the SES testing results that are incorporated into the coating procedure. A pipe sample will be prepared and coated concurrently with the coating repairs at WAS-1. This site represents the deepest water depth (201 feet) and therefore the location with the most challenging environment for successful coating repair. The sample will be allowed to cure at depth and retrieved to the barge after 7 days of cure. While on the barge, Shore D measurements will be completed to confirm a value of 60 or greater. Should the field trial not confirm a Shore D measurement of 60 or greater Enbridge will inform the EPA and the Independent Third Party to discuss next steps relative to the CR Work Plan.

Diver Training and Certification

In order to support the successful implementation of the coating repairs, the divers will be Operator Qualified (OQ) for the work to be completed. To meet 49CFR195.559 requirements for Operator Qualifications, any contractor that is performing an OQ task is required to complete training modules and hands-on training to demonstrate they are qualified. This training process is designed to deliver the basic skills required for each task. After completion of the OQ training, the results are uploaded to ISNET to verify compliance. A list of the OQ covered tasks are listed in Appendix F.

To supplement the OQ certification process, Enbridge will also have the coating manufacturer perform specific training for the materials and coating applications that will be used for the L5 Straits underwater coating repairs. Upon successful completion of the manufacturer's training, the crew members will be issued a certificate of completion.

PRTI training consists of verbal technical training and introduction to the products, their components, and the basic installation procedure. The manufacturer also utilizes audio visual presentations of various installations, wet out procedures and technical aspects of the uses of the products. This is followed by a "hands on" application of the filler, the composite, the stricture banding and the pre cast sleeve.

The marine contractor will also perform a simulated wet trial located close to the dock to test the coating repair plan prior to completing the coating repairs.

Coating Repair Work Plan Deviations

Enbridge has identified two different deviation procedures to ensure the appropriate approvals are received. The deviation procedure outlined in Enbridge's coating repair procedure (Section 2.4, Appendix E) is assigned to the Pipeline Integrity's technical subject matter expert (SME) to sign-off on any deviations as they relate to the Coating Repair procedure. The Pipeline Integrity SME is Enbridge's Coatings Specialist and they will be responsible for evaluating all deviations requested on the coating repair procedure to ensure such deviations are supported by the Manufacturer. This information or decisions made will be communicated to the Project Manager. The Coating Inspector and Manufacturer will be on the barge overseeing the work related to the surface preparation, application and confirming/verifying of the repair. The PI SME will not be on the barge but will be available by cell phone to ensure any deviation requests are addressed.

The deviation procedure for the CR Work Plan is assigned to the Project Manager (PM). The PM will be responsible for the overall work plan related to the plan and how it is executed. The PM will consult with the key stakeholders that include but are not limited to, Pipeline Integrity, Pipeline Compliance. Any deviations required as a result of its execution will require their acceptance. The PM will not be on the barge but will be available via cell phone to ensure any deviation requests are addressed.

Deviations from this work plan shall be brought to the Project Manager (PM) for resolution.

Deviations to this CR Work Plan will also be discussed with the Independent Third Party representative.

Monitoring of Coating Repair Locations

Enbridge understands that our pipeline system, particularly the section through the Straits of Mackinac, is both an important part of the region's energy infrastructure and a point of concern for many people. Enbridge continuously monitors, maintains and modernizes Line 5 to ensure its continued safe operation.

The completed repairs related to this Line 5 CR Work Plan will be captured in Enbridge's OneSource database as part of the L5 Straits section. As such, these sites will continue to be monitored for active external corrosion using inline inspection over the life of the asset. In addition, Enbridge will also visually inspect any exposed coating repairs using a remoted operated vehicle during the scheduled underwater inspection that are completed biannually.

Reporting

Per Paragraph 69c. Enbridge is required to submit a final report to the EPA within 60 days of completion of the BI Work Plan investigation. In particular, in the event that evidence is developed that zebra mussels and other biota have impaired, or threaten to impair, the Dual Pipelines Enbridge shall supplement the final report with a proposed work plan to address such impairments. Enbridge however, is currently unaware of any evidence linking zebra mussels or other biota to the coating repairs identified above.

In addition to the above mentioned report, Enbridge will submit a report to the EPA within 30 days of completion of the CR Work Plan. This report will include a summary of the work completed, any CR Work Plan deviations with justification, and other pertinent information.

ENBRIDGE

Appendix A:
Coating Inspection Reports at the Additional Sites

External Pipeline Inspection Form for L5 Straits of Mackinac

General Information			
Date:	08/15/2017	**Contractor:**	Ballard Marine Co
AFE / W.O.#:	20008990	**Company Rep / Inspector:**	REDACTED
Segment:	EAS-1	**Water Depth (ft):**	R
Longitude:	REDACTED	**Latitude:**	REDACTED

External Pipe Coating Inspection Results			
General Area	☒ Disturbed Area ☐Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	48.84 (46'x 1.74')
Holiday 1	☐ Disturbed Area ☐Dislodged Coating ☒Holiday	**Size of anomaly (ft^2):**	0.01 (3.0"x0.5")
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	
Corrosion present:	☐YES ☒NO	**Biota present:**	☒YES ☐ NO
Dislodged coating observed on the lake floor: ☐YES ☒NO		**Lake floor location wrt pipe:**	N/A (pipe is suspended)

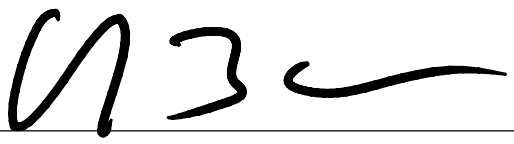
Comments/Issues/Discussion

EAS-1 within span of E-72. Total span is 46' long, within the areas of 10:00 and 2:00.
South End Lat: REDACTED long REDACTED
North End Lat: REDACTED long REDACTED
Center Line listed in general information above.

One (1) feature with DFT measurements below the minimum resolvable thickness of gauge was found. The Polatrak CP gun was used to confirm the existence of bare metal:

Holiday 1 presented average CP reading of -1680mV CSE (holiday confirmed). Holiday found in coating at coordinates Lat: REDACTED Long: REDACTED

No external corrosion was detected by dive team.

	REDACTED
Contractor Signature	**Enbridge Representative/ Inspector Signature**

External Pipeline Inspection Form for L5 Straits of Mackinac

Visual Inspection (General Coating Condition)

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.

Date:	8/15/17	Frame(HH:MM:SS)	09:26:36	Date:	8/15/17	Frame(HH:MM:SS)	09:27:04

Coating Gauge Information

Manufacturer:	Elcometer Inspection Equip	**Product:**	211 Coating Thickness Gauge
Last Calibrated:	08/09/2017	**Next Calibration Due:**	08/09/2018
Gauge verified prior to use:	☒YES ☐ NO		

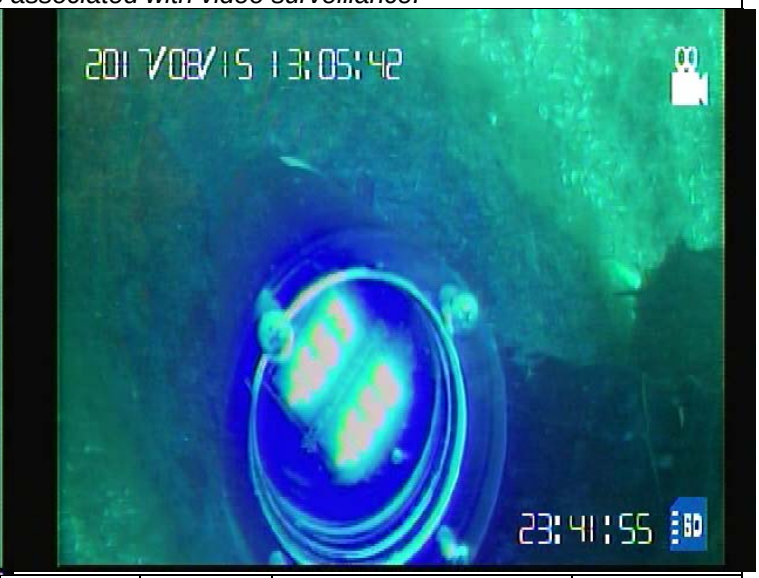
Coating Thickness Inspection Data

Thickness Measure (mil)	Area of Interest	Undisturbed Area (< 2 in.)	Undisturbed Area (> 5 ft.)
North End #1	115	125	130
#2	109	135	130
#3	115	136	140
South End #4	120	145	140
#5	120	128	130
#6	101	130	134
Average Thickness	113	133	134

Additional Coating Thickness Inspection Data (A/R)

	Close as possible to 9 o'clock	Close as possible to 12 o'clock	Close as possible to 2 o'clock
North End	104	120	122
---	104	115	118
South End	130	130	140

ENBRIDGE	External Pipeline Inspection Form for L5 Straits of Mackinac

Cathodic Protection and Coating Measurements (if Holiday is found) - Holiday 1							
CP Reading #1 (mV)	**-1676 -1683**	**CP Reading #2 (mV)**	**-1674 -1681**	**CP Reading #3 (mV)**		**-1690 -1674**	
Temperature (°F)	**NR**	**DFT at Holiday (mil)**	**≤ 25**	**DFT Adjacent to Holiday (mil)**		**96, 94, 95**	
For all sections of dislodged coating or holidays, provide pictures below. Included the date and time stamps associated with video surveillance.							
							
Date:	8/15/17	Frame(HH:MM:SS)	13:02:03	Date:	8/15/17	Frame(HH:MM:SS)	13:05:42

External Pipeline Inspection Form for L5 Straits of Mackinac

General Information			
Date:	08/24/2017	**Contractor:**	Ballard Marine Co
AFE / W.O.#:	20008990	**Company Rep / Inspector:**	REDACTED
Segment:	EAS-2	**Water Depth (ft):**	R
Longitude:	REDACTED	**Latitude:**	REDACTED

External Pipe Coating Inspection Results			
Coating Condition	☐ Disturbed Area ☐Dislodged Coating ☐Holiday ☒Other	**Size of anomaly (ft^2):**	0.14 (2.5" x 8")
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	
Corrosion present:	☐YES ☒NO	**Biota present:**	☒YES ☐ NO
Dislodged coating observed on the lake floor: ☐YES ☒NO		**Lake floor location wrt pipe:**	N/A (pipe is suspended)

Comments/Issues/Discussion

EAS-2 is within span of E-74.

DFT measurements indicate normal coating thickness through majority of area, with one small area of slightly reduced thickness, which may indicate possible dislodgement of outer wrap. This could not be confirmed due to the presence of a white deposit.

The Polatrak CP gun was used to check for coating holiday through the white deposit. CP measurements could not be obtained, indicating the corrosion barrier coating is intact.

It is recommended to revisit this site to destructively remove the white deposit and inspect the coating condition beneath it. This should be performed during the recoating project so that any resulting coating damage can be repaired.

	REDACTED
Contractor Signature	**Enbridge Representative/ Inspector Signature**

ENBRIDGE

External Pipeline Inspection Form for L5 Straits of Mackinac

Visual Inspection (General Coating Condition)

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.

Date:	8/24/17	Frame(HH:MM:SS)	14:11:12	Date:	8/24/17	Frame(HH:MM:SS)	14:38:33

Coating Gauge Information

Manufacturer:	Elcometer Inspection Equip	**Product:**	211 Coating Thickness Gauge
Last Calibrated:	08/09/2017	**Next Calibration Due:**	08/09/2018
Gauge verified prior to use:	☒YES ☐ NO		

Coating Thickness Inspection Data

Thickness Measure (mil)	Area of Interest	Undisturbed Area (< 2 in.)	Undisturbed Area (> 5 ft.)
North End #1	135	130	115
#2	140	130	115
#3	110	140	120
South End #4	117	119	125
#5	130	94	130
#6	70	150	135
Average Thickness	117	127	121

Additional Coating Thickness Inspection Data (A/R)

ENBRIDGE	External Pipeline Inspection Form for L5 Straits of Mackinac

Cathodic Protection and Coating Measurements (if Holiday is found) (note: holiday could not be confirmed)					
CP Reading #1 (mV) See note (below)	-261 -291	CP Reading #2 (mV)	N/R	CP Reading #3 (mV)	N/R
Temperature (°F)	NR	DFT at Feature (mil)	≥ 70 avg.117	DFT Adjacent to Feature (mil)	≥ 94 avg.127

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.

Date:	8/24/17	Frame(HH:MM:SS)	14:11:12	Date:	8/24/17	Frame(HH:MM:SS)	14:38:33

Note: CP readings at this feature were recorded with the probe of Polatrak CP gun pressed firmly through the white substance covering the pipe. These readings were identical to 'open water' CP readings, which were recorded with the CP gun probe close to (but not touching) the pipe.

External Pipeline Inspection Form for L5 Straits of Mackinac

General Information			
Date:	08/29/2017	**Contractor:**	Ballard Marine Co
AFE / W.O.#:	20008990	**Company Rep / Inspector:**	REDACTED
Segment:	EAS-3	**Water Depth (ft):**	RE
Longitude:	REDACTED	**Latitude:**	REDACTED

External Pipe Coating Inspection Results			
Coating Condition	☐ Disturbed Area ☐Dislodged Coating ☒Holiday	**Size of anomaly (ft^2):**	0.93 (8”x1.4’)
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	
Corrosion present:	☐YES ☒NO	**Biota present:**	☒YES ☐ NO
Dislodged coating observed on the lake floor: ☐YES ☒NO		**Lake floor location wrt pipe:**	Pipe suspended

Comments/Issues/Discussion

East Additional Site #3 (South of E-22).

DFT measurements at the feature are below the minimum resolvable thickness of gauge.
The Polatrak CP gun was used to confirm the existence of bare metal:

Holiday 1 presented average CP reading of -848mV CSE (holiday confirmed).

No external corrosion was detected by dive team.

	REDACTED
Contractor Signature	**Enbridge Representative/ Inspector Signature**

External Pipeline Inspection Form for L5 Straits of Mackinac

Visual Inspection (General Coating Condition and Holiday 1)

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.

Date:	8/29/17	Frame(HH:MM:SS)	10:35:09	Date:	8/29/17	Frame(HH:MM:SS)	10:35:44

Coating Gauge Information

Manufacturer:	Elcometer Inspection Equip	**Product:**	211 Coating Thickness Gauge
Last Calibrated:	08/09/2017	**Next Calibration Due:**	08/09/2018
Gauge verified prior to use:	☒YES ☐ NO		

Coating Thickness Inspection Data

Thickness Measure (mil)	Area of Interest	Undisturbed Area (< 2 in.)	Undisturbed Area (> 5 ft.)
North End #1	105	85	130
#2	≤25	120	120
#3	115	115	130
South End #4	≤25	80	100
#5	≤25	80	100
#6	≤25	125	105
Average Thickness		101	114

Additional Coating Thickness Inspection Data (A/R)

ENBRIDGE	External Pipeline Inspection Form for L5 Straits of Mackinac

Cathodic Protection and Coating Measurements (if Holiday is found) - Holiday 1					
CP Reading #1 (mV)	**-852 -886**	**CP Reading #2 (mV)**	**-804 -842**	**CP Reading #3 (mV)**	**-834 -875**
Temperature (°F)	**44**	**DFT at Holiday (mil)**	**≤ 25**	**DFT Adjacent to Holiday (mil)**	**80, 80, 125**

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.

Date:	8/29/17	Frame(HH:MM:SS)	10:35:09	Date:	8/29/17	Frame(HH:MM:SS)	10:35:44

External Pipeline Inspection Form for L5 Straits of Mackinac

General Information			
Date:	08/30/2017	**Contractor:**	Ballard Marine Co
AFE / W.O.#:	20008990	**Company Rep / Inspector:**	REDACTED
Segment:	EAS-4	**Water Depth (ft):**	RE
Longitude:	RREDACTE	**Latitude:**	REDACTE D

External Pipe Coating Inspection Results			
General Area	☒ Disturbed Area ☐Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	3.0 (1'6" X 2')
Holiday 1	☐ Disturbed Area ☐Dislodged Coating ☒Holiday	**Size of anomaly (ft^2):**	0.53 (7" X 11")
Holiday 2	☐ Disturbed Area ☐Dislodged Coating ☒Holiday	**Size of anomaly (ft^2):**	1.11 (1'4" X 10")
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	
Corrosion present:	☐YES ☒NO	**Biota present:**	☐YES ☒ NO
Dislodged coating observed on the lake floor: ☐YES ☒NO		**Lake floor location wrt pipe:**	Pipe buried

Comments/Issues/Discussion

East Additional Site #4.

Two (2) features with DFT measurements below the minimum resolvable thickness of gauge were found. The Polatrak CP gun was used to confirm the existence of bare metal:
Holiday 1 presented average CP reading of -963mV CSE (holiday confirmed).
Holiday 2 presented average CP reading of -958mV CSE (holiday confirmed).

No external corrosion was detected by dive team.

	REDACTED
Contractor Signature	**Enbridge Representative/ Inspector Signature**

External Pipeline Inspection Form for L5 Straits of Mackinac

Visual Inspection (General Coating Condition, Holidays 1 and 2)

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video sdurveillance.

Date:	8/30/17	Frame(HH:MM:SS)	09:17:44	Date:	8/30/17	Frame(HH:MM:SS)	08:55:25

Coating Gauge Information

Manufacturer:	Elcometer Inspection Equip	**Product:**	211 Coating Thickness Gauge
Last Calibrated:	08/09/2017	**Next Calibration Due:**	08/09/2018
Gauge verified prior to use:	☒YES ☐ NO		

Coating Thickness Inspection Data

Thickness Measure (mil)	Area of Interest	Undisturbed Area (< 2 in.)	Undisturbed Area (> 5 ft.)
North End #1	≤25	N/R (see note, below)	N/R
#2	≤25	N/R	N/R
#3	≤25	N/R	N/R
South End #4	≤25	N/R	N/R
#5	≤25	N/R	N/R
#6	≤25	N/R	N/R
Average Thickness			

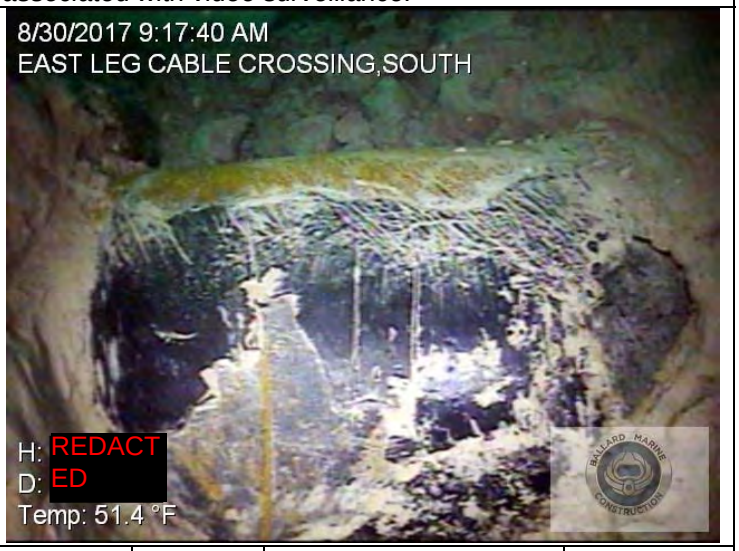
Additional Coating Thickness Inspection Data (A/R)

Note: coating thickness in undisturbed areas around the cable rub could not be obtained due to the presence of silt and soil (lake bed). The pipe is below the level of the lake bed. See Holiday 1 and Holiday 2 *'DFT thicknesses adjacent to the Holidays'* for representative coating thickness in the area.

External Pipeline Inspection Form for L5 Straits of Mackinac

Cathodic Protection and Coating Measurements (if Holiday is found) - Holiday 1					
CP Reading #1 (mV)	-955 -991	CP Reading #2 (mV)	-938 -965	CP Reading #3 (mV)	-951 -979
Temperature (°F)	44	DFT at Holiday (mil)	≤ 25	DFT Adjacent to Holiday (mil)	96, 84, 100, 135

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.



Date:	8/30/17	Frame(HH:MM:SS)	8:58:31	Date:	8/30/17	Frame(HH:MM:SS)	9:17:40

Cathodic Protection and Coating Measurements (if Holiday is found) - Holiday 2					
CP Reading #1 (mV)	-981 -1012	CP Reading #2 (mV)	-907 -933	CP Reading #3 (mV)	-944 -974
Temperature (°F)	44	DFT at Holiday (mil)	≤ 25	DFT Adjacent to Holiday (mil)	105, 140, 76, 95, 84

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.

Date:	8/30/17	Frame(HH:MM:SS)	10:03:31	Date:	8/30/17	Frame(HH:MM:SS)	10:14:55

ENBRIDGE

External Pipeline Inspection Form for L5 Straits of Mackinac

General Information			
Date:	08/25/2017	**Contractor:**	Ballard Marine Co
AFE / W.O.#:	20008990	**Company Rep / Inspector:**	REDACTED
Segment:	WAS-1	**Water Depth (ft):**	RE
Longitude:	REDACTED	**Latitude:**	REDACTED

External Pipe Coating Inspection Results			
General Area	☐ Disturbed Area ☒Dislodged Coating ☐Holiday	**Size of anomaly (ft^2):**	20.8 (13' x 1.6')
Holiday 1	☐ Disturbed Area ☐Dislodged Coating ☒Holiday	**Size of anomaly (ft^2):**	0.06 (9" x 1")
Holiday 2	☐ Disturbed Area ☐Dislodged Coating ☒Holiday	**Size of anomaly (ft^2):**	0.24 (1'2" x 2.5")
Holiday 3	☐ Disturbed Area ☐Dislodged Coating ☒Holiday	**Size of anomaly (ft^2):**	0.07 (1'7" x ½")
Holiday 4	☐ Disturbed Area ☐Dislodged Coating ☒Holiday	**Size of anomaly (ft^2):**	0.01 (1'3" x 1/8")
Corrosion present:	☐YES ☒NO	**Biota present:**	☒YES ☐ NO
Dislodged coating observed on the lake floor: ☐YES ☒NO		**Lake floor location wrt pipe:**	N/A (pipe is suspended)

Comments/Issues/Discussion

WAS-1 within span of W-68A. Four (4) features with DFT measurements below the minimum resolvable thickness of gauge were found. The Polatrak CP gun was used to confirm the existence of bare metal at the following features:

Holiday 1 presented average CP reading of -1312mV CSE (holiday confirmed).
Holiday 2 presented average CP reading of -1312mV CSE (holiday confirmed).
Holiday 3 presented average CP reading of -1365mV CSE (holiday confirmed).
Holiday 4 presented average CP reading of -1408mV CSE (holiday confirmed).

No external corrosion was detected by dive team. A white deposit was found at the holiday area.

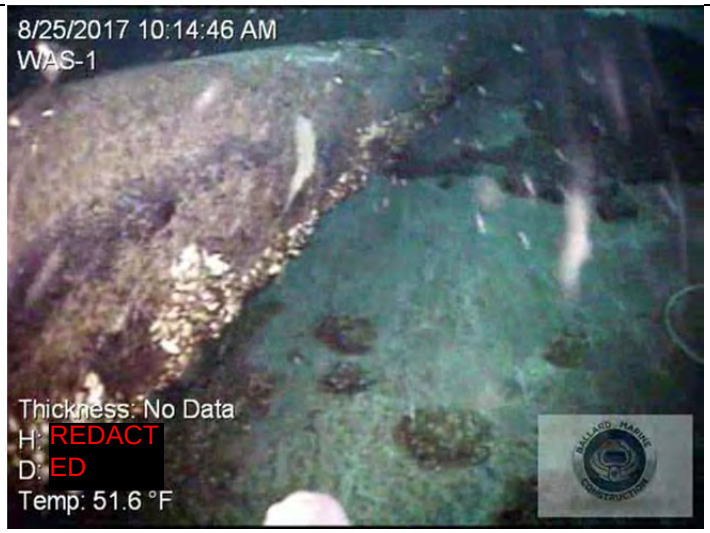
	REDACTED
Contractor Signature	**ture**

ENBRIDGE

External Pipeline Inspection Form for L5 Straits of Mackinac

Visual Inspection (General Coating Condition)

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.



Date:	8/25/17	Frame(HH:MM:SS)	10:15:30	Date:	8/25/17	Frame(HH:MM:SS)	10:14:46

Coating Gauge Information

Manufacturer:	Elcometer Inspection Equip	**Product:**	211 Coating Thickness Gauge
Last Calibrated:	08/09/2017	**Next Calibration Due:**	08/09/2018
Gauge verified prior to use:	☒YES ☐ NO		

Coating Thickness Inspection Data

Thickness Measure (mil)	Area of Interest	Undisturbed Area (< 2 in.)	Undisturbed Area (> 5 ft.)
North End #1	80	105	105
#2	66	110	110
#3	110	105	95
South End #4	110	94	90
#5	105	95	85
#6	105	100	85
Average Thickness	96	102	95

Additional Coating Thickness Inspection Data (A/R)

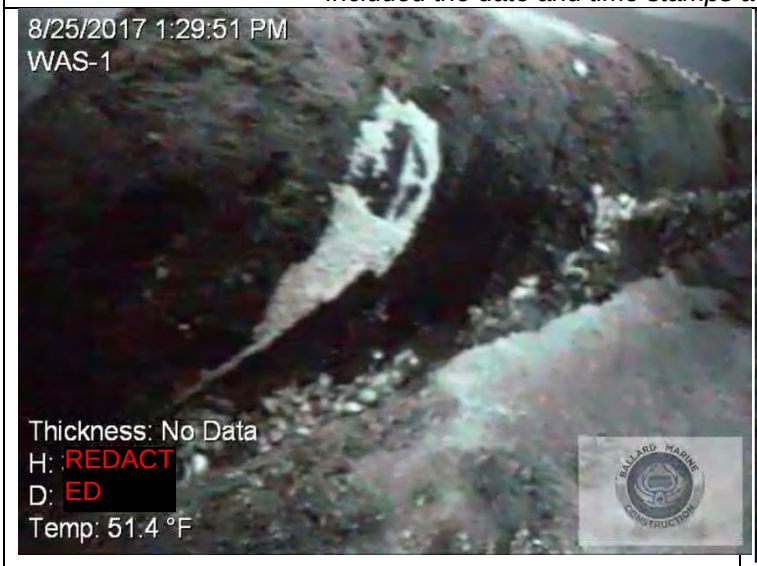
	Within AOI 5’ from North	Within AOI 10’ from North
North End	92	98
---	84	105
South End	80	110

External Pipeline Inspection Form for L5 Straits of Mackinac

Cathodic Protection and Coating Measurements (if Holiday is found) - Holiday 1							
CP Reading #1 (mV)	-1300 -1362	CP Reading #2 (mV)	-1277 -1336	CP Reading #3 (mV)	-1277 -1322		
Temperature (°F)	43	DFT at Holiday (mil)	≤ 25	DFT Adjacent to Holiday (mil)	90, 93, 110		
For all sections of dislodged coating or holidays, provide pictures below. Included the date and time stamps associated with video surveillance.							

Date:	8/25/17	Frame(HH:MM:SS)	09:15:30	Date:	8/25/17	Frame(HH:MM:SS)	10:14:42

Cathodic Protection and Coating Measurements (if Holiday is found) - Holiday 2							
CP Reading #1 (mV)	-1274 -1328	CP Reading #2 (mV)	-1283 -1237	CP Reading #3 (mV)	-1375 -1372		
Temperature (°F)	43	DFT at Holiday (mil)	≤ 25	DFT Adjacent to Holiday (mil)	79, 94, 100		
For all sections of dislodged coating or holidays, provide pictures below. Included the date and time stamps associated with video surveillance.							



Date:	8/25/17	Frame(HH:MM:SS)	13:29:51	Date:	8/25/17	Frame(HH:MM:SS)	13:30:30

ENBRIDGE

External Pipeline Inspection Form for L5 Straits of Mackinac

Cathodic Protection and Coating Measurements (if Holiday is found) - Holiday 3									
CP Reading #1 (mV)	-1340 -1388	CP Reading #2 (mV)	-1342 -1389	CP Reading #3 (mV)	-1343 -1385				
Temperature (°F)	43	DFT at Holiday (mil)	≤ 25	DFT Adjacent to Holiday (mil)	95, 83, 89				
For all sections of dislodged coating or holidays, provide pictures below. Included the date and time stamps associated with video surveillance.									

Date:	8/25/17	Frame(HH:MM:SS)	09:14:35	Date:	8/25/17	Frame(HH:MM:SS)	10:15:41

Cathodic Protection and Coating Measurements (if Holiday is found) - Holiday 4									
CP Reading #1 (mV)	-1384 -1433	CP Reading #2 (mV)	-1390 -1430	CP Reading #1 (mV)	-1380 -1430				
Temperature (°F)	43	DFT at Holiday (mil)	≤ 25	DFT Adjacent to Holiday (mil)	80, 80, 90				
For all sections of dislodged coating or holidays, provide pictures below. Included the date and time stamps associated with video surveillance.									

Date:	8/25/17	Frame(HH:MM:SS)	09:14:19	Date:	8/25/17	Frame(HH:MM:SS)	09:14:26

External Pipeline Inspection Form for L5 Straits of Mackinac

General Information			
Date:	09/08/17	**Contractor:**	Ballard Marine Co
AFE / W.O.#:	20008990	**Company Rep / Inspector:**	REDACTED
Segment:	EAOI-1	**Water Depth (ft):**	194
Longitude:	REDACTED	**Latitude:**	REDACTED

External Pipe Coating Inspection Results			
Coating Condition	☒ Disturbed Area ☐Dislodged Coating ☐Holiday ☐Other	**Size of anomaly (ft^2):**	9.17 (3'4" X 2'9")
Feature 1	☐ Disturbed Area ☐Dislodged Coating ☐Holiday ☒Other	**Size of anomaly (ft^2):**	0.01 (1" X1")
Feature 2	☐ Disturbed Area ☐Dislodged Coating ☐Holiday ☒Other	**Size of anomaly (ft^2):**	0.01 (1" X1.5")
Feature 3	☐ Disturbed Area ☐Dislodged Coating ☐Holiday ☒Other	**Size of anomaly (ft^2):**	0.01 (1" X1")
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday ☐Other	**Size of anomaly (ft^2):**	
Corrosion present:	☐YES ☒NO	**Biota present:**	☒YES ☐ NO
Dislodged coating observed on the lake floor: ☐YES ☒NO		**Lake floor location wrt pipe:**	6 o'clock (pipe resting on lake bed)

Comments/Issues/Discussion

EAOI-1 E-01B-B is an area of disturbed biota and contains three areas of white deposit within a 6" X 1.5" area on the top of the pipe (12 o'clock).

DFT measurements indicate normal coating thickness through the entire area inspected.

CP measurements taken with the Polatrak CP gun through the white deposit areas deviated slightly from reference 'open water' measurements, but they were not sufficiently electronegative to indicate contact with Line 5 pipe metal.

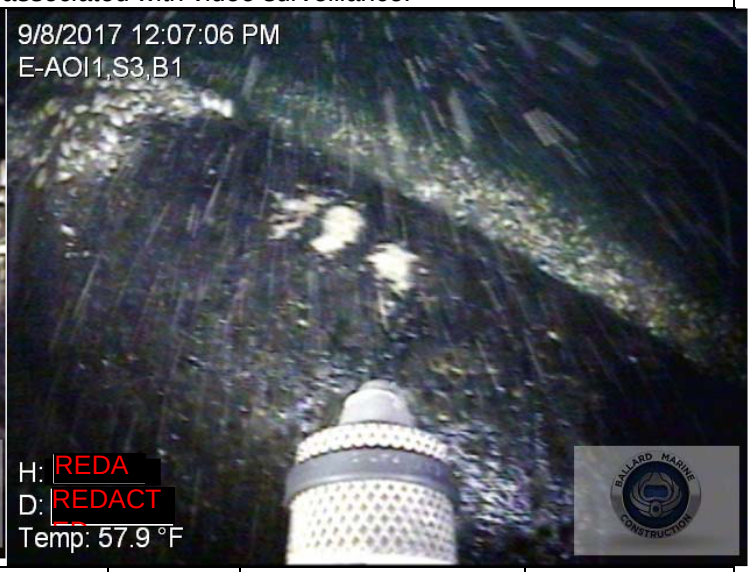
	REDACTED
Contractor Signature	**Enbridge Representative/ Inspector Signature**

ENBRIDGE

External Pipeline Inspection Form for L5 Straits of Mackinac

Visual Inspection (General Coating Condition)

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.



Date:	09/08/17	Frame(HH:MM:SS)	9:01:01	Date:	09/08/17	Frame(HH:MM:SS)	12:07:06

Coating Gauge Information

Manufacturer:	Elcometer Inspection Equip	**Product:**	211 Coating Thickness Gauge
Last Calibrated:	08/09/2017	**Next Calibration Due:**	08/09/2018
Gauge verified prior to use:	☒YES ☐ NO		

Coating Thickness Inspection Data

Thickness Measure (mil)	Area of Interest	Undisturbed Area (< 2 in.)	Undisturbed Area (> 5 ft.)
North End #1	115	105	110
#2	150	125	110
#3	105	98	90
South End #4	105	95	100
#5	105	95	100
#6	110	100	100
Average Thickness	115	103	101

Additional Coating Thickness Inspection Data (A/R)

	Centerline of AOI at 12, 3, and 9 o'clock	
Top	105	
West	125	
East	110	

ENBRIDGE

External Pipeline Inspection Form for L5 Straits of Mackinac

Cathodic Protection and Coating Measurements (if Holiday is found) (note: holiday could not be confirmed)					
CP Reading #1 (mV) (feature 1)	**-234 -281**	**CP Reading #2 (mV) (feature 2)**	**-440 -316**	**CP Reading #3 (mV) (feature 3)**	**-320 -260**
Temperature (°F)	**45**	**DFT at Feature (mil)**	**N/R**	**DFT Adjacent to Features (mil) (features 1, 2, and 3 respectively)**	**130, 145, 140**

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.

Date:	09/08/17	Frame(HH:MM:SS)	12:07:06	Date:		Frame(HH:MM:SS)	

Note: CP readings at this feature were recorded with the probe of Polatrak CP gun pressed firmly into the white substance coating the pipe. These readings were more electronegative than the 'open water' CP readings (-198mV / -170mV), but are not consistent with Line 5 pipe metal contact – indicating that the presence of a resistive coating on the pipe surface.

External Pipeline Inspection Form for L5 Straits of Mackinac

General Information			
Date:	09/06/17	**Contractor:**	Ballard Marine Co
AFE / W.O.#:	20008990	**Company Rep / Inspector:**	REDACTED
Segment:	EAOI-5	**Water Depth (ft):**	103
Longitude:	REDACTED	**Latitude:**	REDACTED

External Pipe Coating Inspection Results			
Coating Condition	☒ Disturbed Area ☐Dislodged Coating ☐Holiday ☐Other	**Size of anomaly (ft^2):**	23.29 (6'6"x3'7")
Feature 1	☐ Disturbed Area ☐Dislodged Coating ☐Holiday ☒Other	**Size of anomaly (ft^2):**	0.01 (1" X1")
Feature 2	☐ Disturbed Area ☒Dislodged Coating ☐Holiday ☐Other	**Size of anomaly (ft^2):**	0.01 (1" x 2")
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday ☐Other	**Size of anomaly (ft^2):**	
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday ☐Other	**Size of anomaly (ft^2):**	
Corrosion present:	☐YES ☒NO	**Biota present:**	☒YES ☐ NO
Dislodged coating observed on the lake floor: ☐YES ☒NO		**Lake floor location wrt pipe:**	N/A (pipe is suspended)

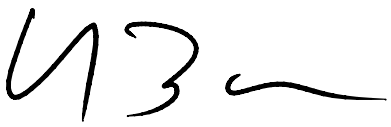
Comments/Issues/Discussion

EAOI-5 E-39 is an area of disturbed biota and contains one area of white deposit approximately the size of a quarter located near the top of the pipe (at 12 o'clock). The white deposit is located adjacent to a coated circumferential seam weld in the pipe.

DFT measurements indicate normal coating thickness through the entire area inspected, with slightly thinner coating adjacent to the white deposit.

CP measurements taken with the Polatrak CP gun through the white deposit areas deviated slightly from reference 'open water' measurements, but they were not sufficiently electronegative to indicate contact with Line 5 pipe metal.

Part of the white deposit broke away during the CP readings without exposing bare metal.

	REDACTED
Contractor Signature	**Enbridge Representative/ Inspector Signature**

ENBRIDGE

External Pipeline Inspection Form for L5 Straits of Mackinac

Visual Inspection (General Coating Condition)

For all sections of dislodged coating or holidays, provide pictures below. Included the date and time stamps associated with video surveillance.

Date:	09/06/17	Frame(HH:MM:SS)	14:45:12	Date:	09/06/17	Frame(HH:MM:SS)	14:47:47

Coating Gauge Information

Manufacturer:	Elcometer Inspection Equip	**Product:**	211 Coating Thickness Gauge
Last Calibrated:	08/09/2017	**Next Calibration Due:**	08/09/2018
Gauge verified prior to use:	☒YES ☐ NO		

Coating Thickness Inspection Data

Thickness Measure (mil)	Area of Interest	Undisturbed Area (< 2 in.)	Undisturbed Area (> 5 ft.)
North End #1	145	72	130
#2	94	115	130
#3	105	100	110
South End #4	130	130	135
#5	110	120	105
#6	105	100	105
Average Thickness	119	106	119

Additional Coating Thickness Inspection Data (A/R)* (see note below)

	16” from South End	34” from South End	52” from South End
West	135	145	145
Top	105	105	120
East	105	125	105

Note: An area of dislodged outer wrap was identified 2.5’ from the south end of the AOI. Coating thickness in this area was 100 mil.

ENBRIDGE

External Pipeline Inspection Form for L5 Straits of Mackinac

Cathodic Protection and Coating Measurements (if Holiday is found) (note: holiday could not be confirmed)							
CP Reading #1 (mV) (feature 1)	**-391 -326**	**CP Reading #2 (mV)**	**N/R**	**CP Reading #3 (mV)**		**N/R**	
Temperature (°F)	**50**	**DFT at Feature (mil)**	**N/R**	**DFT Adjacent to Features (mil)**		**82,72,78,78**	
For all sections of dislodged coating or holidays, provide pictures below. Included the date and time stamps associated with video surveillance.							
							
Date:	09/06/17	Frame(HH:MM:SS)	14:47:47	Date:		Frame(HH:MM:SS)	

Note: CP readings at this feature were recorded with the probe of Polatrak CP gun pressed firmly into the white substance coating the pipe. These readings were more electronegative than the 'open water' CP readings (-101mV / -061mV), but are not consistent with Line 5 pipe metal contact – indicating that the presence of a resistive coating on the pipe surface.

External Pipeline Inspection Form for L5 Straits of Mackinac

General Information			
Date:	09/05/17	**Contractor:**	Ballard Marine Co
AFE / W.O.#:	20008990	**Company Rep / Inspector:**	REDACTED
Segment:	EAOI-7	**Water Depth (ft):**	81
Longitude:	REDACTED	**Latitude:**	REDACTED

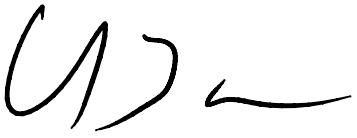
External Pipe Coating Inspection Results			
Coating Condition	☒ Disturbed Area ☐Dislodged Coating ☐Holiday ☐Other	**Size of anomaly (ft^2):**	7.08 (2'5" X 2'10")
Feature 1	☐ Disturbed Area ☐Dislodged Coating ☐Holiday ☒Other	**Size of anomaly (ft^2):**	0.04 (3" X2")
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday ☐Other	**Size of anomaly (ft^2):**	
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday ☐Other	**Size of anomaly (ft^2):**	
	☐ Disturbed Area ☐Dislodged Coating ☐Holiday ☐Other	**Size of anomaly (ft^2):**	
Corrosion present:	☐YES ☒NO	**Biota present:**	☒YES ☐ NO
Dislodged coating observed on the lake floor: ☐YES ☒NO		**Lake floor location wrt pipe:**	N/A (pipe is suspended)

Comments/Issues/Discussion

EAOI-7 is located in Span E-35. This area of disturbed biota contains one area of white deposit.

DFT measurements indicate normal coating thickness through the entire area inspected, with slightly thinner coating adjacent to the white deposit.

The Polatrak CP gun was used to test for coating holiday through the white deposit, but valid CP measurements could not be obtained. This indicates the presence of a resistive or isolating coating on the pipe surface.

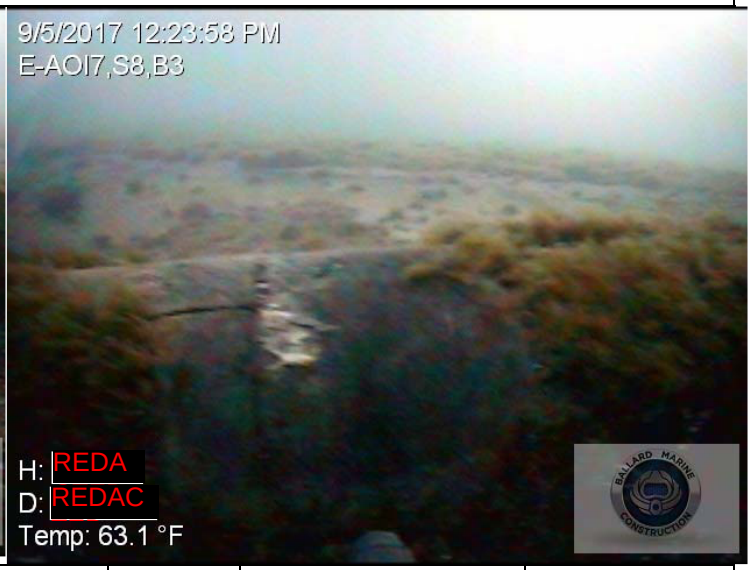
	REDACTED
Contractor Signature	**Enbridge Representative/ Inspector Signature**

ENBRIDGE

External Pipeline Inspection Form for L5 Straits of Mackinac

Visual Inspection (General Coating Condition)

For all sections of dislodged coating or holidays, provide pictures below.
Included the date and time stamps associated with video surveillance.



Date:	09/05/17	Frame(HH:MM:SS)	12:24:13	Date:	09/05/17	Frame(HH:MM:SS)	12:23:58

Coating Gauge Information

Manufacturer:	Elcometer Inspection Equip	**Product:**	211 Coating Thickness Gauge
Last Calibrated:	08/09/2017	**Next Calibration Due:**	08/09/2018
Gauge verified prior to use:	☒YES ☐ NO		

Coating Thickness Inspection Data

Thickness Measure (mil)	Area of Interest	Undisturbed Area (< 2 in.)	Undisturbed Area (> 5 ft.)
South End #1	111	106	114
#2	104	109	100
#3	135	113	126
North End #4	159	160	160
#5	166	200	190
#6	190	120	110
Average Thickness	144	134	133

Additional Coating Thickness Inspection Data (A/R)* (see note below)

	Centerline of AOI	Adjacent to white substance	
	134	63	
	104	75	
	119	95	

CP gun was pressed firmly into the white deposit, but valid CP readings could not be obtained.

ENBRIDGE

Appendix B:
Report from Stress Engineering Services

STRESS ENGINEERING SERVICES INC.

an employee-owned company

Evaluation of Underwater Coating Repairs for Enbridge Line 5

Final Report

SES Document No.: 1254493-PL-RP-01 (Rev 0)

8 September 2017

Prepared for:

Enbridge Pipeline

Edmonton, Alberta, Canada

Contact: REDACTED

Prepared by:

Stress Engineering Services, Inc.

13800 Westfair East Drive

Houston, Texas 77041-1101

Phone: 281-955-2900

Web: www.stress.com

Texas Registered Engineering Firm F-195

Limitations of This Report

This report is prepared for the sole benefit of the Client, and the scope is limited to matters expressly covered within the text. In preparing this report, SES has relied on information provided by the Client and, if requested by the Client, third parties. SES may not have made an independent investigation as to the accuracy or completeness of such information unless specifically requested by the Client or otherwise required. Any inaccuracy, omission, or change in the information or circumstances on which this report is based may affect the recommendations, findings, and conclusions expressed in this report. SES has prepared this report in accordance with the standard of care appropriate for competent professionals in the relevant discipline and the generally applicable industry standards. However, SES is not able to direct or control operation or maintenance of the Client's equipment or processes.

Executive Summary

Stress Engineering Services, Inc. (SES) was contracted by Enbridge Pipeline to evaluate an epoxy coating repair system that is being considered for use on a section of Enbridge's Line 5, which runs through the Straits of Mackinac in Northern Michigan. The coating repair system being evaluated is a product of Piping Repair Technologies (PRT) Incorporated of Hempstead, Texas, and consists of:

- Bio-Dur™ 563 SW epoxy filler used to fill any missing or removed sections of the original coating;
- Four layers of E-glass fabric saturated with a two-part X-100 UW epoxy resin, which is a mixture of X100-UW Epoxy Base – Blue and BIO-SEAL™ X-100 Curing Agent – Clear. The epoxy repair fabric can be applied as either a patch or a full circumferential wrap over either bare steel or the original inner coal-tar coating; and
- Stricture Banding® film wrapped around the repair to compress the fabric layers and hold the repair in place as it cures.

SES performed a series of tests in which repairs were applied to laboratory samples and a representative 20" diameter pipe from Line 5 that was supplied by Enbridge. Both patch and full 360° circumferential repairs were applied to the samples while they were submerged in 40°F water with a composition similar to that found in the Straits.

All repairs cured in approximately 5 to 6 days, and were found to achieve a Shore D hardness of greater than 70.

The relative adhesion of the repairs to the pipe surface was tested using ASTM 4541 methods ("Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers"). Both patch and full repairs exhibited greater adhesion to the pipe surface than the original coal-tar coating.

The effect of the Stricture Banding® film was evaluated by performing repairs both with and without its use during the repair procedure. One patch repair was not wrapped with Stricture Banding®; post-test inspection revealed that this repair was well adhered at its center, but was not fully attached around the perimeter of the fabric. The resulting crevice created at the perimeter indicated that the patch may be susceptible to erosion and/or crevice corrosion during service; therefore, use of the Stricture Banding®, or some other compression method, is recommended during the curing cycle. The remaining repairs that incorporated the Stricture Banding® during installation appeared to be well suited for underwater pipeline coating repair, if they are properly applied.

Table of Contents

List of Tables

List of Figures

1. Introduction

Stress Engineering Services, Inc. (SES) was contracted by Enbridge Pipeline to evaluate the application of an epoxy repair system that is being considered for use on a submerged length of Line 5, located in the Mackinac Straits of northern Michigan (the "Straits"). Throughout this report, the term "Pipeline #5" is intended to refer to this underwater section of the pipeline.

The proposed repair system—X-100 UW Heavy Duty Epoxy—was applied to representative pipe samples by the supplier, PLT of Hempstead, Texas. The simulated repairs were applied while the pipe was submerged in 40°F water with a mineral composition similar to that of the Straits. The hardness of the repaired areas was then tested using a Shore D durometer over 7+ days to document the curing characteristics of the epoxy. The configuration of each repair area was examined using standard metallographic techniques. Additionally, adhesion testing per ASTM D4541, "Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers," was conducted in both the original and repaired areas of the coating to determine their relative adhesion after full curing.

This report documents the results of SES's testing and evaluation.

2. Original Coating Material

A 7 ft section of 20" diameter pipe was provided to SES for the repair system evaluation. The sample pipe section (Figure 1) had a wall thickness of 0.810" and was reportedly the same construction and vintage as Pipeline #5. The pipe section provided had reportedly been in prior service, although not underwater.

The original coating reportedly consists of an inner layer of coal tar or asphalt epoxy with an outer fiber-glass wrap. SES removed a section of the original coating from the pipe and analyzed its composition using Fourier transform infrared spectroscopy (FTIR). The results (Figure 2) indicate that the inner layer is a coal-tar based coating. The outer layer is similar in composition but contains excessive dissolved phase and bound water.

A cross-section through the original coating in Figure 3 shows the two layers[1] of the coating. Visual inspection indicated that the coating is well adhered to the pipe surface with no visible corrosion or delamination.

[1] The top white-colored layer is a mounting resin that was applied to encase the coating to maintain its integrity during metallographic preparation.

Figure 1: Photograph showing as-received 20" diameter pipe sample used for full-scale repair testing.

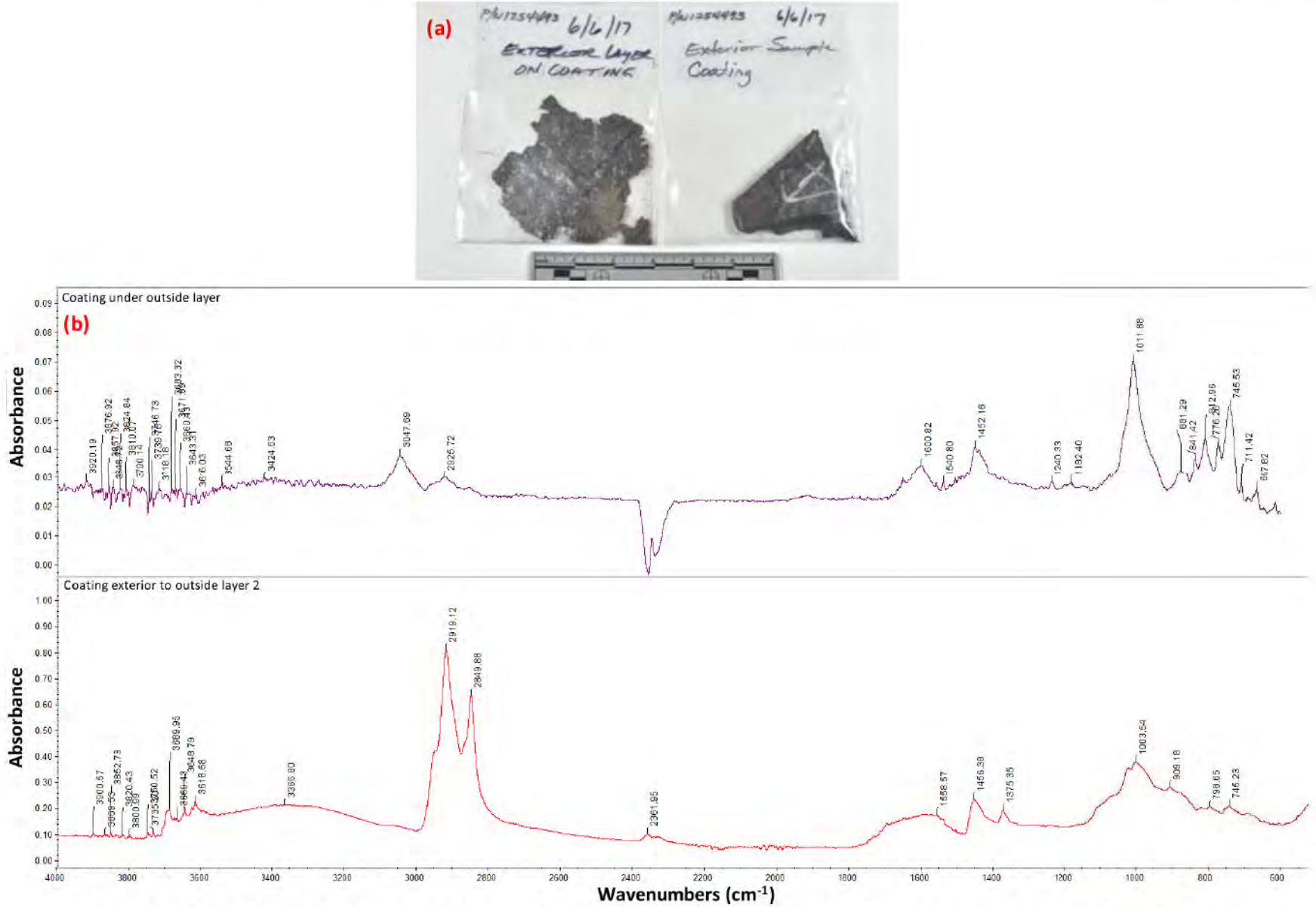


Figure 2: (a) Photograph of coating samples removed for FTIR analysis; (b) FTIR analysis results for original coating of 20" pipe sample.

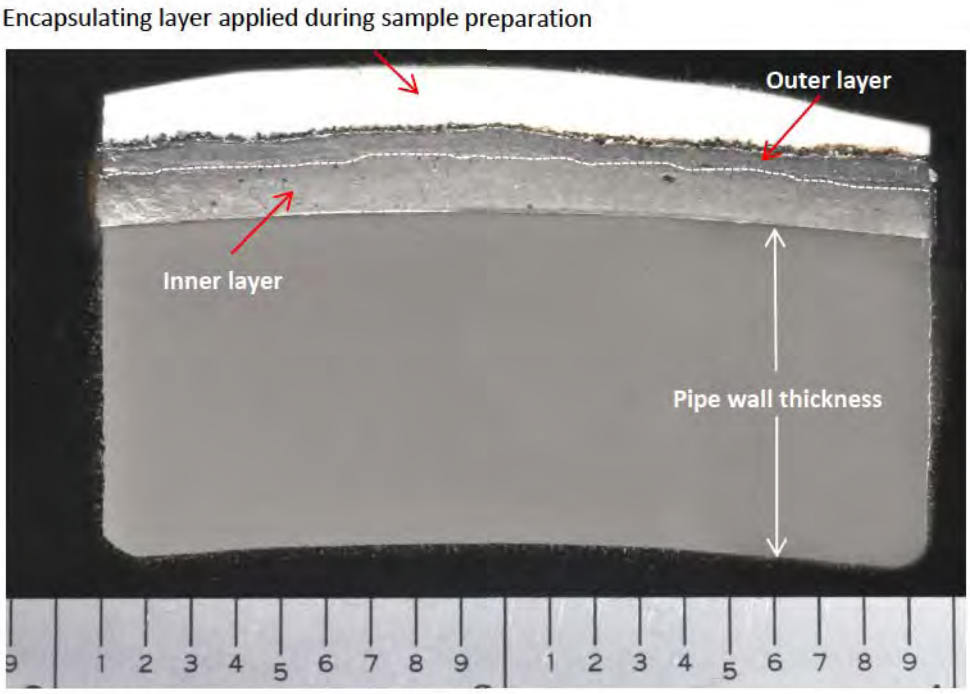


Figure 3: Metallographic cross-section through original coating. Dashed line indicates approximate boundary between inner and outer layers of coating. Numbered scale divisions are 0.1".

3. Laboratory Tests of Repair Coating System

Prior to conducting any repairs on the 20" diameter pipe section, SES performed small-scale tests on scrap pieces of carbon steel pipe. The outer surfaces of two 3-ft lengths of 6" diameter pipe were prepared to a NACE 2[2] finish.

The cure rate of an epoxy (and possibly its ability to cure) is largely a function of temperature. In general, the lower the temperature, the longer it will take for an epoxy to cure. An internet survey of Great Lakes water temperatures, including dive company websites, indicated that the temperature at the bottom of the Straits can be near 40°F, even in summer months. It is also known that 40°F is a standard test temperature for offshore oil & gas applications in the Gulf of Mexico. Thus, 40°F was selected as the coating application temperature for this test program.

Two modified chest freezers were filled with prepared water and chilled to 40°F using a combination of the freezer's compressor and dry ice (Figure 4). The water bath was maintained at 40°F throughout testing.

The repair coating system under evaluation (Figure 5) is a two-part epoxy system. First, the epoxy base (X100 – UW Epoxy Base – Blue) was mixed with curing agent (Bio-Seal X-100 Curing Agent – Clear) and applied to the surface of the pipe as a preparation layer (Figure 6(a)). The mixed epoxy was then saturated into a 12" wide, E-glass fabric that was wrapped around the pipe in at least four layers (Figure

[2] Near-white metal abrasive blast cleaning.

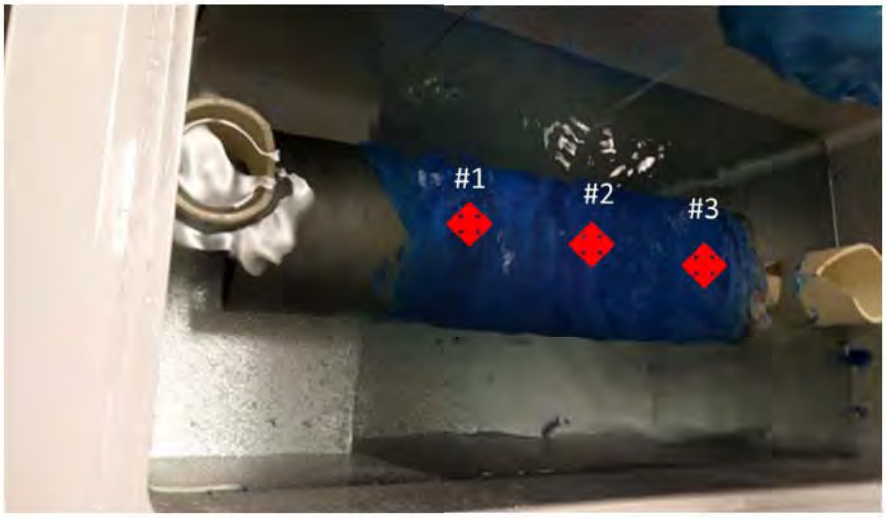
6(a)–(d)). Each layer is approximately 30 mils thick. The repair was held in place for curing using Stricture Banding™ (stricture), which is a thin film of transparent plastic that was wrapped around the repair and circumference of the pipe (Figure 6(e)). After curing, the stricture can be removed.

Full 360° wrap repairs were applied to the center of both sample pipes, and the repairs were allowed to cure for over one week. During the curing cycle, after an initial 72 hr waiting period, the pipe was briefly lifted from the water bath every 24 hr and the hardness of the repair was measured using a Shore D durometer. The location of the hardness tests and the cure curves for the test repairs are shown in Figure 7. Results indicated that coating hardness reached a plateau hardness after approximately 8 days. Hardness continued to increase slightly over the next few days, with a maximum reading of 85 Shore D after 9 days when the testing was suspended.

Figure 4: One of two laboratory test samples used for initial tests of repair material. A 6" pipe section is shown submerged in 40°F water prior to application of repair coating.

Figure 5: Two-part epoxy repair system provided by PRT Incorporated, Hempstead, Texas.

Figure 6: Photographs showing application of laboratory epoxy repair wrap: (a) epoxy applied to bare steel; (b) and (c) fabric impregnated with two-part epoxy; (d) fiber mesh repair wrapped around pipe in four layers; and (e) stricture banding applied over repair.



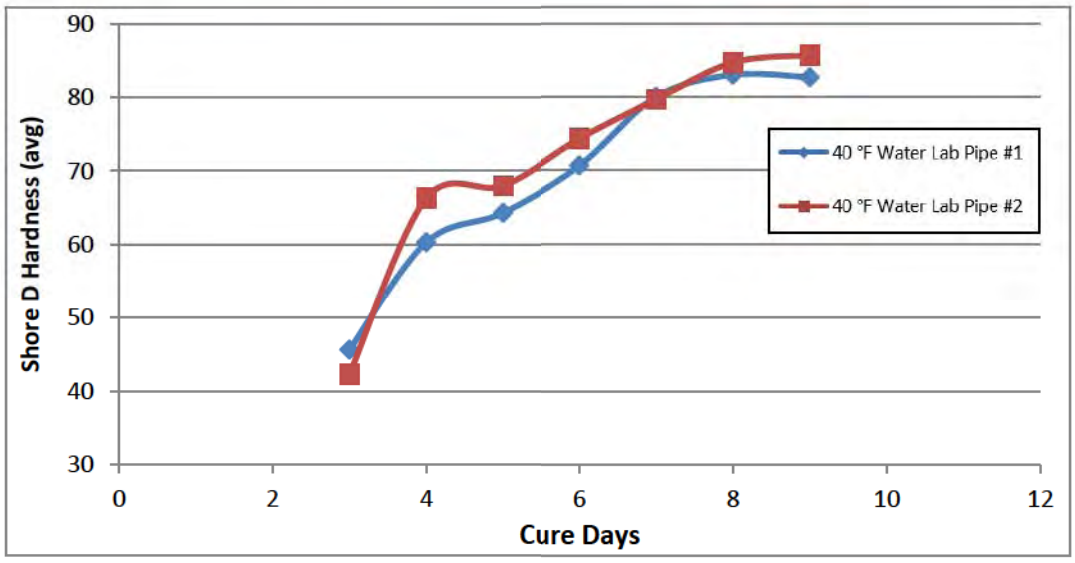


Figure 7: (a) Photograph showing locations of coating hardness measurements and (b) graph of coating hardness results during curing at 40°F.

4. Full-Scale Repairs of 20" Diameter Pipe

4.1 Sample Preparation

The 20" pipe sample provided for this test program is shown in Figure 8 prior to repair or water exposure. To prepare the sample for testing, plastic end plates were affixed to each open end of the pipe, sealed around the circumference using expanding foam insulation, and held in place by a metal dowel running the length of the pipe. The plates were intended to limit water flow through the pipe during testing in order to minimize contamination of the test water from internal surface corrosion and

debris already present in the sample pipe[3]. Prior to affixing the end plates, SES attached two thermocouples to the inside surface of the pipe to monitor metal temperature during the test (Figure 9(a)).

A 2,700 gallon, insulated tank (see Figure 8 background) was filled with water obtained by reverse osmosis. Chemicals were added to simulate the Straits' water composition. The water was pumped continuously through a 10 ton water chiller and circulation pump with a 50 micron sediment filter until a temperature of 40°F was obtained. The water temperature was monitored via two temperature probes submerged in the tank, in addition to the thermocouples attached to the pipe. The temperature at the four probes was continuously recorded throughout the test procedure (Figure 9(b)).

Five separate areas on the 20" diameter pipe were prepared for repair. The schematic in Figure 10 shows the locations and variables of the different repairs. This information is also summarized below and in Table 1. Compass directions refer to the relative orientation of the pipe sample in the laboratory during testing. Clock/circumferential positions are viewed from the west end of the sample, with top dead center at 0°.

- A 16" square section of the (original) outer coating was removed from each end of the pipe along the top surface using a hand grinder and wire wheel. In the center of these squares, a 2" x 4" section of the inner coating was also removed, exposing bare steel. These areas were labeled "A" and "C" and designated as patch repairs.
- A 16" wide area of the outer coating was removed around the circumference of the pipe near the center of the sample length to provide space to apply a full 360° repair.
    - A 4" x 4" area of the inner coating was removed at the top of the pipe from this 16" wide area, exposing bare steel. This location was designated as Area "B."
    - Two 4" x 4" patches of the inner coating were removed at the north (Area "D") and south (Area "E") sides of the sample aligned with Area "B."

Figure 11 shows these prepared areas of the pipe prior to repair.

[3] The interior of the pipe was allowed to fill with water, however, to avoid excessive buoyancy during the test.

Figure 8: Photographs showing 20" diameter pipe used for full-scale testing of epoxy repair material. Note insulated yellow water tank shown in background.

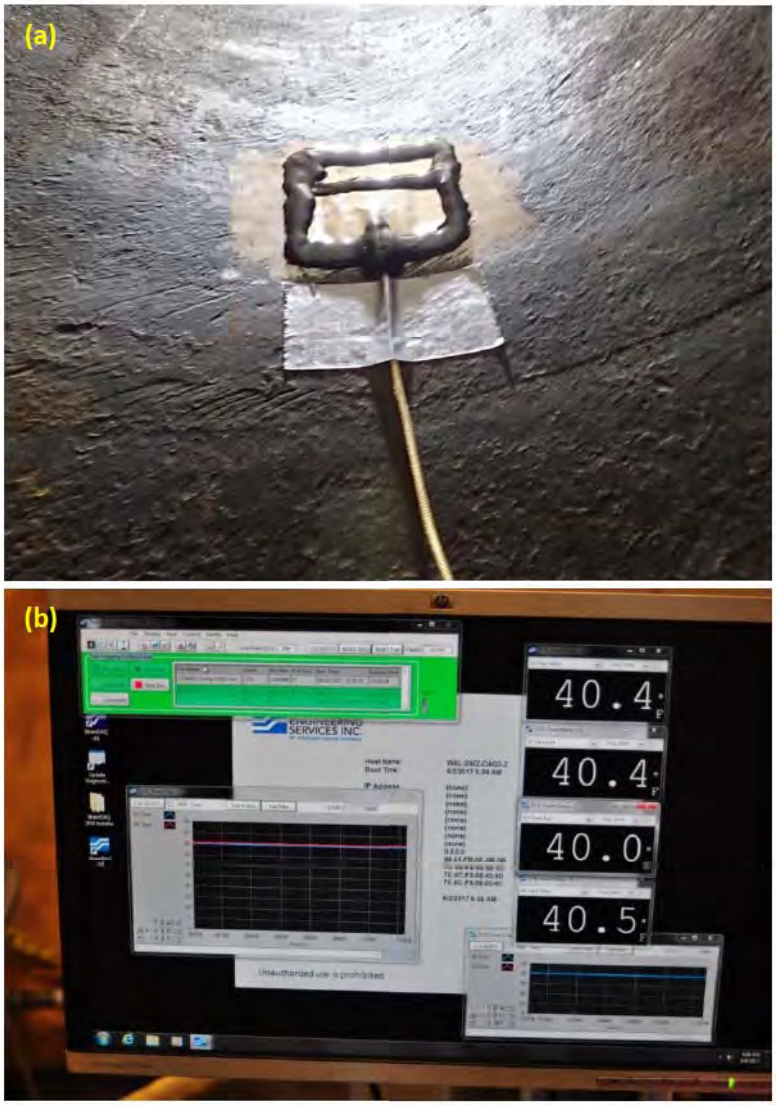


Figure 9: Photograph showing (a) thermocouple attached to inside surface of pipe and (b) temperature readout for water tank and pipe.

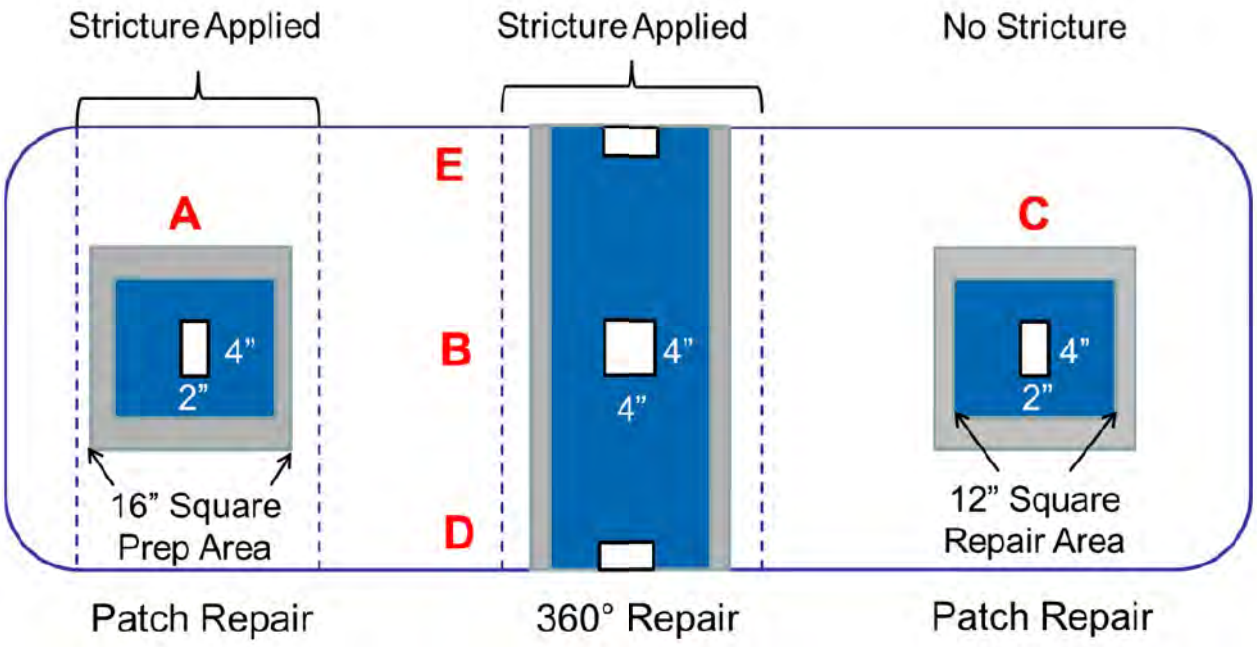


Figure 10: Schematic showing repair locations on 20" diameter full-scale pipe. Table 1 summarizes details of each repair location. (Note: Gray- and blue-shaded areas represent prepared and repaired areas, respectively. Plan view, not to scale.)

Table 1: Summary of Repairs Applied to 20" Pipe.

Repair Location	Axial Position	Circumferential Position	Patch/360°	Stricture?
A	West end	0°	Patch	Yes
B	Center	0°	360°	Yes
C	East end	0°	Patch	No
D	Center	90°	360°	Yes
E	Center	270°	360°	Yes

4.2 Patch Repairs

The pipe sample was submerged in the insulated tank and allowed to stabilize at temperature (Figure 11). Flash rust formed in the five exposed areas during the temperature equilibration; this was removed with a wire brush prior to repair.

The exposed steel at Areas "A" and "C" was covered with a high-density epoxy filler (BIO-DUR™ 563 SW) so that the repair area was flush with the adjacent coal-tar coating. Four layers of a 12" x 12" section of X-100 UW epoxy impregnated E-glass fiber wrap were then applied over these areas. In Area "A," stricture was then wrapped around the circumference of the pipe and over the repair. In Area "C," no stricture was applied. The patch repair application at Area "A" is shown in Figure 12.

Figure 11: Photograph showing 20" pipe in 40°F water prior to application of epoxy repairs. Repair areas are labeled per Table 1 and Figure 10. Flash rust on exposed areas was removed prior to repair.

Figure 12: Application of patch repair at Area "A." Photographs show (a) impregnation of 12" x 12" fabric with epoxy; (b) application of repair on pipe in water tank; (c) wrapping repair with stricture; and (d) completed repair.

4.3 Full Circumferential Repair

For the next full-scale repair test, the exposed steel at Areas "B," "D," and "E" was covered with the BIO-DUR™ 563 SW epoxy filler to the approximate thickness of the original inner coal-tar coating. Four layers of a full 360° wrap repair were then applied to the pipe, covering all three test areas. A layer of stricture plastic was applied over the full circumferential repair to hold it in place during the curing cycle. The circumferential repair process is shown in Figure 13. Temperature data measured during the repair are shown in Figure 14.

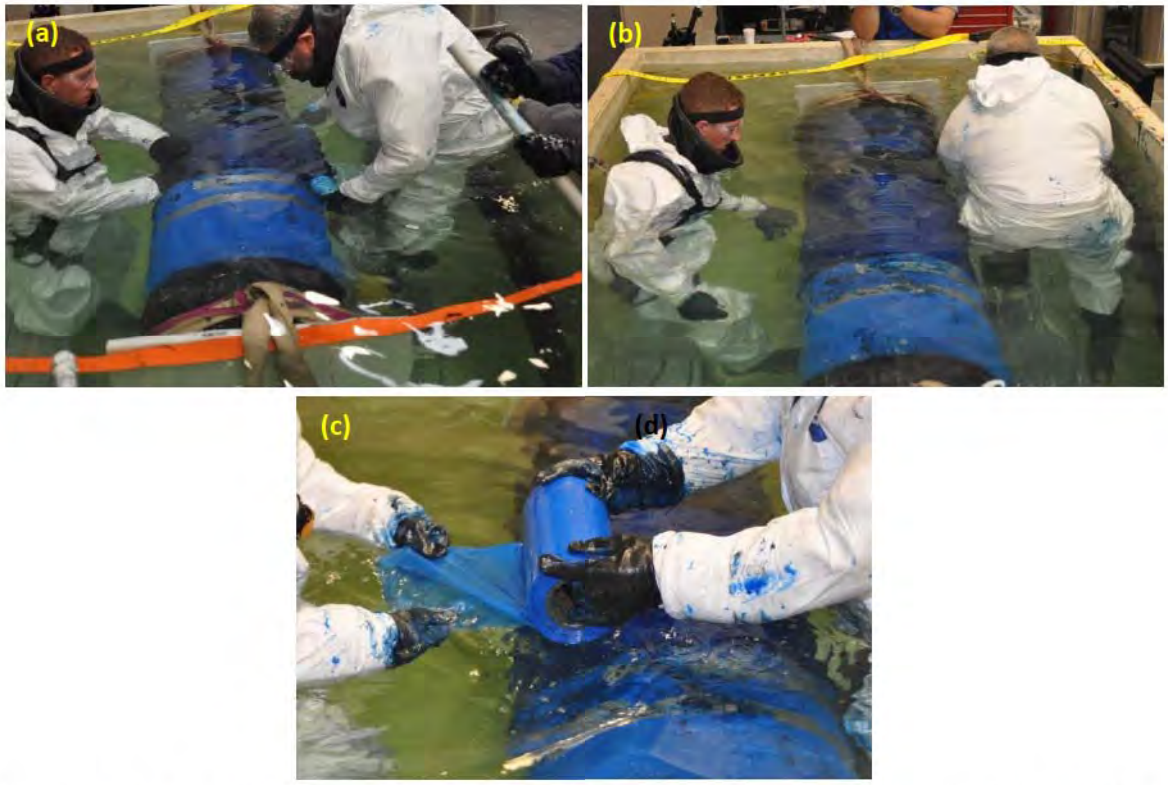


Figure 13: Application of full circumferential repair at Areas "B," "D," and "E." Photographs (a) and (b) show application of impregnated fabric around the circumference of pipe; (c) shows application of stricture.

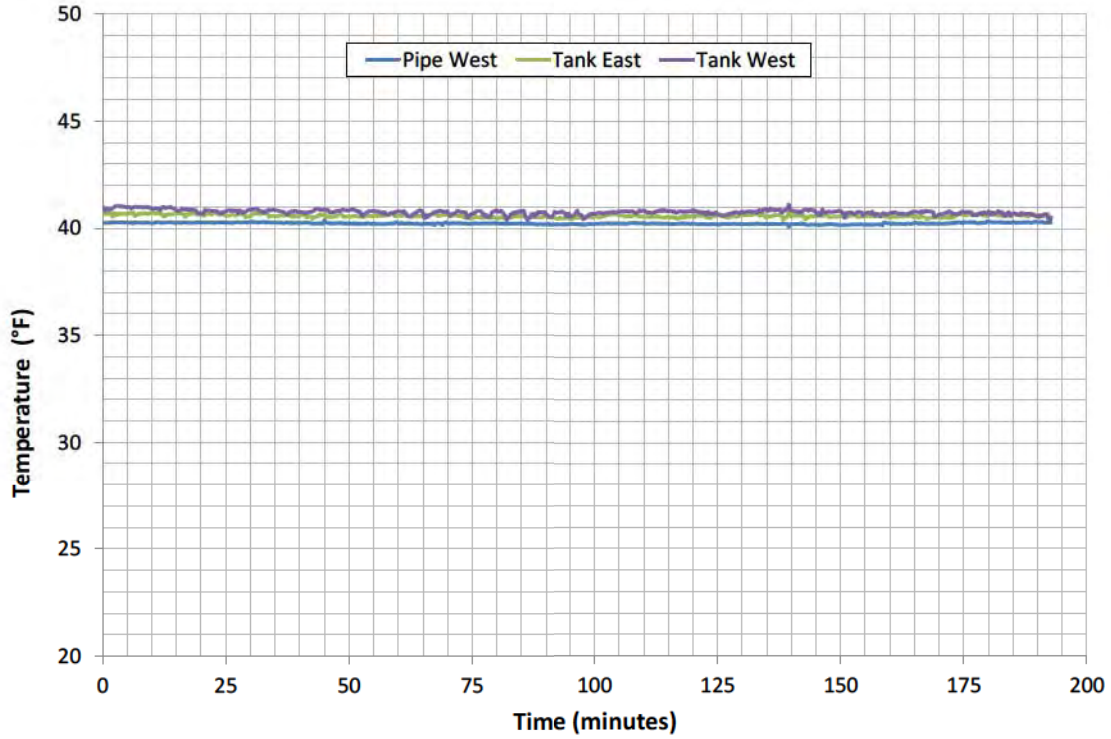


Figure 14: Graph of temperature data during application of full circumferential repair at Areas "B," "D," and "E" (see Figure 13). Water temperature remained near 40°F during installation of all repairs.

4.4 Curing Cycle

As with the laboratory repairs (see Section 3), the 20" diameter pipe was allowed to cure in the 40°F bath for 48 hours before initial durometer hardness testing. Figure 15 shows the water tank closed for testing and a plot of the temperature data, which remained steady at 40°F throughout the curing cycle.

Three durometer hardness readings were taken at each repair area located at the top of the pipe every 24 hours by temporarily lifting the pipe out of the water bath (Figure 16(a)). In Areas "A" and "B," the readings were made through the thin stricture banding. In Area "C," the durometer hardness was measured directly on the fiber wrap. The average hardness results are presented in Figure 16(b) and Table 2. The durometer hardness data from the laboratory test (Section 3) are included in the graph along with air curing data supplied by PRT Incorporated.

The durometer hardness data from the full-scale test plateaued in the mid-70s Shore D after approximately 5 to 6 days at temperature. No significant change in hardness was observed after 6 days, and the measurements were suspended after 8 days in the water bath. According to PRT Incorporated, a Shore D hardness of 70 is considered to reflect a full cure.

PRT Incorporated provided hardness data of repairs cured in air using both a standard and an accelerated resin. This data is included in Table 2 and Figure 15b. The accelerated resin reportedly cured more rapidly during the first few days; however, both samples were measuring in the mid-70s by day 7. The repair tests conducted at SES used only a standard resin. No accelerator was included in the epoxy.

Table 2: Average Durometer Shore D Hardness Results from Test Repairs.

Days After Repair	Lab 40°F Water		Full-Scale 40°F Water			Lab 40°F Air*	
	Pipe #1	Pipe #2	Area "A" Patch-Stricture	Area "B" Full Wrap	Area "C" Patch-No Stricture	Standard Resin	Accelerated Resin
2			43	41	53	47	55
3	46	42	54	58	60	50	69
4	60	66	66	67	66		
5	64	68	73	76	72		
6	71	74	73	75	76		
7	80	80	72	74	77	73	74
8	83	85	75	76	75	73	73
9	83	86				74	72
10						75	72
11						74	71
12						76	75

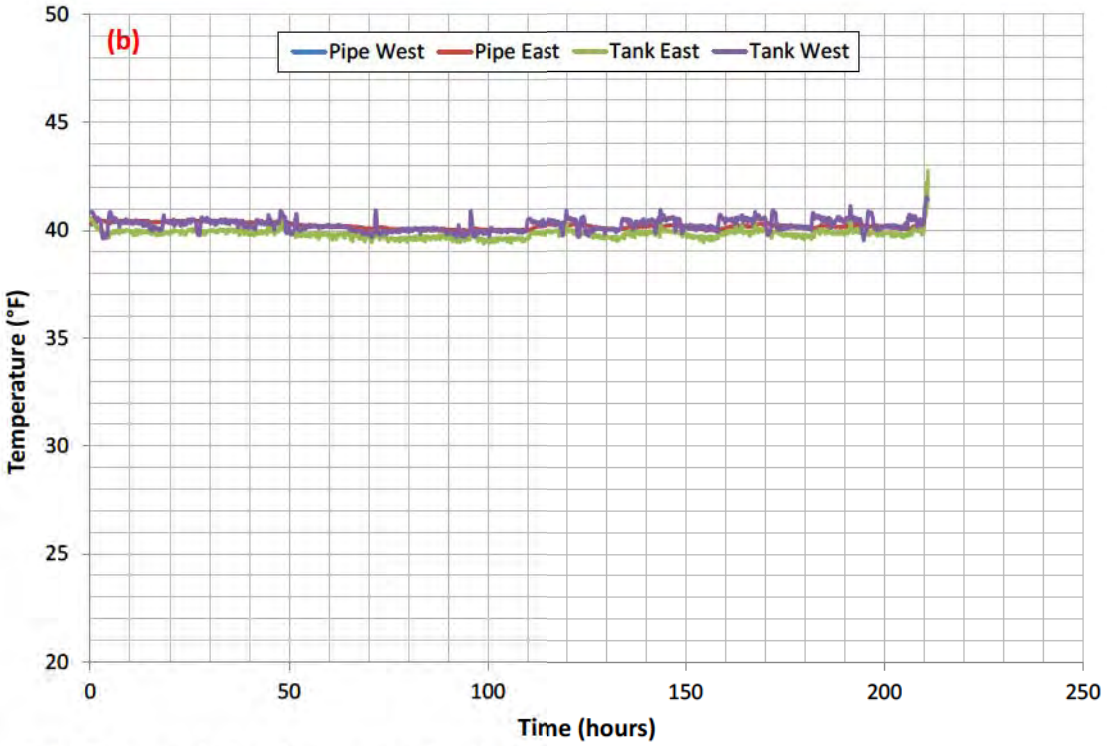
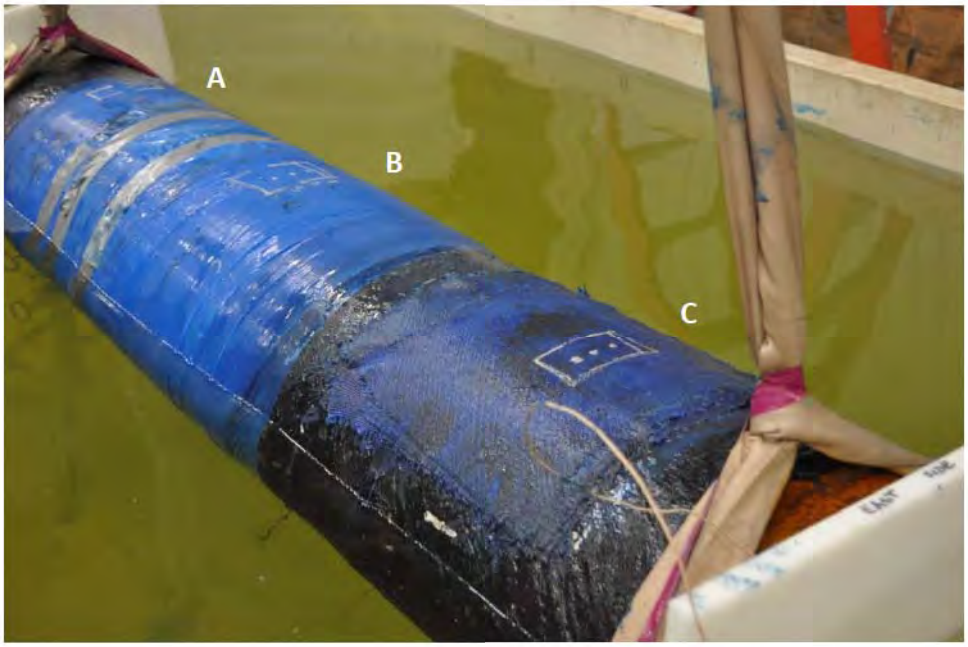


Figure 15: (a) Photograph showing water tank and (b) graph of water-bath temperature during curing period of full-scale repairs.



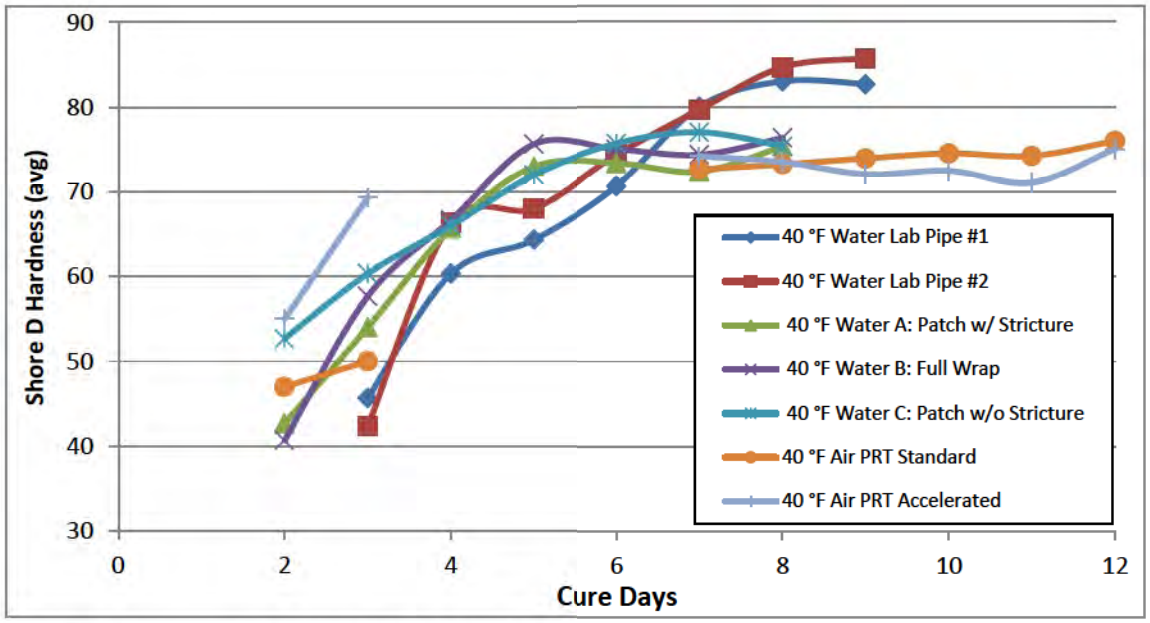


Figure 16: (a) Photograph showing 20" pipe lifted from water tank to allow durometer hardness testing. Areas "A," "B," and "C" were tested every 24 hours after an initial waiting period of 48 hours. (b) Graph of Shore D Hardness as a function of cure time.

5. Evaluation of Full-Scale Repairs

5.1 Overall Appearance

The 20" diameter pipe sample is shown in Figure 17 after it was removed from the water bath and allowed to drain. The locations of the repairs are noted in the photograph. Repair areas "A," "B," "D,"

and "E" are obscured by the stricture banding. Patch repair area "C" exhibits only the repair fiber wrap since no stricture was used in this area.

The full circumferential repair at the center of the pipe is shown in Figure 18(a) after the stricture was removed. The patch repair at Area "A" is shown in Figure 18(b). Both repairs appear to be well attached to the pipe, including along the perimeter of the repair patch and the edges of the circumferential wrap.

The patch repair at Area "C" is shown in Figure 19. While the majority of Area "C" appears well attached to the pipe sample, the edges of the fiber wrap layers were not completely bonded to the pipe, creating a crevice along the perimeter of the patch.

Figure 17: (a) Photograph of 20" pipe sample after removal from water bath; (b) photograph showing stricture still applied to Areas "A" and "B/D/E." Area "C" (patch repair with no stricture) is on right end. Numbered scale divisions are 0.1 feet.

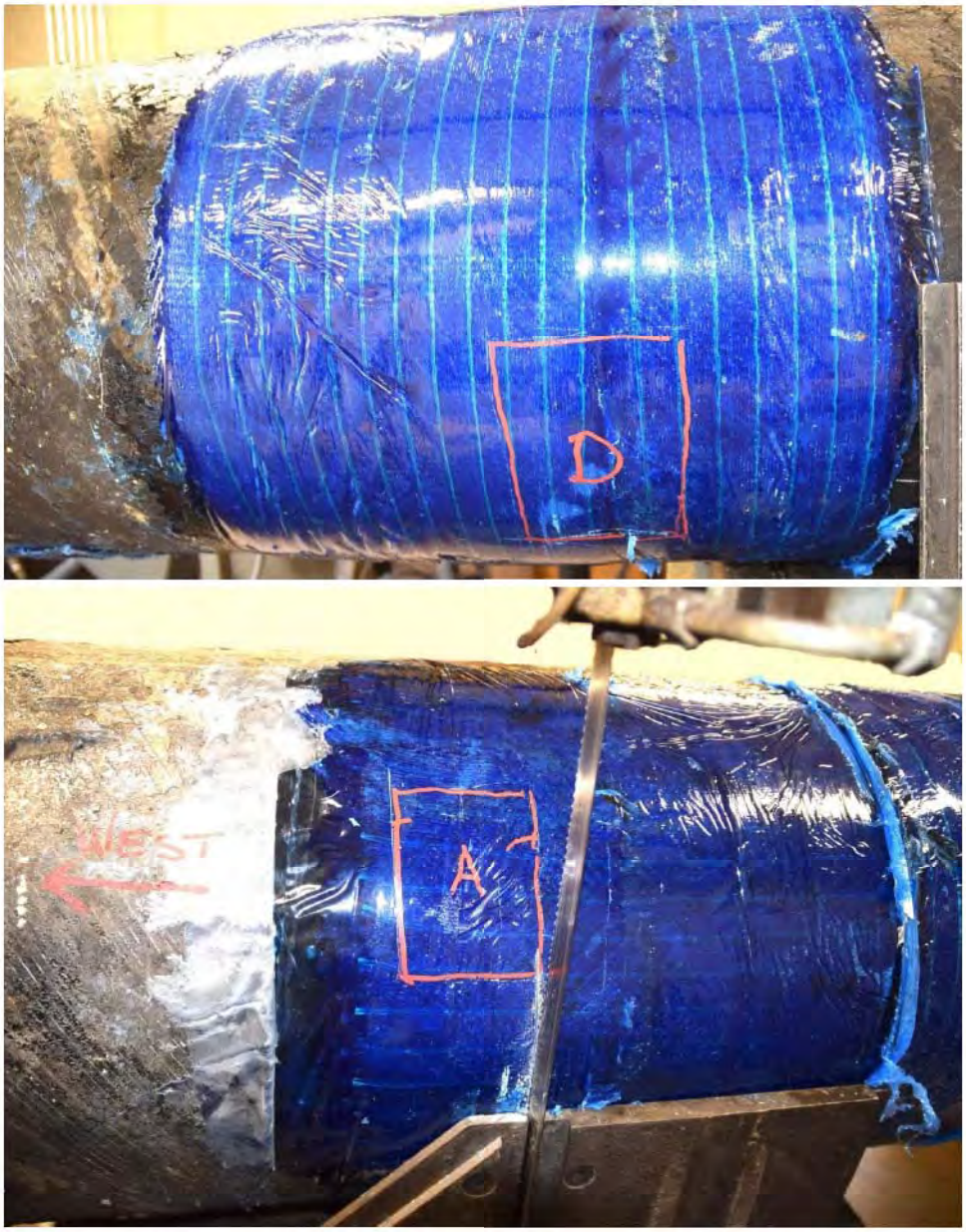


Figure 18: Full circumferential repair (Areas "B/D/E") is shown in upper photograph after stricture was removed. Patch repair Area "A" is shown in lower photograph after stricture was removed.

Figure 19: Photographs showing patch repair at Area "C" where no stricture was applied.

5.2 Cross-Sections of Full-Scale Repairs

SES removed transverse sections through each of the repair areas to document the overall configuration of the repair. Additionally, smaller sections were removed from these cross-sections, mounted, and prepared using standard metallographic techniques. In order to maintain the integrity of the coatings during sample preparation, a large diameter diamond wafer saw was used to cut through the pipe wall thickness, original coating, and repair materials. It was found to not be necessary to encapsulate the samples prior to metallography; the coating layers remained intact using normal mounting and preparation techniques.

5.2.1 *Patch Repair Area "A"*

A cross-section through Area "A" is shown in Figure 20. As mentioned, a stricture wrap was used in this area. The resulting repair appeared to be well bonded to the pipe, including at the outer edges of the wrap. Metallographic cross-sections through the repair (Figure 21(a)) and over the original coal-tar inner coating at the perimeter of the 4" x 4" bare steel area (Figure 21(b)) showed a uniform repair thickness and good adhesion to the pipe wall surface and the original coating. There was no discernable difference in appearance between the repair epoxy filler and original coating.

Figure 20: Photographs of rough cut cross-section through repair Area "A" (a patch repair with stricture banding).

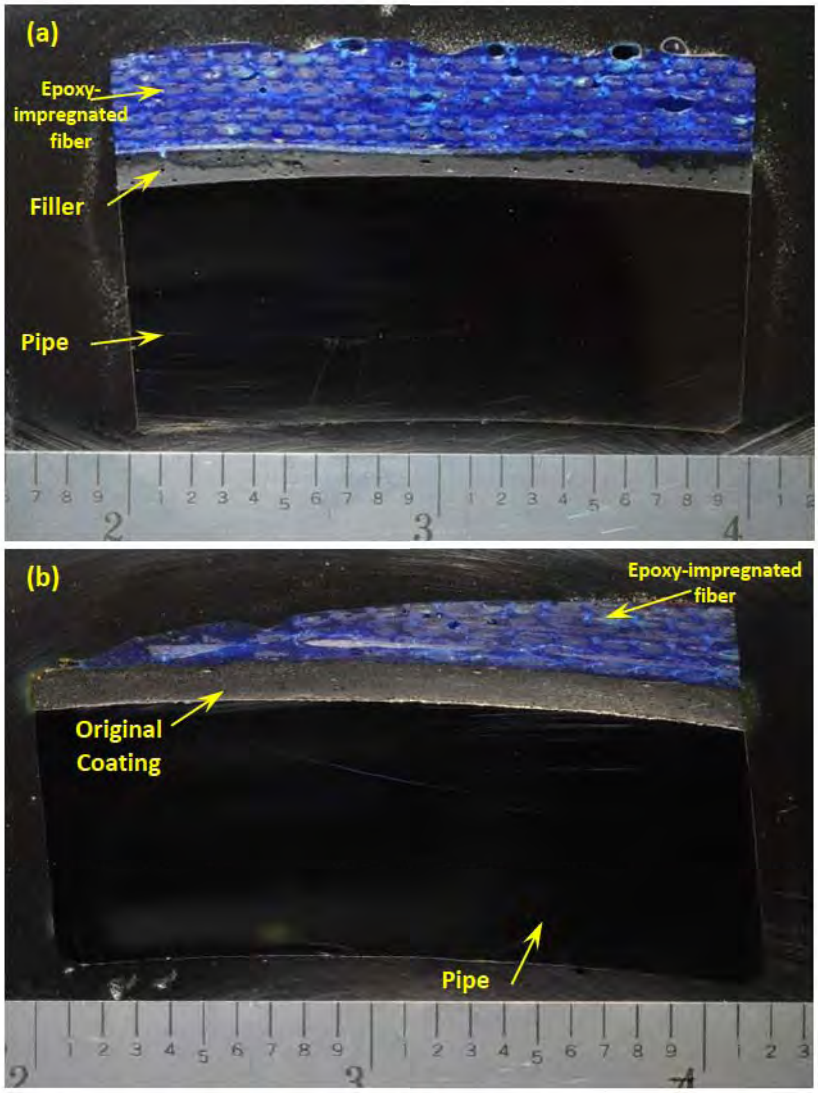


Figure 21: Metallographic cross-sections through repair Area "A." Section in upper photograph was removed through center of repair where original coating was completely removed down to bare metal. Lower photograph shows edge of repair where fiber wrap covers original coating.

5.2.2 Circumferential Repair Areas "B," "D," and "E"

A cross-section through the three areas repaired with a full 360° wrap is shown in Figure 22. Closer views of each area are shown in Figure 23 to Figure 25. As with the patch repair in Area A, the full repairs appeared to be well bonded to the pipe, including at the outer edges of the wrap. Metallographic cross-sections through each area are shown in the lower photographs in Figure 23 to Figure 25, respectively. Again, the repairs were found to be relatively uniform and appeared to have good adhesion to the pipe wall, though areas of porosity were evident in the cross sections. The porosity is not extensive and does not appear to compromise the integrity of the repair.

Figure 22: Photograph of cross-sectional ring cut from center of 20" pipe sample containing repair Areas "B/D/E."

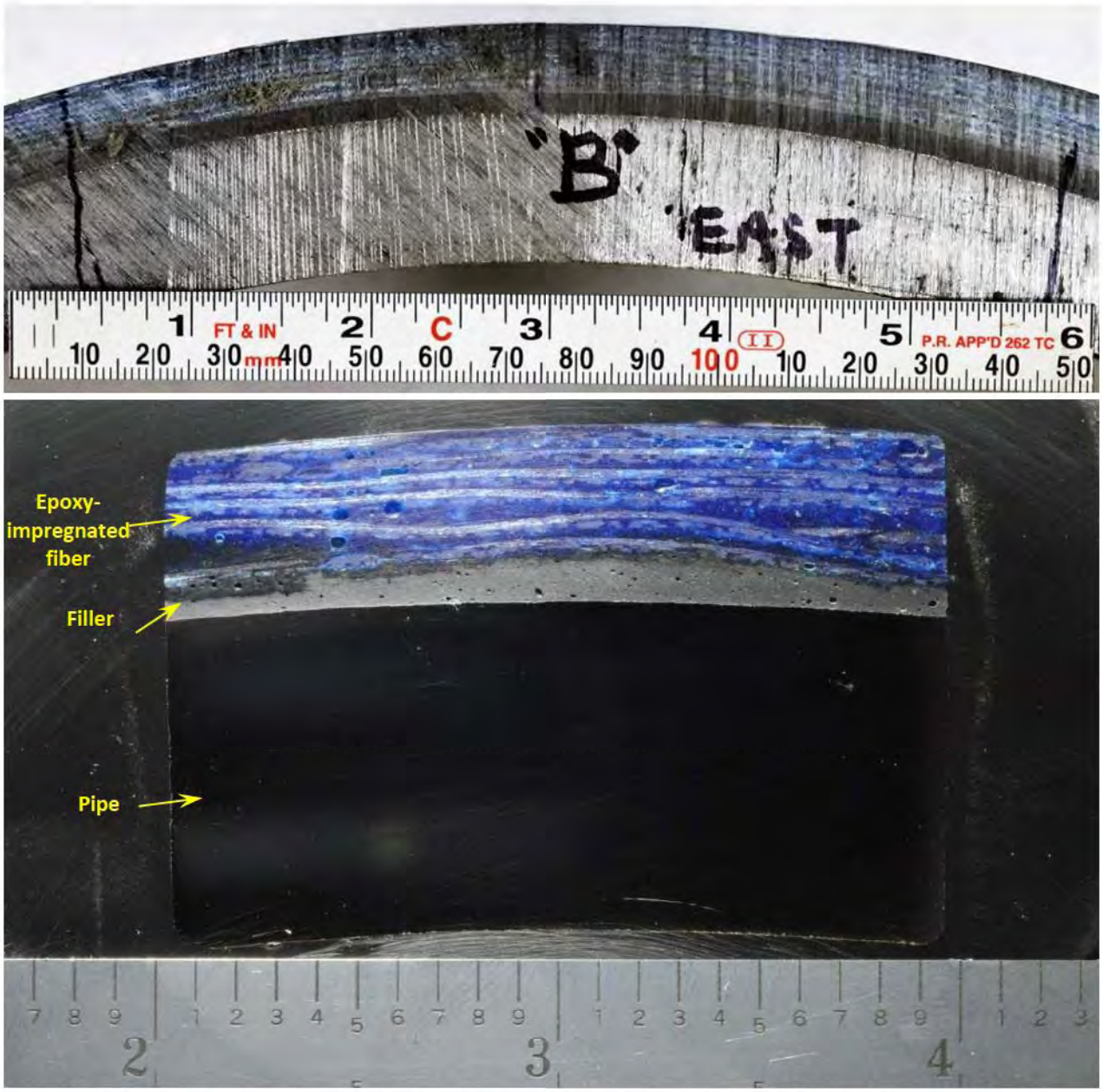


Figure 23: Metallographic cross-section of repair Area "B" located at top of pipe. A full 360° wrap and stricture was used in this repair.

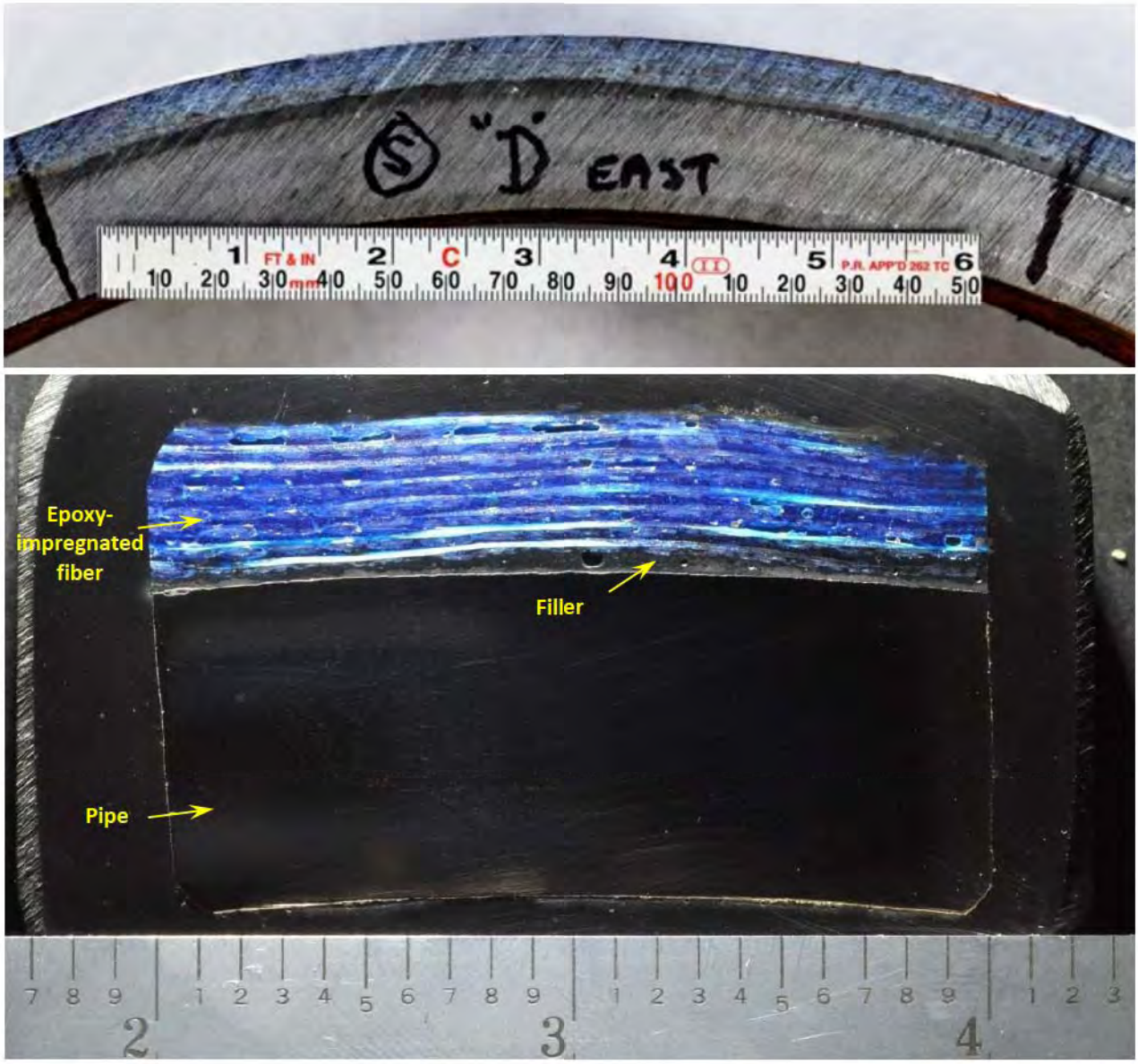


Figure 24: Metallographic cross-section of repair Area "D" located on south side (90°) of pipe. A full 360° wrap and stricture was used in this repair.

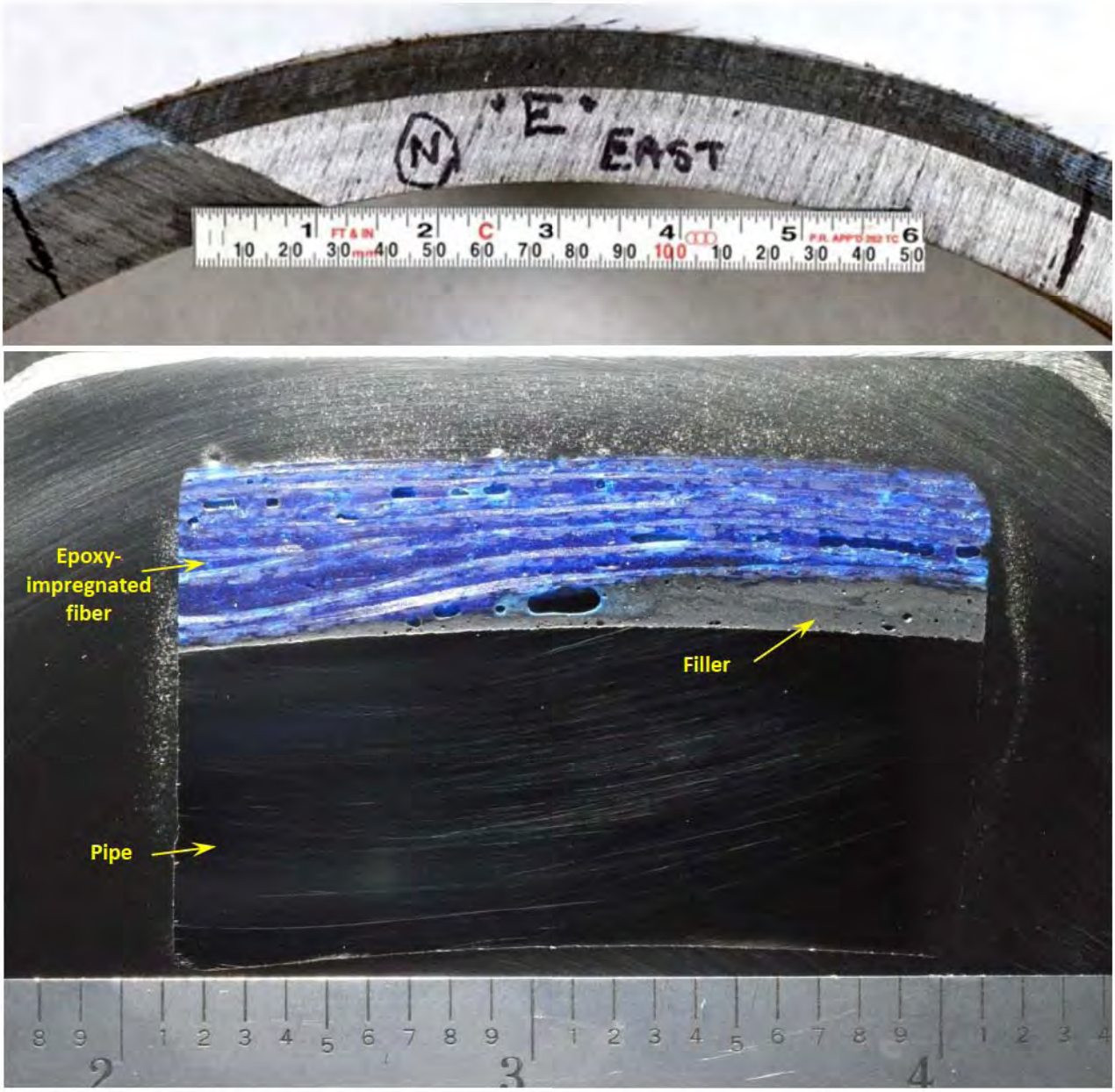


Figure 25: Metallographic cross-section of repair Area "E" located on north side (270°) of pipe. A full 360° wrap and stricture was used in this repair. (Reduction in thickness of filler material at left side of section is due to this section's being taken near edge of repair.)

5.2.3 Patch Repair Area "C"

A cross-section taken through Area "C" is shown in Figure 26 along with closer views at the perimeter of the repair. A stricture wrap was not applied to this repair site. The center of the repair (where the repair was applied over bare steel) was relatively uniform and appeared to have good adhesion to the pipe wall. At the perimeter of repair, however, the wrap layers were found to be cured, but not adhered to the pipe wall. An approximately 1" length of the wrap was not bonded to the surface, which created a small crevice around the perimeter.

A metallographic cross-section was taken through the center of Area "C" (Figure 27); this section was similar to the other repaired areas, exhibiting a relatively uniform thickness, some minor porosity, and good adhesion.

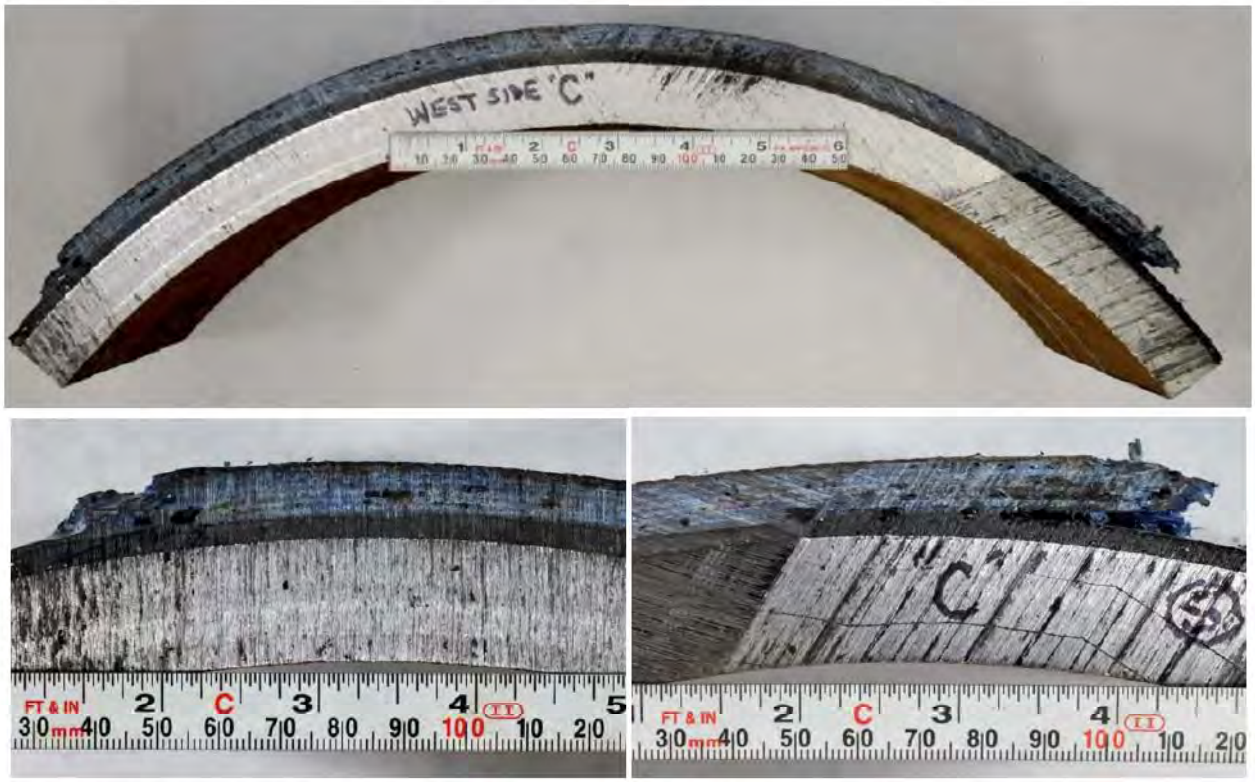


Figure 26: Rough cut cross-section through repair Area "C," a patch repair where no stricture banding was used. While center of repair was well adhered to pipe wall, perimeter of patch was disbonded from pipe.

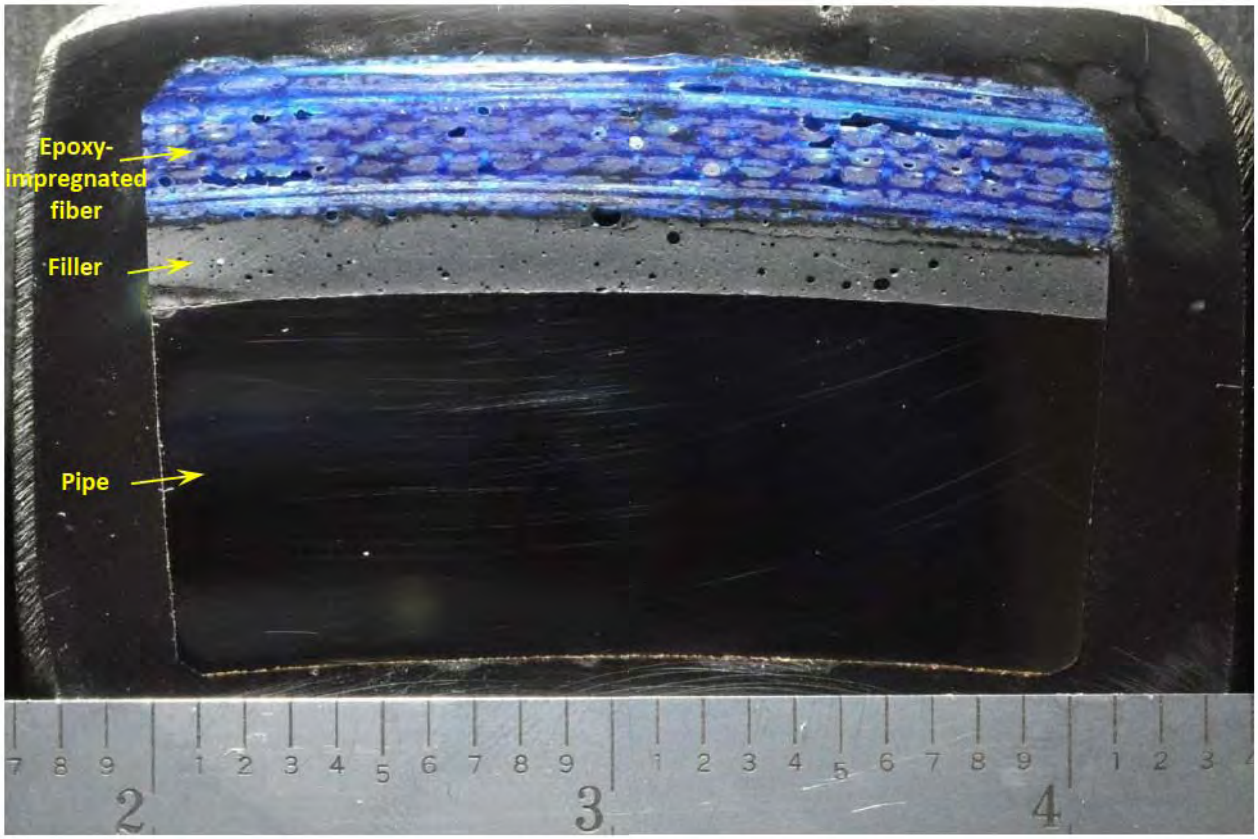


Figure 27: Metallographic cross-section through repair Area "C," a patch repair where no stricture banding was used.

6. ASTM D4541 Coating Adhesion Tests

Following the laboratory and full-scale repair tests, coating adhesion testing per ASTM D4541, "Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers," was conducted in both the original and repaired areas of the coating to determine their relative adhesion after full curing. The results of these tests are summarized in Table 3. Because minimal repair area was available for testing after the cross-sections were removed from the pipe, only three tests could be conducted at each repair location. Additionally, no minimum specified adhesion strength was provided for comparison for the repair material or original coating.

The data show that the fiber-wrap repairs were, in general, more highly adhered than the original coal-tar coating on the sample pipe and that the full 360° repair areas exhibited a higher adhesion than the patch repairs. However, it should be noted that the 20" sample pipe was not exposed to the same operational environment as Pipeline #5. This fact, along with the limited number of data points that could be obtained at each repair location, indicates that these results should be used for general comparison only.

Table 3: Results of ASTM D4541 Coating Pull-Off Strength Tests.

Sample Location	Readings (psi)	Average (psi)
A – Patch repair, stricture	--/61*/553	307
B – Full repair, stricture	395/573/--	484
C – Patch repair, no stricture	195/394/323	304
D – Full repair, stricture	25*/599/1,044	556
E – Full repair, stricture	816/772/629	739
Original, inner & outer layer	--/208/--	208
Original, inner layer only	339/290/271	300

-- No valid result
* Sample broke or cracked

7. Conclusions

Based on the analyses completed during this project, SES concludes the following:

- The original inner coating on the 20" pipe provided for testing was a coal-tar based coating.
- The X-100 UW epoxy fiber repairs applied to both laboratory and full-scale pipe samples bonded well to bare steel and the original coal tar coating. The repairs were able to cure in 5 to 8 days in 40°F water.
- While all repair areas exhibited good adhesion at the center of the repairs, those wrapped with stricture plastic during the cure cycle exhibited good adhesion throughout the width of the repair fabric. The patch repair that cured without a stricture wrap in place was not completely bonded around the perimeter of the patch. The crevice created at the edges of the patch indicates that the repair could be compromised by erosion and/or corrosion during service.
- The results of SES's testing program indicate that X-100 UW is an effective repair system for Pipeline #5. Patches, when secured during the curing cycle; as well as full circumferential wraps; are suitable repair options.

8. Sample Disposition

If metal or other types of samples were obtained by SES to complete services in this matter, these samples will be discarded in 60 days. If the Client wishes that the sample remnants be returned, the SES project manager should be contacted as soon as possible. Otherwise, samples will be disposed of at SES's discretion. Depending on space availability, samples can be stored at a designated SES facility beyond the 60 day period. Storage rates will be quoted on an individual basis.

Appendix C:
Product Data Sheets

BIO-DUR® 563 SW

REINFORCED EPOXY COATING FOR APPLICATION ABOVE OR BELOW WATER

PRT Piping Repair Technologies

PRODUCT DATA SHEET

BIO-DUR® 563 SW is based on a unique blend of liquid epoxy polymer and aliphatic polyamine curing agents, which is able to displace water from wet surfaces in order to make a permanent bond. The formulation is solvent free to ensure safety and maximum technical performance. Kevlar™* fibers are incorporated for reinforcement and viscosity management to achieve high application rates even underwater.

BIO-DUR® 563 SW provides permanent protection under the most adverse conditions. The formula is uniquely field-friendly and uses advanced low toxicity ingredients in a high build brushable/rollable product. One of the active CP compatible products of the BIO-DUR® line where a shorter curing time is required. All colors including white are available and can be shipped "Non-Regulated" by USDOT, IATA and IMO.

**Kevlar is a trademark of E. I. Dupont de Nemours Co.*

RECOMMENDED USES

ANTICORROSIVE COATING: Splash zone, excellent abrasion resistance above or below water.
REPAIR COMPOUND: Patching, leak sealing etc. above and below water.
FIELD JOINT COMPOUND: Rapid curing, surface tolerant and excellent cathodic disbondment properties.
ENCAPSULATING COATING: Smooth, dense, easily decontaminated coating for steel and concrete.
WASTEWATER: Reinforces, smooths and protects concrete exposed to chemical or municipal waste.
CATHODIC PROTECTION: Suitable for application on lines protected by active CP.

TECHNICAL INFORMATION

VEHICLE TYPE	Epoxy/Aliphatic amines
PIGMENTATION	Color/Inert/fibrous reinforcement
COLORS	Standard White, Black, Gray; other available
FINISH	Slight texture
THINNER	Not normally required
CLEANER	MEK or acetone
MIXING RATIO	1.0/1.0 v/v
INDUCTION TIME	Not required
POT LIFE	Approx. 20 min./ 77°F
FLASH POINT	Over 200°F
SOLIDS BY VOLUME	100%
SPREADING RATE/GAL	1604 mil/sq.ft./gal; 53.5 sq.ft./gal @ 30 mils
DRY TIME, (Dust free)	2 hours at 77°F
DRY TIME, (Service)	3 hours light, 24 hours heavy service at 77°F
APPLICATION METHOD	Brush, roller, heated plural airless spray
STORAGE CONDITIONS	Normal, freezing ok
VOC.	Essentially zero
DENSITY	Base 9.6 lb/gal; Cure 13.0 lb/gal, Mix 11.3 lb/gal

APPLICATION NOTES

SURFACE PREPARATION: Remove marine biological settlement and corrosion by >5,000 psi water jetting with or without abrasive. Conventional air/abrasive blasting works well at shallow depths however efficiency falls off sharply below 10 feet. Hand held power tools such as needle guns or grinders can give good results if applied conscientiously in small areas but will be inadequate in large areas. Plan to apply the BIO-DUR®563 SW within 45 minutes maximum after surface preparation to minimize rerusting or initial settlement of fouling slime, which interferes with initial adhesion.

Application above water requires similar high-pressure water blasting or dry abrasive blasting to yield a firm, granular surface free of loose contamination.

MIXING PROCEDURE: BIO-DUR® 563 SW is supplied in 2 gallon kits of 2 x 1 gallon containers each of epoxy base and curing agent. These components are formulated in contrasting colors to facilitate complete mixing. Visible streaks of either component seen during the course of mixing indicate "hotspots" of unmixed components. It is imperative to properly mix the components since unmixed "hotspots" of either base or curing agent will never cure.

Remove equal quantities of base and curing agent from their cans and place them in a clean plastic or steel container. Mixing is accomplished by stirring with a "Jiffy" type mixer in a geared down, (high torque), 1/2" electric drill. Once mixing begins, there will be about 20 minutes of working time available at 77°F. This time may be extended by keeping the components and mixture cool, rather than leaving it in a hot area.

APPLICATION:

1) Using a stiff brush or roller apply mixed components from a tray aiming for a coverage rate of about 50 sq.ft. per gallon.
2) Apply by heated plural component airless spray using the following equipment setup:

Spray Unit:	Graco "King" or similar with heated hoses.
Mix ratio:	1/1 by volume
Fluid pressure:	2,500 psi
Fluid temp:	140°F
Filters:	Remove all filters
Tip size:	.031" -.039" orifice

CURING BEFORE SERVICE: BIO-DUR® 563 SW may be immersed in fresh or salt water immediately after application. It will cure to a hard film within about 3 hours and is suitable for traffic after this time. Allow at least 24 hours at 77°F before subjecting to aggressive chemical service from industrial solvents and similar materials.

TYPICAL PHYSICAL PROPERTIES OF THE CURED FILM:

Compressive strength:	7,380 psi (50.9 N/mm2)
Tensile strength:	6,000 psi (est.)
Flexural strength:	4,550 psi (31.4 M/mm2)
Abrasion resistance:	34.0 mg/1,000 cycles (CS17 wheels with 1,000 gram weights)
Tensile adhesion:	>2,000 psi (“Near White” SA2.5 abrasive blasted dry steel)
Tensile adhesion:	>1,000 psi (>5,000 psi water jetted steel applied/cured underwater)
Tensile adhesion:	>1,000 psi (power tool cleaned then >2,500 psi water jetted dry steel)

Piping Repair Technologies
HEMPSTEAD, TEXAS USA
979-826-0075
mail to: info@pipingrepairtechnologies.com
www.pipingrepairtechnologies.com

Piping Repair Technologies

X-100 UW Field Applied Composite Reinforcement for Dry Surface, Wet Surface or Underwater Piping Repair

- Corrosion Remediation
- Structural Reinforcement
- Leak Containment
- Abrasion Protection

An ISO 9001:2008 Certified Manufacturer

X-100 UW RESIN SYSTEM:

The X-100 UW resin is based on pure liquid epoxy polymers and proprietary polyamine curing agents. The X-100 UW resin system is designed for use on wet surfaces or underwater applications. It is a two-component, ambient temperature epoxy matrix, and is suitable for use with a variety of reinforcement fabrics. The X-100 UW resin wets out easily and is relatively fast setting, approximately 30 minutes at 77°F (25°C). No VOC and is a 100% solids epoxy resin.

SURFACE PREPARATION:

Remove marine biological settlement and corrosion by >5,000 psi water jetting with or without abrasive. Conventional air/abrasive blasting works well at shallow depths however efficiency falls off sharply below 10 feet. Hand held power tools such as needle guns or grinders can give good results if applied conscientiously in small areas but will be inadequate in large areas. Plan to apply the X-100 UW within 45 minutes maximum after surface preparation to minimize re-rusting or initial settlement of fouling slime, which interferes with initial adhesion.

Application above water requires similar high-pressure water blasting or dry abrasive blasting to yield a firm, granular surface free of loose contamination.

MIXING PROCEDURE:

X-100 UW is supplied in size specific, factory pre-measured kits with corresponding reinforcement fabric lengths depending upon application. Kits are comprised of a Part A epoxy base in a partially filled container and a Part B curing agent to be poured into Part A container to assure proper mix ratio. After pouring the curing agent into the base, mix thoroughly for approximately 2 minutes taking care to stir in all base material from the edges and base of the container; *unmixed material will never properly cure.* No induction or "sweat-in" time is required and the mixed material may be used immediately. Pot life and reaction time is heavily dependent on temperature, as a general guide figure that each 18°F, (10°C), variation in temperature above or below 77°F, (25°C), will respectively halve or double the pot life and cure times.

APPLICATION:

When saturating the reinforcement fabric, a roller or flexible spreader should be used to evenly distribute the X-100 UW material throughout the fabric. The material will thicken in cold weather and will be noticeably thicker at temperatures of 50°F and below.

CURING BEFORE SERVICE at 77°F (25°C):

Dry time, dust free, 8 hours; light service, 12 hours; heavy service. Low temperature curing at approximately 40°F (5°C) will require approximately 7 days. Post cured Shore D scale hardness 70+.

- **CAN BE APPLIED AT FULL PRESSURE**
- **FACTORY PRE-MEASURED FOR FAST INSTALLATON**
- **EGLASS AND CARBON FIBER FABRICS AVAILABLE**
- **CAN BE USED ON STRAIGHT RUN PIPING, ELBOWS, TEES AND FLAT SURFACES**
- **ISO 9001:2008 CERTIFIED MANUFACTURER**

Industries Served

- Refining
- Power Generation
- Chemical Plants
- Mining
- Industrial
- Pulp and Paper
- Liquid and Gas Transportation
- Production Facilities
- Water and Wastewater Treatment

AVAILABLE PRT PRODUCT SUPPORT SERVICES

- Project assessment
- Engineering consultation
- Repair design, calculation and documentation
- Project supervision, domestic and international
- Supporting installation supplies

#

#

TECHNICAL SUPPORT ASSISTANCE CONTACT:

Jesse R. Sanders or Chris Sanders
Piping Repair Technologies, Inc.
Office: 979-826-0075
Jesse cell: 713-906-8650
Chris cell: 281-840-1260

Piping Repair Technologies, Inc.
40164 FM 2979 Hempstead, Texas, USA
979-826-0075 office 979-826-9498 fax
Email: info@pipingrepairtechnologies.com
www.pipingrepairtechnologies.com

ENBRIDGE

Appendix D:
Letter from Manufacturer

Piping Repair Technologies

06 September, 2017

Re: PHMSA Regulations, 49 CFR 195.559
BIO-DUR 563SW and X-100UW Epoxy Coatings

To whom it may concern,

Further to the request for information regarding our coatings compliance with the requirements of subject regulations we are pleased to respond that individually and/or the combination of BIO-DUR 563SW and X-100 UW resins may be described as follows:

a) Individually or in combination they are designed to mitigate corrosion on buried or submerged pipelines.
b) Individually or in combination has sufficient adhesion to the metal or coated substrate to exclude and resist under film moisture.
c) Individually or in combination, the products are sufficiently flexible to resist cracking.
d) Individually or in combination the products have sufficient strength to resist damage due to handling, moderate impact and soil stress.
e) Individually and in combination the products will support any supplemental protective cathodic protection system when used properly.

The family of underwater capable epoxy coating materials being employed on this project have been in use since 1989. Variations have been created to suit specific requirements over the years, but all are 100% solids epoxies with proprietary additives to displace water from the surface. This enables these coatings to obtain high levels of adhesion to bond with the substrate. Many underwater installations have been performed all over the world by us, by our customers and by third party, end users; below is a brief summary:

- Power station pier rehabilitation, Mexico, 1998
- Nuclear installation by ROV, WA, USA, 1999
- Underwater tank installation, Australia, 2001
- Structural steel rehabilitation, U.K., 2002
- Municipal repairs, FL, USA, 2004
- Hydro Dam repairs, Wales, 2005, 2007
- Nuclear storage pool sealing, USA, 2005
- Offshore platform structural recoating, China, 2008
- Nuclear submarine repair, USA, 2008
- Reservoir penstock repairs, USA, 2009
- Municipal rehabilitation, USA, 2010
- Offshore platform riser, UAE, 2011
- Subsea pipeline reinforcement, UAE, ongoing 2014-current

Please do not hesitate to contact us if we may supply any additional information to support the statements above.

With thanks for your interest in our products,

Sincerely,

Jesse R. Sanders
President and Technical Director
Piping Repair Technologies, Inc.

40164 FM 2979 Hempstead, Texas 77445 / office (979) 826-0075 / Cell (713 906-8650

Email: jsanders@pipingrepairtechnologies.com

Website: www.pipingrepairtechnologies.com

ENBRIDGE

Appendix E:
Application of Underwater Repair Coatings for Line 5 Straits

APPLICATION OF UNDERWATER REPAIR COATINGS FOR LINE 5 STRAITS

Version #: 2.0

Version Date: 09/08/2017

This page intentionally left blank

Table of Contents

1.0 Scope

This procedure defines the requirements for application of repair coatings to pipe previously coated with coal tar enamel (parent coating) that are located underwater (e.g., lake bottom, straits crossing). Coating repairs consist of two approved methods that include:

- Method 1 – Epoxy Filler/ X-100 Epoxy/Full Circumferential Composite Wrap Repair/Stricture Banding®
- Method 2 – Epoxy Filler/ X-100 epoxy/Composite Patch Repair/Stricture Banding®

2.0 General

2.1 Manufacturer Support

This procedure was developed with support of the product Manufacturer (Piping Repair Technologies Incorporated). The Manufacturer's instructions and technical datasheet form an integral part of this procedure and have been incorporated herein.

2.2 Operator Qualifications and Training

Any contractor that is performing an OQ task is required to complete training modules and hands-on training to demonstrate qualifications. This training process is designed to deliver the basic skills required for each task. After completion of the OQ training, the results are uploaded to ISNET to verify compliance.

To supplement the OQ certification process, the coating manufacturer shall perform specific training for the materials and coating applications that will be used for the L5 Straits underwater coating repairs. Upon successful completion of the manufacturer's training, the Manufacturer shall issue a certificate of training or other documentation that supports the competency of the individual divers with application of the product.

Note: At its discretion, the coating Manufacturer may designate in writing a representative to conduct this training on its behalf.

The marine contractor will also perform a simulated wet trial located close to the dock to test the coating repair plan prior to completing the repairs.

2.3 Pipe Excavation

If pipe is buried in the lake floor, full circumferential access at the repair area may be accomplished by water blasting or other appropriate excavation methods to allow the circumferential application of the composite wrap and/or the Stricture Banding®.

2.4 Deviations

Any deviations from this procedure shall be brought to the Pipeline Integrity (PI) Coating Specialists for resolution. The PI Coating Specialist will consult with the key stakeholders that

include, but are not limited to, the onsite Company Inspector, the Diver, and the coating Manufacturer. If the deviation is accepted, the requested deviation, key stakeholder inputs and risk assessment associated with the deviation will be uploaded into the Company's Business Information Management (BIM) system.

Note: No deviations will be accepted if they are not supported by the coating Manufacturer.

3.0 Surface Preparation

3.1 Pre-Preparation

The steel surface shall be cleaned using scarpers, hydroblasting cleaning, wet abrasive blasting, or pneumatic power wire wheel brush. The repair area shall be abraded using either wet abrasive blasting or pneumatic power wire wheel brush. The method shall be capable of providing a surface profile of 2.5 – 5 mils.

3.2 Parent Coating

3.2.1

Feathering shall remove the sharp edge at the transition from the parent coating.

3.2.2

The parent coating shall be roughened (abraded) using a cup disk brush to remove the loosely adherent biota, coating and provide a surface for overcoating.

3.2.3

For full circumferential composite wrap repairs (Method 1), the roughening shall extend at least 6 inches from the upstream and downstream edge of the repair area and around the entire circumference of the pipe.

For composite patch repairs (Method 2), the roughening shall extend onto the parent coating at least 6 inches from the edge of the repair area.

4.0 Coating Application

4.1 Surface Condition for Coating

Immediately prior to coating application, the Diver shall remove any flash rust and/or accumulated debris (silt, clay, etc.) using a wire brush or other method approved by the Manufacturer.

Note: The surface of the pipe shall meet all preparation requirements listed in Section 3.0 before the coating application.

4.2 Preparation and Application of the Epoxy Filler

4.2.1

The BIO-DUR epoxy filler shall be prepared by thoroughly mixing the BIO- DUR™ 563 SW Epoxy Base – Black and the BIO – DUR ™ 563SW Curing Agent – White.

4.2.2

The diver shall apply the BIO-DUR epoxy filler so that the bare steel is completely covered and the repair area is flush with the adjacent parent coating.

4.2.3

The diver shall confirm that the thickness of the BIO-DUR epoxy filler is sufficient using a straight edge tool that bridges the adjacent parent coating on each side of the repair. If the BIO-DUR epoxy filler is below the straight edge tool, additional filler shall be added to ensure the repair area is flush with the adjacent parent coating.

4.3 Preparation and Application of Full Circumferential Wrap Repairs (Method 1)

4.3.1

The X-100 epoxy shall be prepared by thoroughly mixing the X100 – UW Epoxy Base – Blue and the BIO-SEAL ™ X-100 Curing Agent – Clear.

4.3.2

The E-glass fabric shall be cut into approximately 12 inch wide x 12 feet long strips and impregnated with the X-100 epoxy to form the composite wraps.

4.3.3

Prior to application of the composite wrap, the X-100 epoxy shall be applied to the surface of the epoxy filler and abraded adjacent parent coating.

4.3.4

The composite wrap shall be applied 360 degrees around the pipe to a minimum thickness of 4 full layers and shall extend over the epoxy filler and abraded adjacent parent coating. Wider repairs will require additional side by side layups that are each 12 inches wide with a minimum two inch overlap at the seams.

4.3.5

Blue Stricture Banding® will be tightly applied in the same direction as the composite wrap to a minimum of three (3) layers to assure the radial compression and retention of the repair in place during cure.

Note: alternative protective wraps or encasements are allowed if approved by the coating Manufacturer.

4.3.6

The Stricture Bandings® shall extend at least 4 inches upstream and downstream of the repair.

Note: the Stricture Banding is applied in the same direction of the composite wrap and shall have tension in order to secure the composite wrap.

4.4 Preparation and Application of Composite Repairs (Method 2)

4.4.1

The X-100 epoxy shall be prepared by thoroughly mixing the X100 – UW Epoxy Base – Blue and the BIO-SEAL ™ X-100 Curing Agent – Clear.

4.4.2

The E-glass fabric shall be cut into approximately 12 inch x 12 inch patches and impregnated with the X-100 epoxy to form the composite patches.

4.4.3

Composite patch repairs shall consist of a minimum of 4 layers of the patch applied directly over the epoxy filler and abraded adjacent parent coating. The patches shall be applied in 4 layer patches until the entire repair area (filler and abraded adjacent parent coating) is coated.

4.4.4

Blue Stricture Banding® will be tightly applied 360 degrees around the pipe over the composite patch repairs to a minimum of three (3) layers to assure the radial compression and retention of the repair in place during cure.

Note: alternative protective wraps or encasements are allowed if approved by the coating Manufacturer.

4.4.5

The Stricture Bandings® shall extend at least 4 inches upstream and downstream of the edge of the coating repairs.

4.5 Cure Time

4.5.1

After application, the coating system will be allowed to cure in place for a minimum of 7 days at 40 °F.

Note: full scale testing has shown that the coating repair will reach a Shore D greater than 60 in less than 5 days at 40 °F. The Manufacturer requires a Shore D value of 60 or greater before removal of the Stricture Banding®.

4.5.2

Prior to removing the Stricture Banding®, the diver shall ensure the coating repair does not indent when pressed with a thumbnail or other device approved by the Manufacturer with moderate pressure.

5.0 Quality Control

5.1 Diver

The Diver shall be responsible for the quality of the coating repair work.

5.2 Company Inspector

5.2.1

The Company Inspector shall have access to and shall be allowed to witness or audit the Divers' work, equipment, and records.

5.2.2

The competency requirements for the Company Inspector are as follows:

a) Minimum NACE-certified CIP Level 2 (or equivalent certification such as SSPC)
b) Trained and knowledgeable with regard to the application techniques, materials, and product data sheets covered by this specification

5.2.3

The Company Inspector reserves the right to stop any or all work at any time for non-compliance with the stated requirements of this procedure, during emergency situations, or for other justifiable reasons.

<End of Document>

ENBRIDGE

Appendix F:
OQ Checklist

APPENDIX E: CONTRACTOR REQUIREMENTS
E.02 OQ Covered Task Checklist Assignment

ENBRIDGE

Contractor Name:	Location:	Date:	Project Name & Tracking Project Number:	Project Manager:
		5/30/2017	20008990	

Individual responsible for verifying Contractor OQs: _____

Individual responsible for verifying Enbridge Employee OQs: _____

PROJECT MANAGER/DESIGNEE: Place an **X** in the appropriate **Check Person Responsible** column for covered task(s) to be performed during this project by Company or Contract personnel.

NOTE: *This OQ Checklist Assignment form is not all inclusive, as it may be subject to change due to project scope changes. The Project Manager/Designee is responsible for adding, deleting or modifying this list.*

CONTRACTOR: For each covered task with **X** in the **Check Person Responsible - Contractor** column, the Contractor is responsible for submitting contractor OQ information to ISNetworld.
Project Manager/Designee **MUST** receive Contractor-required OQ covered task information at least **two full working days** prior to work commencement (See **Appendix E.03 Contractor OQ Responsibilities**, **Appendix E.04 ISN Verification of Contractor OQ Records** and, if required, **Appendix E.05 Covered Task Worker ID/Contractor Report**.)

API #	Covered Task Name	CHECK PERSON RESPONSIBLE (Put X in box if person needs to be qualified on the covered task)				Enbridge OQ Covered Task Name
		Contractor	Span of control ratio	Span of control ratio	Enbridge Employee	
1.0	Abnormal Operating Conditions (AOC)	x				
1	**Conduct Annual Surveys to Electrically Inspect Unprotected Bare Pipe**	**Group Heading Only**				
1.1	Measurement of structure-to-soil potentials	x	1:1	1:1		#1.1: Measure structure-to-soil (electrolyte) potentials
1.2	Conduct close interval survey		1:1	1:1		#1: Cathodic protection survey
1.3	Test to detect interference		1:1	1:1		#2: Interference testing
1.4	Inspect and perform electrical test of bonds		1:1	1:1		#3: Inspect and electrically test bonds
1.5	Inspect and test electrical isolation	x	1:1	1:1		#5: Inspect and test isolation devices
2	**Maintain Test Leads**	**Group Heading Only**				
2.1	Verify test lead continuity		1:1	1:1		#4: Maintain test leads
2.2	Repair damaged test leads		1:1	1:1		#4: Maintain test leads
2.3	Install test leads by non-exothermic welding methods		1:1	1:1		#4: Maintain test leads
2.4	Install test leads by exothermic welding methods		1:1	1:1		#4: Maintain test leads
3	**Inspect Rectifier**	**Group Heading Only**				
3.0	Obtain a voltage and current output reading from a rectifier to verify proper performance		1:1	1:1		#6: Inspect and test rectifier
4	**Maintain Rectifier**	**Group Heading Only**				
4.1	Troubleshoot rectifier		1:1	1:1		#7: Rectifier maintenance and repair
4.2	Repair or replace defective rectifier components		1:1	1:1		#7: Rectifier maintenance and repair
4.3	Adjustment of rectifier		1:1	1:1		#9: Rectifier adjustment

API #	Covered Task Name	CHECK PERSON RESPONSIBLE (Put X in box if person needs to be qualified on the covered task)				Enbridge OQ Covered Task Name
		Contractor	Span of control ratio	Span of control ratio	Enbridge Employee	
5	**Inspect Buried Pipe When Exposed**	**Group Heading Only**				
5.1	Examine for mechanical damage on buried or submerged pipe	x	1:1	1:2 1:1		#15: External defect investigation #21: Inspect/examine buried pipe when exposed
5.2	Examine for external corrosion on buried or submerged pipe	x	1:1	1:1		#21: Inspect/examine buried pipe when exposed
5.3	Inspect the condition of external coating on buried or submerged pipe	x	1:1	1:2 1:1		#19: Pipe and valve coating #21: Inspect/examine buried pipe when exposed
7	**Application and Repair of External Coatings**	**Group Heading Only**				
7.1	Visual inspection of atmospheric coatings	x	1:1	1:1		#18: Atmospheric corrosion inspection
7.2	Prepare surface for atmospheric coating using hand and power tools	x	1:2	1:2		#20: Corrosion prevention methods
7.3	Prepare surface for coating by abrasive water blasting	x	1:2	1:2		#20: Corrosion prevention methods
7.4	Prepare surface for coating by abrasive blasting methods other than water	x	1:2	1:2		#20: Corrosion prevention methods
7.5	Apply coating using hand application methods	x	1:2	1:2		#20: Corrosion prevention methods
7.6	Apply coating using spray applications		1:2	1:2		#20: Corrosion prevention methods
7.7	Perform coating inspection	x	1:2	1:2		#20: Corrosion prevention methods
8	**Measure Wall Thickness of Pipe**	**Group Heading Only**				
8.1	Measure pit depth with pit gauge	x	1:1	1:1		#22: Measure wall thickness of pipe
8.2	Measure wall thickness with ultrasonic meter	x	1:1	1:1		#22: Measure wall thickness of pipe
8.3	Measure corroded area	x	1:1	1:1		#22: Measure wall thickness of pipe
9	**Cathodic Protection Remediation**	**Group Heading Only**				
9.1	Install bonds		1:1	1:1		#10.1: Install bonds
9.2	Install galvanic anodes		1:1	1:1		#10.1: Install bonds
9.3	Install rectifiers		1:1	1:1		#8: Rectifier installation
9.4	Install impressed current groundbeds		1:1	1:1		#10: Groundbed installation and repair
9.5	Repair shorted casings	x	1:3	1:3		#11: Shorted casing inspection #12: Shorted casing clearing/repair
9.6	Install electrical insulating device		1:1	1:1		**Under Development**
10	**Monitoring for Internal Corrosion**	**Group Heading Only**				
10.1	Insert and remove coupons		1:1	1:1		#13: Insert and remove coupons
10.2	Monitor probes (on-line)		1:1	1:1		#14: Hydrogen foil inspection
11	**Internal Corrosion Remediation**	**Group Heading Only**				
11.0	Monitoring and controlling the injection rate of the corrosion inhibitor		1:2	1:2		#17: Corrosion inhibitor injection
12	**Inspect Internal Pipe Surfaces**	**Group Heading Only**				
12.0	Visually Inspect internal pipe surface		1:2	1:2		#16: Defect investigation- internal corrosion

API #	Covered Task Name	CHECK PERSON RESPONSIBLE (Put X in box if person needs to be qualified on the covered task)				Enbridge OQ Covered Task Name
		Contractor	Span of control ratio	Span of control ratio	Enbridge Employee	
14	**Place and Maintain Line Markers**	**Group Heading Only**				
14.1	Locate line	x	1:0	1:0		#46: Foreign line crossing during excavation activities #47: Line locate
14.2	Install, inspect and maintain permanent marker		1:2	1:2		#48: Install and maintain line markers
14.5	Install, inspect and maintain temporary marker		1:2	1:2		#48: Install and maintain line markers
15	**Inspect Surface Conditions of Right of Way**	**Group Heading Only**				
15.1	Visually inspect surface conditions of right-of-way	x	1:2	1:2 1:1		#49: Right-of-way inspections #85: Leak survey following excavation activities using explosives
16	**Inspect Navigable Waterway Crossing**	**Group Heading Only**				
16.1	Inspect navigable waterway crossing	x	1:0			**Performed Only by Contractor**
19	**Maintain Valves**	**Group Heading Only**				
19.1	Valve body winterization or corrosion inhibition		1:1	1:2 1:1		#50: Local operation of valves #51: Valves and actuators
19.2	Valve lubrication		1:1	1:1		#50: Local operation of valves #51: Valves and actuators
19.3	Valve seat sealing		1:1	1:1		#50: Local operation of valves #51:Valves and actuators
19.4	Valve stem packing maintenance		1:1	1:1		#50: Local operation of valves #51: Valves and actuators
19.5	Adjust actuator/operator, electric		1:1	1:1		#87: Inspect and test valve and operator
19.6	Adjust actuator/operator, pneumatic		1:1	1:1		#87: Inspect and test valve and operator
19.7	Adjust actuator/operator, hydraulic		1:1	1:1		#87: Inspect and test valve and operator
20	**Inspect Valves**	**Group Heading Only**				
20.0	Inspect mainline valves		1:1	1:1 1:1 1:2		#51: Valves and actuators #86: Remote communicated valve check #88: In-service valve repair
21	**Repair Valves**	**Group Heading Only**				
21.1	Repair valve actuator/operator, pneumatic		1:2	1:2		#87: Inspect and test valve and operator #88: In-service valve repair
21.2	Disassembly/re-assembly of valve		1:2	1:2		#87: Inspect and test valve and operator #88: In-service valve repair
21.3	Internal inspection of valve and components		1:2	1:2		#87: Inspect and test valve and operator #88: In-service valve repair
21.4	Repair valve actuator/operator, hydraulic		1:2	1:2		#87: Inspect and test valve and operator #88: In-service valve repair
21.5	Repair valve actuator/operator, electric		1:2	1:2		#87: Inspect and test valve and operator #88: In-service valve repair

API #	Covered Task Name	CHECK PERSON RESPONSIBLE (Put X in box if person needs to be qualified on the covered task)				Enbridge OQ Covered Task Name
		Contractor	Span of control ratio	Span of control ratio	Enbridge Employee	
22	**Inspect, Maintain and Calibrate Relief Valves**	**Group Heading Only**				
22.1	Inspect tank pressure/vacuum breakers		1:1	1:1		#83: Inspect, test and calibrate overfill protection devices #91: Pressure relief valve test
22.2	Inspect, test and calibrate HVL tank pressure relief valves		1:1	1:1		#83: Inspect, test and calibrate overfill protection devices #91: Pressure relief valve test #CC5: Control Center: Monitor tank levels
23	**Maintain/Repair Relief Valves**	**Group Heading Only**				
23.1	Maintain/repair relief valves		1:2	1:2		#88: In-service valve repair
23.2	Inspect, test and calibrate relief valves		1:2	1:2		#91: Pressure relief valve test
24	**Inspect, test and calibrate pressure limiting devices**	**Group Heading Only**				
24.1	Maintain/repair pressure limiting devices		1:1	1:1		#91: Pressure relief valve test
24.2	Inspect, test and calibrate pressure limiting devices		1:1	1:1		#89: Pressure control Valve (PCV) maintenance
25	**Inspect, test and calibrate pressure limiting devices**	**Group Heading Only**				
25.1	Inspect, test and calibrate pressure switches		1:1	1:1		#92: Pressure switch calibration
25.2	Inspect, test and calibrate pressure transmitters		1:1	1:1		#93: Inspect and test pressure transmitter
26	**Verify or Set Protection Parameters for Programmable Controllers and/or Instrumentation Control Loops**	**Group Heading Only**				
26.0	Verify or set protection parameters for programmable controllers and/or other instrumentation control loops		1:1	1:1		#90: Pressure allowable set points
27	**Inspect and Repair Breakout Tanks**	**Group Heading Only**				
27.1	Routine inspection of breakout tanks (API 653 monthly or DOT Annual)		1:0	1:1		#52: Tank inspection
27.2	API 653 inspection of in-service breakout tanks		1:0			**Performed Only by Contractor**
27.3	API 510 inspection of in-service breakout tanks		1:0			**Performed Only by Contractor**
29	**Protect Breakout Tanks from Static Electricity, Lightning, and Stray Electrical Currents**	**Group Heading Only**				
29.1	Launching in-line inspection devices		1:2	1:2		#54: Launching tool (pig) in scraper trap
29.2	Receiving in-line inspection devices		1:2	1:2		#55: Receiving tool (pig) in scraper trap
30	**Test Overfill Protective Devices**	**Group Heading Only**				
30.0	Test overfill protective devices		1:1	1:1		#83: Inspect, test and calibrate overfill protection devices
31	**Inspect and Calibrate Overfill Protective Devices**	**Group Heading Only**				

API #	Covered Task Name	CHECK PERSON RESPONSIBLE (Put X in box if person needs to be qualified on the covered task)				Enbridge OQ Covered Task Name
		Contractor	Span of control ratio	Span of control ratio	Enbridge Employee	
31.0	Inspect and calibrate overfill protective devices		1:1	1:1		#83: Inspect, test and calibrate overfill protection devices

API #	Covered Task Name	CHECK PERSON RESPONSIBLE (Put X in box if person needs to be qualified on the covered task)				Enbridge OQ Covered Task Name
		Contractor	Span of control ratio	Span of control ratio	Enbridge Employee	
32	**Monitoring Excavation Activities**	**Group Heading Only**				
32.0	Observation of excavation activities		1:1	1:1		#56: Damage prevention during excavation activities
33	**Moving In-Service Pipe**	**Group Heading Only**				
33.1	Determine allowable line pressure in section to be moved		1:2	1:2		#58: Line lowering
33.2	Preparation for movement activities		1:2	1:2		#58: Line lowering
33.3	Moving in-service pipeline		1:2	1:2		#58: Line lowering
34	**Inspect Existing Pipe Following Movement**	**Group Heading Only**				
34.0	Inspect existing pipe following movement	x	1:2	1:2		#49: Right-of-way inspections
36	**Abandoning, Safe Disconnect, Purging, and Sealing of Pipeline Facilities**	**Group Heading Only**				
36.1	Safe disconnect of pipeline facilities		1:2	1:2		#59: Line deactivation
36.2	Purging of pipeline facilities		1:2	1:2		#59: Line deactivation
36.3	Sealing a disconnected portion of pipeline		1:2	1:2		#59: Line deactivation
37	**Installation or Repair of Support Structures on Existing Aboveground Components**	**x**				
37.0	Install or repair support structures on existing above ground components		1:2	1:2		#82: Install or repair support structures on existing or above ground components
38	**Inspection Activities for Tie-Ins, Pipe Replacement, or Other Components Connecting to an Existing Pipeline**	**Group Heading Only**				
38.1	Visually inspect pipe and pipe components prior to installation		1:2	1:2		#15: External defect investigation
38.3	Visually inspect that welds meet DOT requirements (in accordance with API 1104)		1:0			**Performed Only by Certified Weld Inspectors (API 1104 Certification)**
38.4	NDT - radiographic testing		1:0			**Performed Only by Contractor**
38.5	NDT - liquid penetrant testing		1:0			**Performed Only by Contractor**
38.6	NDT - magnetic particle testing		1:0			**Performed Only by Contractor**
38.7	NDT - ultrasonic testing		1:0			**Performed Only by Contractor**
39	**Backfilling a Trench Following Maintenance**	**Group Heading Only**				
39.0	Backfilling a trench following maintenance		1:1	1:1		#57: Backfilling activities

API #	Covered Task Name	CHECK PERSON RESPONSIBLE (Put X in box if person needs to be qualified on the covered task) Contractor	Span of control ratio	Span of control ratio	Enbridge Employee	Enbridge OQ Covered Task Name
40	**Perform General Pipeline Repair Activities**	**Group Heading Only**				
40.1	Fit full encirclement welded split sleeve (oversleeve, tight fitting sleeve, etc.)		1:2	1:2		#66: Pipeline repair: Oversleeve #67: Pipeline repair: Tight fitting sleeve
40.3	Apply composite sleeve		1:2	1:2		#69: Pipeline repair: Composite sleeve
40.4	Install mechanical bolt-on split repair sleeve		1:2	1:2		#68: Pipeline repair: Plidco split repair
40.5	Install weldable compression coupling		1:2	1:2		#70: Pipeline repair: Weld + ends coupling
40.6	Install and remove plugging machine		1:0	1:2		#71: Installation of tapping or plugging tees #74.1: Plugging a pipeline 2" and under #74.2: Plugging a pipeline 2 1/2" and larger
40.7	Installing a tap 2 inches and under on a pipeline system		1:0	1:2		#72: Pipeline repair: Tapping
40.8	Installing a tap larger than 2 inches on a pipeline system		1:0	1:2		#72: Pipeline repair: Tapping
40.9	Install and remove completion plug on pipelines larger than 2 inches		1:2	1:2		#73: Plugging
41	**Conduct Pressure Tests**	**Group Heading Only**				
41.0	Conduct pressure test		1:2	1:2		#76: Pressure testing of pipe
42	**Welding on Existing Pipeline Systems**	**Group Heading Only**				
42.7	Welding		1:0	1:0		API 1104 Code Book OMM Book 4: 02-02-04 (page 1 and page 3) #77: Welding: Side Seam Weld #78: Welding: Circumferential Fillet Weld #79: Welding: Butt weld API 1104 Code Book #80: Welding: Defective weld repair #81: Welding: Nozzle Weld
43	**Operations of Pipeline Systems**	**Group Heading Only**				
43.1	Start-up of a liquid pipeline (control center)			1:1		#CC3: Control Center: Operation of remote pumps #CC6: Control Center: Start-up of a liquid pipeline system
43.2	Shutdown of a liquid pipeline (control center)			1:1		#CC3: Control Center: Operation of remote pumps #CC7: Control Center: Shutdown of a liquid pipeline system
43.3	Monitor pressures, flows, communications, and line integrity and maintain them within allowable limits on a liquid pipeline			1:1		#CC1: Control Center: Monitor and control pressure and/or flows
43.4	Remotely operate valves on a liquid pipeline system			1:1		#CC2: Control Center: Operation of remote valves #86: Remote communicated valve check

API #	Covered Task Name	CHECK PERSON RESPONSIBLE (Put X in box if person needs to be qualified on the covered task)				Enbridge OQ Covered Task Name
		Contractor	Span of control ratio	Span of control ratio	Enbridge Employee	
44	**CPM Leak Detection**	**Group Heading Only**				
44.3	Inspect, test and maintain flow computer for hazardous liquid leak detection			1:1		#CC4: Control Center: Monitor leak detection - Computational Pipeline Monitoring (CPM) (**Liquid Pipelines only) #CC5: Control Center: Monitor tank levels
44.4	Inspection, testing, corrective and preventative maintenance of tank gauging for hazardous liquid leak detection		1:1			**Under Development**
44.5	Prove flow meters for hazardous liquid leak detection			1:1		#CC8: Control Center: Prove Flow Meters for Hazardous Liquid Leak Detection
44.6	Maintain flow meters for hazardous liquid leak detection		1:1			**Under Development**
44.7	Inspect, test and maintain gravitometers/densitometers for hazardous liquid leak detection		1:1			**Under Development**
44.8	Inspect, test and maintain temperature transmitters for hazardous liquid leak detection		1:1			**Under Development**
52	**Leakage Survey (retained from previous version)**	**Group Heading Only**				
52.1	Conduct vegetation survey		1:1	1:1		#84 Gas leakage survey
52.2	Conduct a leak survey with a CGD		1:1	1:1		#84 Gas leakage survey
52.3	Conduct a leak survey with a flame ionization unit		1:1	1:1		#84 Gas leakage survey
55	**Fixed Gas Detection (retained from previous version)**	**Group Heading Only**				
55.0	Maintain fixed gas detection equipment		1:1	1:1		#94: Station gas detection calibration
63	**Operation of a Pipeline System**	**Group Heading Only**				
63.1	Start-up of a liquid pipeline (field)		1:1	1:1		#95: Local operation of pumps (start up/shut down of a pump)
63.2	Shutdown of a liquid pipeline (field)		1:1	1:1		#95: Local operation of pumps (start up/shut down of a pump)
63.3	Monitor pressure, flows, communications and line integrity and maintain them within allowable limits on a liquid pipeline system (field)		1:1	1:1		#89: Pressure Control Valve (PCV) maintenance #96: Pressures, flows and communications monitoring - field ops
63.4	Locally operate valves on a liquid pipeline system		1:1	1:1		#50: Local operation of valves #86: Remote communicated valve check

Enbridge LP Representative (Print Name):

API #	Covered Task Name	CHECK PERSON RESPONSIBLE (Put X in box if person needs to be qualified on the covered task)				Enbridge OQ Covered Task Name
		Contractor	Span of control ratio	Span of control ratio	Enbridge Employee	
	Date:	**Signature:**				