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SUBJECT: ASME PCC-2 Certification of the Armor Plate 360 ZED Repair System

Dear Cindy,

Testing performed by Stress Engineering Services Inc. (SES) has demonstrated that the AP 360 ZED repair system meets the minimum requirements of *ASME PCC-2-2015 (2015 edition), Article 4.1- Nonmetallic Composite Repair Systems: High Risk Applications*. Testing included the three mandatory appendices of PCC-2 and two additional SES-required tests (inter-layer strain and pressure cycling). All testing was performed at the elevated temperature of 104°F. All of these tests are critically important in terms of qualifying product performance, and together they validate that the AP ZED composite repair system fulfills the requirements in the ASME PCC-2-2015 Standard. Since all testing occurred at or above 104°F, the ZED repair system is ASME PCC-2 qualified for repair applications of 104°F or lower.

The test results presented in the table on the following page summarize the AP ZED repair system's qualification to ASME PCC-2, Article 4.1, Mandatory Appendices II, III, and V. The material properties listed in this table meet all the requirements of Appendix II. The AP ZED system survived the spool survival test in Appendix III at temperatures above 104°F with no visible damage to the repair. The long-term strength (s_{lt}) of the repair system at 104°F from the 1,000-hr testing of Appendix V was 23,761 psi (based off ASME PCC-2, Article 4.1, Appendix V, Equation V-2). The 0.5 service factor from Table 4 in ASME PCC-2 for 1,000 hour test data is used to calculate the composite design stress of 11,880 psi (i.e., 0.5 x 23,761 psi). Whenever ZED repair system is installed to repair a pipeline, the stresses in the composite material must be less than this value. The design stress limit for the AP 360 ZED repair system is approximately 19% of the short-term composite tensile strength (s_c) of 60,375 psi at 104°F. In other words, the AP ZED repair system has a safety factor of 5.1 with respect to the short-term composite tensile strength.

Please contact me if you have any questions.

Regards,



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Texas Registered Engineering Firm F-195

Armor Plate ZED – ASME PCC-2 Qualification Test Summary				
Property	Details	Temperature	Test Standard	Test Results
Layer Thickness	--	--	--	0.0625
Tensile Strength	Hoop	70°F	ASTM D 3039	73,200 psi
Ultimate Tensile Strain	Hoop		ASTM D 3039	2.70%
Modulus	Hoop		ASTM D 3039	3,565,000 psi
Tensile Strength	Hoop	104°F	ASTM D 3039	60,700 psi
Ultimate Tensile Strain	Hoop		ASTM D 3039	2.70%
Modulus	Hoop		ASTM D 3039	3,579,000 psi
Tensile Strength	Axial	70°F	ASTM D 3039	9,850
Ultimate Tensile Strain	Axial		ASTM D 3039	1.9%
Modulus	Axial		ASTM D 3039	1,328,000
Tensile Strength	Axial	104°F	ASTM D 3039	9,500
Ultimate Tensile Strain	Axial		ASTM D 3039	1.9%
Modulus	Axial		ASTM D 3039	1,196,000
Compressive Modulus	Filler	70°F	ASTM D695	536,400 psi
Compressive Strength	Filler		ASTM D695	11,200 psi
Compressive Modulus	Filler	104°F	ASTM D695	208,500 psi
Compressive Strength	Filler		ASTM D695	7,600 psi
Poisson's Ratio	Longitudinal	Above 32°F	ASTM D 3039	0.222
Hardness	Shore D		ASTM D 2583	90.2
CTE*	Hoop		ASTM E 831	$34.8 \cdot 10^{-6} 1/°F$
CTE*	Axial		ASTM E 831	$16.0 \cdot 10^{-6} 1/°F$
Glass Transition Temp - Tg	Filler	N/A	ASTM E 1640	128°F
Glass Transition Temp - Tg	Epoxy		ASTM E 1640	121°F
Lap Shear Adhesion	Adhesive strength	70°F	ASTM D 5868	5,100
		104°F	ASTM D 5868	7,400
Cathodic Disbondment	28 Day Test Duration	N/A	NACE TM0115-2015	No Observed Disbondment
Long Term Strength	1,000 hours	104°F	ASME PCC-2	23,760 psi
Spool Survival Test	75% WT Defect		ASME PCC-2	Survived
Inter-Layer Strain	75% WT Defect	104°F	SES Additional	Completed
Pressure Cycle Fatigue	75% WT Defect		SES Additional	Completed

*CTE - Coefficient of Thermal Expansion



Limitations of This Report

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Revision History

Document Control					
Rev	Date	Description	Originator	Checker	Reviewer
0	17-Jan-2017	Issued for Client Use	C. Denowh	--	C. Alexander