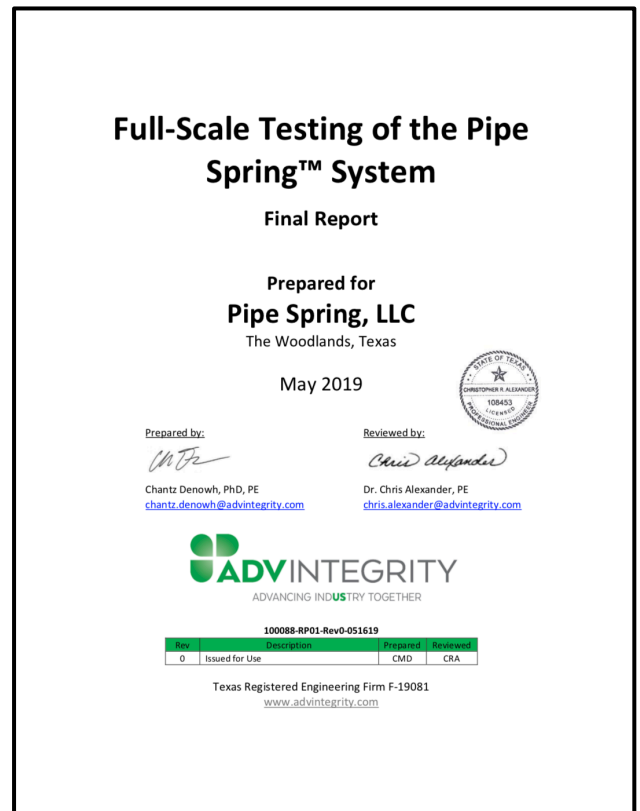
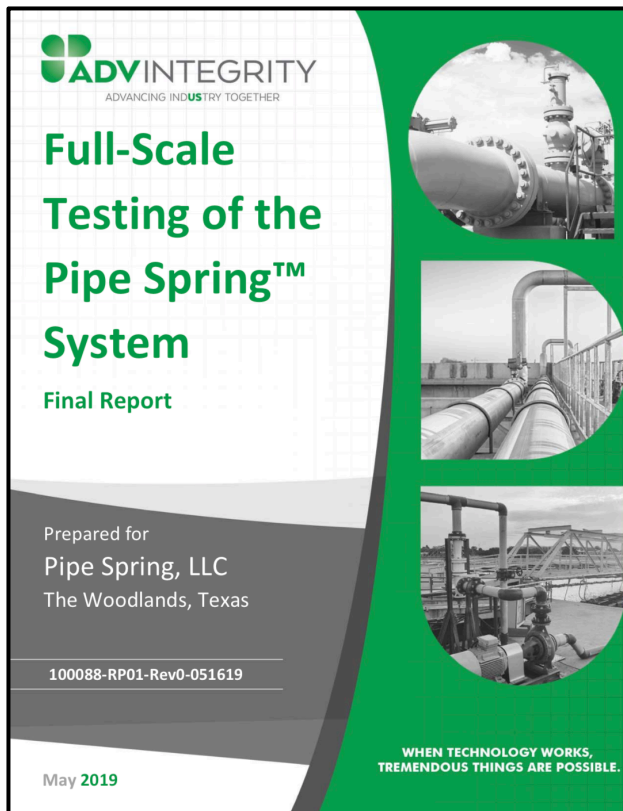




Summary of Pipe Spring™ Full Scale Testing

Introduction

Pipe Spring LLC is pleased to announce the successful test and evaluation of the Pipe Spring™ system completed by ADV Integrity in May 2019. The technical staff of ADV Integrity are highly experienced regarding the development, testing, and performance evaluation of non-metallic repairs. They have completed several hundred tests with similar configurations. The full report is available upon request via email at info@pipespring.net or by contacting a Pipe Spring LLC representative.



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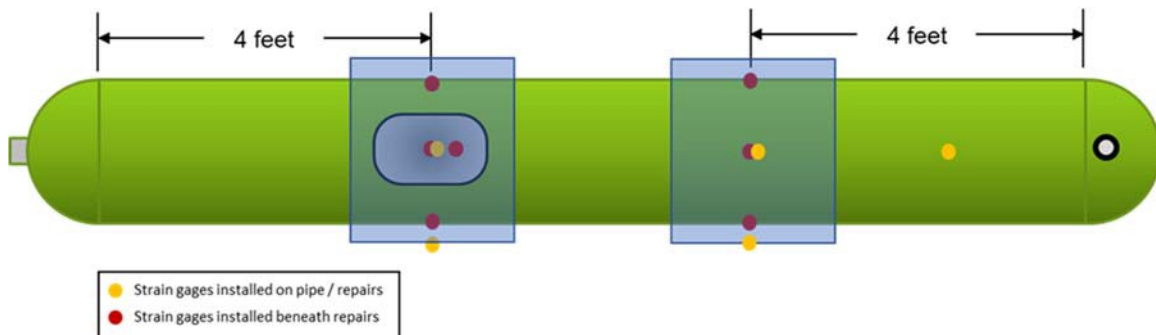
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Program Summary

Two Pipe Spring installations were completed and tested on one section of nominal X42, 12-inch diameter, .375-inch thick steel pipe. One unit was installed over a significant metal loss defect. ADV Integrity's report refers to this unit as the "Corrosion Pipe Spring". One unit was installed on solid pipe with no known defect present. ADV Integrity's report refers to this unit as the "Effective Modulus Pipe Spring." The schematic below demonstrates the set up.



Schematic 1: Installation Diagram

Eighteen (18) biaxial strain gages were installed on the carrier (base) pipe and Pipe Springs™ as shown in the tables below. Table 1 and Table 2 provide the locations of the 17 strain gages located on Corrosion Pipe Spring™ and Effective Modulus Pipe Spring™ systems, respectively. The 18th strain gage was installed on the base pipe halfway between the Effective Modulus Pipe Spring™ and the endcap girth weld to provide a measure of the unreinforced pipe strains. The two (2) strain gages installed in the corrosion defect are shown in Image 1.

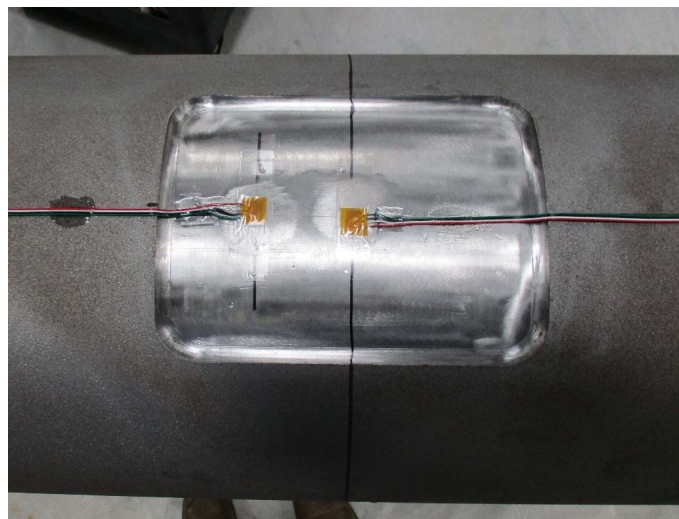


Image 1: Biaxial strain gages installed in the corrosion defect beneath the Corrosion Pipe Spring™ (Gages 1 and 2 in Table 1)

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Three (3) gages were installed between the layers of the Effective Modulus Pipe Spring™ to characterize the stress through the repair during pressure testing. The thickness of the strain gage wires for all gages was 0.037-inches. Gages 1 through 4 in Image 2 were installed beneath the Effective Modulus Pipe Spring™ provided the strain measurements for calculation of the hoop stress. Image 2 illustrates these four (4) gages installed on the base pipe prior to installation of the Pipe Spring™.



Image 2: Biaxial strain gages installed beneath the Effective Modulus Pipe Spring™ (Gages 1 through 4 in Table 2)

Table 1: Corrosion Pipe Spring™ biaxial strain gage locations and description

Gage	Location Description	Gage Label
1	Centered in corrosion defect (0°)	A Defect
2	2-inches from center in the corrosion defect (0°)	B Defect
3	Surface of the load transfer material and center over the corrosion defect (0°)	Filler
4	Base pipe beneath the Pipe Spring™ and 90° from corrosion defect	BP 90
5	Base pipe beneath the Pipe Spring™ and 180° from corrosion defect	BP 180
6	Base pipe beneath the Pipe Spring™ and 270° from corrosion defect	BP 270
7	Outer surface of the Pipe Spring™ at 0°	Repair
8	Outer surface of the Pipe Spring™ at 90°	Repair

Table 2: Effective Modulus Spring™ biaxial strain gage locations and description

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Gage	Location Description	Gage Label
1	Base pipe centered beneath the Pipe Spring™ at 0°	BP 0
2	Base pipe centered beneath the Pipe Spring™ at 90°	BP 90
3	Base pipe centered beneath the Pipe Spring™ at 180°	BP 180
4	Base pipe centered beneath the Pipe Spring™ at 270°	BP 270
5	Interlayer gage installed on top of Layer 3 (0°)	L3
6	Interlayer gage installed on top of Layer 6 (0°)	L6
7	Interlayer gage installed on top of Layer 9 (0°)	L9
8	Outer surface of the Pipe Spring™ at 0°	Repair
9	Outer surface of the Pipe Spring™ at 90°	Repair

Results

The following paragraph is a direct excerpt from the Executive Summary of the ADV Integrity report:

The results of this test successfully demonstrated that the Pipe Spring™ system can restore the structural integrity of a damaged pipe with a 75% wall loss corrosion defect. The Pipe Spring™ succeeded in restoring the damaged pipe past its theoretical failure pressure. The Pipe Spring™ system is not a true non-metallic repair, but this test sample and procedure mirrors the pipe sample configuration for the ASME PCC-2, Article 4.1, Appendix III, Short Term Spool Survival Test.

Highlights of the program include:

- 1) A 77% wall loss defect with an 8-inch length and 6-inch width was restored to a capacity well above the potential operating range of the pipe. The SMYS of the pipe was 2470 psi. The MAOP (72% of SMYS) was 1779 psi. The defect successfully held until 3885 psi. This represents a pressure of 218% of the MAOP and 700 psi above the yield point of the unrepaired base pipe.

Typical industry assessment methods of the defect include:

- Theoretical contribution from the remaining thin ligament (.088 inch wall remaining) from ASME PCC-2 equation #12
 - At nominal X42 = 580 psi
 - At laboratory reported yield point of the steel (60.5 KSI) = 835 psi
 - At the apparent base pipe yield point (56.4 KSI) = 779 psi
- ASME B31G (failure pressure)
 - At X 42 nominal= 1556 psi
 - At laboratory reported yield = 2242 psi
 - At apparent base pipe yield = 2090 psi
- Modified ASME B31G (failure pressure)

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- At nominal X42 = 1355 psi
- At laboratory reported yield = 1837 psi
- At apparent yield of base pipe = 1730 psi

2) In addition to the standard defect geometry, a second Pipe Spring™ unit was installed on the pipe with no defect. This was done to develop data for evaluation of performance associated with strain dependent features and concerns.

The highlights include:

- Interlayer strain gauges indicate load sharing essentially immediately as the pipe experienced internal pressure (below 100 micro strain in the base pipe).
- At MAOP, 1779 psi, the stain in the pipe under the Pipe Spring™ system was 5.5% below the stain in the unrepaired base pipe.
- At SMYS, 2470 psi, the stain in the pipe under the Pipe Spring™ system was 6.5% below the strain in the base pipe.
- At the actual yield of the unrepaired base pipe (3184 psi) the strain in the pipe under the Pipe Spring™ was reduced by 42.2 %.
- At 10,000 microstrain of the base pipe (3445 psi, 140% of SMYS) the strain in the pipe under the Pipe Spring was reduced by 80.0%

This program involved significant instrumentation. The pipe specimen had a total of 18 bi-directional strain gauges for a total of 36 channels of data. Some select data is presented below:

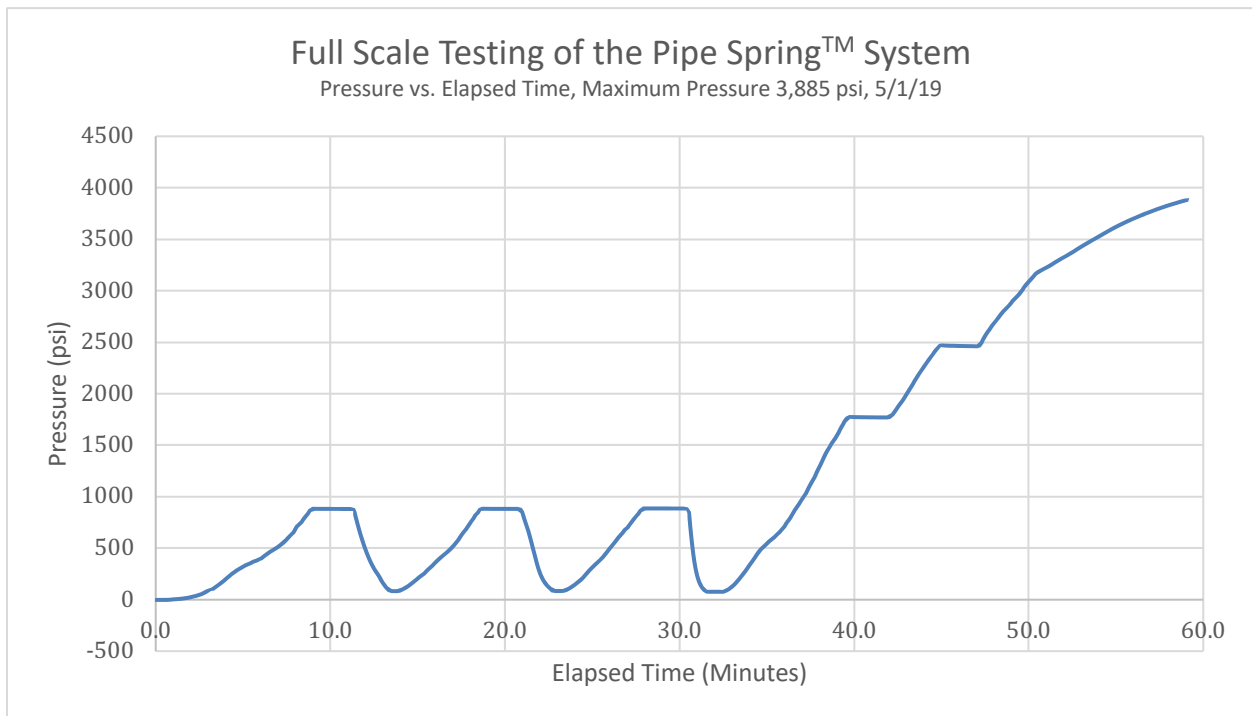


Figure 1



Figure 1 provides the internal pressure profile of the test program. A few cycles were included at 36% of SMYS or 890 psi. The pressure held for 2 minutes. Then, the pressure increased to 72% of SMYS or 1779 psi with a 2-minute hold. Next, the pressure was increased to 100% of SYMS, 2470 psi, with a 2-minute hold.

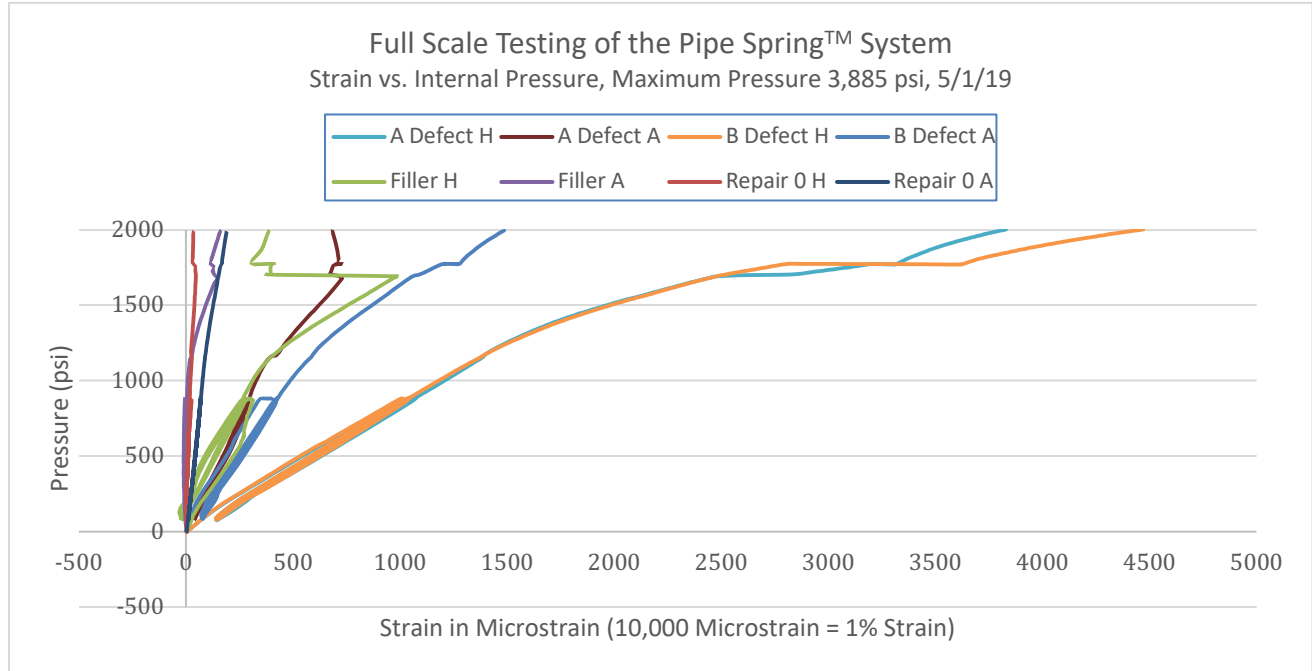


Figure 2

Figure 2 shows the 77% wall loss defect behavior. Two strain gauges were placed in the bottom of the 77% wall loss defect. At MAOP, 1779 psi, the average strain at the defect was 3488 micro-strain. This is well below the suggested ADV Integrity Key Performance Indicator (KPI) of excellence of 4000 microstrain for this defect configuration.

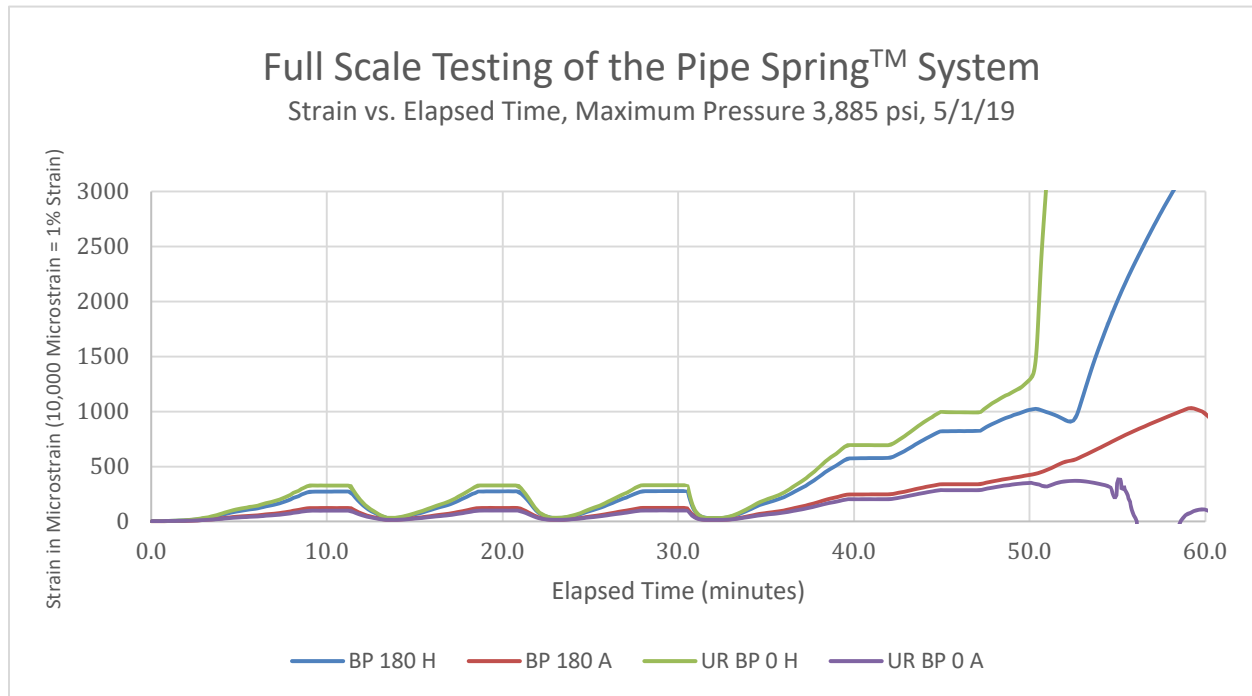


Figure 3

Figure 3 shows the strain developed within the interlayer strain gauges, the unrepaired base pipe performance, and the pipe under the Pipe Spring™ system. Performance of the pipe is greatly enhanced.

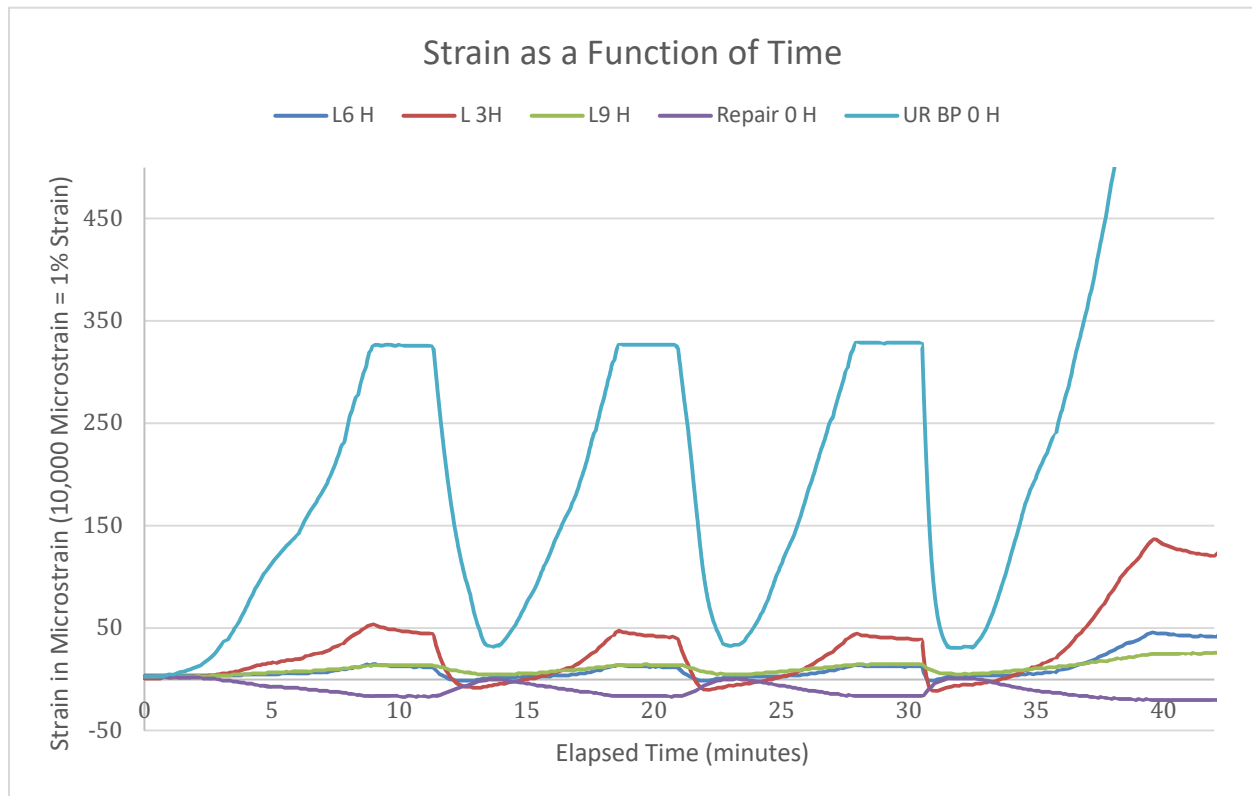


Figure 4

Figure 4 shows the behavior at very low pressure and strain. The results indicate that the Pipe Spring™ shares stress with essentially no delay.

Additional Information:

For strained based concerns, a modulus of elasticity value is important. This evaluation program does include the determination and discussion of modulus. This value will be available soon.