Influence of Backing Strip Mill Groove on Integrity of Type B Sleeve

Final Report

Prepared for Allan Edwards, Inc.

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November 2021

Testing performed by ADV Integrity, Inc.

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Final Report

Prepared for

Allan Edwards

Tulsa, OK

November 2021

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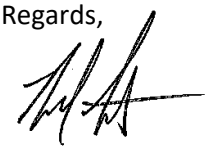
Chip Edwards
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6468 N. Yale Ave.
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Dear Chip and Josh,

Attached is the final report for the 12-inch Steel Sleeve Type B testing program. The purpose of this test was to examine the influence that an installed long seam weld backing strip mill groove relief has on the long-term integrity of a fully welded Type B steel sleeve. The test program included cyclic fatigue of a carrier pipe dent reinforced with a Type B Steel Sleeve, one sample with a mill groove and one without a mill groove. This report provides an introduction on the topic, description of the tests setup and procedures, the results of the tests, and a discussion of the results.

Thank you for the opportunity to complete this work and please do not hesitate to contact us with any questions.

Regards,



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1.0 INTRODUCTION

Allan Edwards, Inc. (Allan Edwards) contracted ADV Integrity, Inc. (ADV) to examine the influence that an installed long seam weld backing strip mill groove relief has on the long-term integrity of a fully-welded Type B steel sleeve. Mill grooves are commonly specified as a means for providing relief for the long seam backing strip to allow the sleeve to provide tighter contact to the pipe. The mill groove also reduces concern of the backing strip from shifting during sleeve fit-up, reducing or eliminating the risk of welding the long seam directly to the pipe. A mill groove relief is shown in Figure 1-1.

As shown in Figure 1-1, the mill groove locally reduces the sleeve wall thickness along the length of the sleeve, compared to a non-mill-grooved sleeve. While this common practice provides benefit as described above, the long-term integrity of a sleeve with a mill groove has not been thoroughly examined.

To better examine the influence of a mill groove, ADV designed a test program that results in stress at the sleeve long seam weld by placing a carrier pipe dent directly behind the sleeve long seam weld. This configuration, although not typical of field installations, would apply the greatest amount of stress to the sleeve long seam weld. Two sample configurations were examined: one with a mill groove and one without. Early failure of the sleeve during pressure cycling would occur in the event the mill groove influenced the long-term integrity of the sleeve. The full-scale pressure cycling of the installed sleeves are discussed in this report.



Figure 1-1: Photograph showing varying sleeve long seam weld design: with and without mill groove relief for the backing strip.

2.0 TEST PROCEDURE

The following procedure was used to prepare and test the two (2) 12-inch OD samples containing a dent. A single dent was installed by applying an indenter on the outside surface of the pipe, and 10 pressure cycles were applied to form the pipe around the indenter. Following the dent installation, the AE Type B Steel Sleeve was fit and welded to the pipe to reinforce the dent. The sample was then cycled to 100,000 cycles or failure, whichever occurred first. All pressure transducer calibration sheets are provided in Appendix A.

2.1 Preparation of 12" Dent Samples

1. Labeled sample with sample number (100306 – Sample#)
2. Measured diameter and wall thickness
    a. Recorded measurements in technician notes
    b. Recorded measurements on samples
3. Installed Dent at midspan of samples
    a. Installed dents to 15% depth (1.9 in) of the OD pipe
    b. Held indenter in place while sample was pressurized to 1186 psig (72% SMYS) for 10-minutes
    c. Reduced internal pressure to 0-psig
    d. Released indenter and measured profile with no pressure in pipe
        i. Measured dent profile at 1-inch increments, recorded in hand notes
4. Inspected pipe with dye penetrant or mag particle to assure no cracks were formed
5. Applied 10 pressure cycles from 100-psig (6% SMYS) to 1285-psig (78% SMYS) and measured dent profile again in Table 3-1
6. Installed biaxial strain gages near dents in transition area on "halo" region of dent to measure hoop and axial strains. Details shown in Figure 2-1 for strain gage locations.
7. Took photographs of:
    a. Full Pipe
    b. Close-up of dents
8. Scanned the OD of the pipe using Creaform 3D laser scanner. Scanned the ID surface of the sleeve using the Creaform 3D laser scanner.
9. Apply hardenable fill to the dent area and weld sleeve with long seam welds directly over the dent.

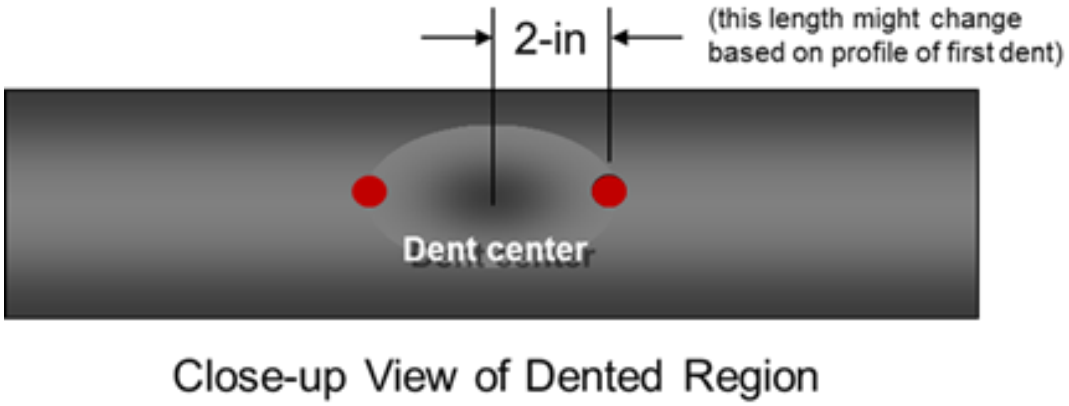


Figure 2-1. Strain gage placement for 12" samples at "halo" points of the dents

2.2 Testing 12" Dent Samples

1. Pressure cycled samples from 132-psig (8% SMYS) to 1318-psig (80% SMYS) until failure or 100,000 cycles.
    a. Recorded strain gage data during pressure cycling.
2. Took photographs of:
    i. Full sample
    ii. Failure location

3.0 TEST RESULTS

The dent was installed at the midspan of each pipe to a maximum depth of 1.9 inches or 15% of the diameter of the pipe. After the indenter was released, the dent relaxed, and the residual depth is recorded in Table 3-1. Ten (10) pressure cycles were then applied to each sample with the indenter locked in place to form the pipe around the indenter. The final max depth of the dent after the pressure cycles is also provided in Table 3-1. An image of the dent at the midspan after installation is shown in Figure 3-1 and an image of the dent profile captured via a 3D laser scan is shown in Figure 3-2.

Table 3-1: Dent depth after installation and after cycles

Sample ID	Description	Dent Depth after Indentation (in)	Dent Depth after 10-Cycles (in)
12 – MG	12” Sample with Mill Groove	0.928	0.597
12 – W	12” Sample without Mill Groove	0.870	0.486



Figure 3-1: Installed dent after 10 pressure cycles

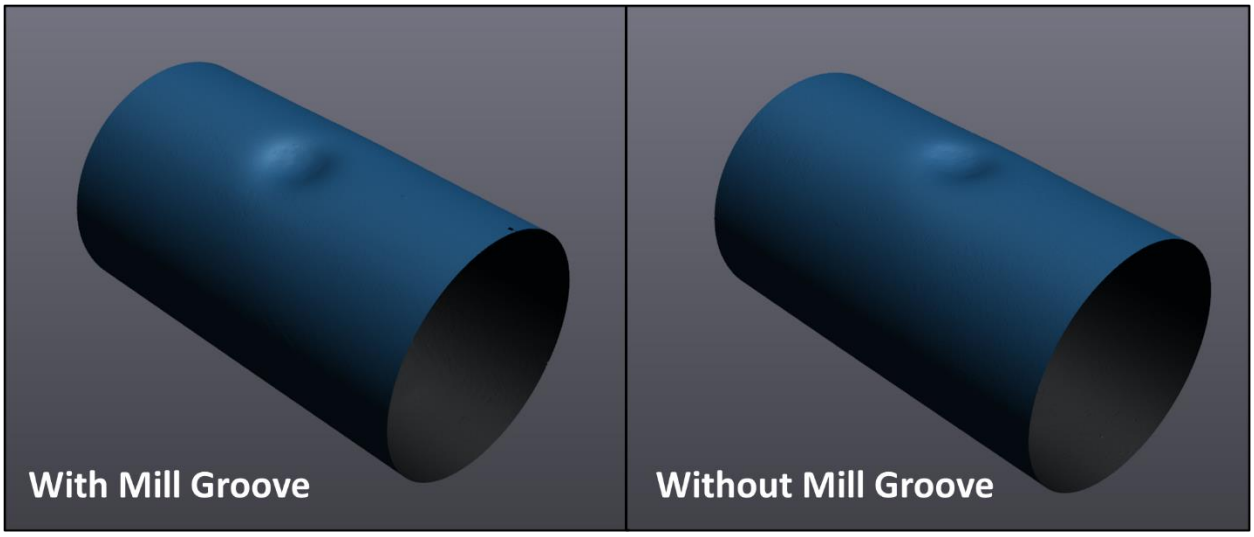


Figure 3-2: 3D scan rendering of dent after installation.

The dent was filled with hardenable filler material (Figure 3-3), sleeve was fitted and clamped down using chain clamps (Figure 3-4), then welded by a subcontractor at ADV's test facility (Figure 3-5), and inspected for quality prior to cyclic testing. During sleeve installation, the strain gages lost contact on both samples, therefore, no strain data are included in this report. The samples were pressure cycled simultaneously between 100 psig and 1,285 psig. A plot of the maximum and minimum pressure for the first ten (10) cycles for both samples is shown in Figure 3-6. Both samples survived 100,000 cycles of pressure cycling. At 92,416 cycles the 12-W sample leaked in the pressure port on the end cap, but it was repaired and cycling continued. After the repair, the sample held pressure and continued cycling to 100,000 cycles showing the damage was isolated to the pressure port. Both samples hit the runout condition of 100,000 cycles and the test was ended.



Figure 3-3: Mixing of hardenable fill.



Figure 3-4: Fit-up of sleeve.



Figure 3-5: Welding of sleeve long seam weld.

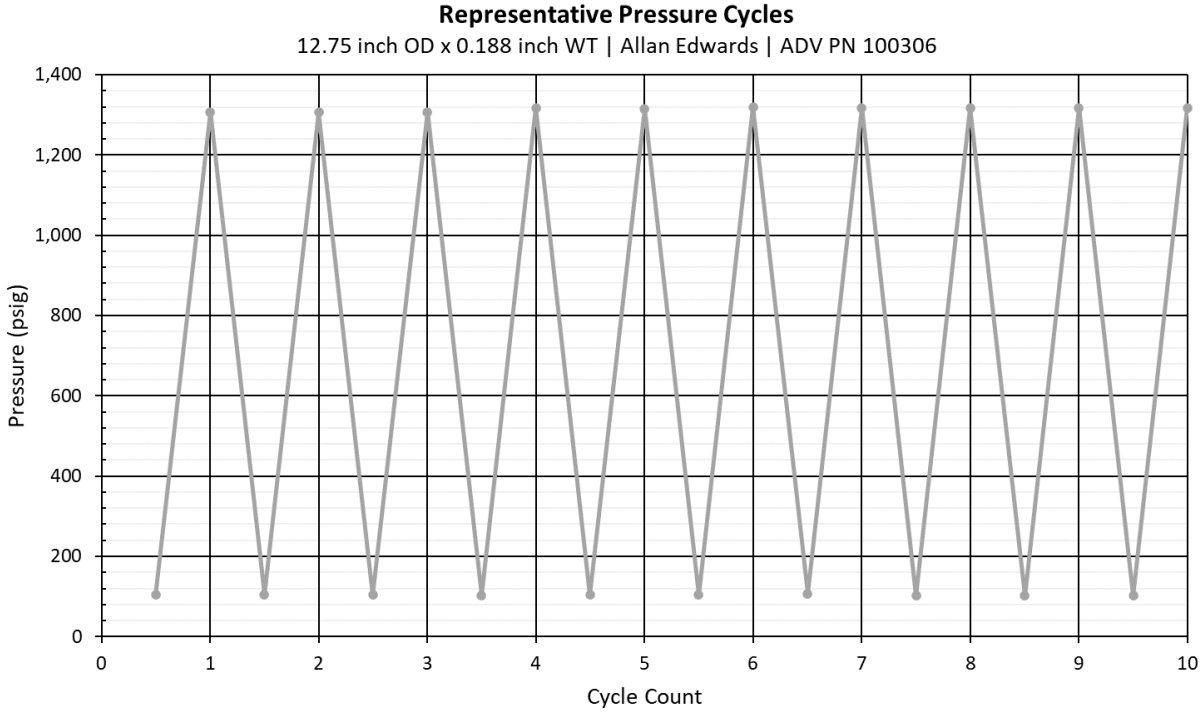


Figure 3-6: Ten (10) Pressure Cycles for the 12" AE Type B Reinforced Samples

4.0 DISCUSSION AND SUMMARY

The two tested sleeve configurations (with and without a mill groove) both survived the 100,000-cycle runout. After the test concluded, ADV sectioned and removed the Type B sleeve, then inspected the inside surface of the sleeve mill groove and outside surface of the dent via magnetic particle inspection. No relevant indications were identified. Therefore, the mill groove did not influence the long-term cyclic integrity of the sleeve (at least to 100,000 cycles between 10 and 72% SMYS).

Relating 100,000 pressure cycles at the tested range (10 to 72% SMYS) results in an equivalent 57,764 cycles with a ΔP of 72% SMYS. For some time, the pipeline industry has employed the data compiled by John Kiefner where he classified pressure cycling in four categories based on industry surveys: *Very Aggressive*, *Aggressive*, *Moderate*, and *Light* (refer to data presented in Table 4-1). As noted, a *Very Aggressive* condition will result in 276 cycles per year and a *Light* condition will result in 10 cycles per year assuming a pressure range of 72% SMYS. Gas transmission pipelines typically experience minimal cycling, so a *Light* pressure cycle condition is appropriate. Accounting for a safety factor of 5, results in an approximate cyclic life tested of 42 years in a Very Aggressive pressure cycling regime and 1,155 years in a Light pressure cycling regime – both significantly long periods when examining the 100,000 cycles each sleeve survived in this study.

Table 4-1: Annual Cyclic Pressure Conditions Based on Kiefner Study Industry Survey[1]
(Estimated number of annual cycles as a function of cyclic pressure condition)

Percent SMYS	Very Aggressive	Aggressive	Moderate	Light
72	20	4	1	0
65	40	8	2	0
55	100	25	10	0
45	500	125	50	25
35	1000	250	100	50
25	2000	500	200	100
Total	3660	912	363	175
Single equivalent number of annual cycles with ΔP as noted				
72%	276	67	25	10
61%	512	124	47	18
36%	3,683	889	337	128

However, upon further examination of the sleeves, the mill grooves greatly benefited the fit-up between the sleeve and the pipe. The mill groove provided relief for the approximately 1/16 inch backing strip resulting in tighter fit, shown in Figure 4-1. The gap generated due to the backing strip in the non-mill-

[1] Kiefner, J.F. et al., Estimating Fatigue Life for Pipeline Integrity Management, Paper No. IPC04-0167, Presented at the International Pipeline Conference, Calgary, Canada, October 4–8, 2008.

groove sample results in a looser fit-up. The effect of sleeve fit-up was examined in a previous study performed at ADV and funded by Allan Edwards (ADV PN 100160). This study found that a looser fitting sleeve resulted in an expected life 3.5 times shorter than a tighter fitting sleeve once the annulus space is pressurized. This result only occurs when the annulus space becomes pressurized, so if the underlying feature remains stable, this effect does not come into consideration.

The installed mill groove locally reduces the wall thickness along the length of the sleeve. Therefore, it seems reasonable to account for and consider the reduction in wall thickness when specifying the sleeve wall thickness to ensure full pressure capacity either to the pipeline's maximum operating pressure or full pressure capacity based on the nominal carrier pipe properties.



Figure 4-1: Photograph after sectioning sleeves: Left – sleeve without mill groove; Right – sleeve with mill groove. Numbered scale divisions are inches.

APPENDIX A: CALIBRATION SHEETS

Specialloy Texas, Inc.
11702 Brittmoore Park
Houston, Texas 77041
(713) 827-7776

SPECIALLOY INSTRUMENTATION

Certificate of Calibration

Transmitter

Certificate No. 050421-1 **Print Date** 5/4/2021

Unit Under Test(UUT)

UUT ID:	88609-GS	**Calibration Date:**	5/4/2021
Model:	TD10000BGS00003Q002X	**Expiration Date:**	5/4/2022
Range:	[0~5000]psi	**Manufacturer:**	TRANSDUCERS DIRECT
Resolution:	0.001mA	**Customer:**	ADV INTEGRITY
Application Site:	Specialloy Calibration Laboratory		
Accuracy:	0.25% FS		

Calibration Results

	Result	Max Error	Temperature	Humidity	Atmospheric pressure
As Found	In tolerance	0.92 %	73°F	52%	0.991 kPa
As Left	In tolerance	0.92 %	73°F	52%	0.991 kPa

Calibration Data - As Found

Max Error: 0.92 %

SetPoints psi	Reference psi	Nominal mA	Reference mA	Tolerance mA	Deviation mA	Error (%)
0	0	4.000	4.074	0.040	0.074	0.46
1250	1248	7.987	8.087	0.040	0.100	0.62
2500	2497	11.990	12.106	0.040	0.115	0.72
3750	3746	15.987	16.118	0.040	0.131	0.82
5000	4994	19.981	20.127	0.040	0.147	0.92
3750	3752	16.006	16.116	0.040	0.110	0.69
2500	2501	12.003	12.102	0.040	0.099	0.62
1250	1256	8.019	8.084	0.040	0.065	0.40
0	0	4.000	4.067	0.040	0.067	0.42

=== As Found Calibration Data End ===

Calibration Data - As Left

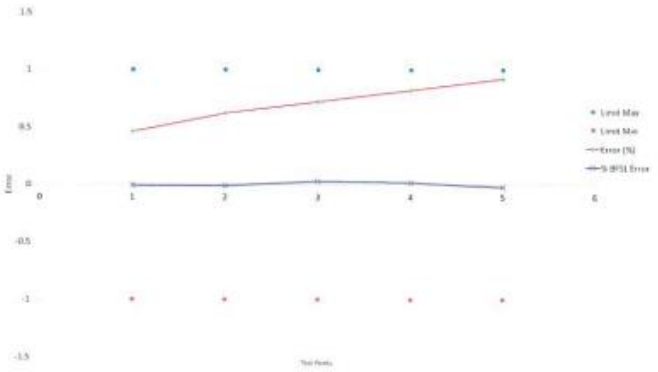
Max Error: 0.92 %

Test Point	Limit Max	Limit Min	SetPoints psi	Reference psi	Nominal mA	Reference mA	Tolerance mA	Deviation mA	Error (%)	BFSL
1	1	-1	0	0	4.000	4.074	0.040	0.074	0.46	4.0746
2	1	-1	1250	1246	7.987	8.087	0.040	0.100	0.62	8.0884
3	1	-1	2500	2497	11.990	12.106	0.040	0.115	0.72	12.1023
4	1	-1	3750	3746	15.987	16.118	0.040	0.131	0.82	16.1162
5	1	-1	5000	4994	19.981	20.127	0.040	0.147	0.92	20.1301
6	1	-1	3750	3752	16.006	16.116	0.040	0.110	0.69	16.1162
7	1	-1	2500	2501	12.003	12.102	0.040	0.099	0.62	
8	1	-1	1250	1256	8.019	8.084	0.040	0.065	0.40	
9	1	-1	0	0	4.000	4.067	0.040	0.067	0.42	

=== As Left Calibration Data End ===

References

Manufacturer	Model	Serial Number	Certificate No.	Due Date	Accuracy	BFSL ERROR: 0.026
Additel Corporation	ADT681 [0~10000]PSI	211H16920048	234805	4/30/2022	0.05%	
—	—	—	—	—	—	
LA CROSSE	584107	TX141TH-BV2	5399219	1/11/2022	(+/-)2F 1%H	



Inspector

All inspections are traceable to the National Institute of Standards and Technology. The Calibration & Certifications have been performed to Specialloy's Quality & Laboratory Procedures. All Calibration Equipment used per ANSI/NCSL Z540-1-1994