Strain-Based Design and Assessment in Critical Areas of Pipeline Systems with Realistic Anomalies

Appendix G: Task 12 Full-Scale Test Results

Draft Final Report

Contract No. DTPH56-14-H-00003

Prepared for

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Pipeline and Hazardous Materials Safety Administration
Office of Pipeline Safety

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C-FER Technologies

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Notice

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Nomenclature

Abbreviations

D	Diameter
D_{min}	Minimum Diameter
D_{may}	Maximum Diameter
D_{nom}	Nominal Diameter
OD	Outside Diameter
ID	Inside Diameter
1D	One Diameter
2D	Two Diameters
SMYS	Specified Minimum Yield Strength
VIC	Visual image correlation,

Symbols

ε	Strain

Organizations

PHMSA	Pipeline and Hazardous Materials Safety Administration,
C-FER	C-FER Technologies Inc. (1999)
CRES	Center for Reliable Energy Systems

Appendix G Task 12 Full-Scale Test Results

Task 12 Tension Test

Specimen Identification: **12 Baseline (Tension)**
C-FER Specimen Number: **X70-ERW-3-12bl**

C-FER Test Summary: **Rev. 3,June 23, 2017**
Test Date: **8-Jul-15**

Pipe Characteristics

Nominal OD (mm) =	323.85
Average OD (mm) =	324.96
Nominal Wall Thickness (mm) =	7.14
Average Wall Thickness (mm) =	7.11
Specimen Length (mm) =	1778.8
Length/OD =	5.5
SMYS (MPa) =	483

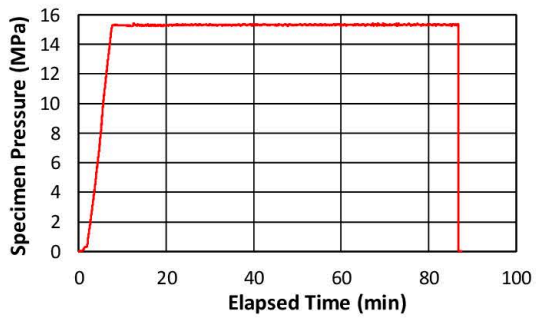
Test Loading Procedure

1. Specimen was pressurized at at rate of ~2.8 MPa/min to 15.3 MPa while the machine held the ends fixed.
2. Specimen was then subjected to axial tension at a rate of 1.6 mm/min (with internal pressure maintained) until the specimen ruptured.

Test Parameters

Target Net Pressure (72% SMYS) (MPa) =	15.3
Actual Mean Net Pressure During Testing (MPa) =	2.6

Internal Pressure vs Time



Test Results

Maximum Net Tensile Load (kN) =	4769
Maximum Net Axial Stress (MPa) =	671
Pressure at Failure (MPa) =	15.3

Displacement Transducers

Remote Top Strain at Failure (%) =	6.08
Remote Bottom Strain at Failure (%) =	7.18
2D Bridging Strain at Failure (%) =	7.56

VIC 3D

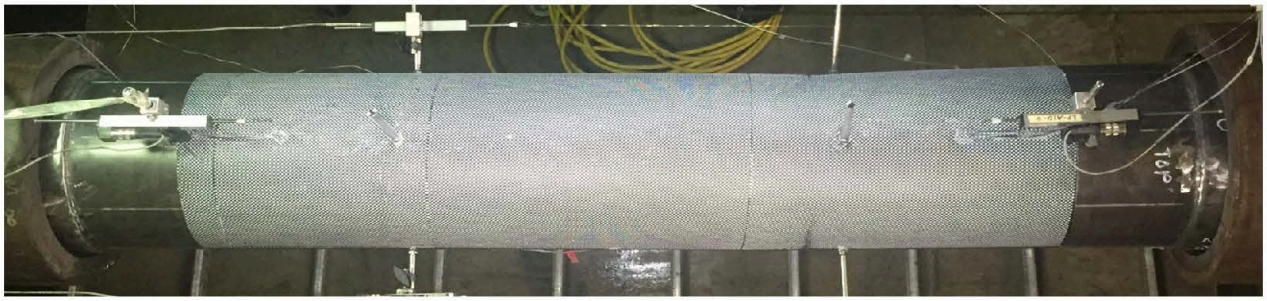
Remote Top Strain at Failure (%) =	6.68
Remote Bottom Strain at Failure (%) =	7.30
2D Bridging Strain at Failure (%) =	7.66

Strain Gauges

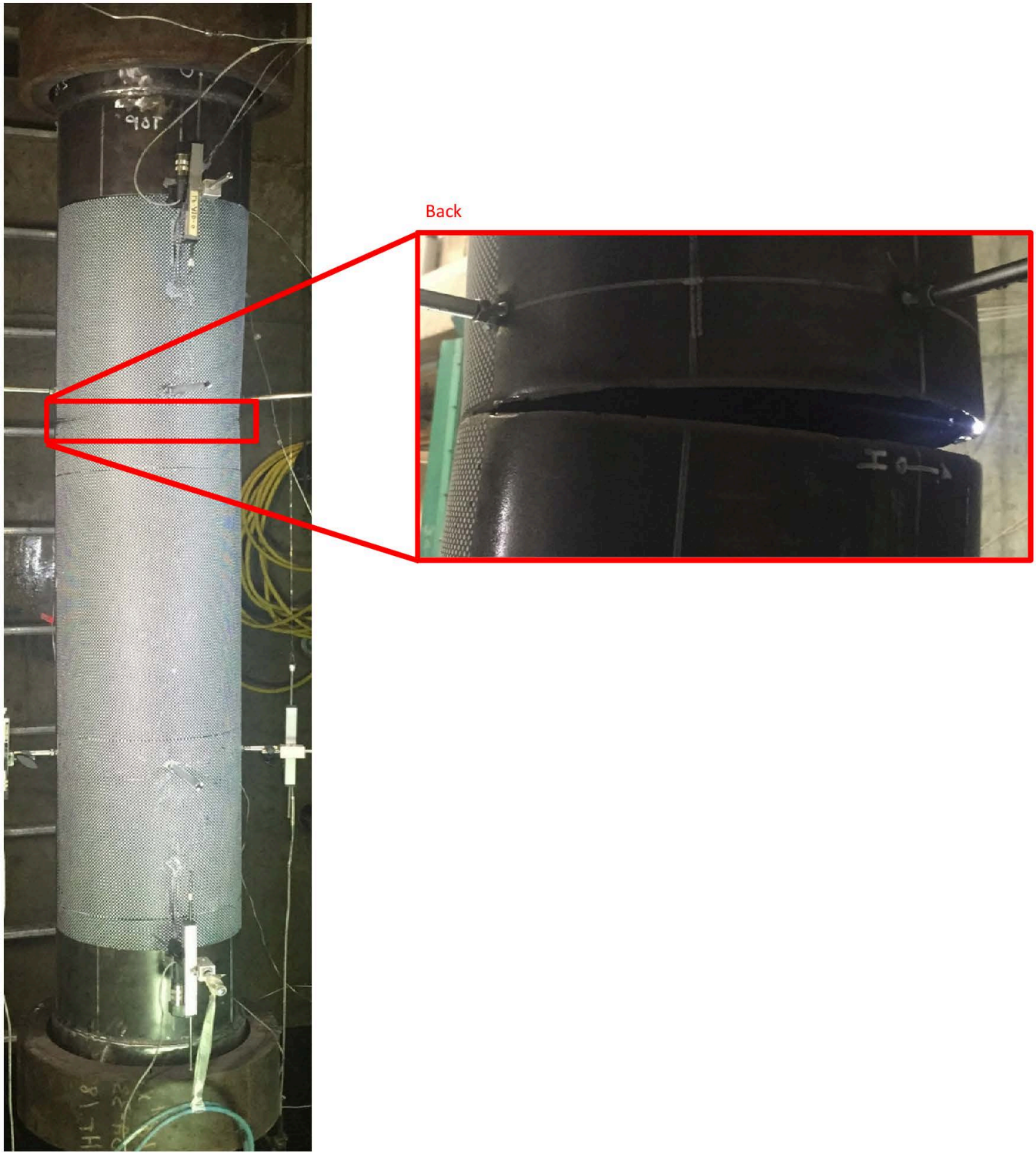
Top Strain at Failure (%) =	10.86
Bottom Strain at Failure (%) =	11.09
Hoop Strain at Failure (%) =	10.88

General Comments:

Pipe after Testing:

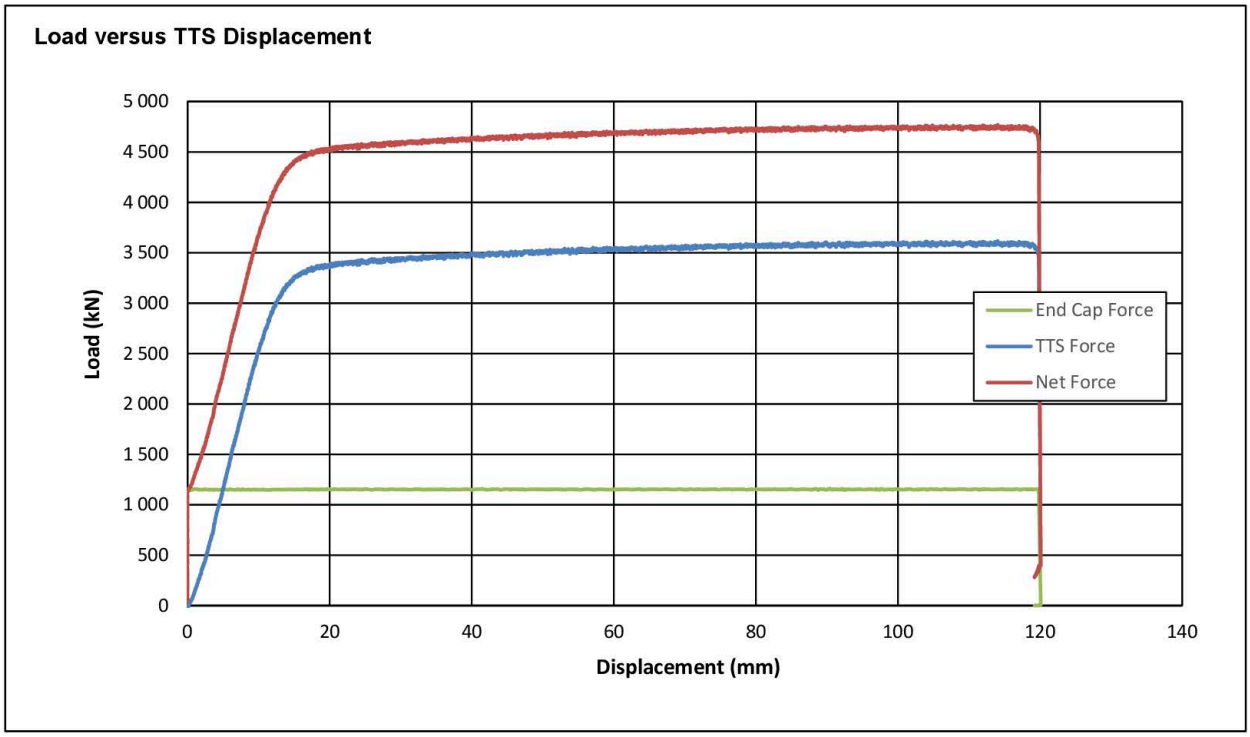


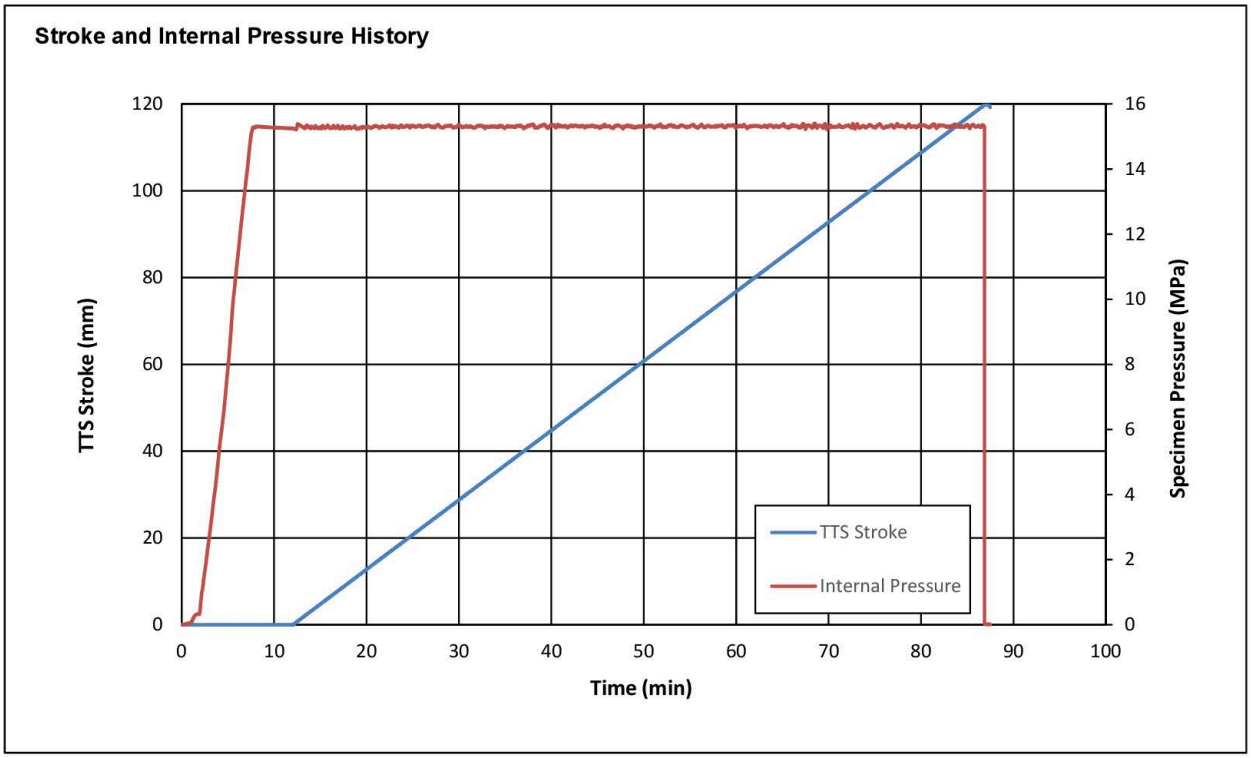
Failure Location



Compiled By:	Date:	Title:	C-FER Technologies
SLS	16-May-16	**Failure Location**	
Reviewed:	Date:	Specimen Identification:	
CMJT	19-May-17	**12 Baseline (Tension)**	Page 2 of 9

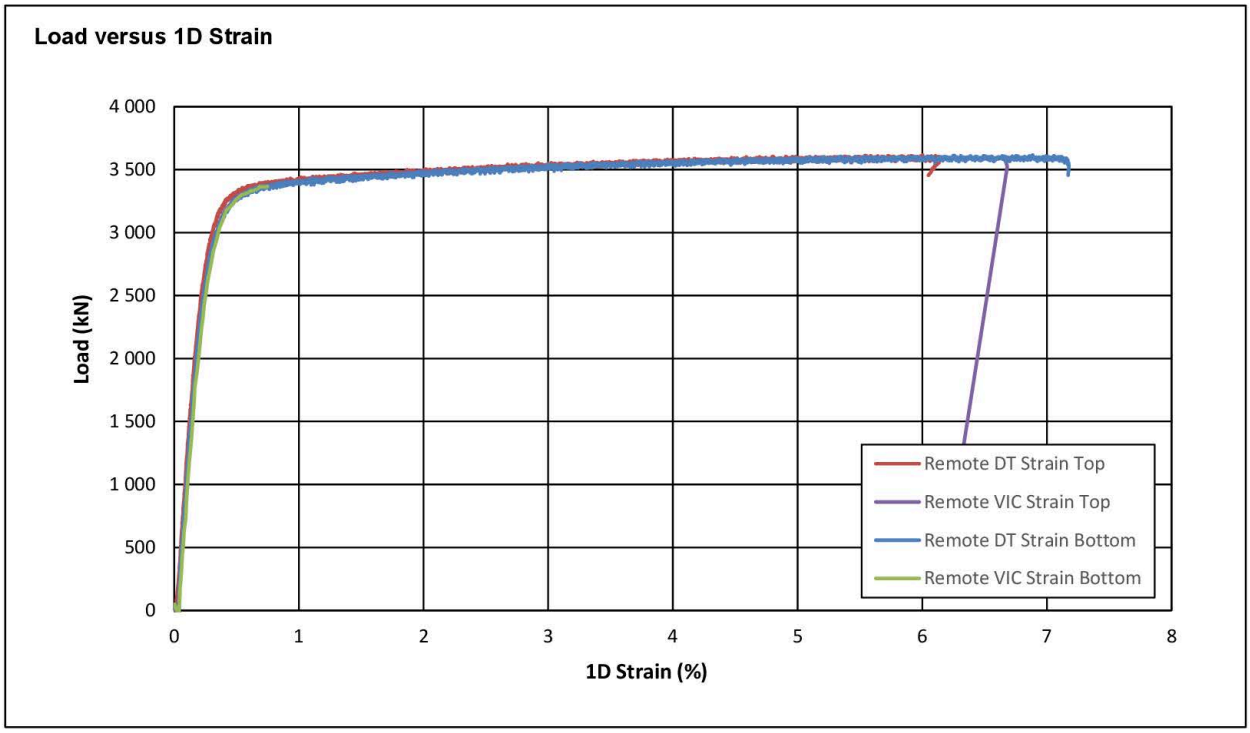
Load Plots

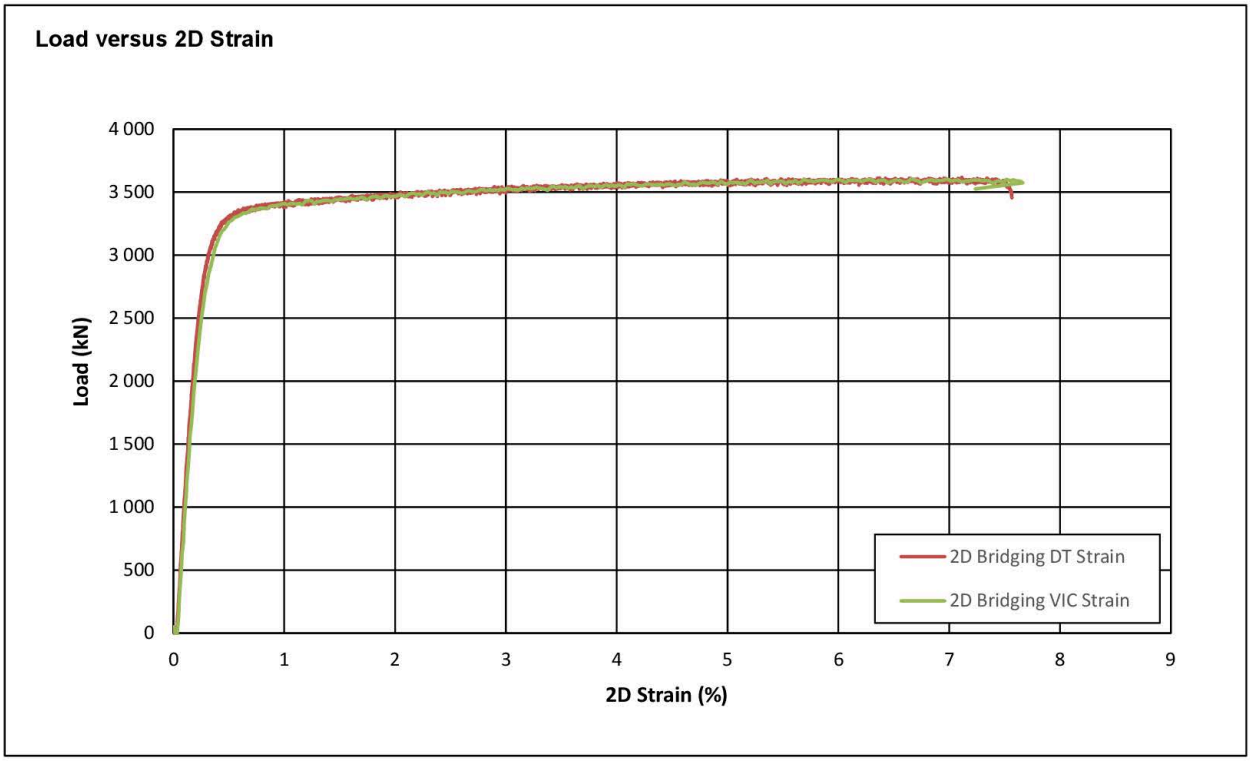




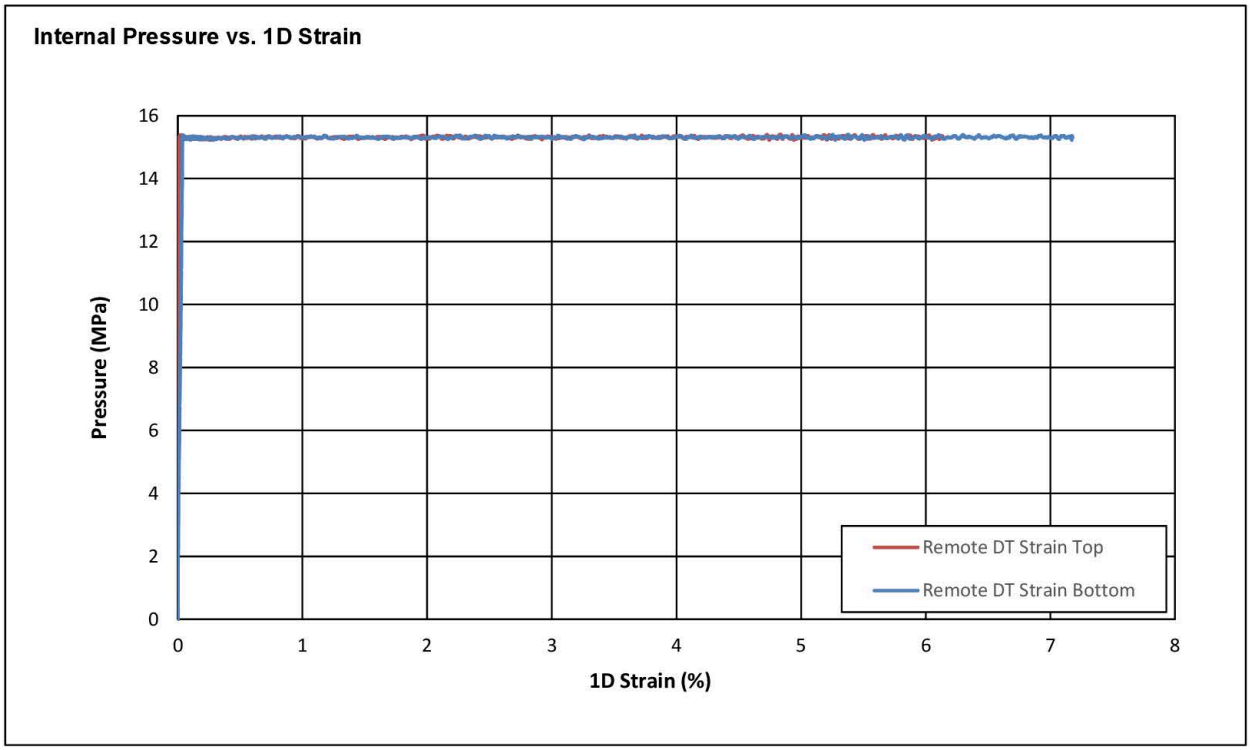
Compiled By:	Date:	Title:	C-FER Technologies
SLS	12-May-16	**Task 12 Tension Test**	
Reviewed:	Date:	Specimen Identification:	
CMJT	19-May-17	**12 Baseline (Tension)**	Page 3 of 9

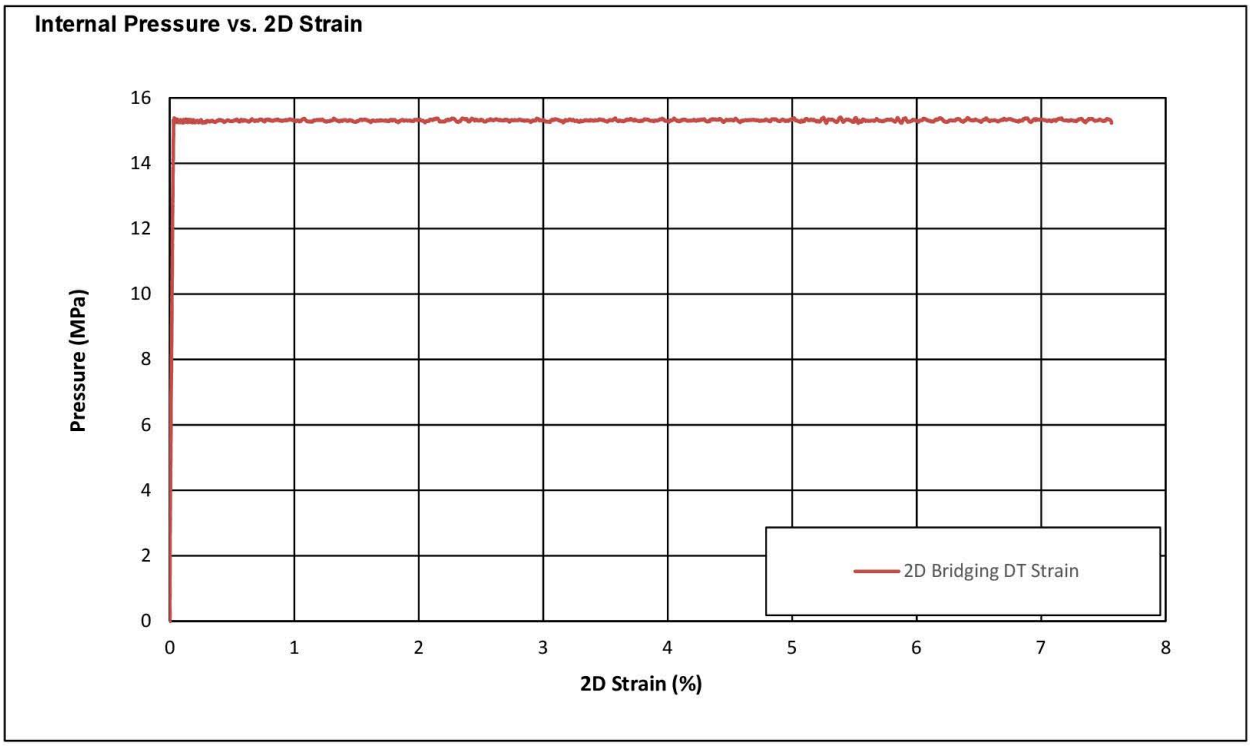
Strain Plots





Strain Plots





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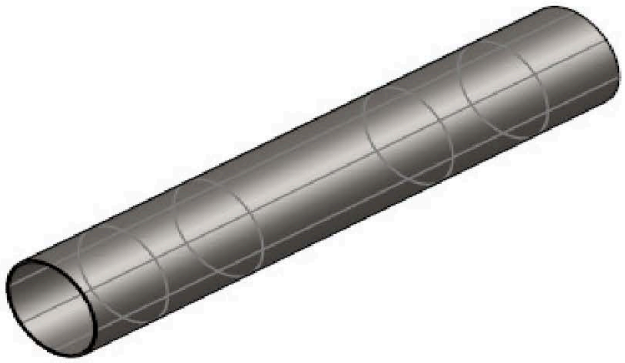
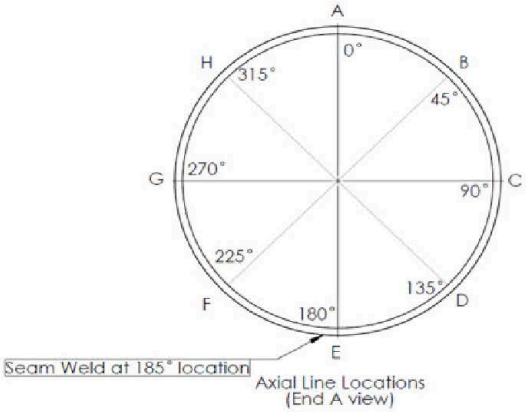
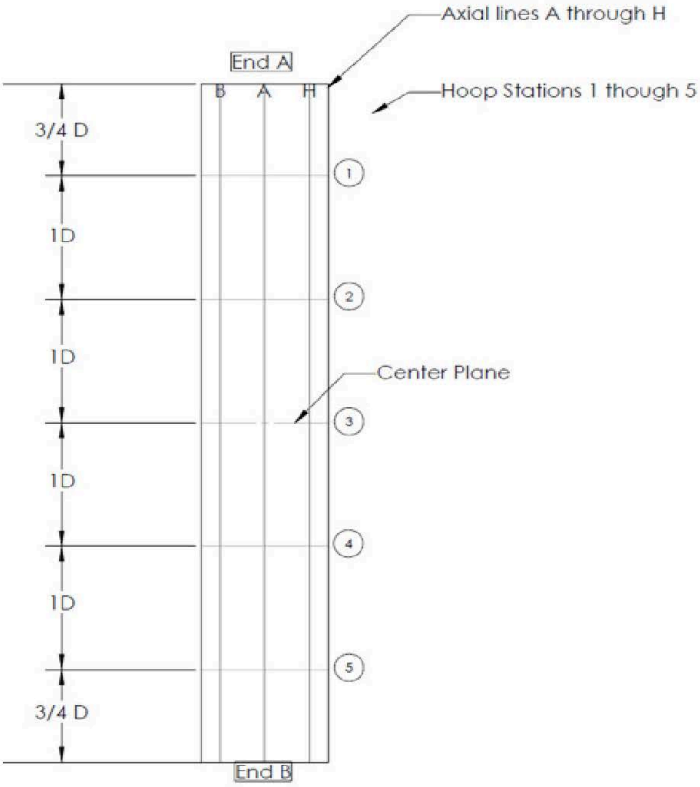
SLS	4-May-16	**Task 12 Tension Test**	
Reviewed:	Date:	Specimen Identification:	
CMJT	19-May-17	**12 Baseline (Tension)**	Page 5 of 9

Pipe Measurements







Pre test Pup Lengths:

End A to 1	239	mm
1 to 2	324	mm
2 to 3	325	mm
3 to 4	326	mm
4 to 5	323	mm
5 to End B	239	mm
Total Length	1 775	mm

Pre Test Pipe Lengths:

Position B	1 775	mm
Position D	1 782	mm
Position F	1 783	mm
Position H	1 775	mm
Average	1 779	mm

Circumferences:

End A measured circumference	1 023	mm
End B measured circumference	1 022	mm

Measurements Taken By:	Date:	Title:	C-FER Technologies
SEB	3-Mar-15	**Task 12 Tension Test**	
Measurements Approved By:	Date:	Specimen Identification:	Page 6 of 9
JHB	3-Mar-15	**12 Baseline (Tension)**	

Diameter Measurements

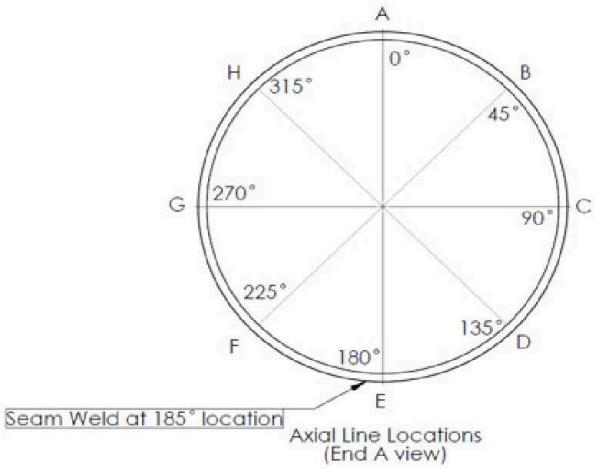
Micrometer: Mitutoyo 12-18" No.1018

304.8 mm (12 in) Configuration (all spans) *

12 inch Verification rod reading No.167-152: 12.001 inch

13 inch Verification rod reading No.167-152: 13.001 inch

Station	Spanned Positions (mm)			
	A-E	B-F	C-G	D-H
1	325.1	324.9	324.9	325.1
2	325.0	324.8	324.7	325.1
3	324.9	324.7	324.8	325.1
4	325.1	324.8	324.8	325.0
5	325.2	324.9	324.9	325.0



Station	Max. OD (mm)	@ Position	Min. OD (mm)	@ Position	Avg. OD (mm)	Stdev. (mm)	Ovality** (%)	Ovality incl. angle (°)
1	325.15	0	324.89	90	325.02	0.13	0.04	90
2	325.07	135	324.74	90	324.91	0.16	0.05	45
3	325.15	135	324.74	45	324.92	0.17	0.07	90
4	325.15	0	324.79	90	324.95	0.17	0.06	90
5	325.22	0	324.87	90	325.02	0.15	0.06	90

* Imperial micrometer was used and measurements were converted.

$$** Ovality = \frac{(D_{max} - D_{min})}{(D_{nom})} * 100\%$$

Measurements Taken By:	Date:	Title:	C-FER Technologies
SEB	3-Mar-15	**Task 12 Tension Test**	
Measurements Approved By:	Date:	Specimen Identification:	Page 7 of 9
JHB	3-Mar-15	**12 Baseline (Tension)**	

Wall Thickness Measurements

Micrometer Measurements

Pipe Ring Verification

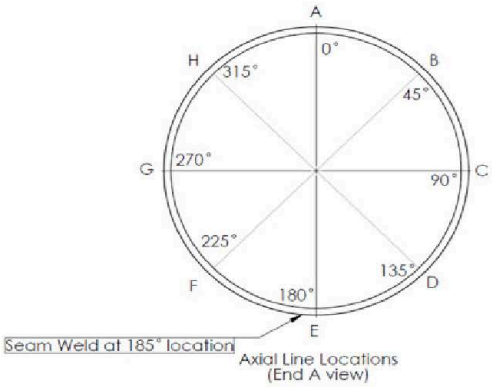
	Micrometer (mm)	Ultrasonic probe (mm)
End A - Position B	7.18	7.19
End A - Position D	7.11	7.14
End A - Position F	7.15	7.14
End A - Position H	7.19	7.18
End B - Position B	7.19	7.18
End B - Position D	7.12	7.11
End B - Position F	7.12	7.10
End B - Position H	7.18	7.17

Micrometer ID:

Mitutoyo 0-1"
No. 293-180
Calibration (1"): 1.00010"

Ultrasonic Probe ID:

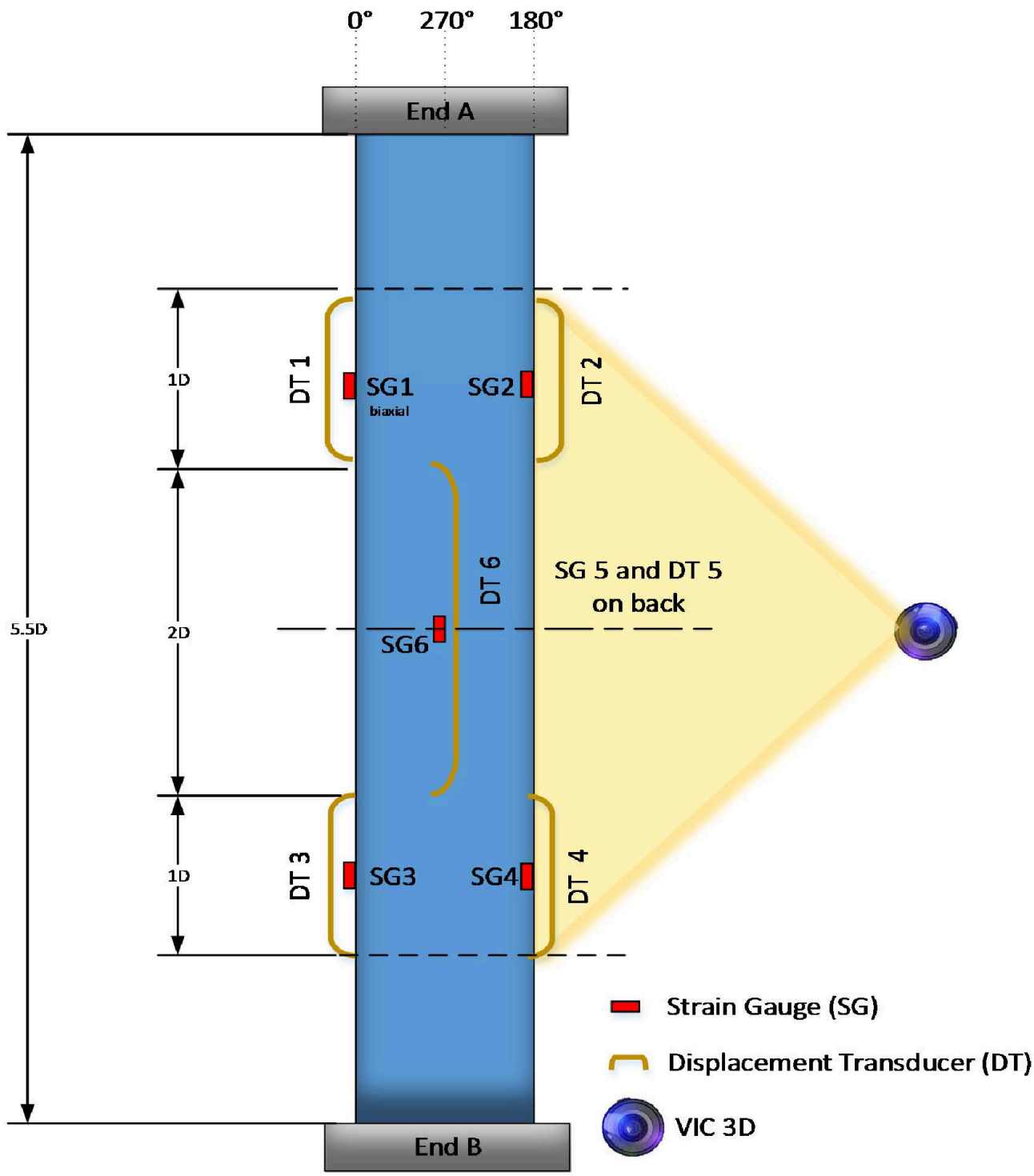
Model: Dakota Ultrasonics MVX ±0.001"
Serial Number: 78000



Ultrasonic Measurements

Station	Wall Thickness (mm)							
	Circumferential Position							
	0°	45°	90°	135°	180°	225°	270°	315°
1	7.17	7.13	7.09	7.07	7.20	7.06	7.11	7.13
2	7.16	7.13	7.07	7.07	7.17	7.08	7.13	7.13
3	7.16	7.13	7.08	7.08	7.21	7.05	7.10	7.12
4	7.16	7.12	7.09	7.07	7.15	7.04	7.11	7.13
5	7.13	7.16	7.08	7.03	7.12	7.06	7.09	7.11

Average Thickness	7.11	**mm**
Standard Deviation	0.04	**mm**



Drawing Done By:	Date:	Title:	C-FER Technologies
SLS	11-May-16	**Task 12 Tension Test**	
Drawing Approved By:	Date:	Specimen Identification:	Page 9 of 9
CMJT	19-May-17	**12 Baseline (Tension)**	

Task 12 Tension Test

Specimen Identification:	**12.a (Tension 1)**	C-FER Test Summary:	**Rev. 3,June 23, 2017**
C-FER Specimen Number:	**X70-ERW-3-12a**	Test Date:	**29-Jun-15**

Pipe Characteristics

Nominal OD (mm) =	323.85
Average OD (mm) =	324.99
Nominal Wall Thickness (mm) =	7.14
Average Wall Thickness (mm) =	7.20
Specimen Length (mm) =	1786.9
Length/OD =	5.5
SMYS (MPa) =	483

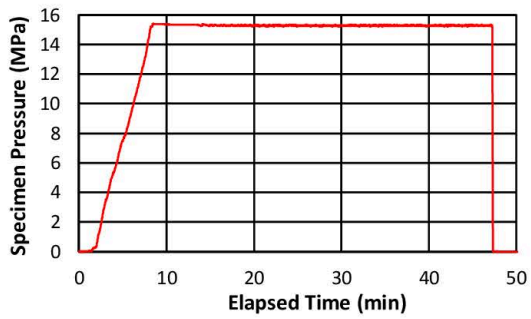
Test Loading Procedure

1. Specimen was pressurized at at rate of ~2.8 MPa/min to 15.3 MPa while the machine held the ends fixed.
2. Specimen was then subjected to axial tension at a rate of 1.6 mm/min (with internal pressure maintained) until the specimen ruptured.

Test Parameters

Target Net Pressure (72% SMYS) (MPa) =	15.3
Actual Mean Net Pressure During Testing (MPa) =	15.3

Internal Pressure vs Time



Test Results

Maximum Net Tensile Load (kN) =	4671
Maximum Net Axial Stress (MPa) =	658
Pressure at Failure (MPa) =	15.3

Displacement Transducers

Remote Top Strain at Failure (%) =	2.49
Remote Bottom Strain at Failure (%) =	2.83
2D Bridging Strain at Failure (%) =	2.96

VIC 3D

Remote Top Strain at Failure (%) =	2.39
Remote Bottom Strain at Failure (%) =	2.67
2D Bridging Strain at Failure (%) =	2.93

Strain Gauges

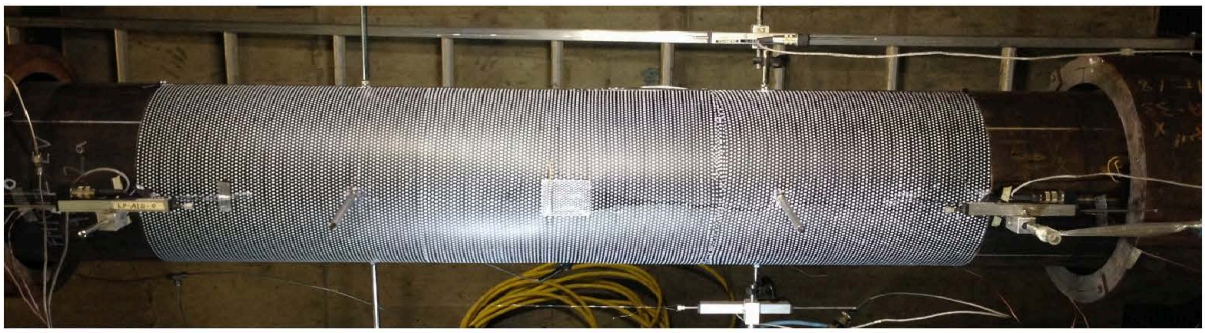
Top Strain at Failure (%) =	2.60
Bottom Strain at Failure (%) =	2.83
Hoop Strain at Failure (%) =	0.06

Anomaly - Shallow Corrosion Patch

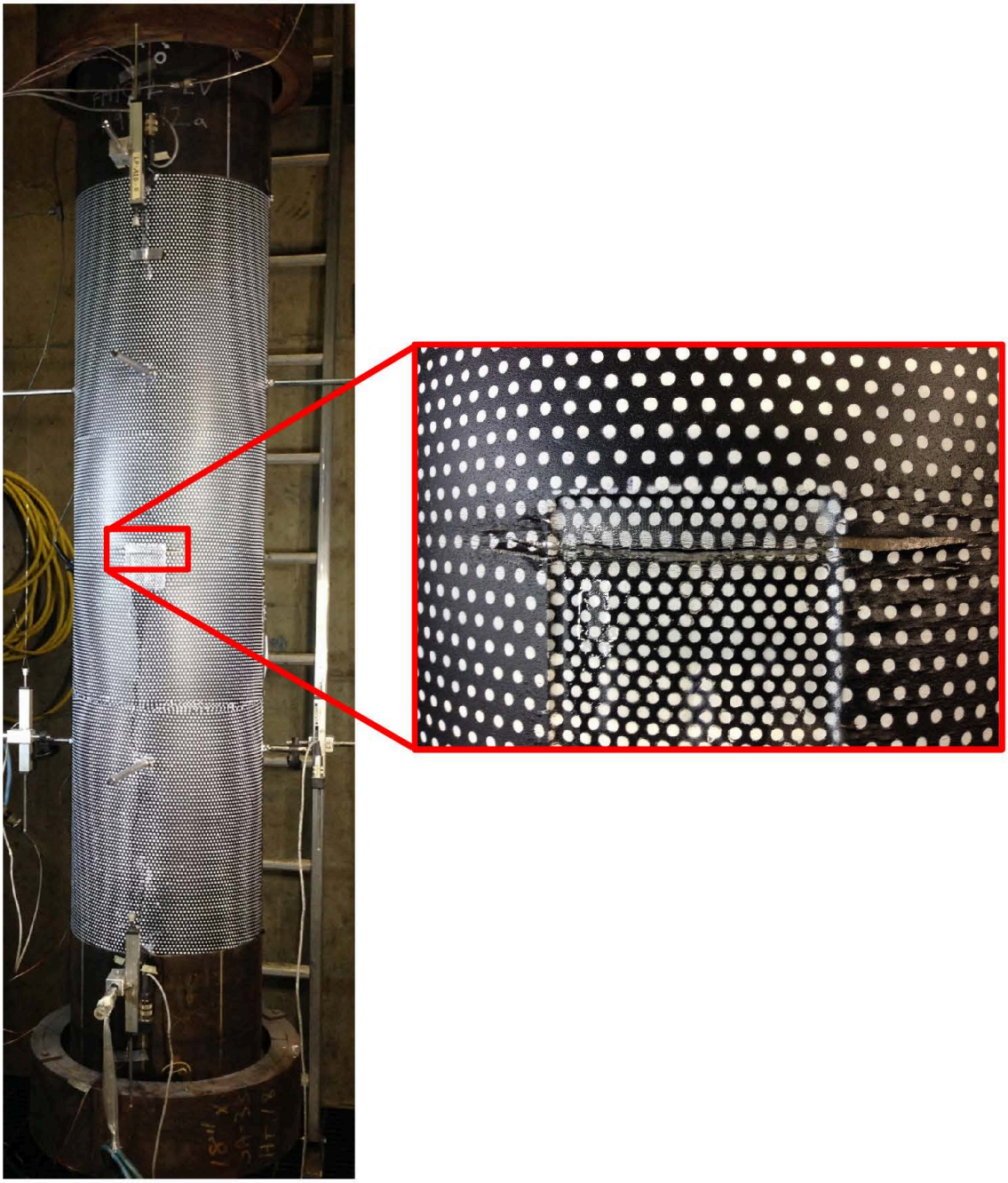
	Length	Width	Depth
Nominal Dimensions =	0.2D	0.2D	0.25t
Nominal Dimensions (mm) =	64.77	64.77	1.78
Measured Dimensions (mm) =	64.8	62.7	1.70

General Comments:

Pipe after Testing:

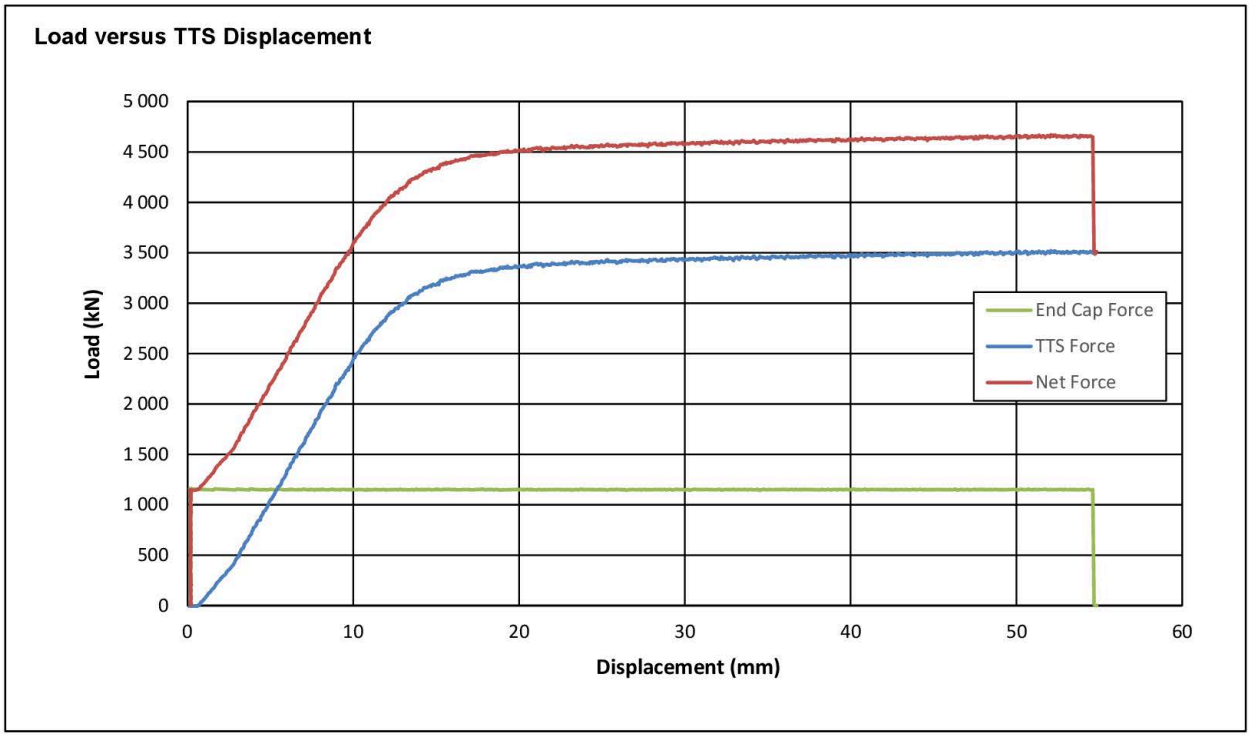


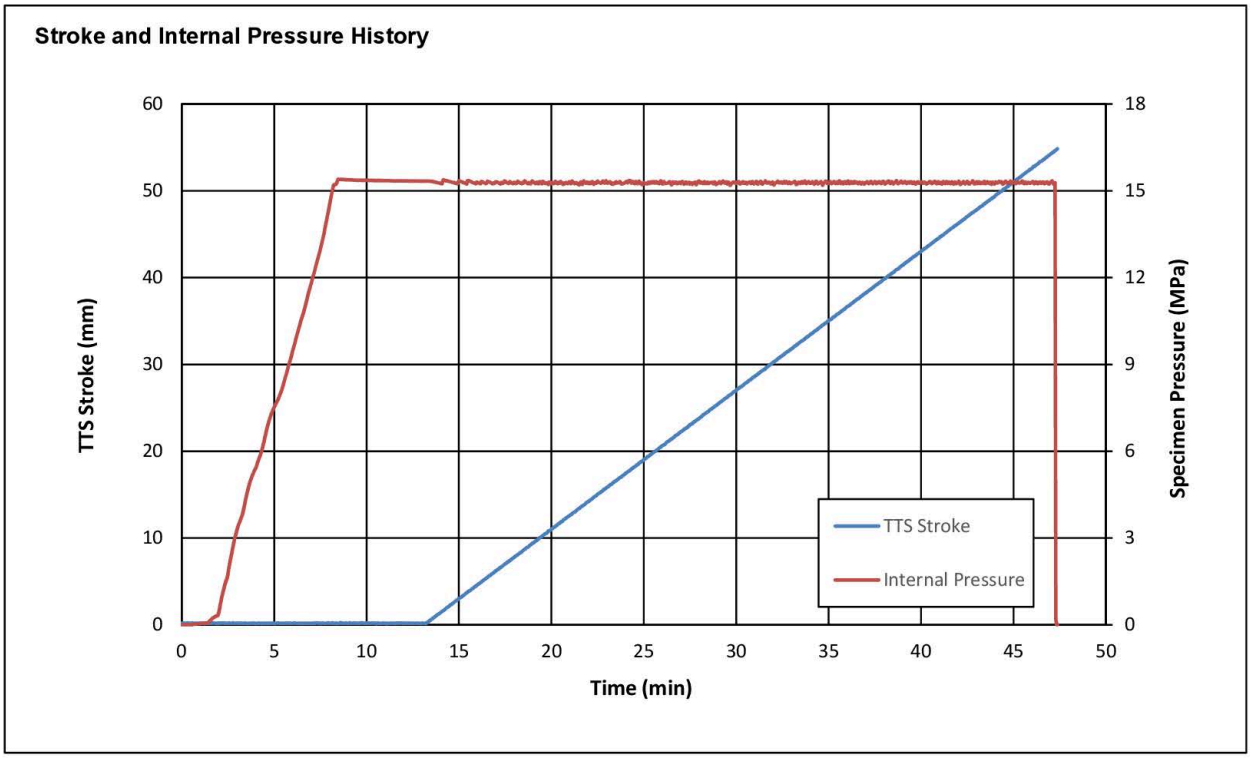
Failure Location



Compiled By:	Date:	Title:	C-FER Technologies
SLS	16-May-16	**Failure Location**	
Reviewed:	Date:	Specimen Identification:	Page 2 of 9
CMJT	19-May-17	**12.a (Tension 1)**	

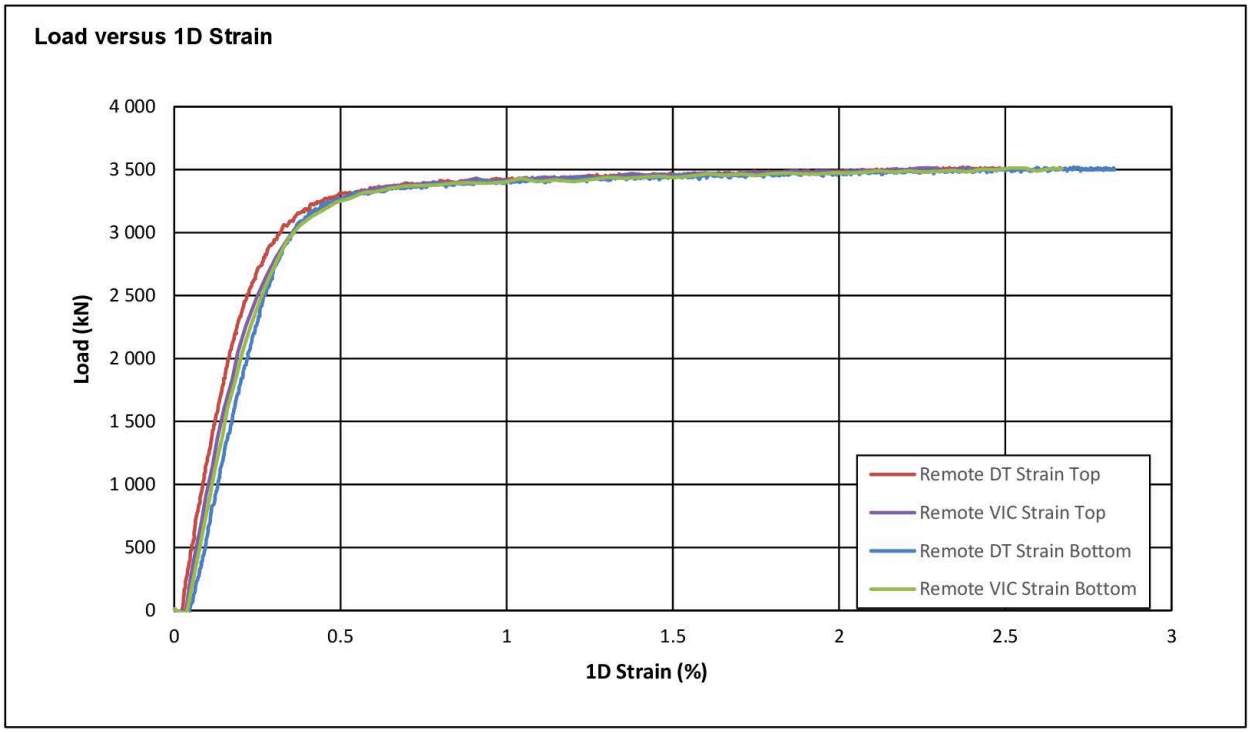
Load Plots

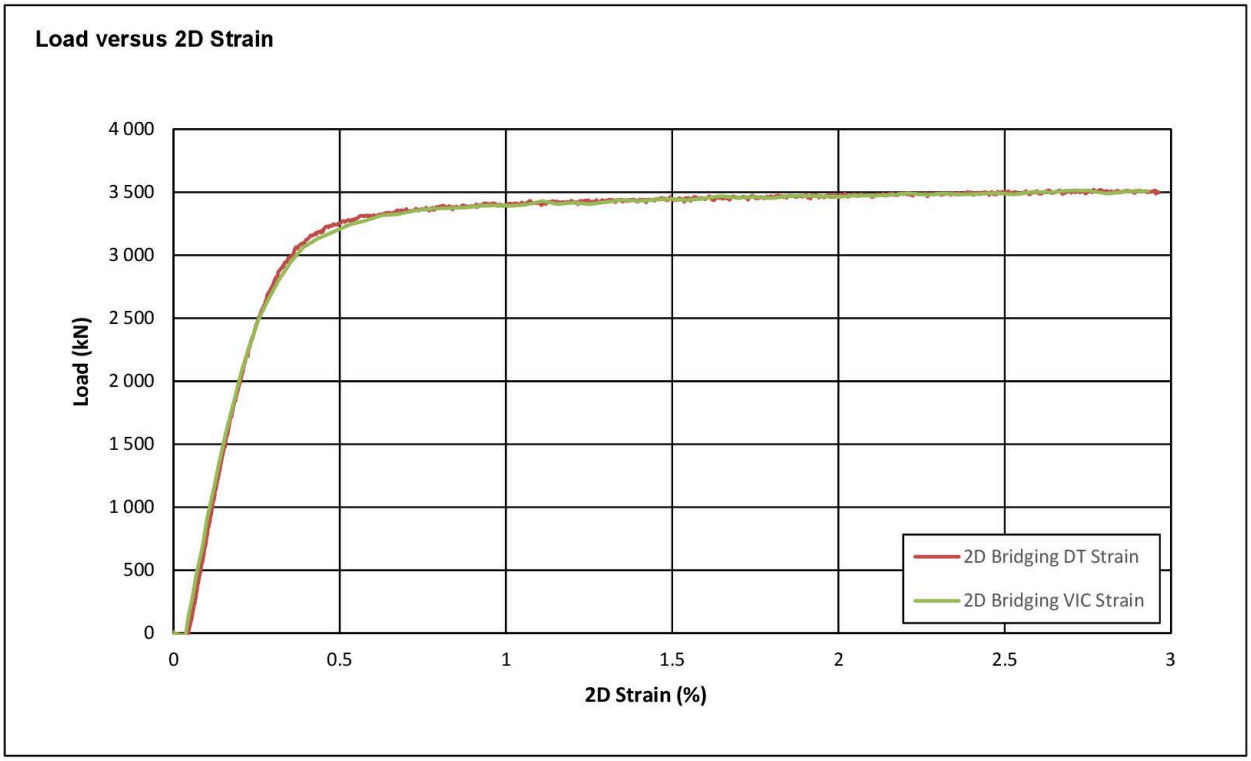




Compiled By:	Date:	Title:	C-FER Technologies
SLS	4-May-16	**Task 12 Tension Test**	
Reviewed:	Date:	Specimen Identification:	
CMJT	19-May-17	**12.a (Tension 1)**	Page 3 of 9

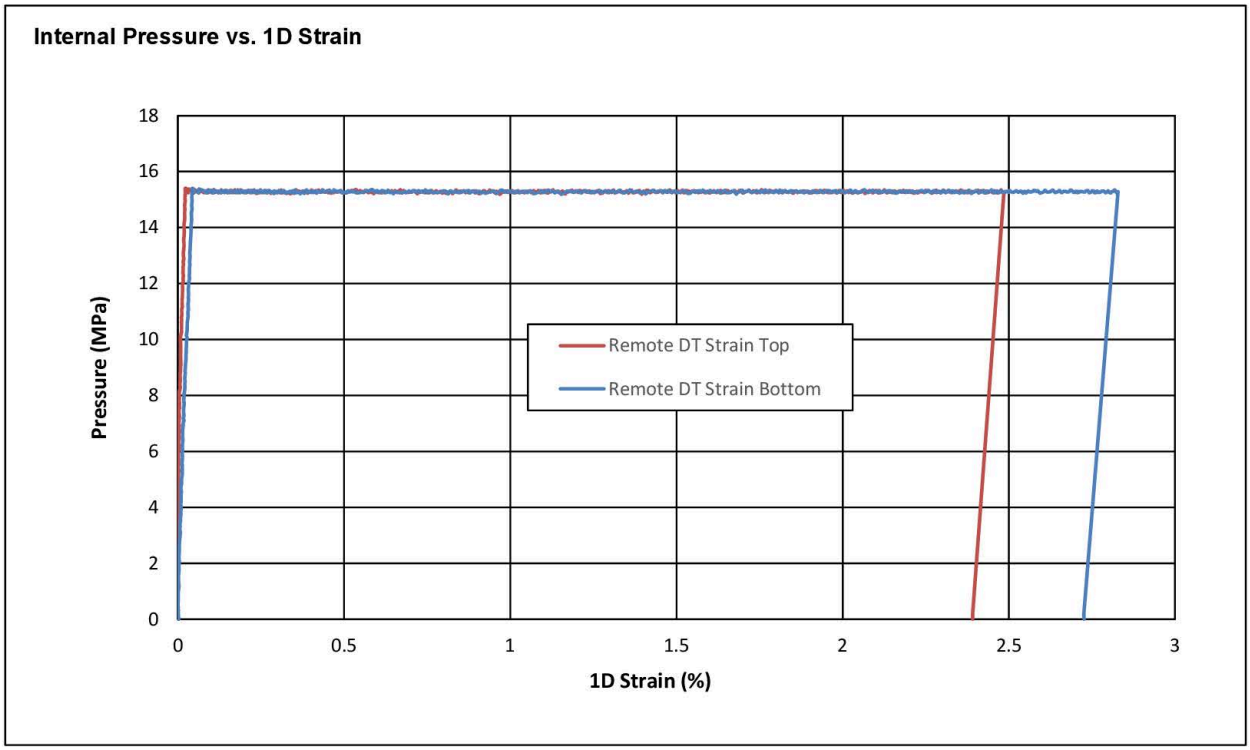
Strain Plots

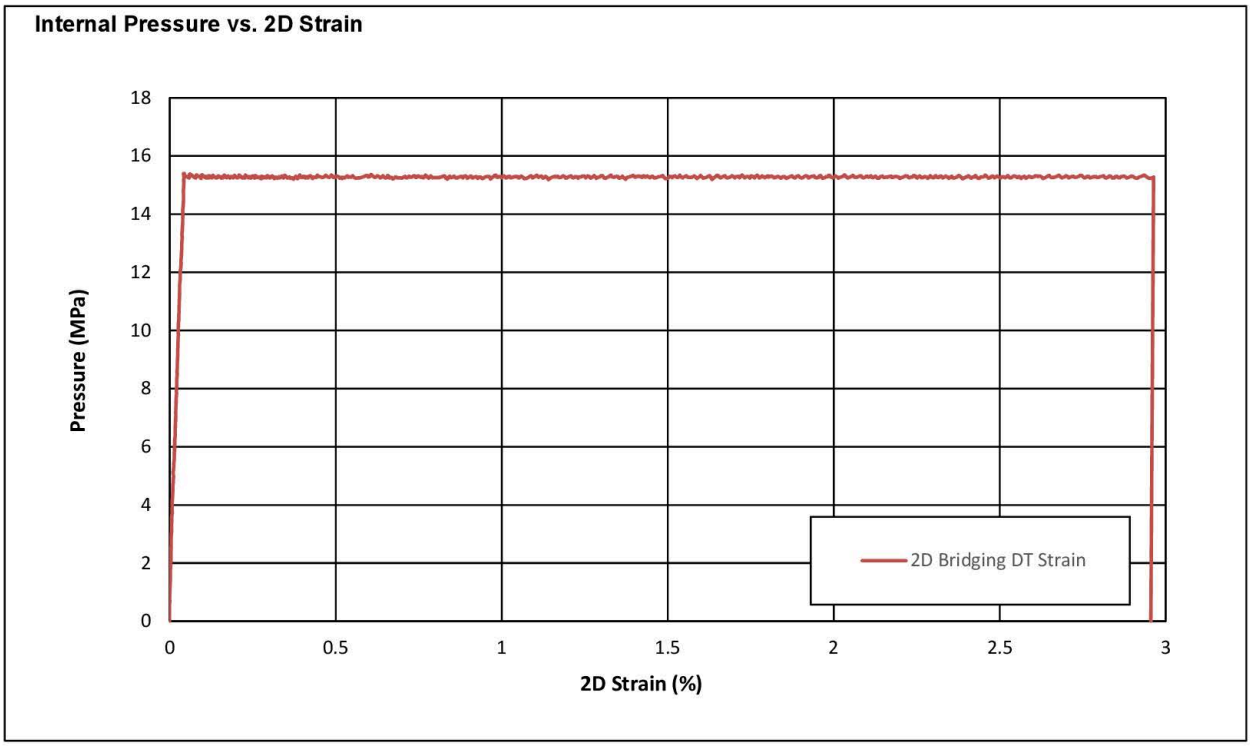




Compiled By:	Date:	Title:	C-FER Technologies
SLS	4-May-16	**Task 12 Tension Test**	
Reviewed:	Date:	Specimen Identification:	
CMJT	19-May-17	**12.a (Tension 1)**	Page 4 of 9

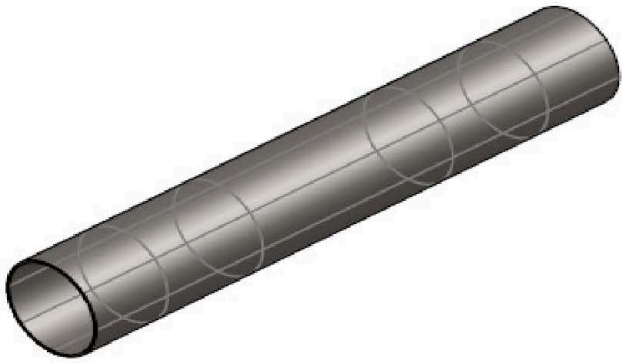
Strain Plots

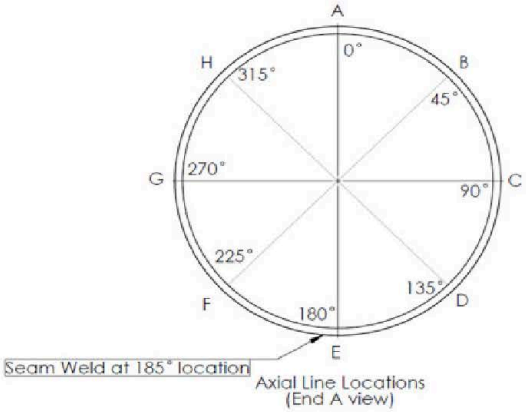


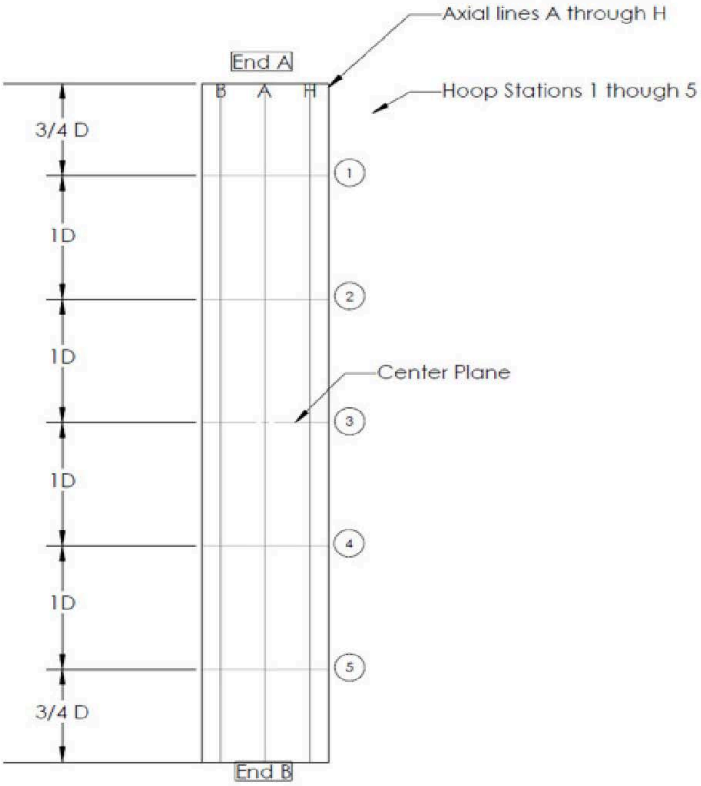


Compiled By:	Date:	Title:	C-FER Technologies
SLS	4-May-16	**Task 12 Tension Test**	
Reviewed:	Date:	Specimen Identification:	
CMJT	19-May-17	**12.a (Tension 1)**	Page 5 of 9

Pipe Measurements







Pre test Pup Lengths:

End A to 1	243	mm
1 to 2	325	mm
2 to 3	324	mm
3 to 4	324	mm
4 to 5	324	mm
5 to End B	247	mm
Total Length	1 785	mm

Pre Test Pipe Lengths:

Position B	1 786	mm
Position D	1 788	mm
Position F	1 787	mm
Position H	1 787	mm
Average	1 787	mm

Circumferences:

End A measured circumference	1 023	mm
End B measured circumference	1 023	mm

Measurements Taken By:	Date:	Title:	C-FER Technologies
SEB	3-Mar-15	**Task 12 Tension Test**	
Measurements Approved By:	Date:	Specimen Identification:	Page 6 of 9
JHB	3-Mar-15	**12.a (Tension 1)**	

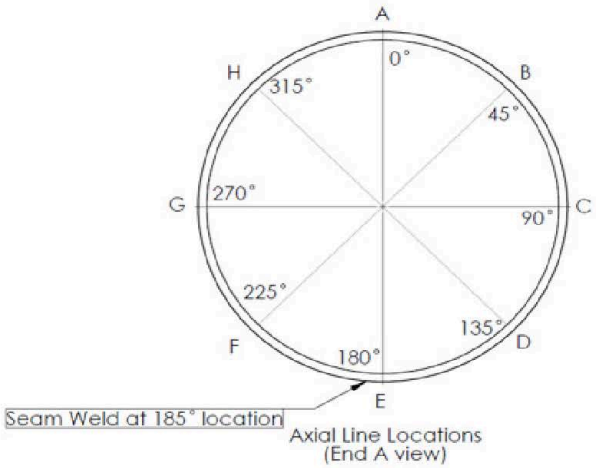
Diameter Measurements

Micrometer: Mitutoyo 12-18" No 167-152

304.8 mm (12 in) Configuration (all spans) *

304.8 mm Verification rod reading No.167-152: 304.80 mm

Station	Spanned Positions (mm)			
	A-E	B-F	C-G	D-H
1	325.22	324.99	324.76	324.87
2	325.09	325.02	324.97	324.97
3	324.89	324.87	324.76	324.92
4	325.27	324.99	324.82	325.12
5	325.09	325.12	325.02	324.99



Station	Max. OD (mm)	@ Position	Min. OD (mm)	@ Position	Avg. OD (mm)	Stdev. (mm)	Ovality** (%)	Ovality incl. angle (°)
1	325.22	0	324.76	90	324.96	0.20	0.08	90
2	325.09	0	324.97	90	325.01	0.06	0.02	90
3	324.92	135	324.76	90	324.86	0.07	0.03	45
4	325.27	0	324.82	90	325.05	0.19	0.07	90
5	325.12	45	324.99	135	325.06	0.06	0.02	90

* Imperial micrometer was used and measurements were converted.

$$** Ovality = \frac{(D_{max} - D_{min})}{(D_{nom})} * 100\%$$

Measurements Taken By:	Date:	Title:	C-FER Technologies
SEB	3-Mar-15	**Task 12 Tension Test**	
Measurements Approved By:	Date:	Specimen Identification:	Page 7 of 9
JHB	3-Mar-15	**12.a (Tension 1)**	

Wall Thickness Measurements

Micrometer Measurements

Pipe Ring Verification

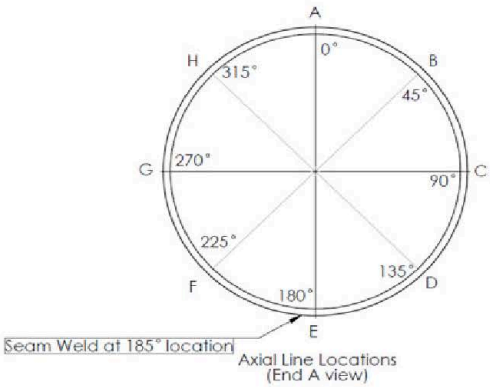
	Micrometer (mm)	Ultrasonic probe (mm)
End A - Position B	7.26	7.26
End A - Position D	7.19	7.17
End A - Position F	7.23	7.21
End A - Position H	7.26	7.25
End B - Position B	7.22	7.23
End B - Position D	7.16	7.16
End B - Position F	7.18	7.18
End B - Position H	7.22	7.22

Micrometer ID:

Mitutoyo 0-1"
No. 293-180
Calibration (1"): 1.00045"

Ultrasonic Probe ID:

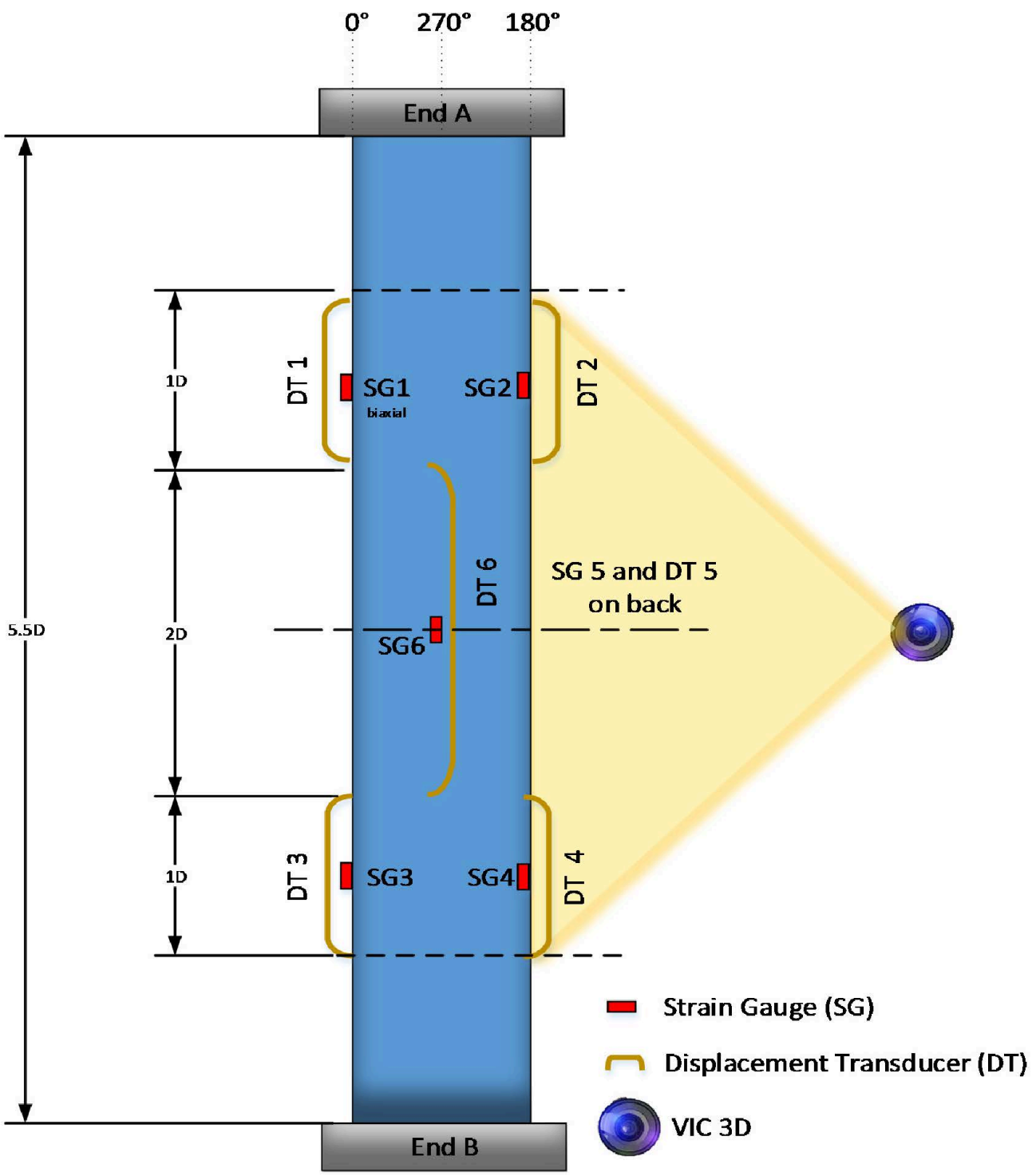
Model: Dakota Ultrasonics MVX ±0.001"
Serial Number: 78000



Ultrasonic Measurements

Station	Wall Thickness (mm)							
	Circumferential Position							
	0°	45°	90°	135°	180°	225°	270°	315°
1	7.28	7.21	7.24	7.18	7.17	7.19	7.22	7.21
2	7.27	7.22	7.22	7.18	7.13	7.19	7.20	7.24
3	7.28	7.24	7.22	7.18	7.17	7.12	7.18	7.26
4	7.23	7.26	7.17	7.15	7.13	7.12	7.17	7.24
5	7.19	7.24	7.19	7.15	7.17	7.15	7.21	7.23

Average Thickness	7.20	**mm**
Standard Deviation	0.04	**mm**



Drawing Done By:	Date:	Title:	C-FER Technologies
SLS	11-May-16	**Task 12 Tension Test**	
Drawing Approved By:	Date:	Specimen Identification:	Page 9 of 9
CMJT	19-May-17	**12.a (Tension 1)**	

Task 12 Tension Test

Specimen Identification:	**12.b (Tension 2)**	C-FER Test Summary:	**Rev. 3,June 23, 2017**
C-FER Specimen Number:	**X70-ERW-3-12b**	Test Date:	**1-Jul-15**

Pipe Characteristics

Nominal OD (mm) =	323.85
Average OD (mm) =	325.05
Nominal Wall Thickness (mm) =	7.14
Average Wall Thickness (mm) =	7.16
Specimen Length (mm) =	1 780.8
Length/OD =	5.5
SMYS (MPa) =	483

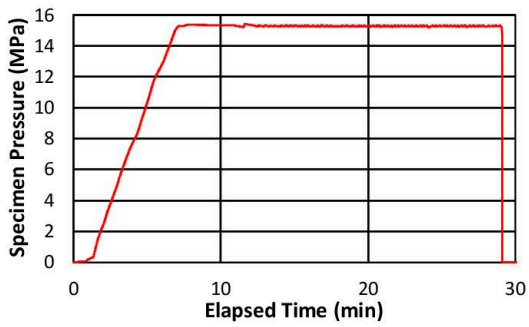
Test Loading Procedure

1. Specimen was pressurized at at rate of ~2.8 MPa/min to 15.3 MPa while the machine held the ends fixed.
2. Specimen was then subjected to axial tension at a rate of 1.6 mm/min (with internal pressure maintained) until the specimen ruptured.

Test Parameters

Target Net Pressure (72% SMYS) (MPa) =	15.3
Actual Mean Net Pressure During Testing (MPa) =	15.3

Internal Pressure vs Time



Test Results

Maximum Net Tensile Load (kN) =	4 613
Maximum Net Axial Stress (MPa) =	649
Pressure at Failure (MPa) =	15.2

Displacement Transducers

Remote Top Strain at Failure (%) =	1.36
Remote Bottom Strain at Failure (%) =	1.05
2D Bridging Strain at Failure (%) =	1.37

VIC 3D

Remote Top Strain at Failure (%) =	1.26
Remote Bottom Strain at Failure (%) =	1.04
2D Strain at Failure (%) =	1.40

Strain Gauges

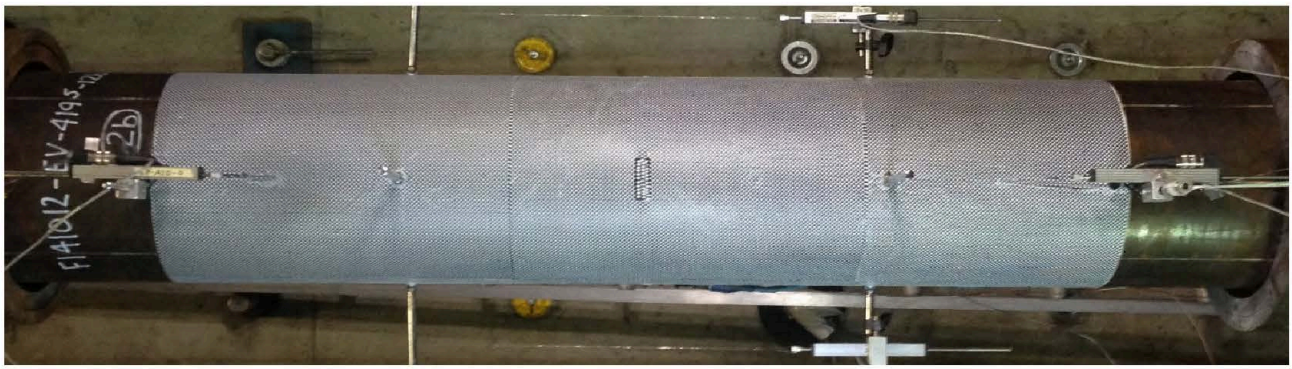
Top Strain at Failure (%) =	1.47
Bottom Strain at Failure (%) =	1.10
Hoop Strain at Failure (%) =	0.09

Anomaly - Circumferential Groove

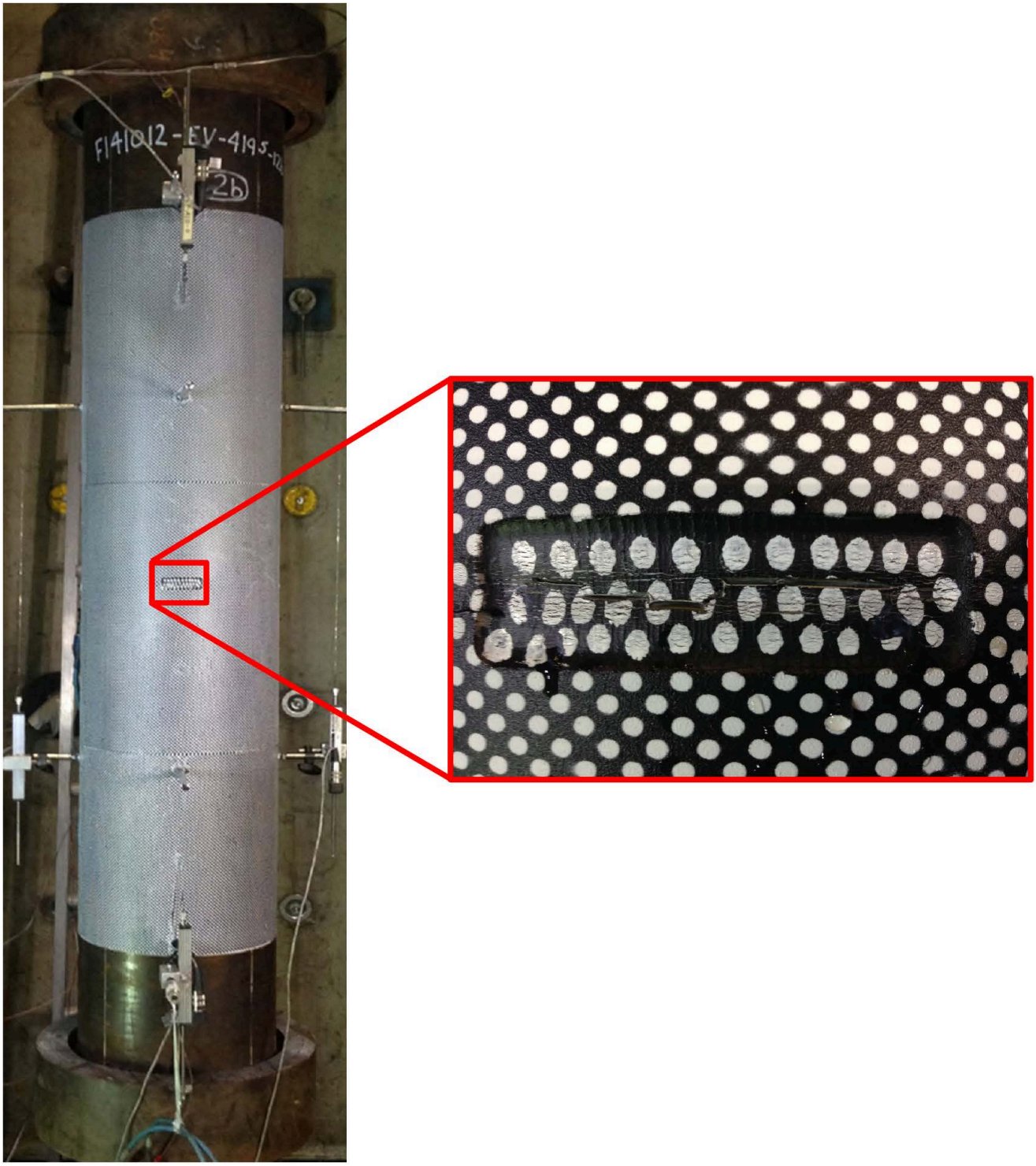
	Length	Width	Depth
Nominal Dimensions =	0.05D	0.2D	0.25t
Nominal Dimensions (mm) =	16.19	64.77	1.78
Measured Dimensions (mm) =	15.7	63.0	1.55

General Comments:

Pipe after Testing:

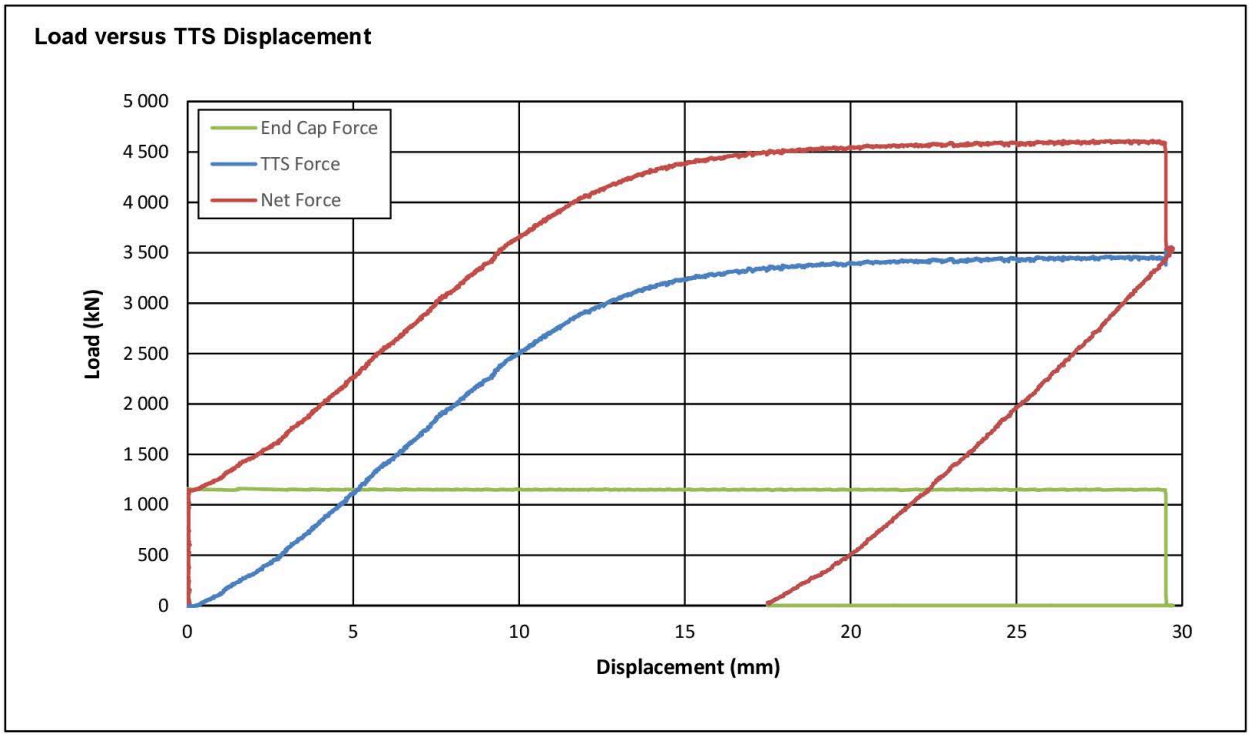


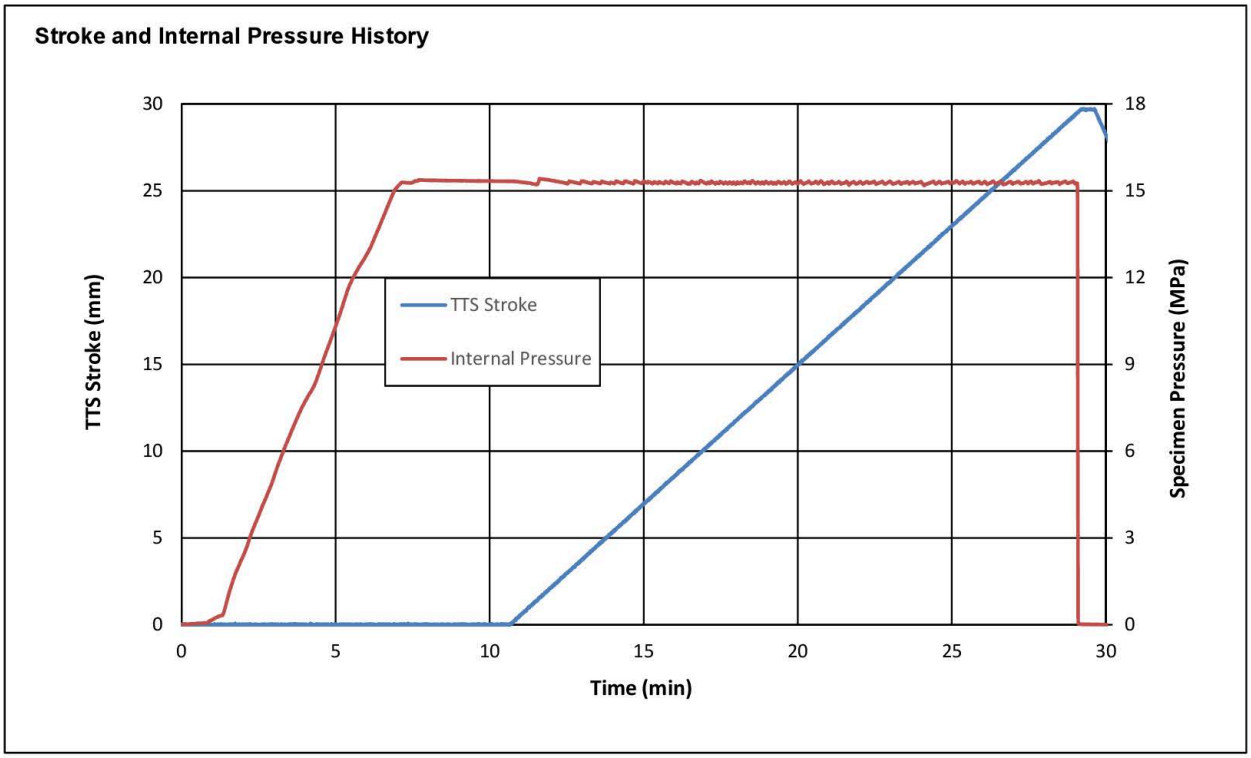
Failure Location



Compiled By:	Date:	Title:	C-FER Technologies
SLS	16-May-16	**Failure Location**	
Reviewed:	Date:	Specimen Identification:	Page 2 of 9
CMJT	19-May-17	**12.b (Tension 2)**	

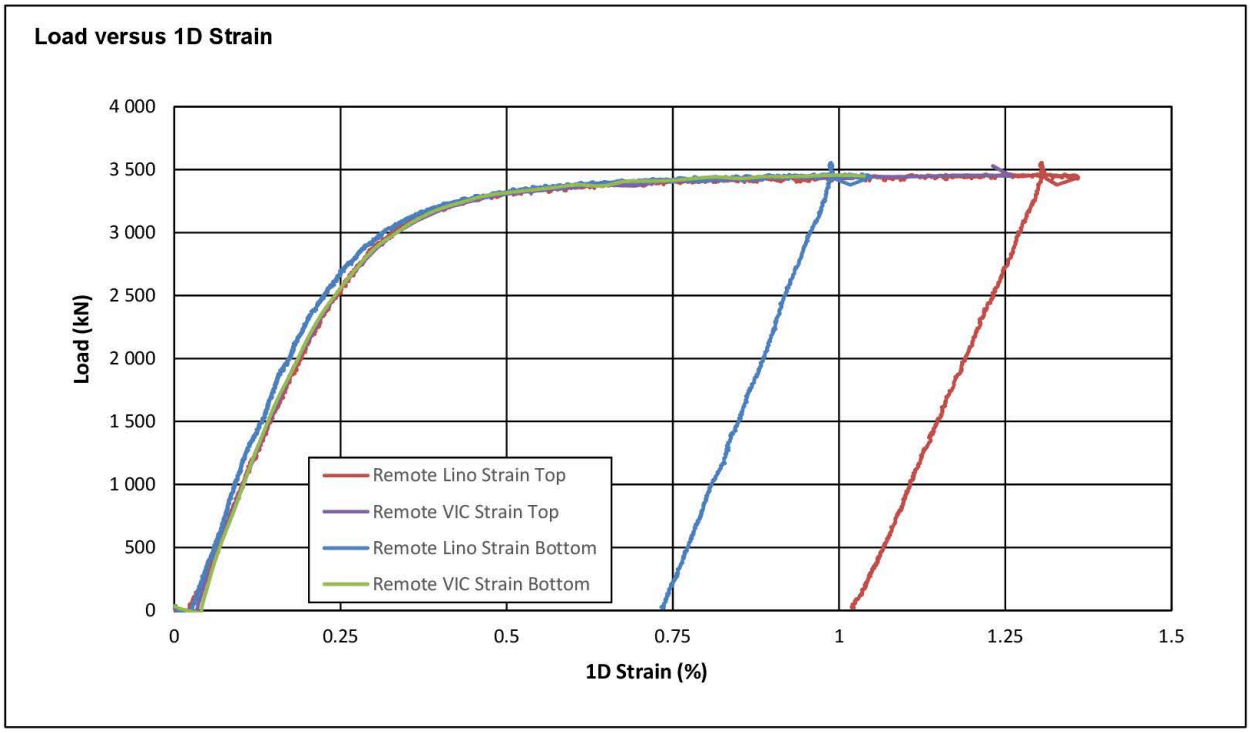
Load Plots

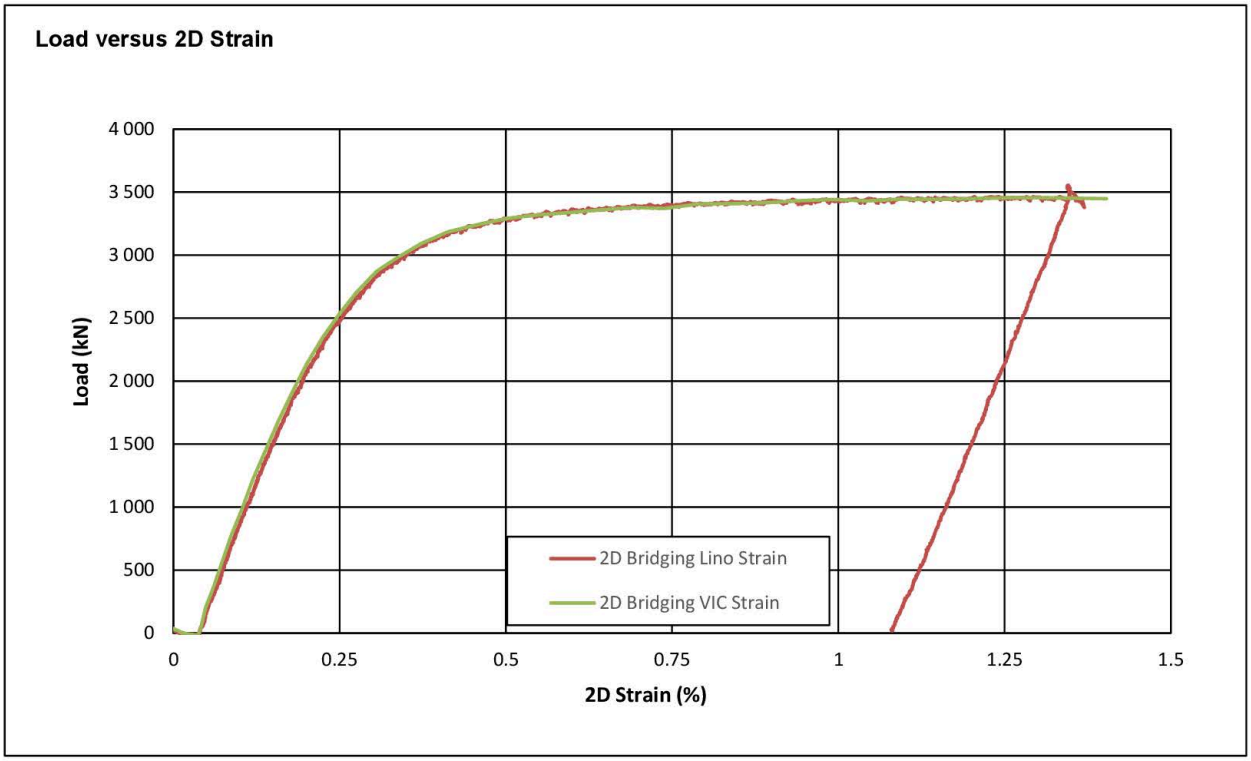




Compiled By:	Date:	Title:	C-FER Technologies
SLS	12-May-16	**Task 12 Tension Test**	
Reviewed:	Date:	Specimen Identification:	
CMJT	19-May-17	**12.b (Tension 2)**	Page 3 of 9

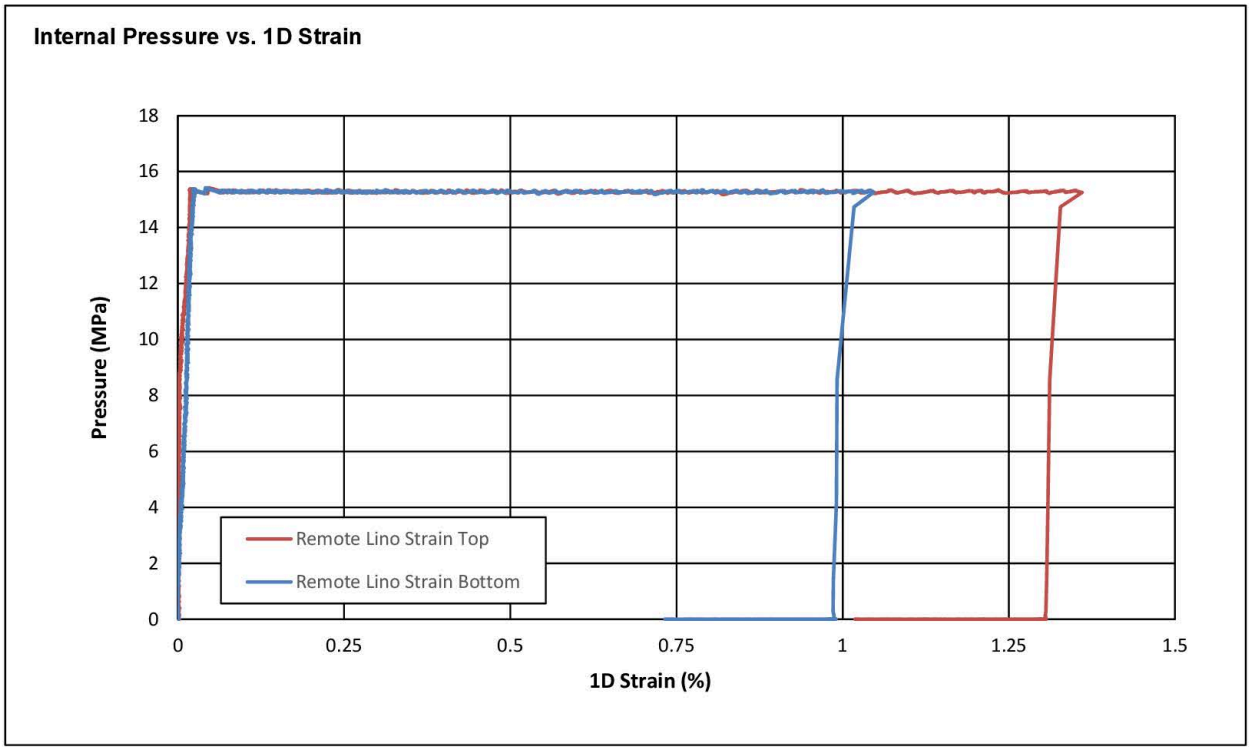
Strain Plots

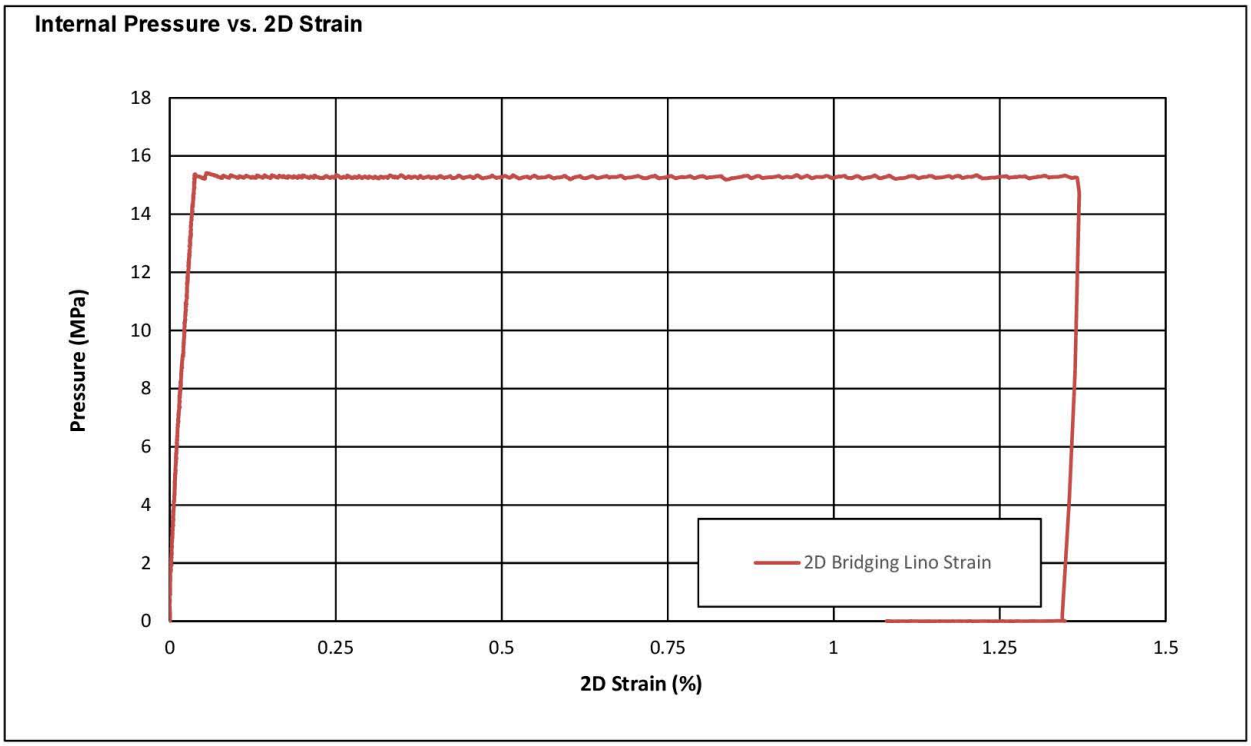




Compiled By:	Date:	Title:	C-FER Technologies
SLS	12-May-16	**Task 12 Tension Test**	
Reviewed:	Date:	Specimen Identification:	Page 4 of 9
CMJT	19-May-17	**12.b (Tension 2)**	

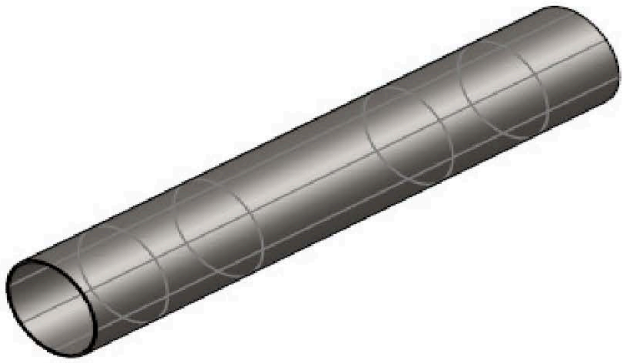
Strain Plots

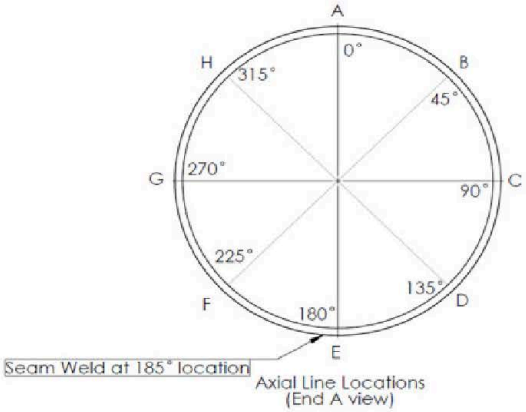


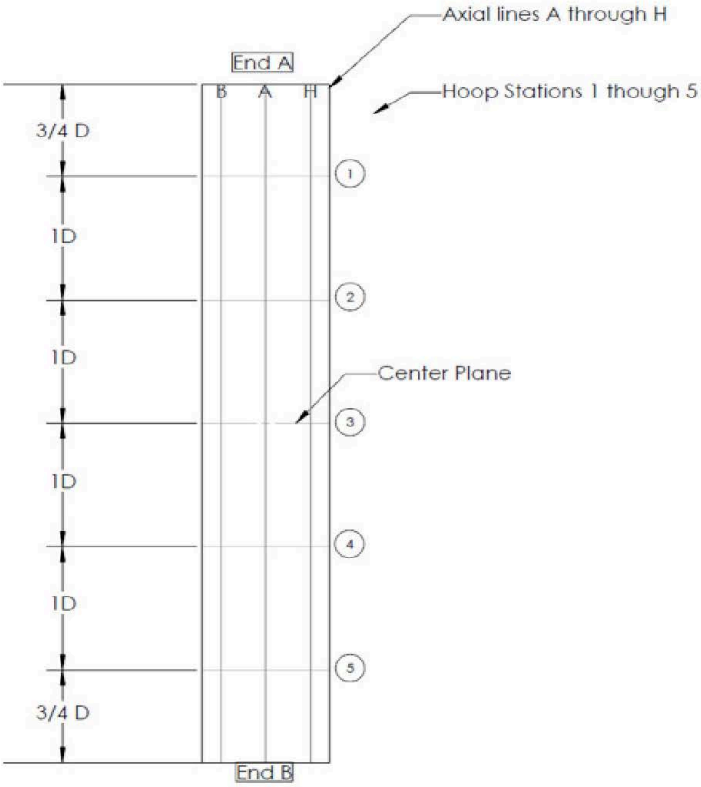


Compiled By:	Date:	Title:	C-FER Technologies
SLS	12-May-16	**Task 12 Tension Test**	
Reviewed:	Date:	Specimen Identification:	Page 5 of 9
CMJT	19-May-17	**12.b (Tension 2)**	

Pipe Measurements







Pre test Pup Lengths:

End A to 1	242	mm
1 to 2	324	mm
2 to 3	323	mm
3 to 4	324	mm
4 to 5	322	mm
5 to End B	246	mm
Total Length	1 781	mm

Pre Test Pipe Lengths:

Position B	1 781	mm
Position D	1 780	mm
Position F	1 780	mm
Position H	1 782	mm
Average	1 781	mm

Circumferences:

End A measured circumference	1 023	mm
End B measured circumference	1 023	mm

Measurements Taken By:	Date:	Title:	C-FER Technologies
SEB	3-Mar-15	**Task 12 Tension Test**	
Measurements Approved By:	Date:	Specimen Identification:	Page 6 of 9
JHB	3-Mar-15	**12.b (Tension 2)**	

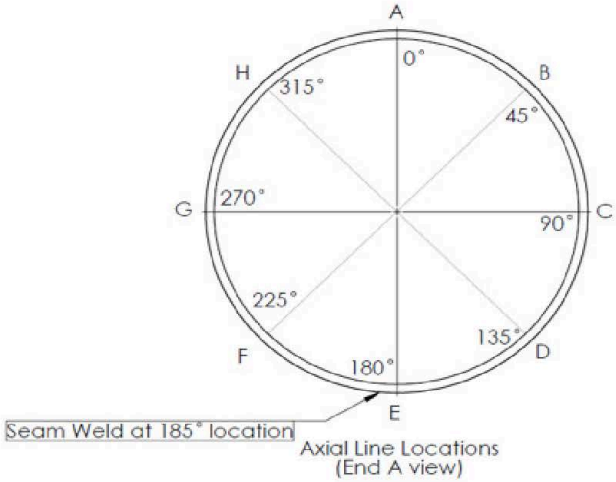
Diameter Measurements

Micrometer: Mitutoyo 12-18" No 1018

609.6 mm (12 in) Configuration (all spans) *

304.8 mm Verification rod reading No.167-152: 304.80 mm

Station	Spanned Positions (mm)			
	A-E	B-F	C-G	D-H
1	325.04	325.20	325.20	324.82
2	325.12	324.92	324.94	324.82
3	325.27	324.99	325.04	324.92
4	325.17	325.04	325.07	324.79
5	325.17	325.09	325.30	325.12



Station	Max. OD (mm)	@ Position	Min. OD (mm)	@ Position	Avg. OD (mm)	Stdev. (mm)	Ovality** (%)	Ovality incl. angle (°)
1	325.20	45	324.82	135	325.06	0.18	0.06	90
2	325.12	0	324.82	135	324.95	0.13	0.05	135
3	325.27	0	324.92	135	325.06	0.15	0.06	135
4	325.17	0	324.79	135	325.02	0.16	0.06	135
5	325.30	90	325.09	45	325.17	0.09	0.03	45

* Imperial micrometer was used and measurements were converted.

$$** Ovality = \frac{(D_{max} - D_{min})}{(D_{nom})} * 100\%$$

Measurements Taken By:	Date:	Title:	C-FER Technologies
SEB	3-Mar-15	**Task 12 Tension Test**	
Measurements Approved By:	Date:	Specimen Identification:	Page 7 of 9
JHB	3-Mar-15	**12.b (Tension 2)**	

Wall Thickness Measurements

Micrometer Measurements

Pipe Ring Verification

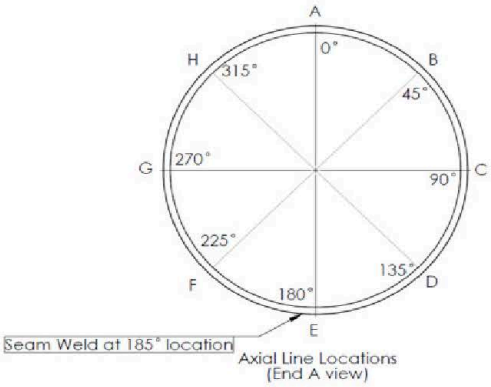
	Micrometer (mm)	Ultrasonic probe (mm)
End A - Position B	7.22	7.22
End A - Position D	7.15	7.13
End A - Position F	7.16	7.16
End A - Position H	7.14	7.15
End B - Position B	7.23	7.23
End B - Position D	7.18	7.18
End B - Position F	7.13	7.13
End B - Position H	7.19	7.19

Micrometer ID:

Mitutoyo 0-1"
No. 293-180
Calibration (1"): 1.00015"

Ultrasonic Probe ID:

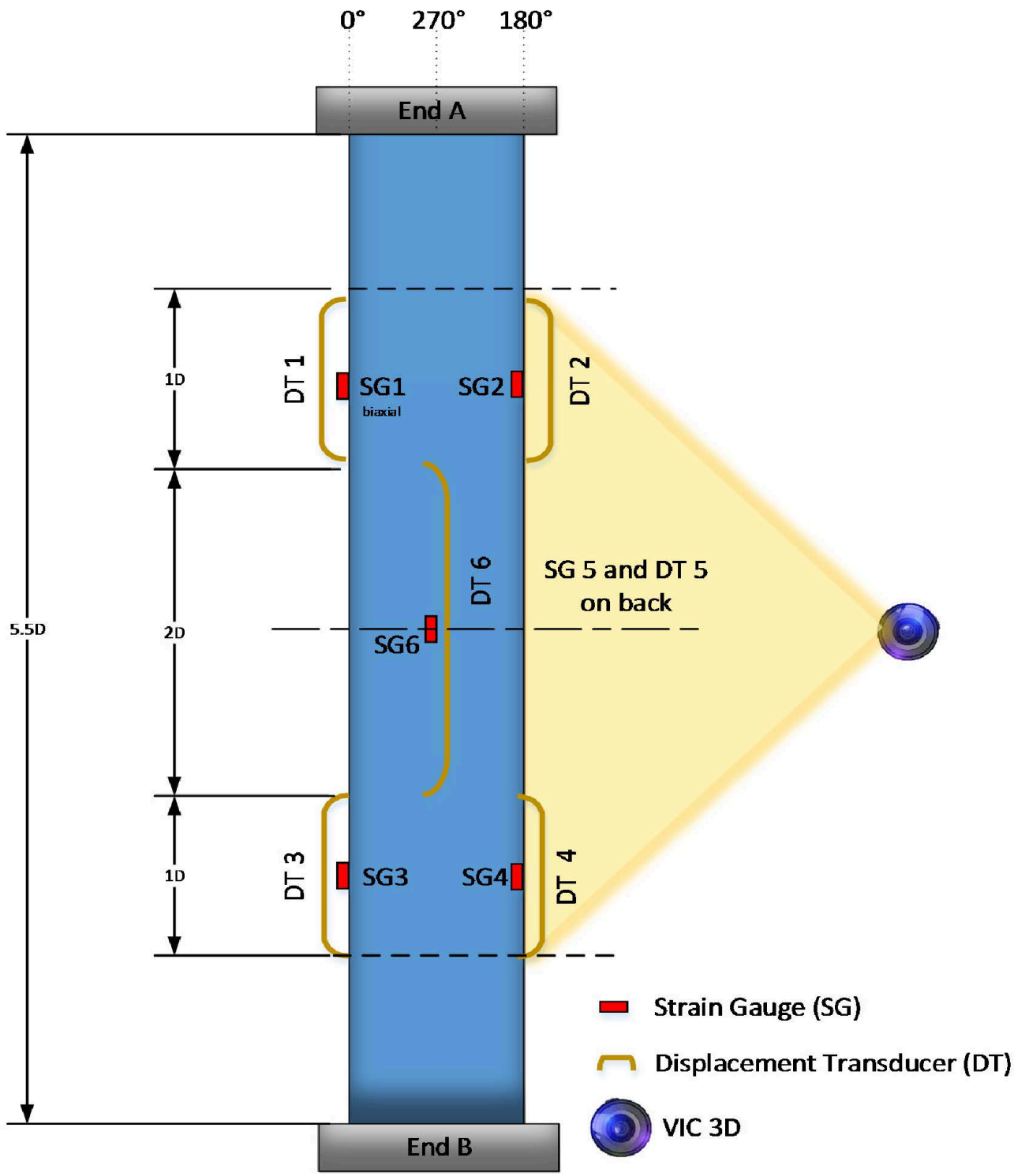
Model: Dakota Ultrasonics MVX ±0.001"
Serial Number: 78000



Ultrasonic Measurements

Station	Wall Thickness (mm)							
	Circumferential Position							
	0°	45°	90°	135°	180°	225°	270°	315°
1	7.16	7.25	7.19	7.12	7.17	7.08	7.11	7.14
2	7.16	7.22	7.18	7.14	7.15	7.04	7.12	7.13
3	7.17	7.23	7.20	7.13	7.14	7.08	7.13	7.16
4	7.19	7.21	7.23	7.19	7.16	7.08	7.15	7.17
5	7.22	7.23	7.22	7.16	7.18	7.08	7.16	7.18

Average Thickness	7.16	**mm**
Standard Deviation	0.05	**mm**



Drawing Done By:	Date:	Title:	C-FER Technologies
SLS	11-May-16	**Task 12 Tension Test**	
Drawing Approved By:	Date:	Specimen Identification:	Page 9 of 9
CMJT	19-May-17	**12.b (Tension 2)**	

Task 12 Tension Test

Specimen Identification:	**12.c (Tension 3)**	C-FER Test Summary:	**Rev. 3,June 23, 2017**
C-FER Specimen Number:	**X70-ERW-3-12c**	Test Date:	**2-Jul-15**

Pipe Characteristics

Nominal OD (mm) =	323.85
Average OD (mm) =	325.02
Nominal Wall Thickness (mm) =	7.14
Average Wall Thickness (mm) =	7.13
Specimen Length (mm) =	1 786.5
Length/OD =	5.5
SMYS (MPa) =	483

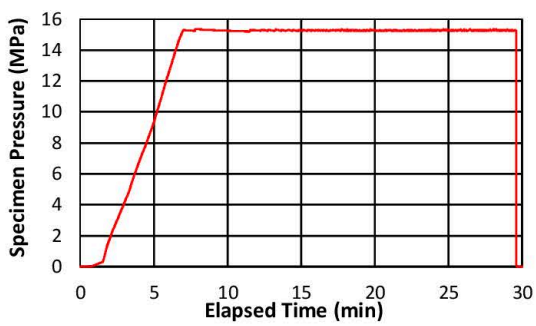
Test Loading Procedure

1. Specimen was pressurized at at rate of ~2.8 MPa/min to 15.3 MPa while the machine held the ends fixed.
2. Specimen was then subjected to axial tension at a rate of 1.6 mm/min (with internal pressure maintained) until the specimen ruptured.

Test Parameters

Target Net Pressure (72% SMYS) (MPa) =	15.3
Actual Mean Net Pressure During Testing (MPa) =	15.3

Internal Pressure vs Time



Test Results

Maximum Net Tensile Foce (kN) =	4 564
Maximum Net Axial Stress (MPa) =	642
Pressure at Failure (MPa) =	15.3

Displacement Transducers

Remote Top Strain at Failure (%) =	1.02
Remote Bottom Strain at Failure (%) =	1.05
2D Bridging Strain at Failure (%) =	1.68

VIC 3D

Remote Top Strain at Failure (%) =	0.86
Remote Bottom Strain at Failure (%) =	0.85
2D Bridging Strain at Failure (%) =	1.62

Strain Gauges

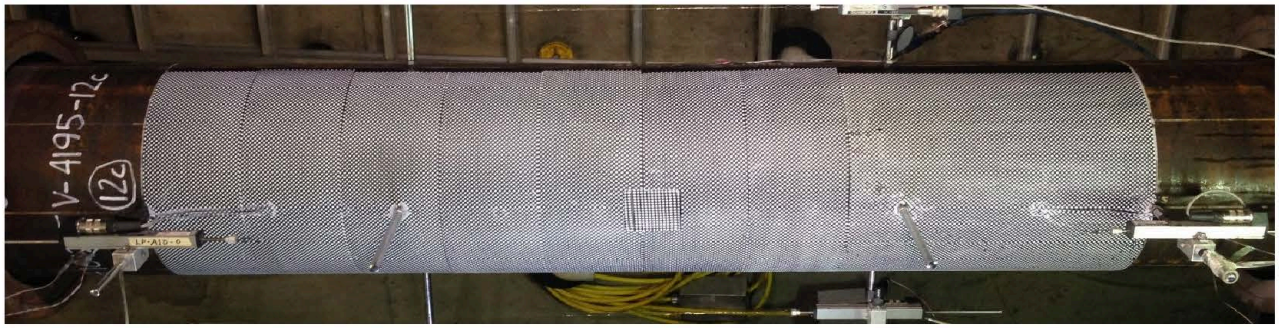
Top Strain at Failure (%) =	1.01
Bottom Strain at Failure (%) =	1.05
Hoop Strain at Failure (%) =	0.08

Anomaly - Deep Corrosion Patch

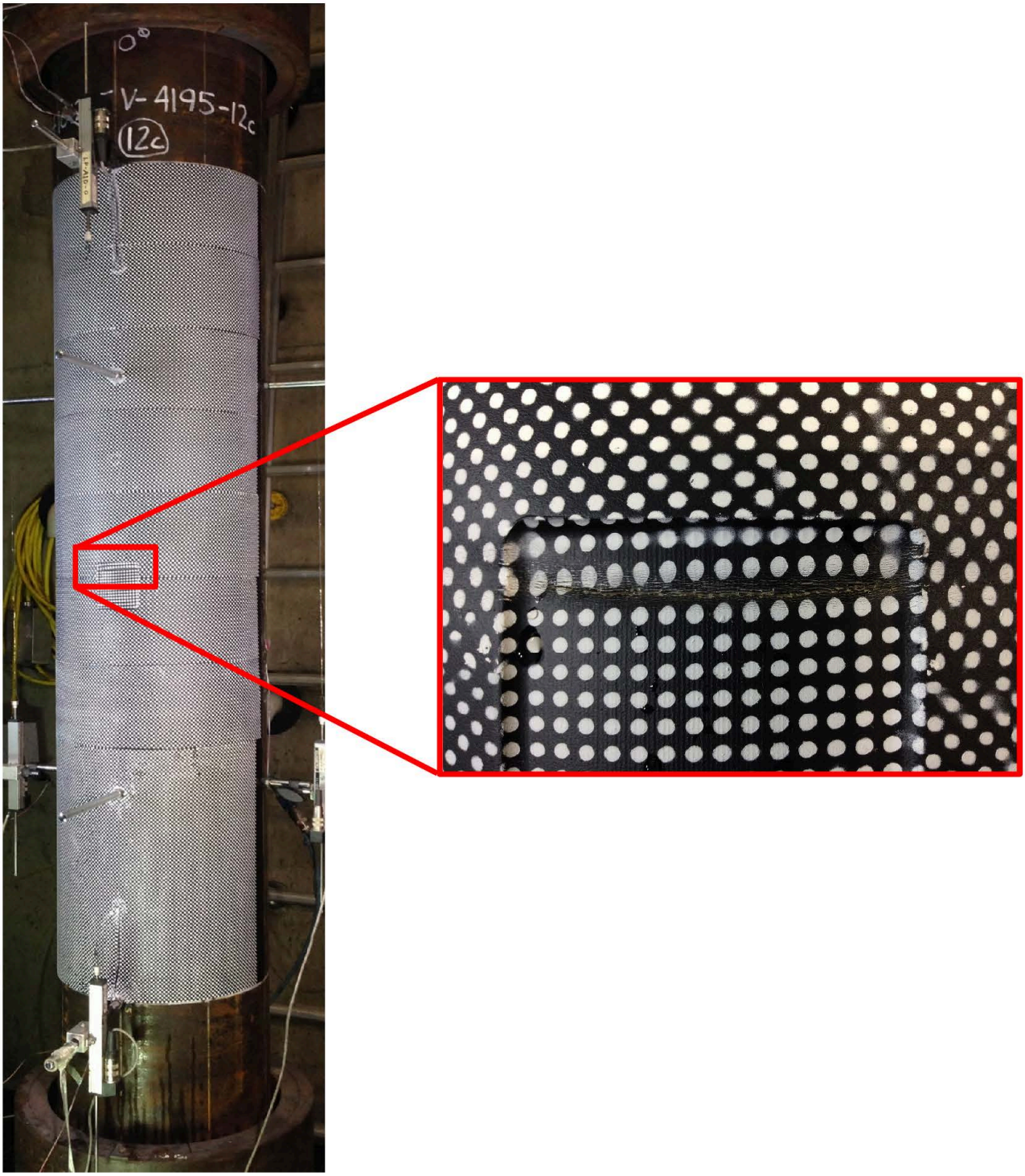
	Length	Width	Depth
Nominal Dimensions =	0.2D	0.2D	0.4t
Nominal Dimensions (mm) =	64.77	64.77	2.85
Measured Dimensions (mm) =	63.5	64.5	2.67

General Comments:

Pipe after Testing:

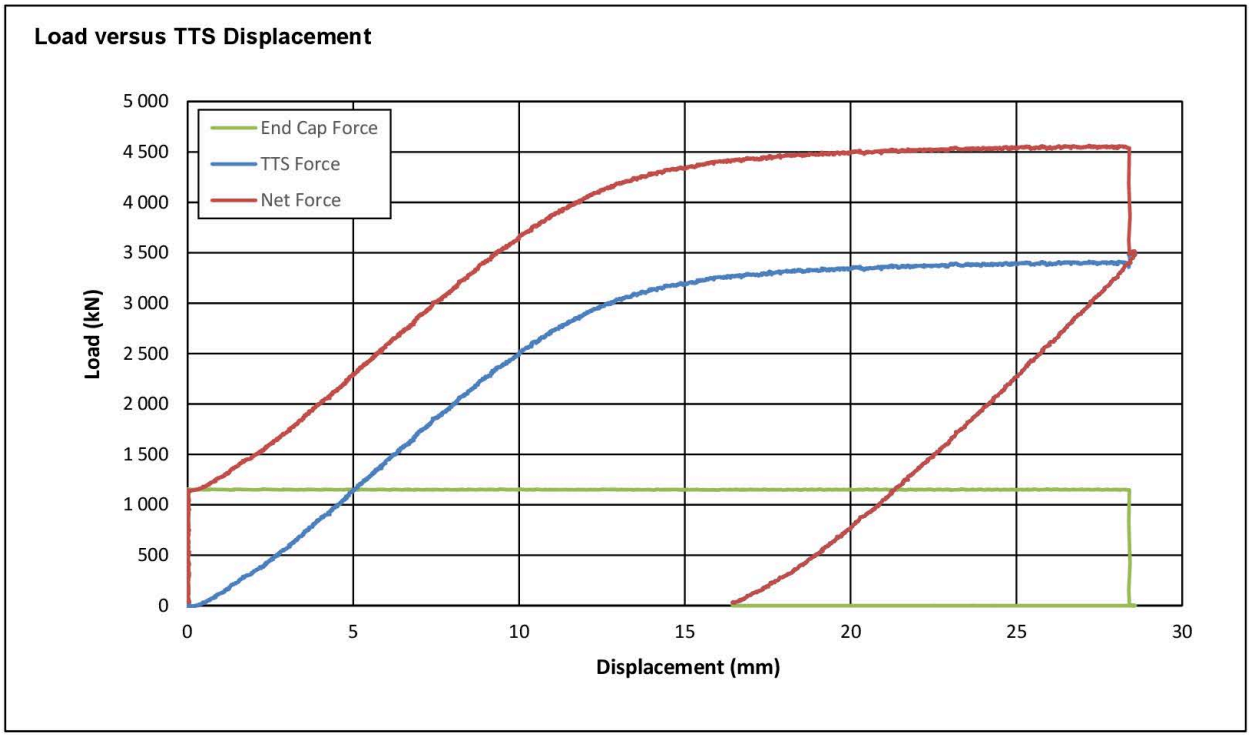


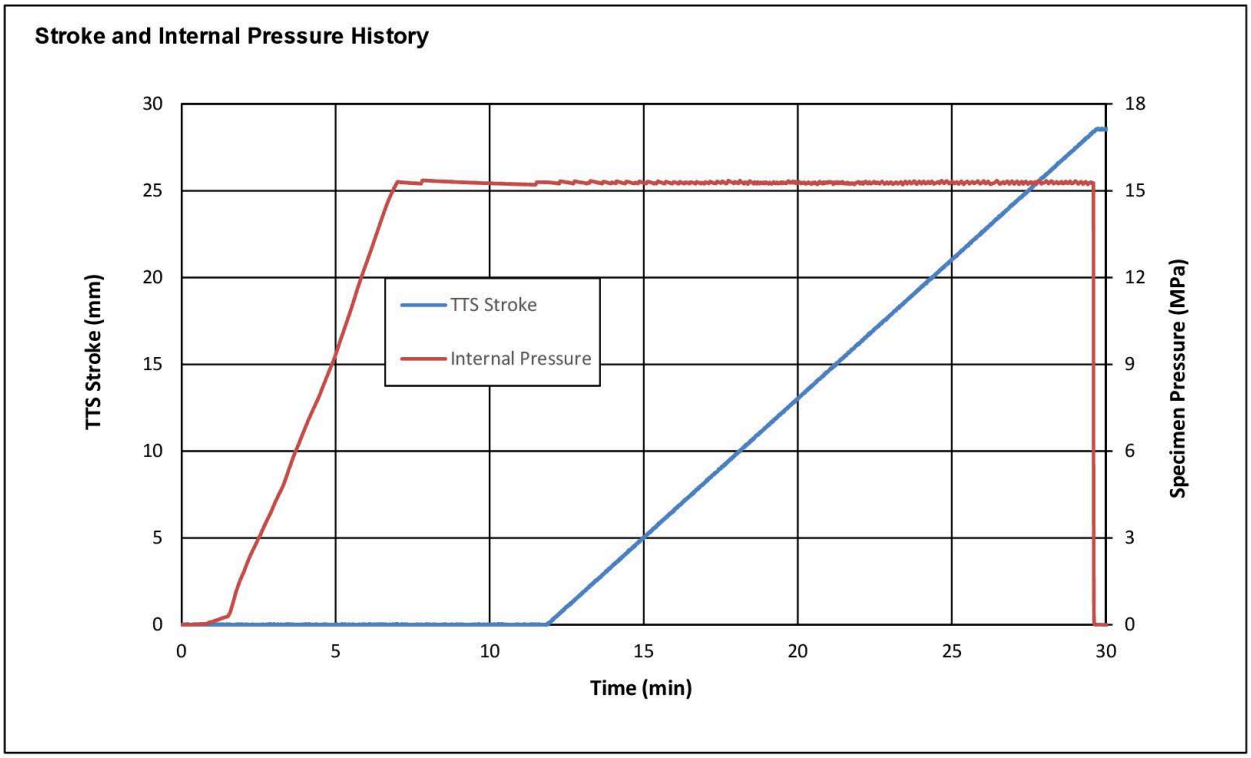
Failure Location



Compiled By:	Date:	Title:	C-FER Technologies
SLS	16-May-16	**Failure Location**	
Reviewed:	Date:	Specimen Identification:	Page 2 of 9
CMJT	19-May-17	**12.c (Tension 3)**	

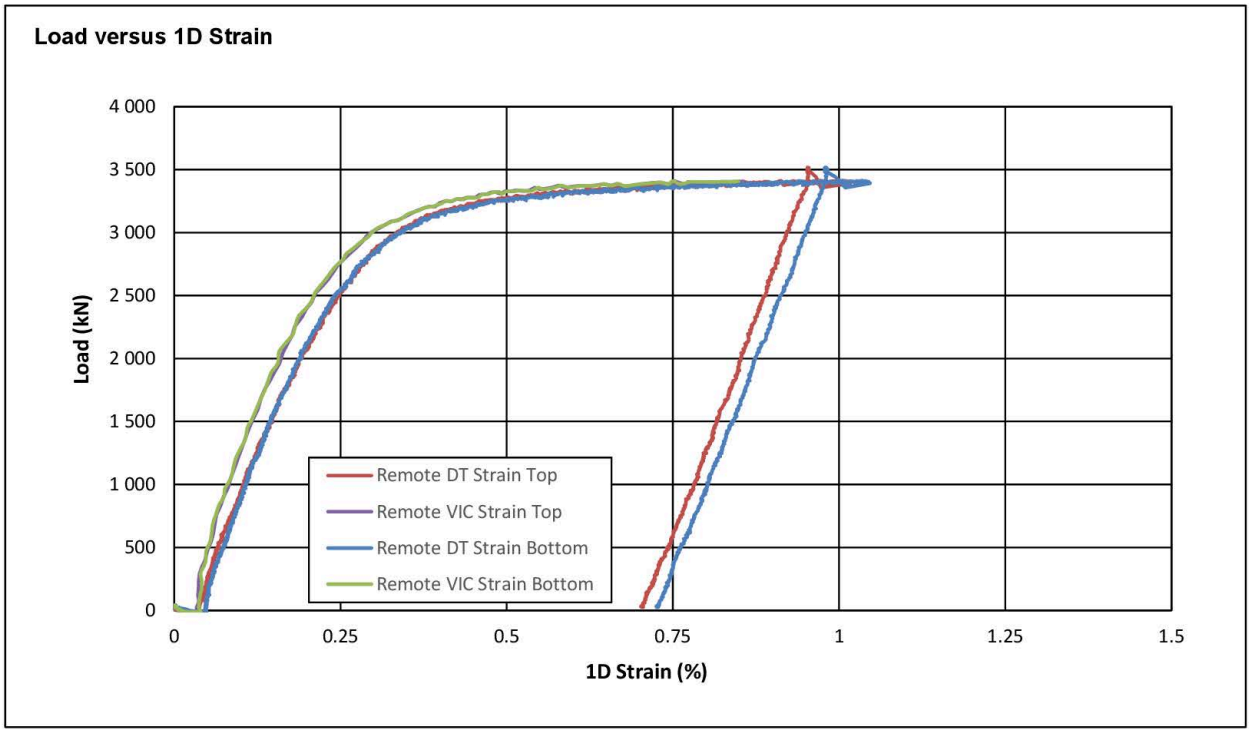
Load Plots

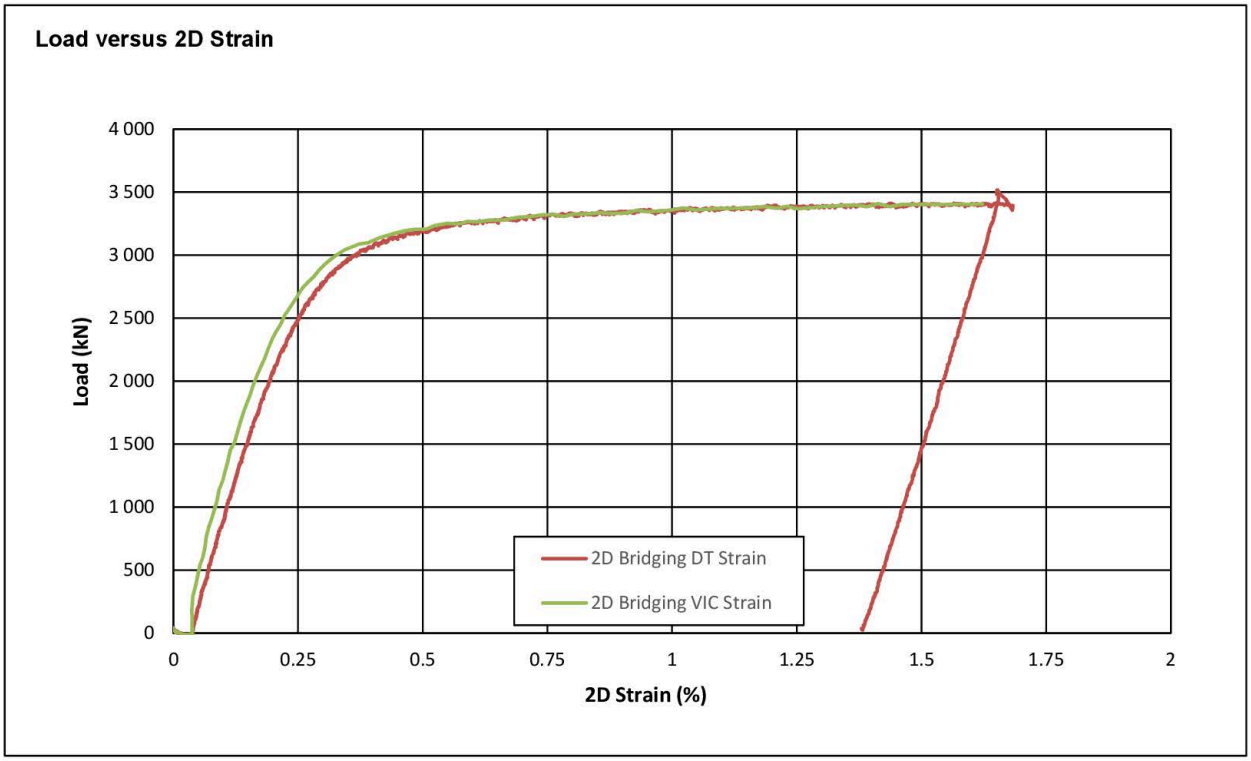




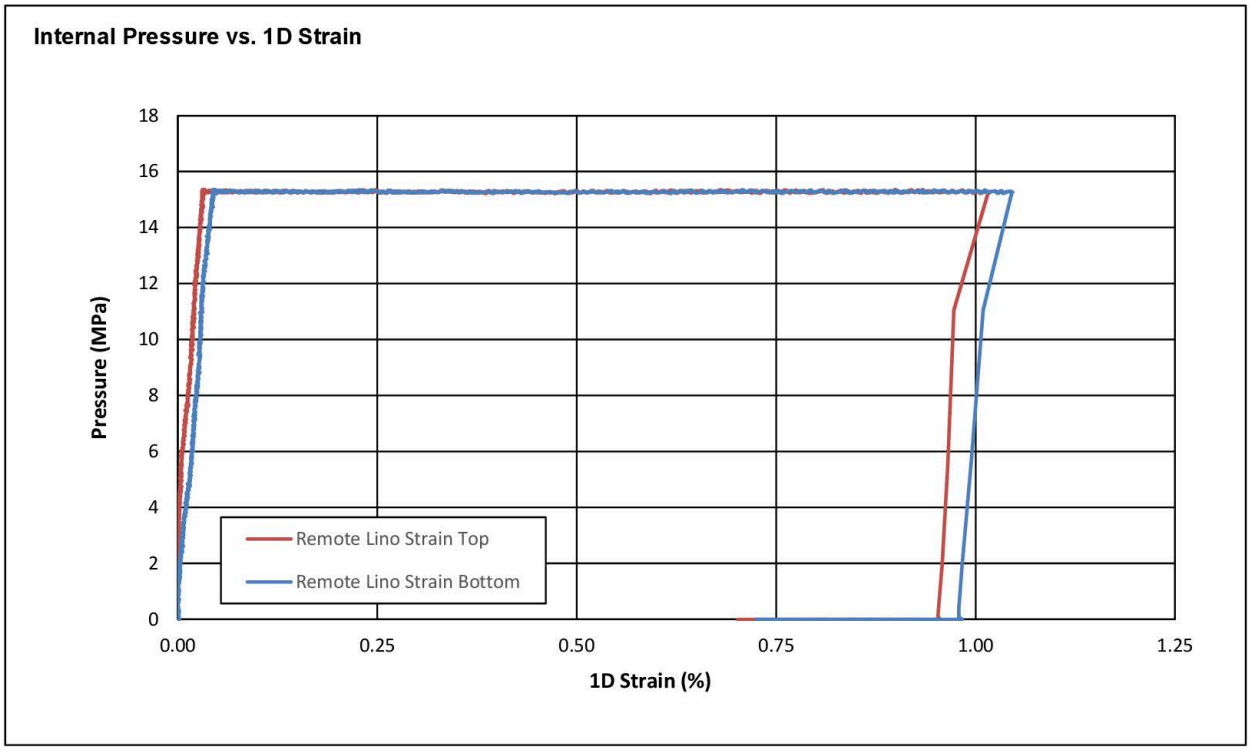
Compiled By:	Date:	Title:	C-FER Technologies
SLS	12-May-16	**Task 12 Tension Test**	
Reviewed:	Date:	Specimen Identification:	
CMJT	19-May-17	**12.c (Tension 3)**	Page 3 of 9

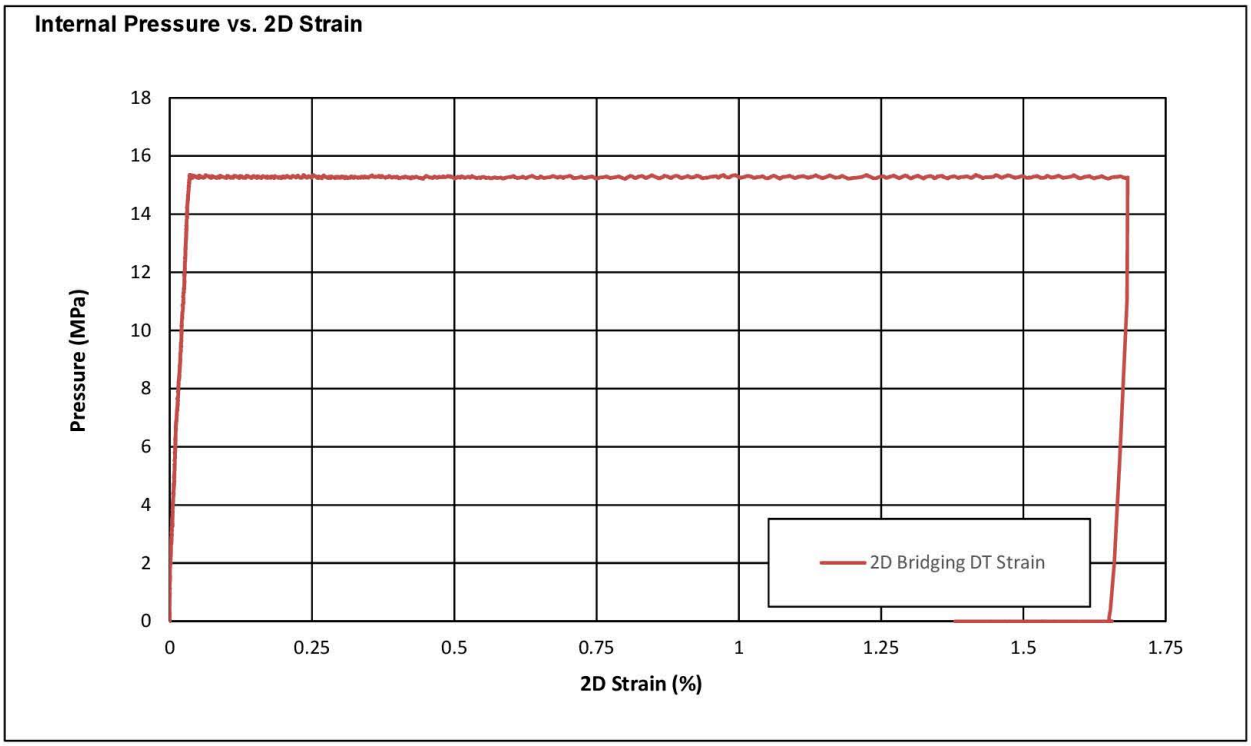
Strain Plots





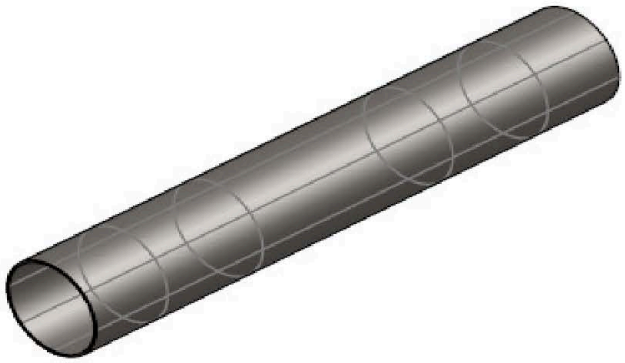
Strain Plots

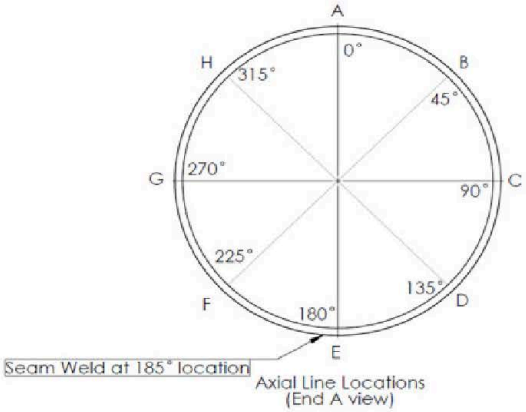


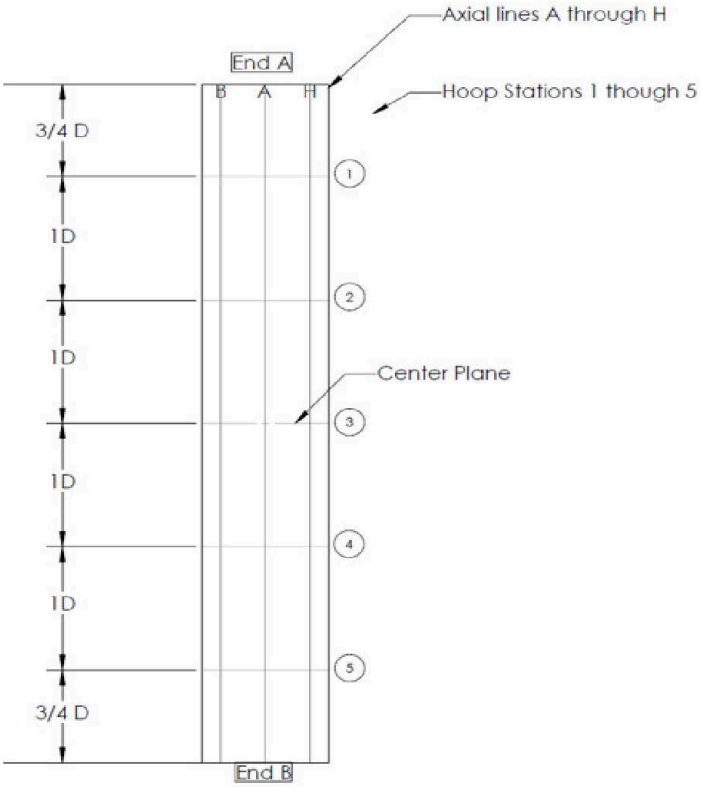


Compiled By:	Date:	Title:	C-FER Technologies
SLS	12-May-16	**Task 12 Tension Test**	
Reviewed:	Date:	Specimen Identification:	
CMJT	19-May-17	**12.c (Tension 3)**	Page 5 of 9

Pipe Measurements







Pre test Pup Lengths:

End A to 1	244	mm
1 to 2	321	mm
2 to 3	325	mm
3 to 4	328	mm
4 to 5	317	mm
5 to End B	253	mm
Total Length	1 788	mm

Pre Test Pipe Lengths:

Position B	1 788	mm
Position D	1 786	mm
Position F	1 785	mm
Position H	1 787	mm
Average	1 787	mm

Circumferences:

End A measured circumference	1 023	mm
End B measured circumference	1 023	mm

Measurements Taken By:	Date:	Title:	C-FER Technologies
SEB	3-Mar-15	**Task 12 Tension Test**	
Measurements Approved By:	Date:	Specimen Identification:	Page 6 of 9
JHB	3-Mar-15	**12.c (Tension 3)**	

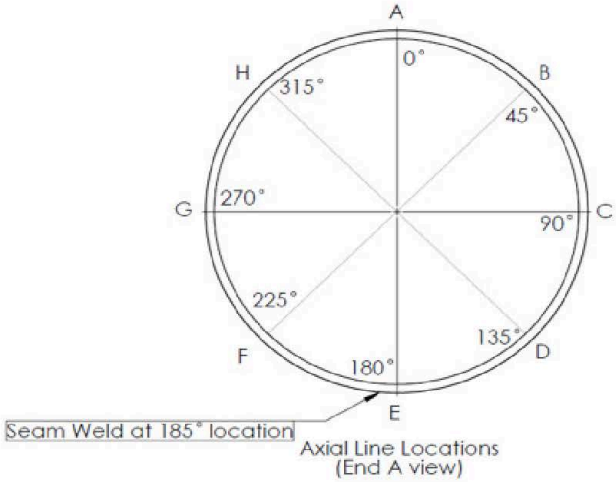
Diameter Measurements

Micrometer: Mitutoyo 12-18" No 167-152

304.8 mm (12 in) Configuration (all spans) *

304.8 mm Verification rod reading No.167-152: 304.80 mm

Station	Spanned Positions (mm)			
	A-E	B-F	C-G	D-H
1	325.20	324.92	324.92	324.82
2	325.20	325.12	325.02	324.74
3	325.17	325.07	324.94	324.92
4	325.12	325.04	325.07	325.04
5	325.15	325.07	325.07	324.82



Station	Max. OD (mm)	@ Position	Min. OD (mm)	@ Position	Avg. OD (mm)	Stdev. (mm)	Ovality** (%)	Ovality incl. angle (°)
1	325.20	0	324.82	135	324.96	0.16	0.06	135
2	325.20	0	324.74	135	325.02	0.20	0.08	135
3	325.17	0	324.92	135	325.02	0.12	0.04	135
4	325.12	0	325.04	45	325.07	0.04	0.01	45
5	325.15	0	324.82	135	325.02	0.14	0.05	135

* Imperial micrometer was used and measurements were converted.

** $Ovality = \frac{(D_{max} - D_{min})}{(D_{nom})} * 100\%$

Measurements Taken By:	Date:	Title:	C-FER Technologies
SEB	3-Mar-15	**Task 12 Tension Test**	
Measurements Approved By:	Date:	Specimen Identification:	Page 7 of 9
JHB	3-Mar-15	**12.c (Tension 3)**	

Wall Thickness Measurements

Micrometer Measurements

Pipe Ring Verification

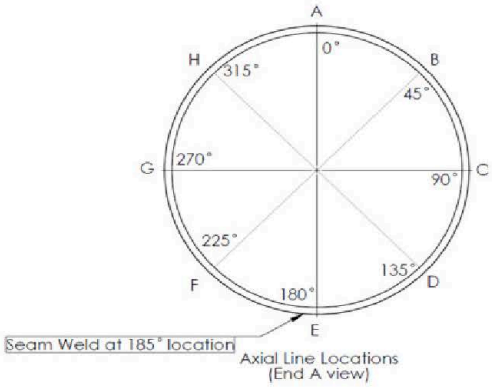
	Micrometer (mm)	Ultrasonic probe (mm)
End A - Position B	7.22	7.22
End A - Position D	7.17	7.18
End A - Position F	7.12	7.11
End A - Position H	7.16	7.17
End B - Position B	7.21	7.21
End B - Position D	7.15	7.15
End B - Position F	7.16	7.14
End B - Position H	7.15	7.15

Micrometer ID:

Mitutoyo 0-1"
No. 293-180
Calibration (1"): 1.00045"

Ultrasonic Probe ID:

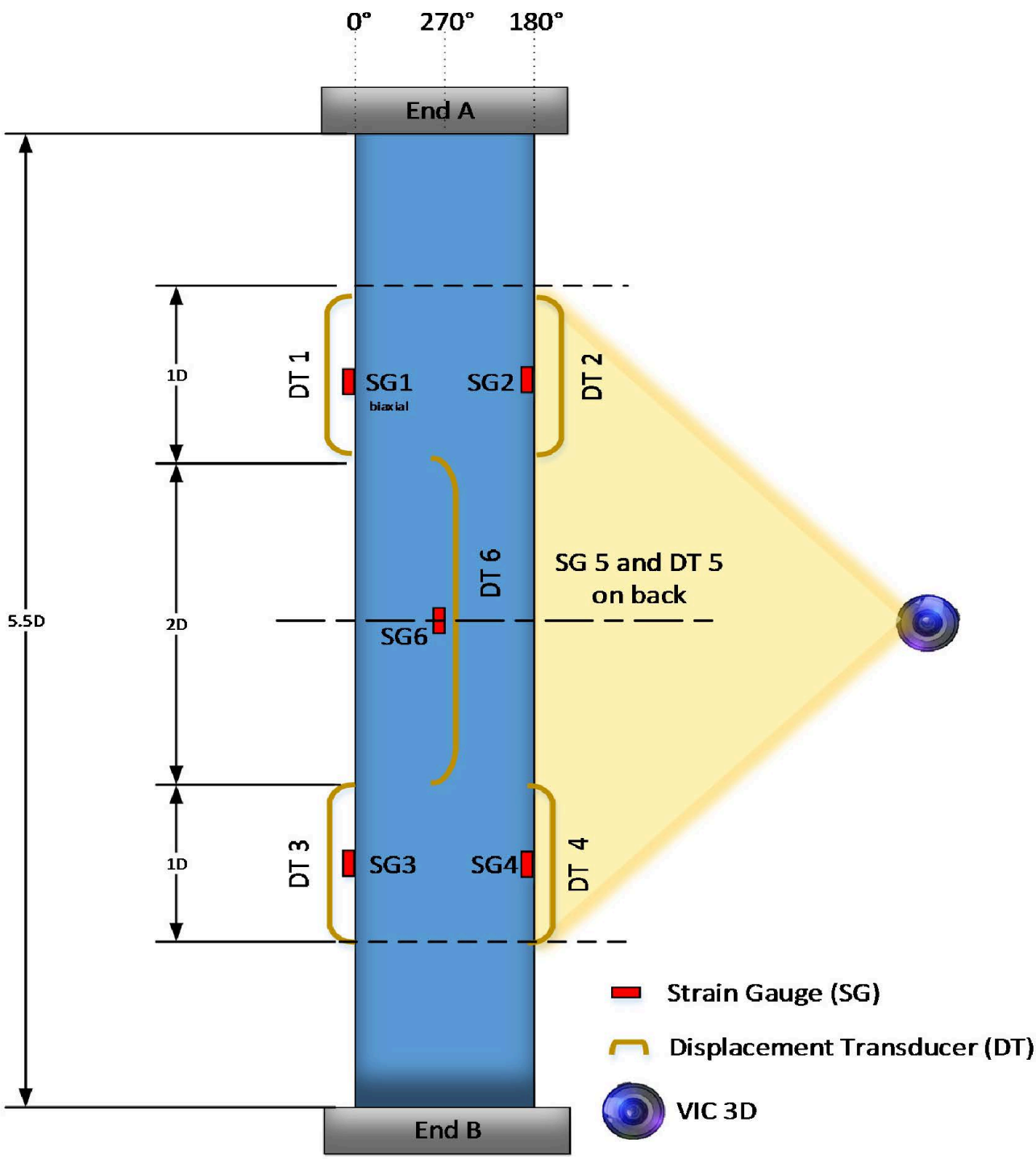
Model: Dakota Ultrasonics MVX ±0.001"
Serial Number: 78000



Ultrasonic Measurements

Station	Wall Thickness (mm)							
	Circumferential Position							
	0°	45°	90°	135°	180°	225°	270°	315°
1	7.17	7.19	7.17	7.18	7.17	7.08	7.12	7.14
2	7.16	7.17	7.14	7.12	7.14	7.05	7.04	7.09
3	7.16	7.15	7.13	7.13	7.15	7.02	7.05	7.07
4	7.17	7.20	7.17	7.16	7.17	7.06	7.07	7.10
5	7.19	7.18	7.19	7.15	7.22	7.10	7.13	7.10

Average Thickness	7.13	**mm**
Standard Deviation	0.05	**mm**



Drawing Done By:	Date:	Title:	C-FER Technologies
SLS	11-May-16	**Task 12 Tension Test**	
Drawing Approved By:	Date:	Specimen Identification:	Page 9 of 9
CMJT	19-May-17	**12.c (Tension 3)**	