World Oil® HPHT

DRILLING, COMPLETIONS & PRODUCTION CONFERENCE

September 26–27, 2017

Norris Conference Centers – CityCentre, Houston, Texas

HPHTConference.com

Enhance Casing Collapse Ratings through Testing and Dimensional Measurements

Lisa M. Ely, P.E.

Associate II

Stress Engineering Services, Inc.

What kind of collapse are we talking about?

Why does collapse happen?

- Anytime the external pressure minus the internal pressure exceeds the collapse resistance of the pipe.
  - Subsea Pipelines
    - Potential Loss of Miles of Pipeline
    - Loss of Production
  - Downhole Tubing and Casing
    - Potential Loss of Entire Well
    - Loss of Production

Why Collapse Test?

- Why Test?
  - To confirm the collapse values for actual pipe meet specifications.
  - API 5C3, API 1111, and BS 8010 contain collapse prediction equations.
  - Improve the manufacturing for pipe by identifying how changes in the process affect the end product.

Factors that Affect the Collapse Pressure

Collapse is an instability event affected by:

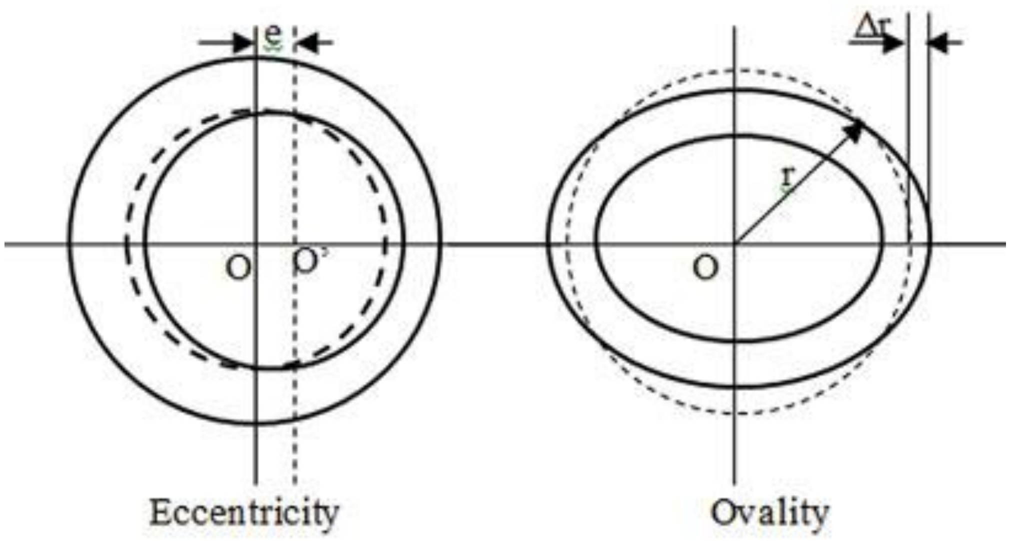
- Ovality / Eccentricity
- Residual Stress
- Axial Tension/Compression (must be zero for API-compliant testing)
- Internal Pressure
- Yield Strength/Modulus of Elasticity

It's difficult to calculate the collapse pressure of pipe because the initiation of collapse is looking for "the weak link."

Weak Links – Eccentricity and Ovality

Eccentricity – how centered is the bore?

Ovality – how round is the pipe?



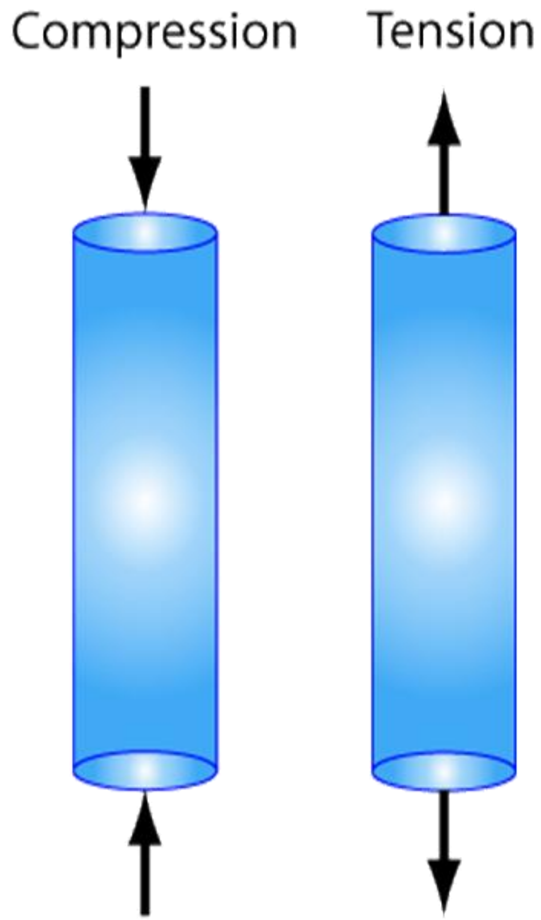
Weak Link – Residual Stress

- The pipe is under stress prior to testing from the straightening processes used in the mills or welding of the seam.
- 2D length tested at ambient temperature in accordance with ASTM E1928.

Weak Link – Axial Load

For Testing:

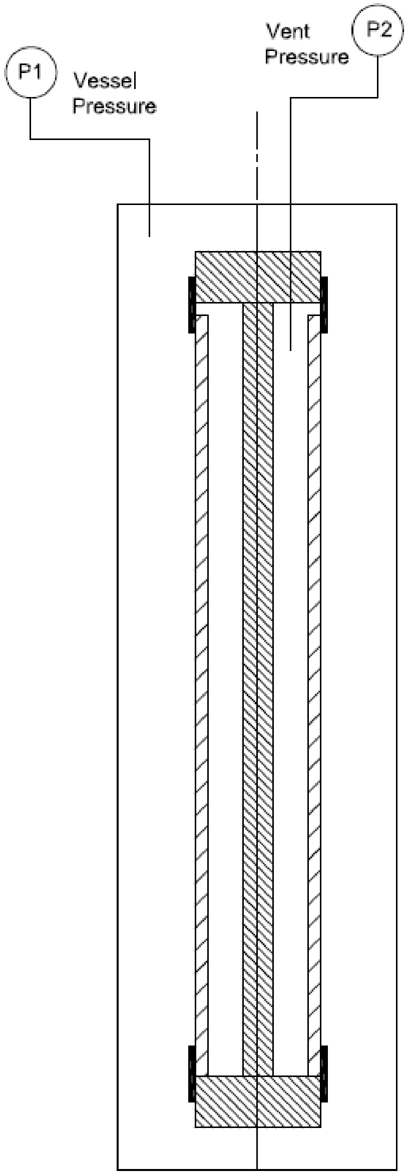
- The sample must be free to collapse anywhere along the sample length
- Axial load will affect the collapse rating of a sample:
  - Compression will increase the collapse value
  - Tension will decrease the collapse value



SES's Collapse Test System

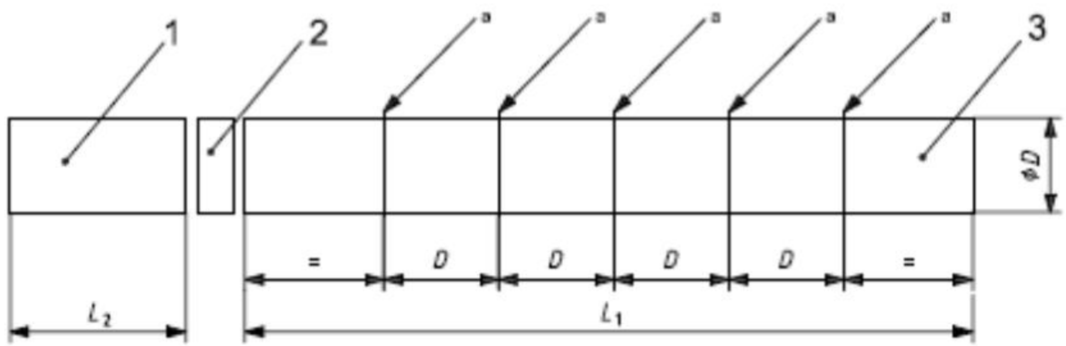
SES's testing is <u>fully compliant</u> with API 5C3, Annex I:

- Collapse sample length:
  - 8D lengths up to 9-5/8" OD
  - 7D for larger than 9-5/8" OD
- Test apparatus:
  - Vertical orientation in subterranean cased hole
  - 4.5" to 20" OD up to 25,000 psi
  - Test pressure applied to full sample length
  - NO radial or axial restraints, either mechanically or hydraulically
  - NO pressure applied to the inside surface of the specimen.



Dimensional Mapping – API 5C3, Annex I

- Measurements performed prior to collapse testing.
- Used to calculate ovality and eccentricity of each sample.
- Outer diameter and wall thickness measurements are recommended at five equally-spaced, cross-sectional planes.



Key

1 residual stress test specimen
2 tensile test specimen
3 collapse test specimen

Outer Diameter

- API 5C3 specified that the diameter should be measured with a pi tape at each ring and averaged.
- SES collects OD measurements at eight equally-spaced positions (45° intervals) using a wireless Mitutoyo digital micrometer which is calibrated every 6 months.

Wall Thickness

- SES uses a digital UT thickness meter.
- Wall thicknesses are measured at eight equally-spaced positions (45° intervals) and averaged.
- Meter is calibrated every 6 months.

Example Data Sheet

Values calculated from thickness and OD measurements:

$$\text{Eccentricity: } 100\,\frac{t_{max} - t_{min}}{t_{avg}}$$

$$\text{Ovality: } 100\,\frac{D_{max} - D_{min}}{D_{avg}}$$

Client ID #	Nominal OD (in)	Nominal Wall (in)	Heat	Grade	Collapse Pressure (psi)
SES-01	9.625"	0.595"	Q123	HC P110	10,000

% Eccentricity: 3.98
% Ovality: 0.16

WALL THICKNESS [in]						
Position	"1"	"2"	"3"	"4"	"5"	
0°	0.604	0.608	0.609	0.599	0.592	MAX
45°	0.611	0.606	0.608	0.602	0.599	0.615
90°	0.607	0.599	0.600	0.596	0.605	MIN
135°	0.598	0.594	0.591	0.608	0.602	0.591
180°	0.598	0.601	0.596	0.601	0.610	
225°	0.599	0.607	0.601	0.595	0.605	
270°	0.597	0.609	0.606	0.603	0.611	
315°	0.607	0.614	0.615	0.605	0.600	Tot. Avg.
Average	0.603	0.605	0.603	0.601	0.603	0.603

OUTER DIAMETER (OD) [in]						MAX
0°-180°	9.677	9.677	9.674	9.673	9.676	9.685
45°-225°	9.685	9.680	9.679	9.685	9.681	MIN
90°-270°	9.675	9.670	9.671	9.676	9.677	9.670
135°-315°	9.679	9.679	9.680	9.677	9.679	Tot. Avg.
OD avg.	9.679	9.677	9.676	9.678	9.678	9.677

High Temperature Collapse Test Facility

- Operational since 2015
- Temperature rating: 383°F (195°C)
- Pressure rating: 15,000 psi
- Tubular range: 4.5” to 9.625” OD
- Test media: peanut oil
- Test at least 3 samples per day
- Samples, mandrel, and pressure vessel are heated via induction heaters
- K-type thermocouples are used to measure temperature

Thank You for your time!

Lisa M. Ely
Lisa.Ely@stress.com
(281) 469-2177

Houston Cincinnati New Orleans Calgary Singapore

LASERSTREAM, L.P.

"The more you see, the more you know..."

Problem: API Collapse is based on minimums, potentially a higher collapse could be used to design wells.

Solution:

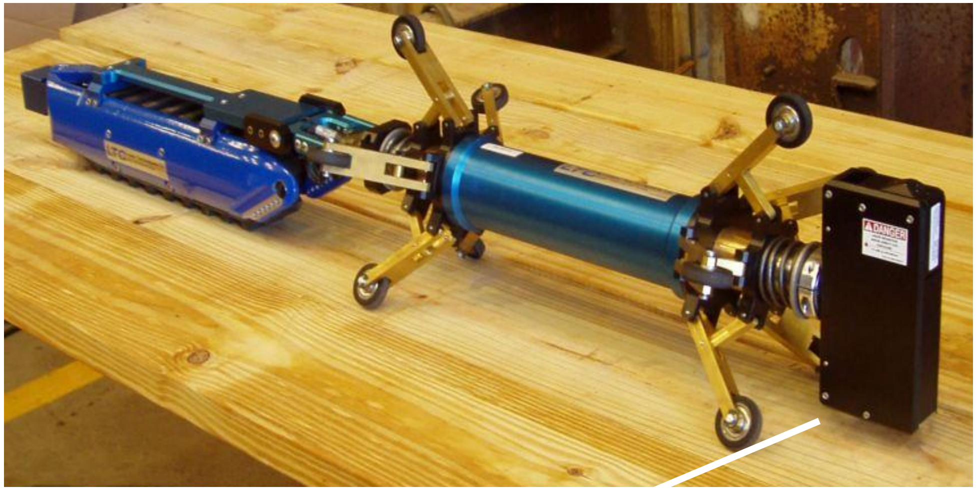
Laserstream, LP with the BEMIS™ system measures the ID and Ovality of Casing to .002" inch – End to End. This data, along with full length UT data, will allow an inventory of pipe to be sorted into groups based on physical characteristics. Properties of each group can be quantified by collapse testing.

Phase 1: Data Collection

- Heat and Batch (Yield)
- ID Profilometry for min/max/average ID (Ovality)
- Full Length UT to obtain min/max/average wall (Eccentricity)
  - *may have been performed during receiving inspection*

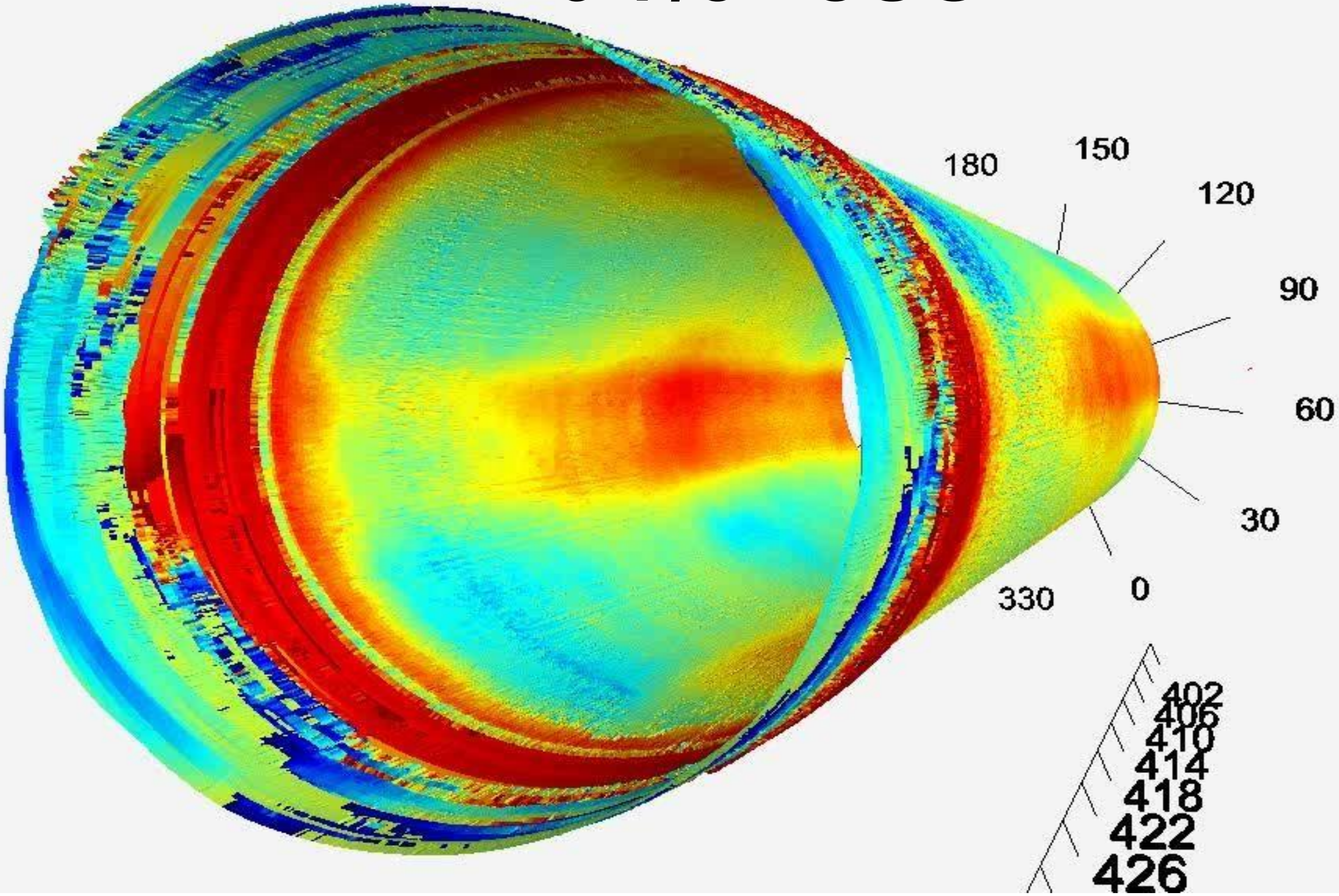
Laser ID Profilometry

BEMIS™ Pipe Scanner

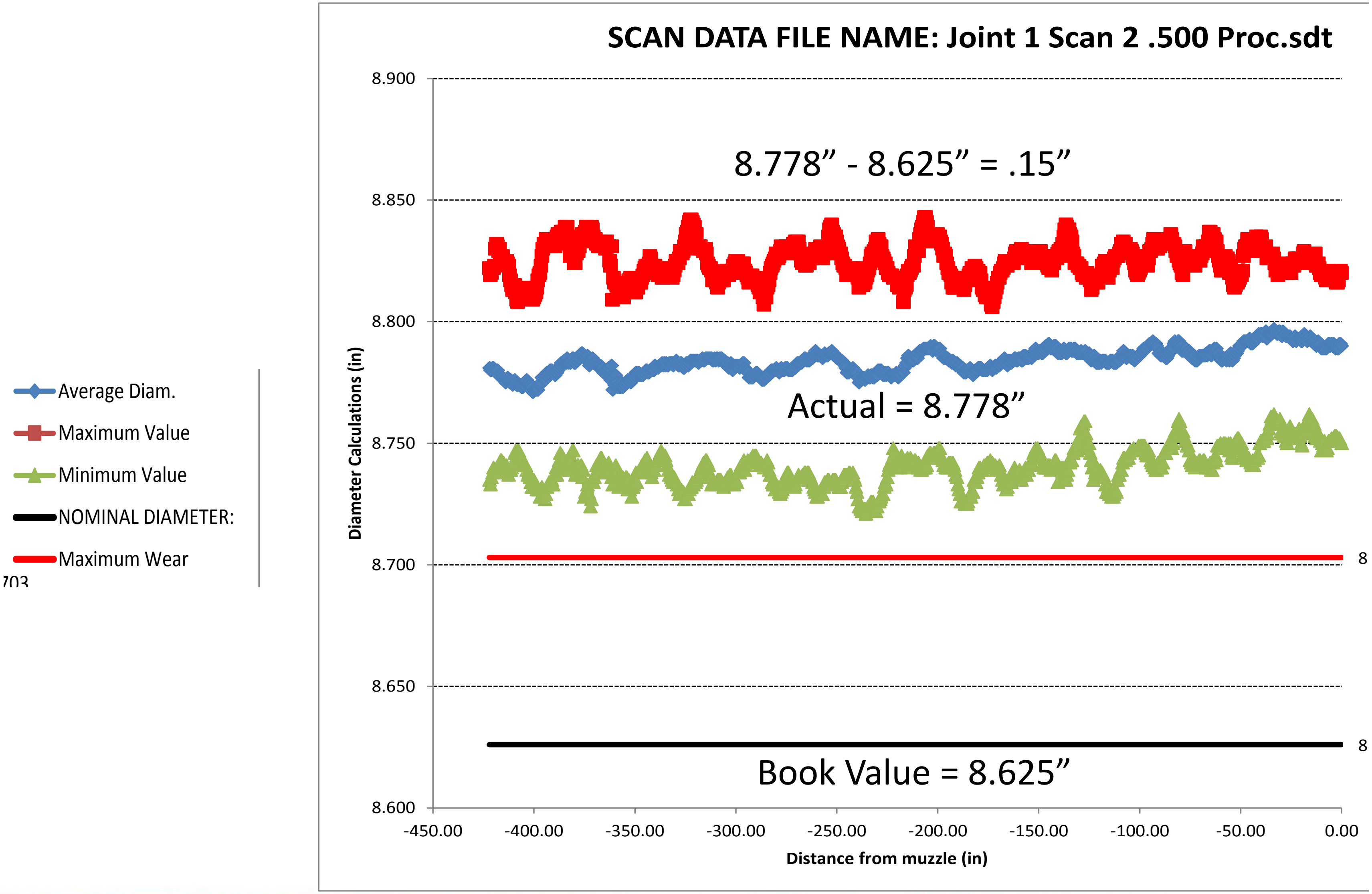


Adjustable scan head

Threads and Ovality
9 7/8” CSG

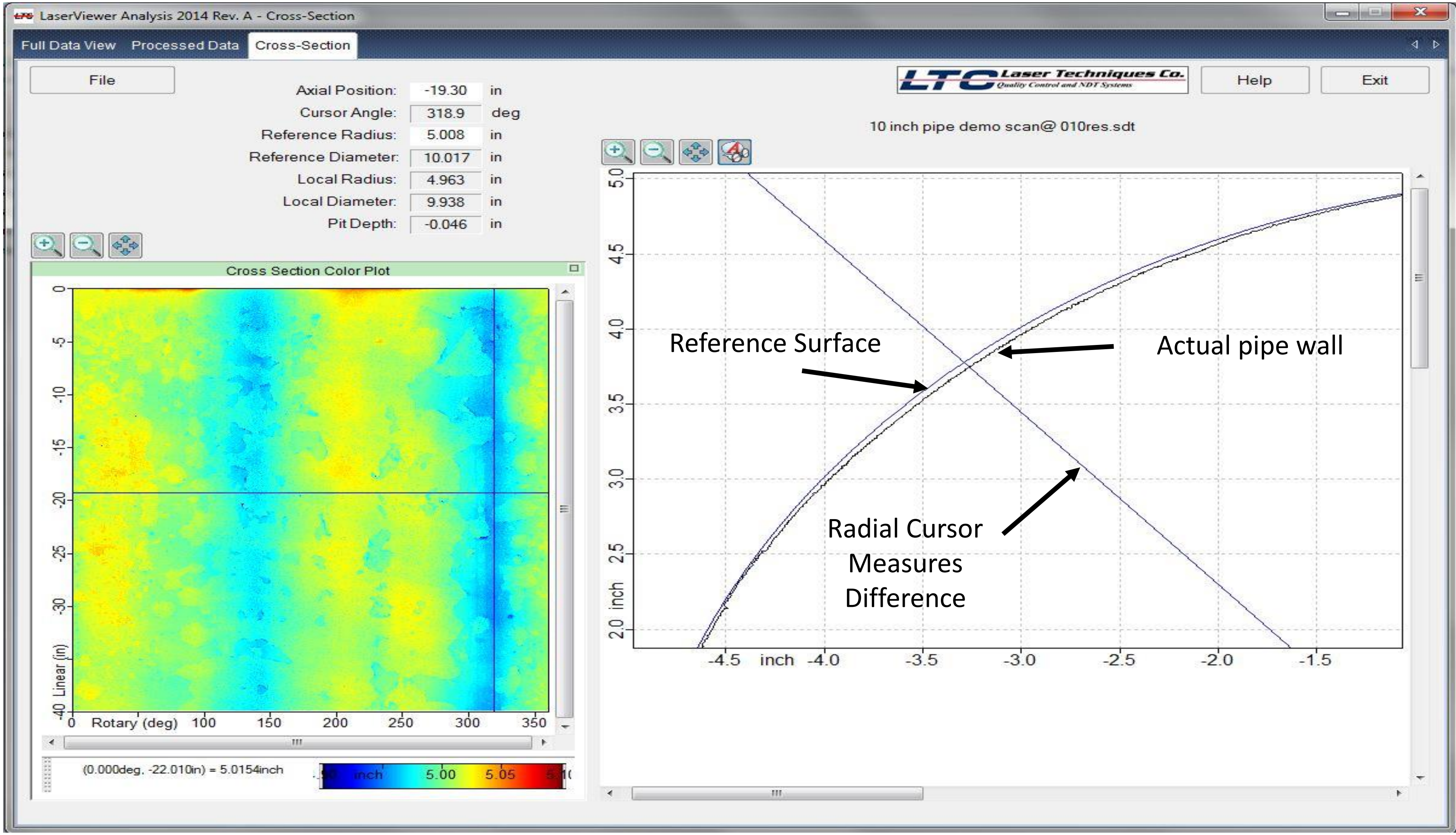


ID Stats of 9 7/8" CSG

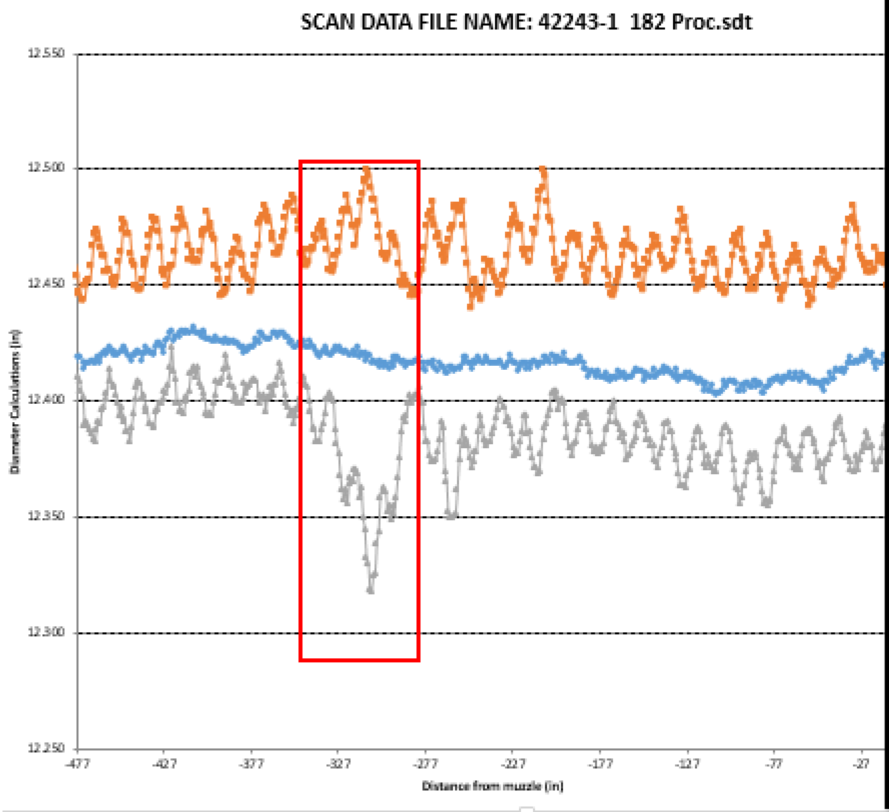


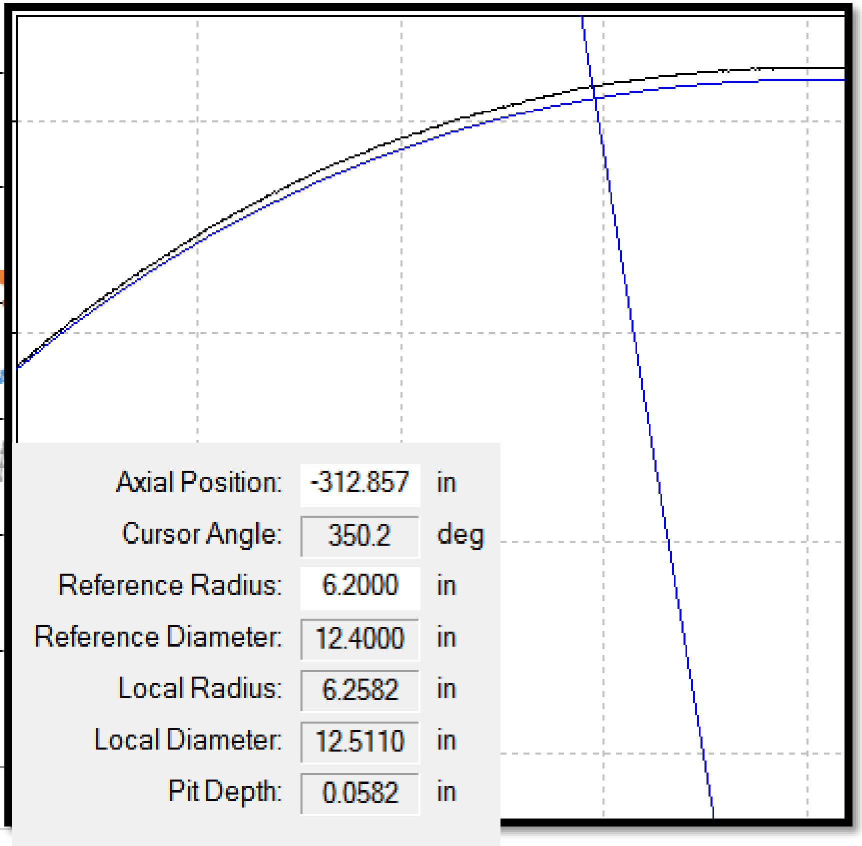
Distance from Pin

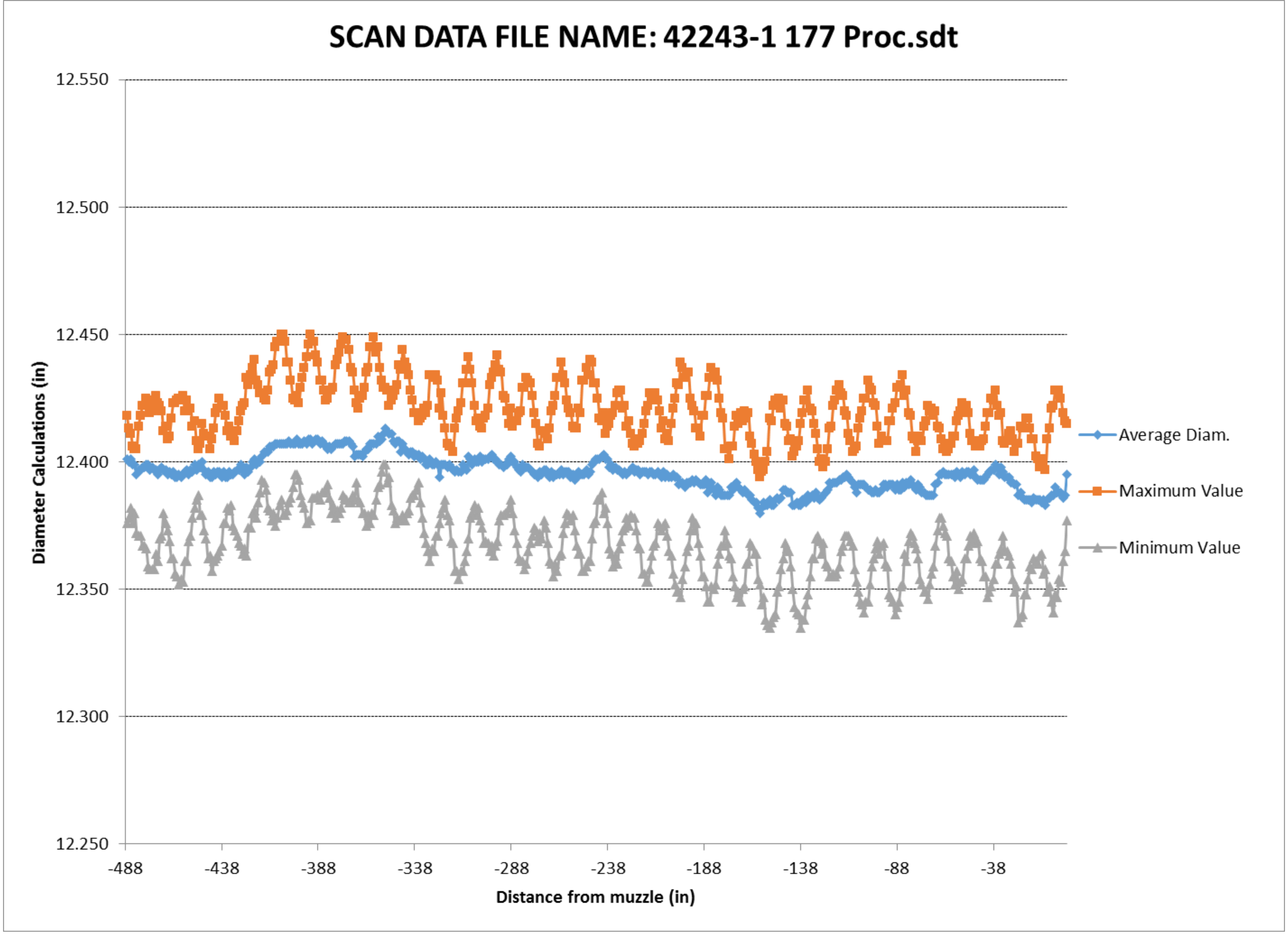
Laser Measurement of Ovality



Pipe Out of Round for Short Section







Distance from Pin

ID Variance Provided Every Inch Over the Length of the Joint

Diameter Calculations							
Axial Location	Average Diam.	Maximum Value	Maximum Location	Minimum Value	Minimum Location	ID Range	ID Variance
1.00	12.445	12.466	45/225	12.399	135/315	0.067	0.54%
2.00	12.444	12.463	45/225	12.401	135/315	0.062	0.50%
3.00	12.446	12.468	45/225	12.401	135/315	0.067	0.54%
4.00	12.451	12.479	45/225	12.392	135/315	0.087	0.70%
5.00	12.438	12.465	45/225	12.394	135/315	0.071	0.57%
6.00	12.440	12.461	45/225	12.394	135/315	0.067	0.54%
7.00	12.439	12.460	45/225	12.391	135/315	0.069	0.56%
8.00	12.437	12.455	45/225	12.395	135/315	0.060	0.49%
9.00	12.437	12.455	45/225	12.396	135/315	0.059	0.48%
10.00	12.442	12.460	45/225	12.403	135/315	0.057	0.46%
11.00	12.440	12.459	45/225	12.403	135/315	0.056	0.45%
12.00	12.440	12.458	45/225	12.405	135/315	0.053	0.43%
13.00	12.441	12.458	45/225	12.404	135/315	0.054	0.44%
14.00	12.441	12.460	45/225	12.404	135/315	0.056	0.45%
15.00	12.440	12.457	45/225	12.401	135/315	0.056	0.45%
16.00	12.439	12.458	45/225	12.402	135/315	0.056	0.45%
17.00	12.438	12.456	45/225	12.403	135/315	0.053	0.43%

AVERAGE ID VARIANCE	**0.21%**
MAX ID VARIANCE	**0.70%**
AVERAGE ID	**12.464'**

Note: Exact ID for Cement Displacements, Max ID for Packer Setting Integrity, and Caliper Baseline

Phase 2: The ID Data Would be Entered Into a Tally Sheet, with Wall Thickness Data, and Collapse Calculated

#57

AVERAGE ID ENTIRE JOINT	12.464"
AVERAGE ID VARIANCE	0.21%
MAX ID VARIANCE	0.70%
MIN WALL	0.708
MAX ECCENTRICITY	14%

Joint #	AVERAGE ID ENTIRE JOINT	AVERAGE ID VARIANCE	MAX ID VARIANCE	MIN WALL	ECCEN-TRICITY	Length	BBLs/jt	Calculated Collapse
57	**12.464**	**0.21%**	**0.70%**	**0.708**	**14 %**	41.8	6.3082	7255
58	12.378	0.25%	0.89%	0.67	12%	44.2	6.5787	7585
59	12.489	0.24%	1.10%	0.68	13%	38	5.7578	7047

Klever–Tamano equations can be used to estimate collapse based on actual characteristics.

Phase 3: Pipe is Grouped Based on Estimated Value

Joint #	Group Number	AVERAGE ID ENTIRE JOINT	Length	Calculated Collapse
58	A	12.378	44.2	7585
60	A	12.337	44.5	7430
57	A	12.464	42.8	7255
61	A	12.443	41.3	7135
56	B	12.389	43.4	7077
59	B	12.489	38	7047

Joints that meet a set criteria would be given a certain Grouping (A, B, C). The lowest value in the grouping would be sent for collapse testing.

For example: Group A is sorted as everything that calculates greater than 7100 psi. Therefore joint #61 would be sent for collapse testing.

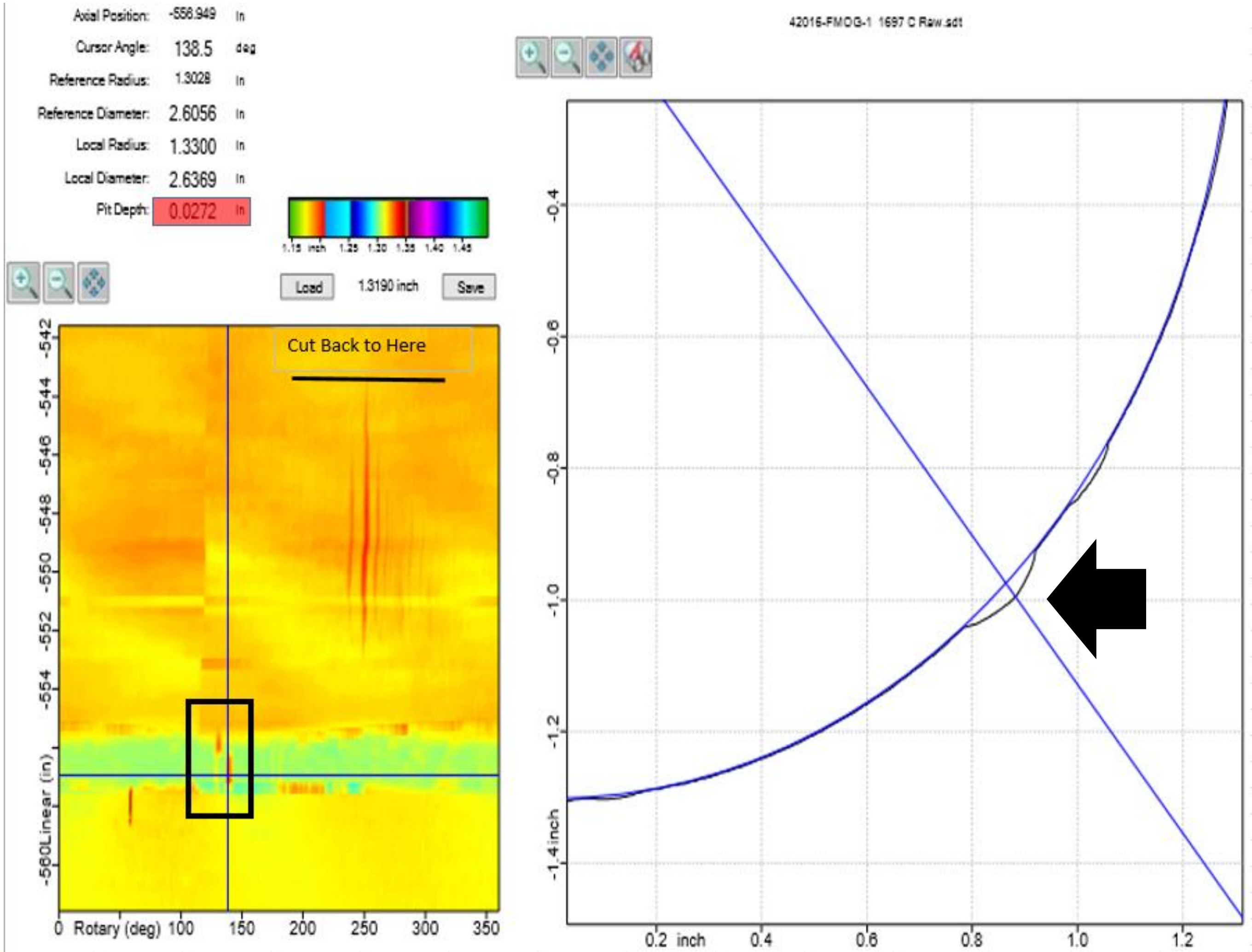
Phase 4: Collapse Testing to Be Done Per API TR 5C3

- Collapse Testing to be performed on specimens for each grouping.
- Minimums for each grouping established.
- Tally would be designed to place pipe for optimized string performance.

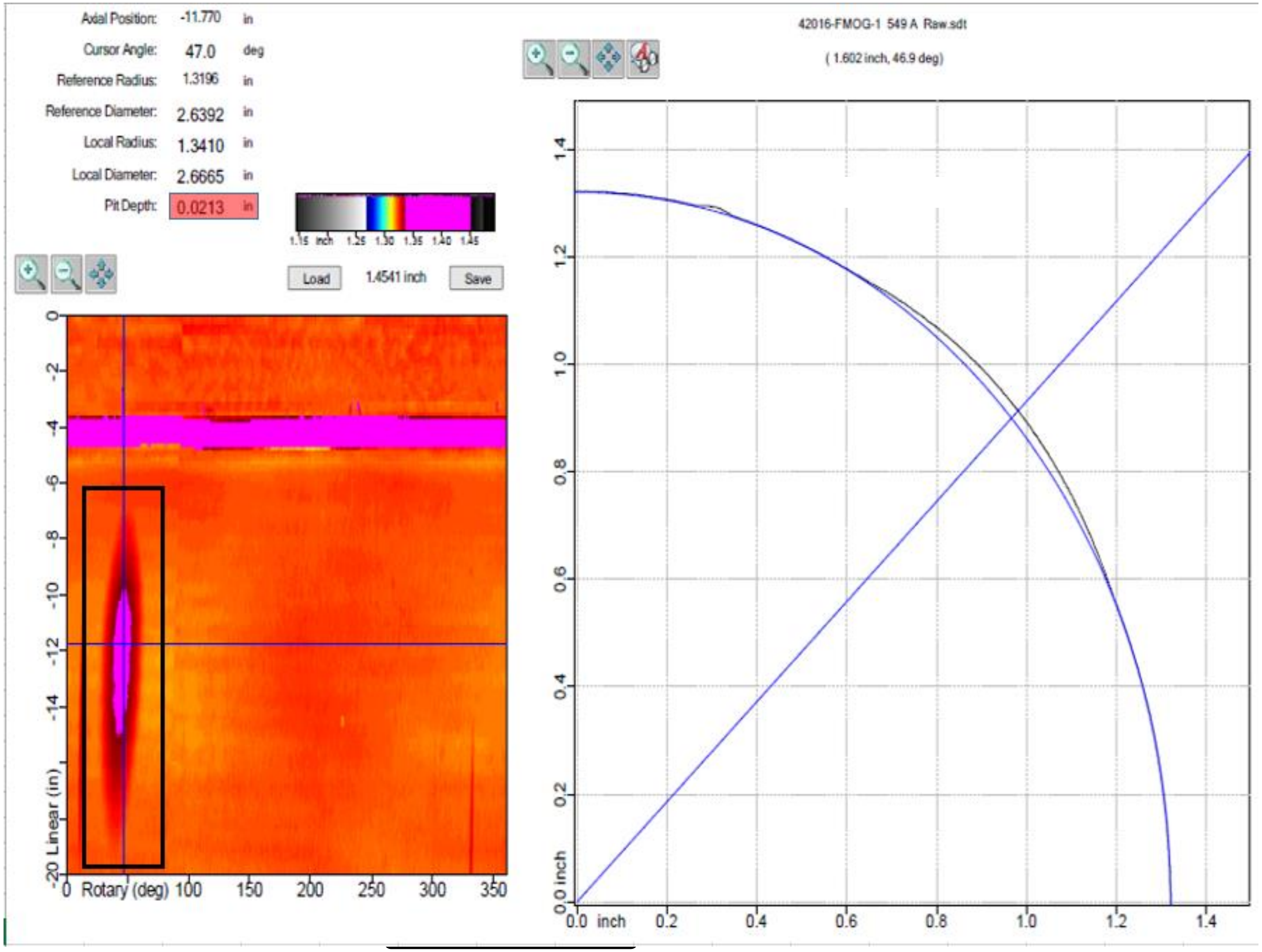
What else can Laserstream Do?

Measure WL and Drillpipe Keyseat

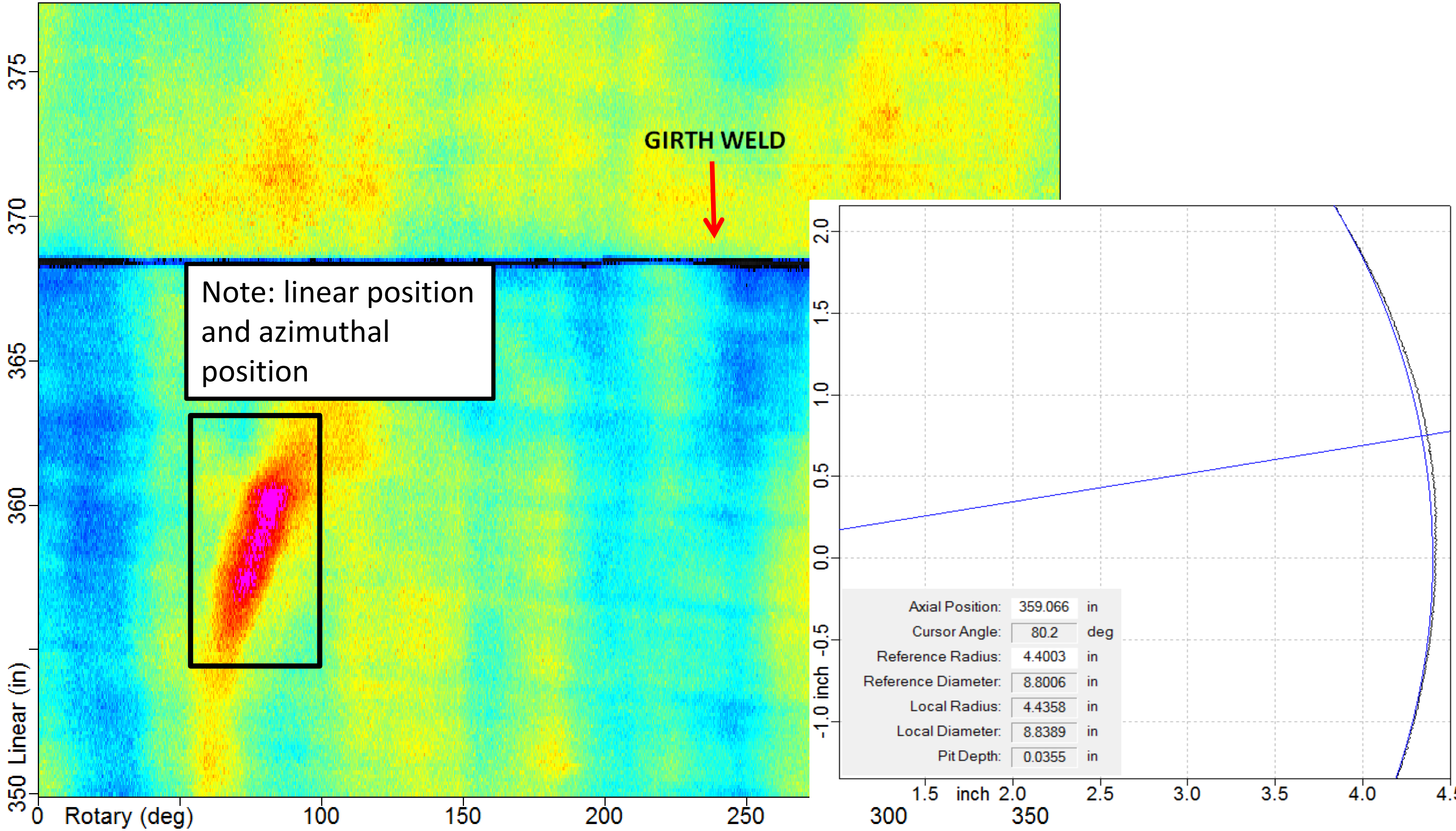
Deep Well = ⬆ WLTension ⬆ Normal Force = ⬆ Damage



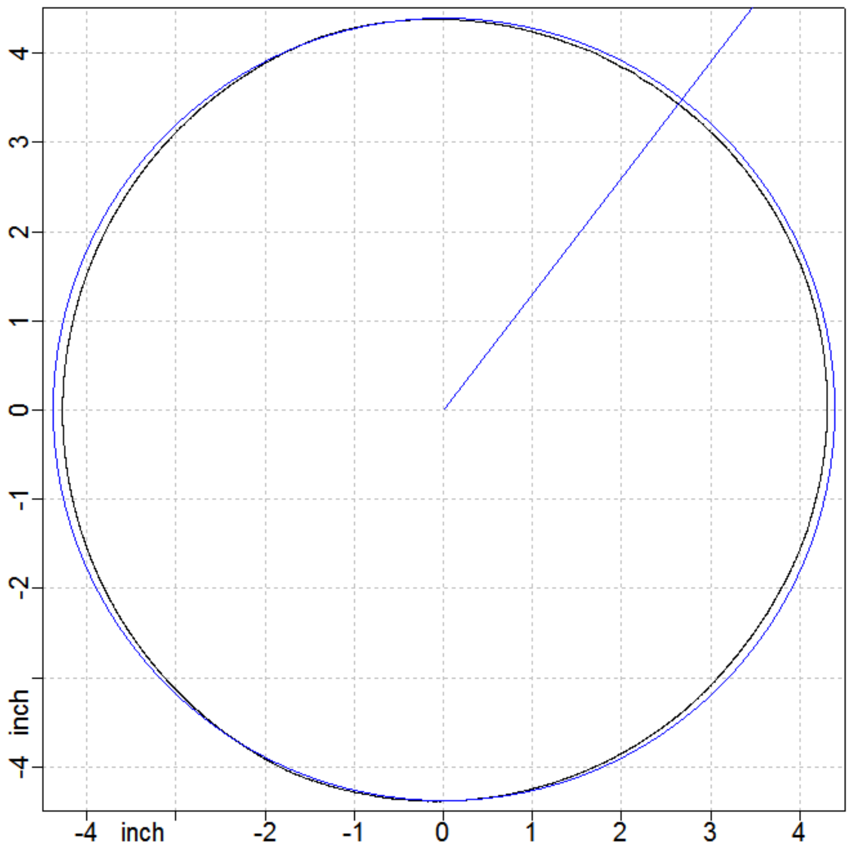
CRA Tubing / VIT



Flow Erosion

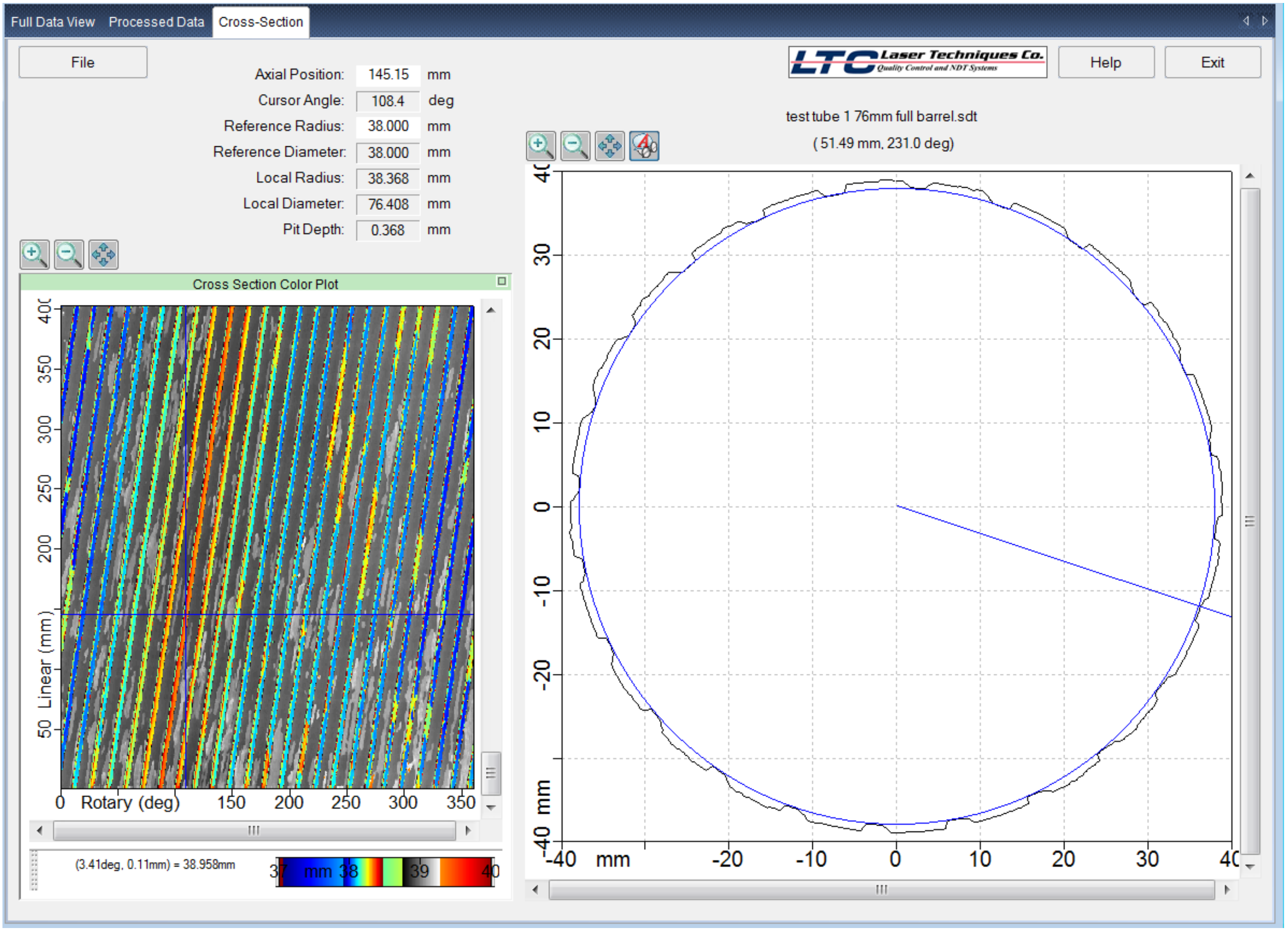


What You Can Use an Accurate Internal Diameter For…..



- FEA Your HPHT Packer with the Actual Casing Measurements
- Bump the Plug: 1 % in 30K ft well = 75 bbls
- Hydraulics Models: Pi R^2

Cross Section
Rifled Barrel



LASERSTREAM, L.P.

Scott King – 281-883-3697
jscott.king@laserstreamlp.com

Jason Waligura – 713-775-4455
jason.waligura@laserstreamlp.com