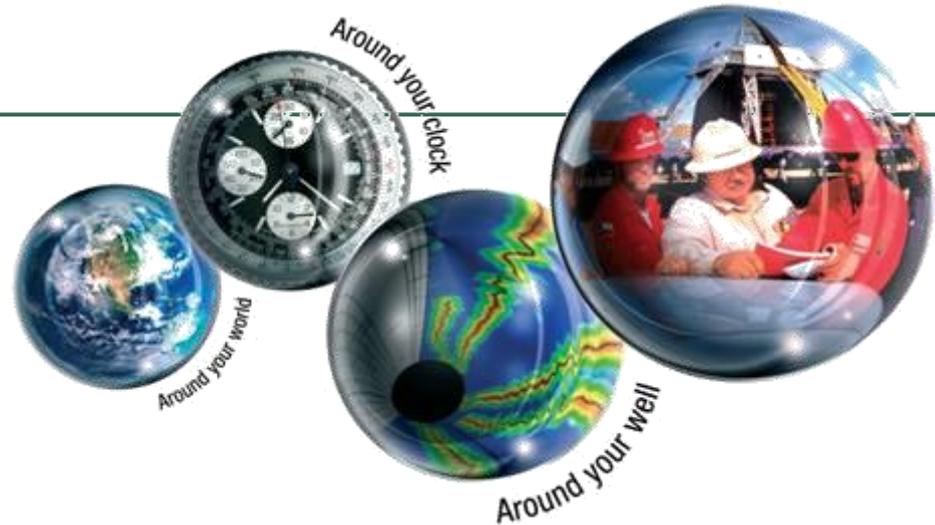




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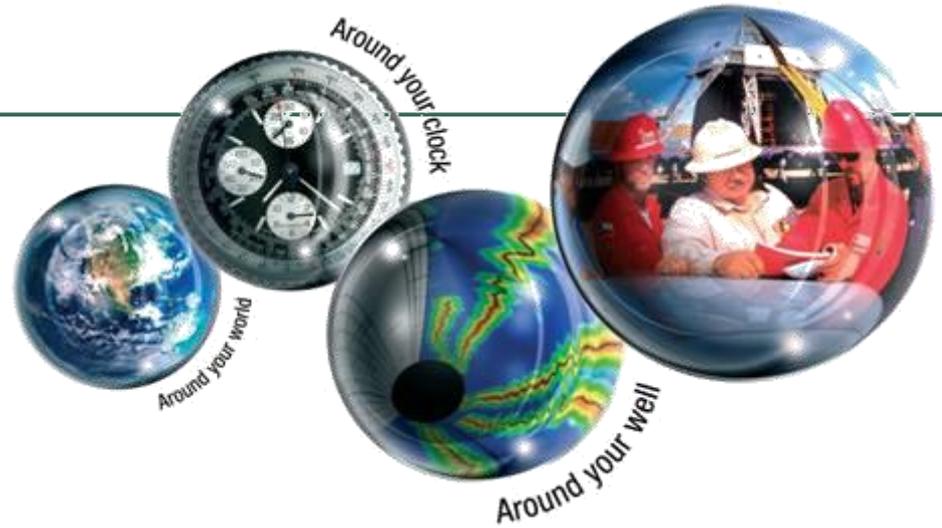
Casing Integrity Tools

- Multi Sensor Caliper (MSC)
- Casing Imaging Tool (CIT)

By: Kory Rutledge
Kory.Rutledge@Weatherford.com
January 2015



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Multi-Sensor Caliper (MSC)



Multi-Sensor Caliper (MSC)

Features and Benefits

- Individual arms able to take independent readings (40 or 60 arm configurations)
- Radius information for each arm is recorded and displayed
- Provides detailed wellbore geometry
- Hole deviation measurement referenced to Arm 1 for high side directional reference
- X-Y accelerometers for trajectory determination
- Wellbore temperature measurement
- 3D graphical analysis package

Temperature Probe

Electronics Package

Spring-loaded
Feeler Arms



Multi-Sensor Caliper (MSC)

Technical Specifications

	<u>Ratings</u>
Temperature	177 C (350 F)
Pressure	137.9 MPa (20,000 PSI)
Logging Speed	9.1-36.6 m/min (30-120ft/min)
Sampling Rate	40 samples/m (12 samples/ft)

<u>Tool Model</u>	<u>OD</u>	<u>Length</u>	<u>Weight</u>	<u>Casing Range</u>
A	93mm(3.635in)	2.23m(87.8in)	56kg(123.5lb)	114.3-144mm (3.92-7.625in)
B	140mm(5.5in)	2.30m(90.55in)	91.6kg(201.9lb)	193-273mm (7.625-10.75in)
w/ Kit EXK-AA	216mm(8.5in)	2.36m(92.75in)	113.4kg(250lb)	244-273mm (9.625-14in)
w/ Kit EXK-BA	273mm(10.8in)	2.39m(94.0in)	117.9kg(260lb)	356-558mm (14-22in)





Multi-Sensor Caliper (MSC)

Technical Specifications

<u>Tool Model</u>	<u>OD</u>	<u>Resolution</u>	<u>Accuracy</u>
	(mm/in)	(mm/in)	(mm/in)
A	93(3.635)	0.025/0.001	(+/-0.25)/(+/-0.01)
B	140(5.5)	0.025/0.001	(+/-0.25)/(+/-0.01)
14"	216(8.5)	0.050/0.002	(+/-0.30)/(+/-0.012)
22"	273(10.8)	0.075/0.003	(+/-0.625)/(+/-0.025)

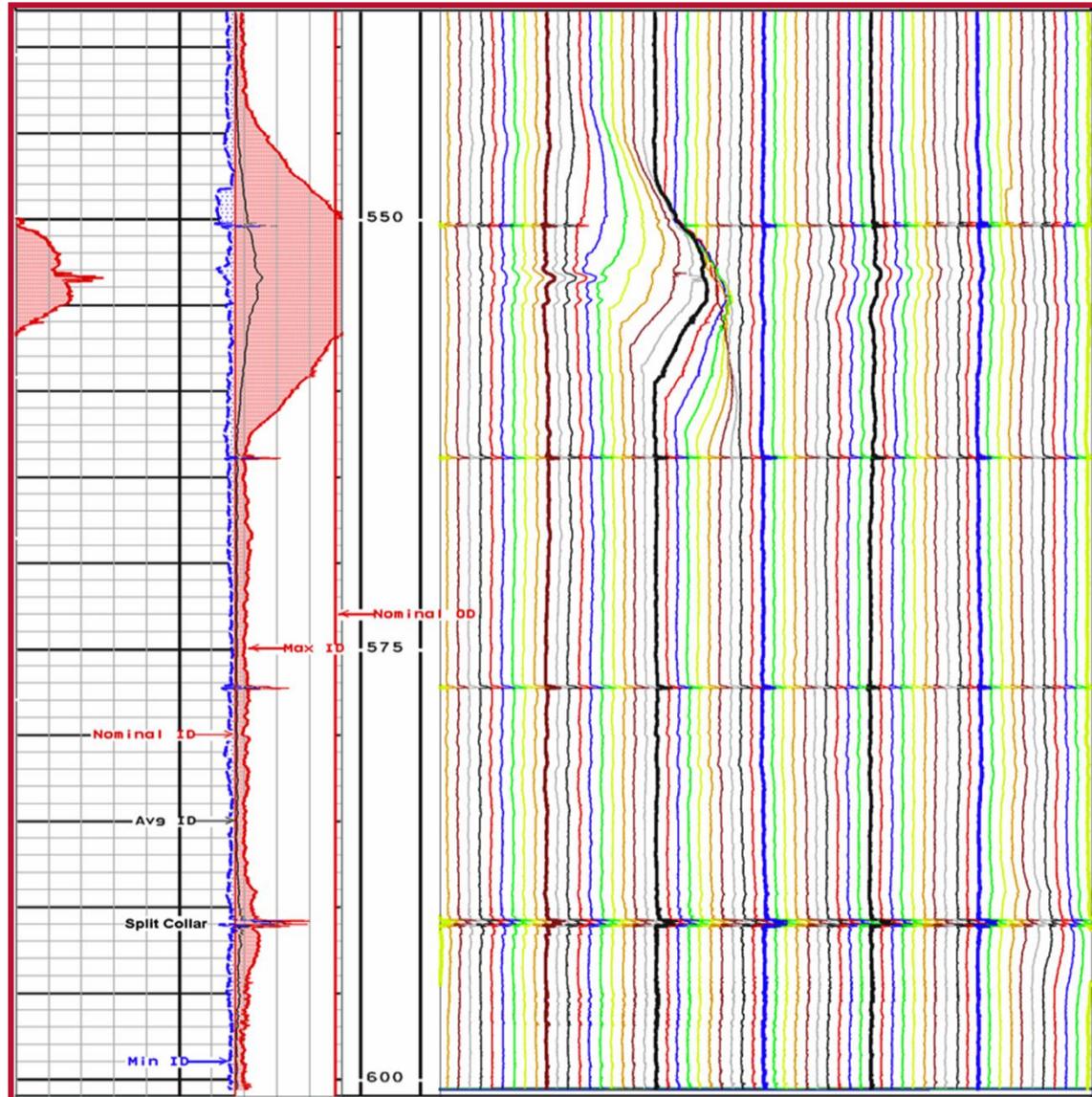




Multi-Sensor Caliper (MSC)

Data Interpretation

- **Field presentation**
- Displays radial information from 40 or 60 arms
- Min, max and average diameter
- Nominal OD and ID for general comparison to calculated field curves





Multi-Sensor Caliper (MSC)

TVision™ Visualization Software

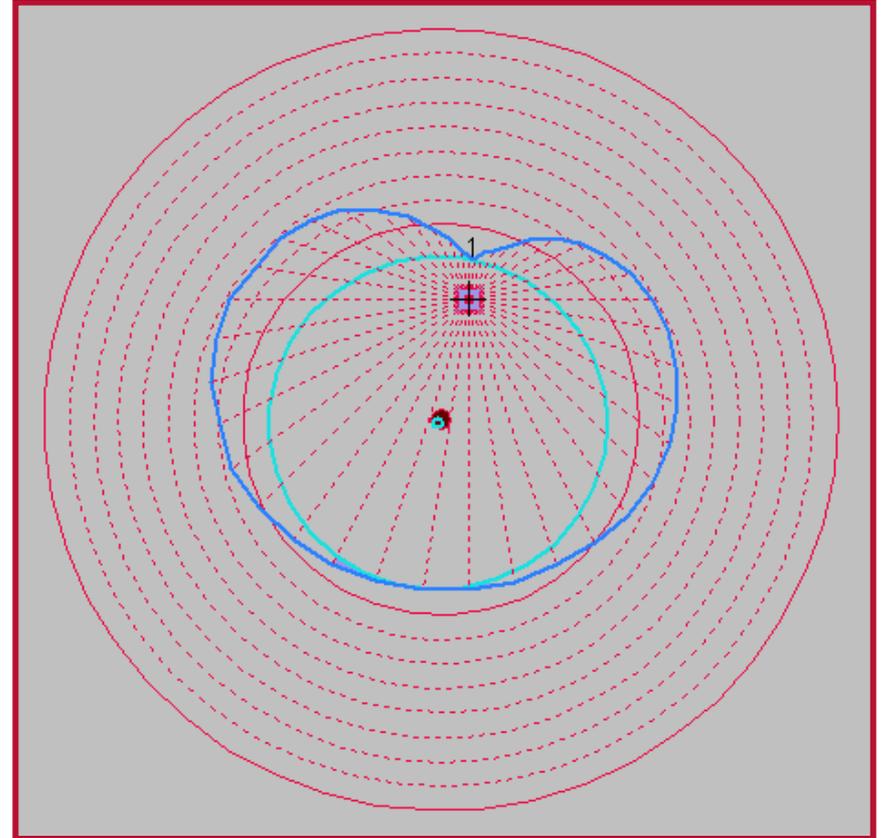
- **Developed to take advantage of the accuracy and precision of the MSC tool**
- **Provides:**
 - 2D pipe cross-section & 3D interactive view
 - Provides the basis for pipe axis deformation evaluation
 - Clearance and drift diameter analysis
 - Ovality analysis for determining the size and direction of the ovality mode of deformation



Multi-Sensor Caliper (MSC)

TVision™ Visualization Software

- **Clearance diameter defines the minimum restriction at that sample depth**
- **Displays actual shape of pipe at that sample depth and nominal diameter for reference.**
- **Multiple clearance diameters, in conjunction with well trajectory, used to create Drift Diameter**

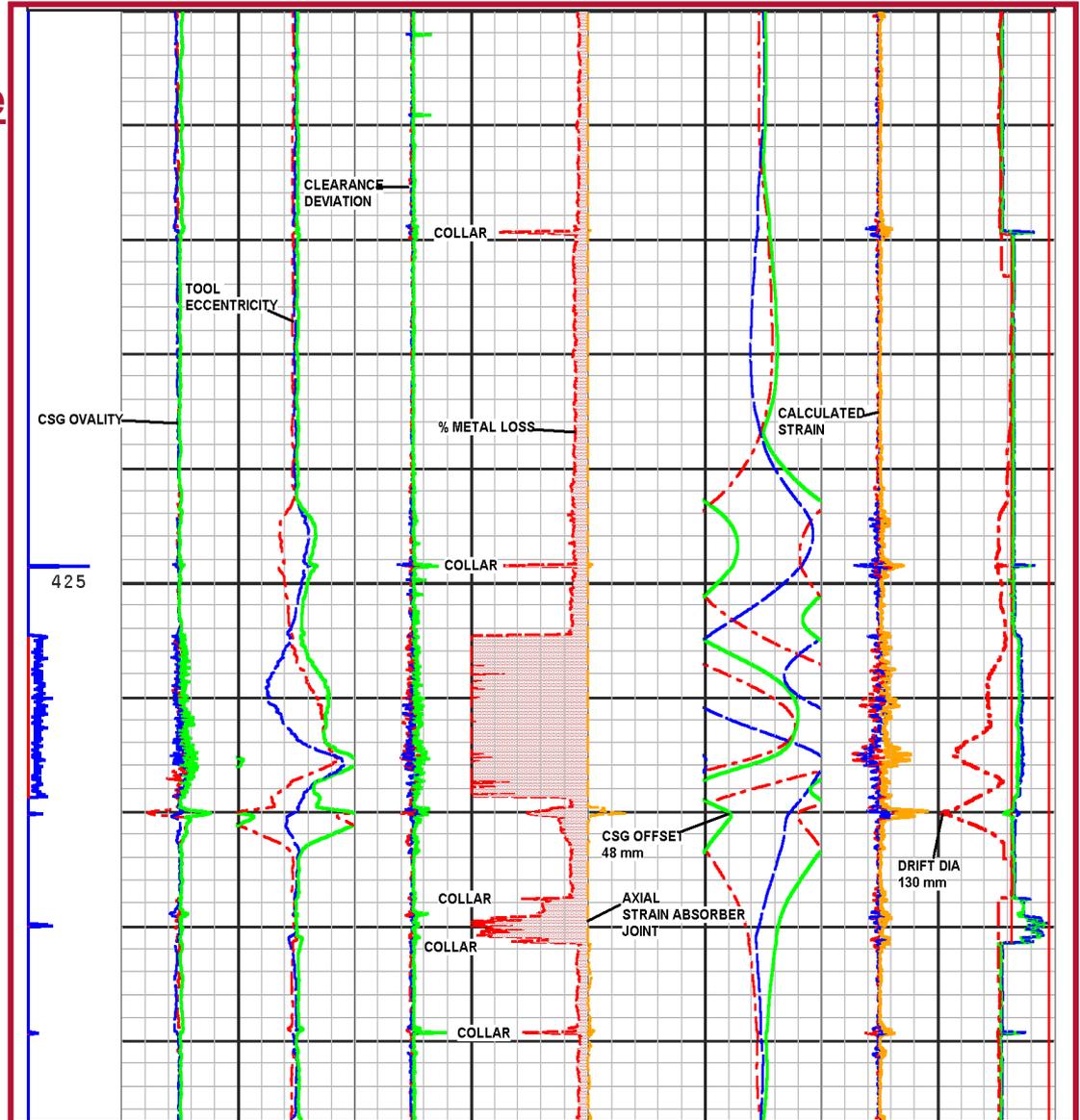




Multi-Sensor Caliper (MSC)

TVision™ Visualization Software

- MAD Arm
- BAD Arm
- Casing Ovality
- Tool Eccentricity
- Clearance Deviation
- Metal loss (%)
- Trajectory
- Strain
- Drift Diameter (48")

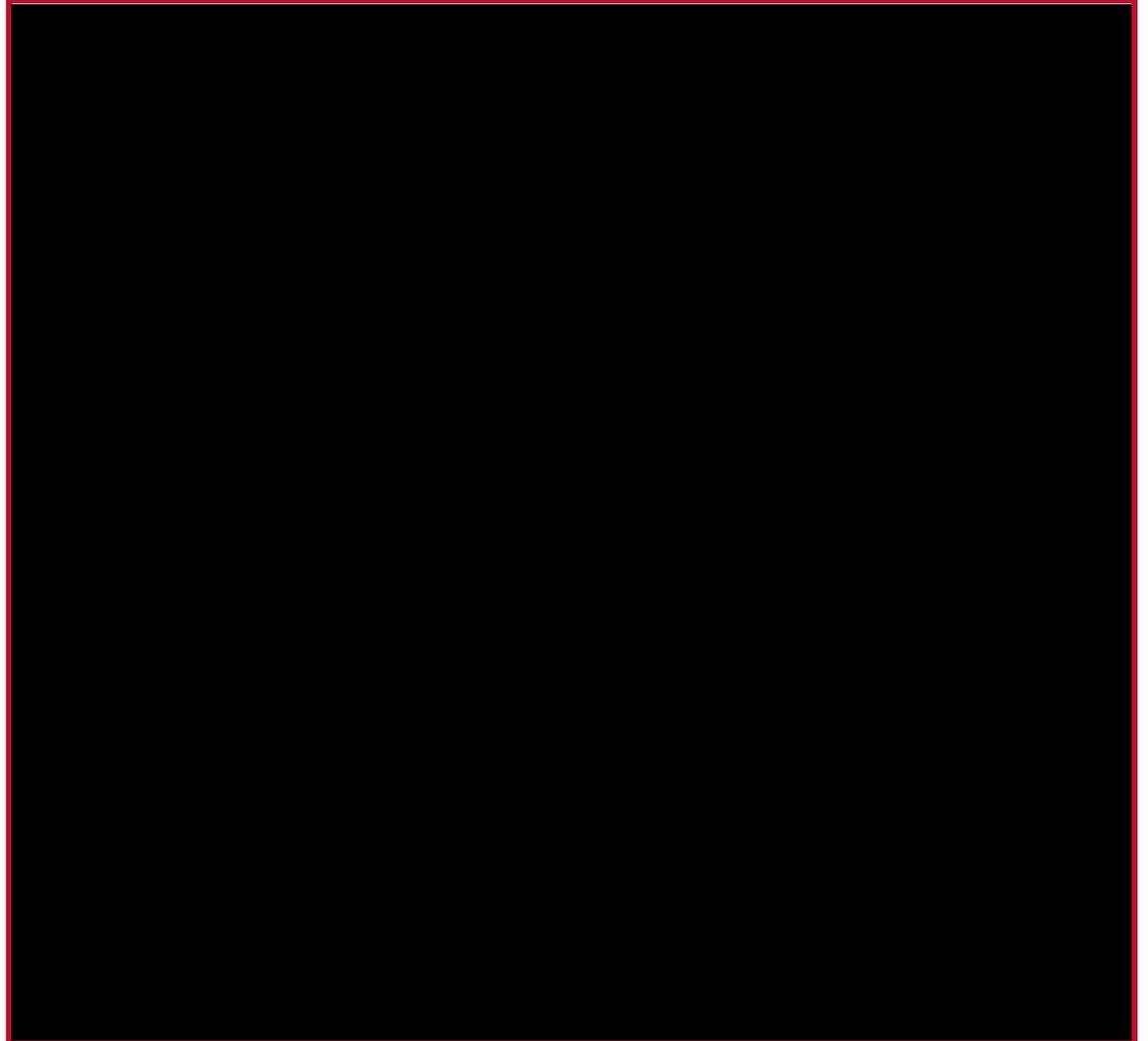




Multi-Sensor Caliper (MSC)

TVision™ Visualization Software

- 3D Visualization





New Products

- **High Resolution MSC**
 - 122 samples/ft
- **Burst Pressure Calculations**
 - Barlow – Standard Or High Resolution MSC
 - Linear based equation using depth of penetration of worst case defect of each joint
 - Modified B31G (MB31G) – High Resolution MSC Only
 - Geometry based equation using geometry of defect, and depth of penetration for worst case defect of each joint



MSC Joint Table (word document)

MSC Summary Interpretation

Casing	Size (in)	Wt (lb/ft)	Grade	Wall (in)	ID (in)	From (ftKB)	To (ftKB)
String 1	13.375"	48#	H-40			Surface	299'
String 2	9.625"	40#	J-55			Surface	3917'
String 3	5.5"	20#	P-110			Surface	13170'

Joint Classification	Color	Percent Penetration	No. of Unclassed Joints	0
Class 1	Green	0-20%	No. Class 1 Joints	205
Class 2	Yellow	21-40%	No. Class 2 Joints	13
Class 3	Orange	41-60%	No. Class 3 Joints	0
Class 4	Red	61-80%	No. Class 4 Joints	0
Class 5	Dark Red	81-100%	No. Joints with Penetration	0

Joint Table

Joint No.	From	To	Length	Percent Loss	Position	Class	Comments
1	16.90	29.20	12.30	16.9	19.90	C1	
2	29.20	68.40	39.20	11.8	55.90	C1	
3	68.40	108.60	40.20	17.4	101.30	C1	
4	108.60	148.80	40.20	18.4	141.10	C1	
5	148.80	187.10	38.30	20.8	164.90	C2	
6	187.10	226.60	39.50	13.6	196.50	C1	
7	226.60	265.80	39.20	18.1	261.80	C1	
8	265.80	304.80	39.00	14.4	287.20	C1	
9	304.80	344.40	39.60	11.7	336.40	C1	
10	344.40	384.40	40.00	21.2	381.30	C2	
11	384.40	423.60	39.20	13.5	391.10	C1	
12	423.60	463.20	39.60	15.1	459.60	C1	
13	463.20	499.60	36.40	18.6	476.90	C1	
14	499.60	536.50	36.90	19.8	509.40	C1	
15	536.50	573.10	36.60	13.5	551.00	C1	
16	573.10	612.80	39.70	15.1	601.00	C1	
17	612.80	652.60	39.80	12.1	616.70	C1	
18	652.60	692.40	39.80	12.0	660.40	C1	
19	692.40	731.50	39.10	14.0	728.00	C1	
20	731.50	768.10	36.60	17.6	739.30	C1	
21	768.10	807.90	39.80	20.0	804.50	C2	
22	807.90	847.30	39.40	16.1	812.70	C1	
23	847.30	884.10	36.80	12.2	852.30	C1	
24	884.10	921.00	36.90	17.3	911.20	C1	
25	921.00	960.70	39.70	15.4	957.00	C1	
26	960.70	1000.60	39.90	11.2	965.20	C1	
27	1000.60	1037.20	36.60	12.9	1023.80	C1	
28	1037.20	1077.00	39.80	13.4	1066.30	C1	
29	1077.00	1117.00	40.00	20.6	1102.20	C2	
30	1117.00	1153.90	36.90	13.0	1121.70	C1	
31	1153.90	1193.90	40.00	13.2	1157.10	C1	
32	1193.90	1230.30	36.40	15.9	1219.90	C1	
33	1230.30	1266.80	36.50	13.1	1234.50	C1	
34	1266.80	1305.80	39.00	13.7	1301.40	C1	
35	1305.80	1344.50	38.70	14.4	1310.20	C1	
36	1344.50	1381.70	37.20	21.3	1372.30	C2	
37	1381.70	1420.60	38.90	11.6	1412.90	C1	



MSC Joint Table (word document) cont.



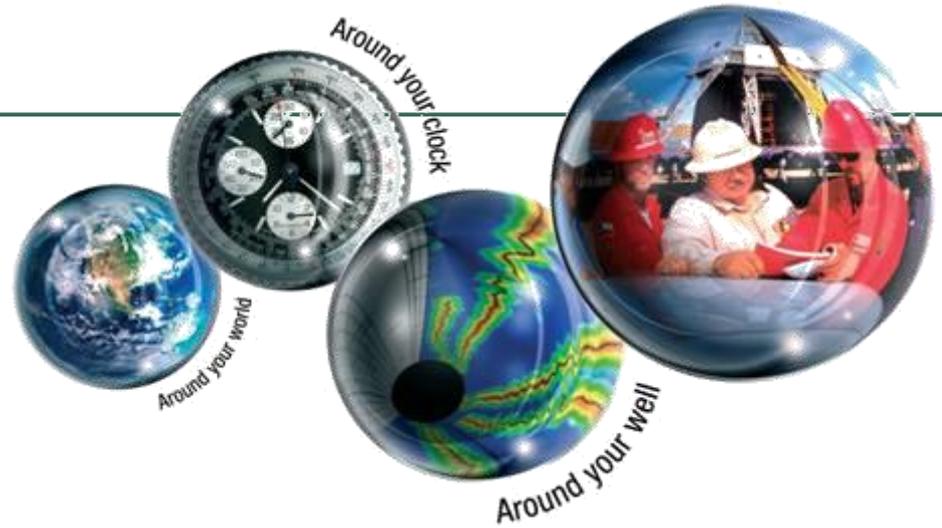


Final MSC Products Summary

- **Burst Pressure Calculations**
- **Joint-Summary Report (Word Document)**
- **TVision Interactive CD**
- **TVision Logplot**
- **MSC Field Logplot**



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Casing Imaging Tool (CIT)



Casing Imaging Tool (CIT)

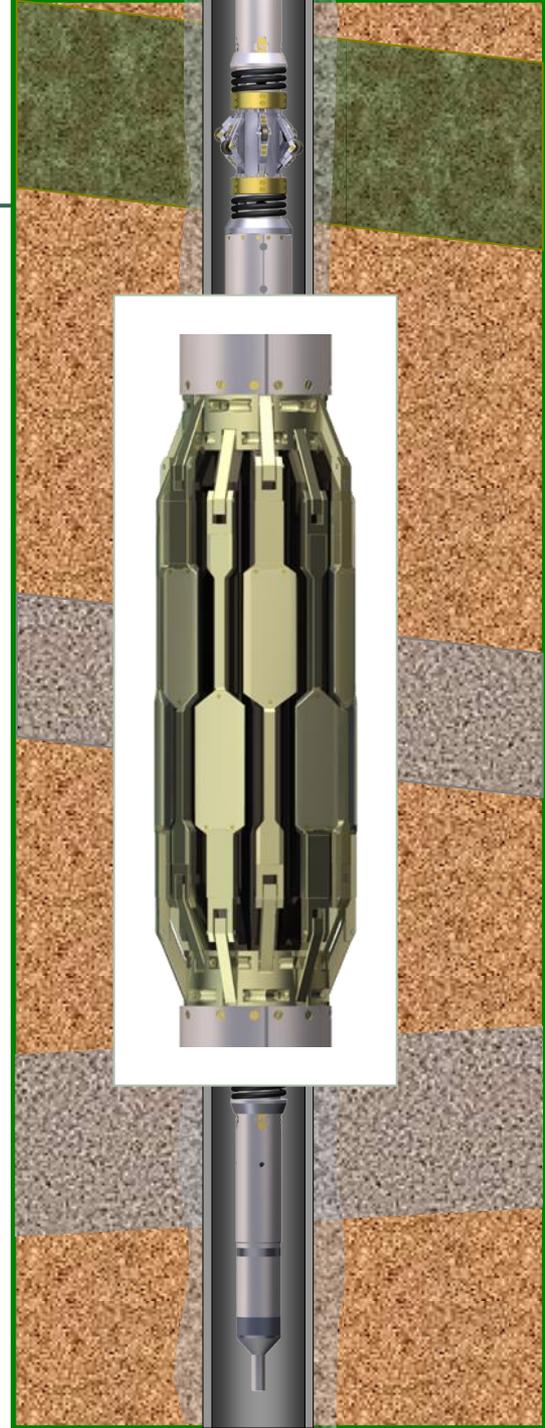
Tool Configuration

Magnet/Flux Source

- **Permanent magnet** produces lines of flux within the casing wall.
- Magnetic field temporarily **saturates** the casing during each pass, eliminating residual magnetism issues, ensuring excellent repeatability.
- The need for a surface powered electromagnet, which can be difficult to properly maintain power and flux saturation, is eliminated.

Sensors

- Two overlapping arrays of **Hall-Effect sensors** mounted within the CIT's pads, **detect changes in the internal surface flux leakage** caused by:
 - inside or outside defects in the pipe
 - size, weight, and/or grade changes
 - in-line or external hardware
 - external casing strings



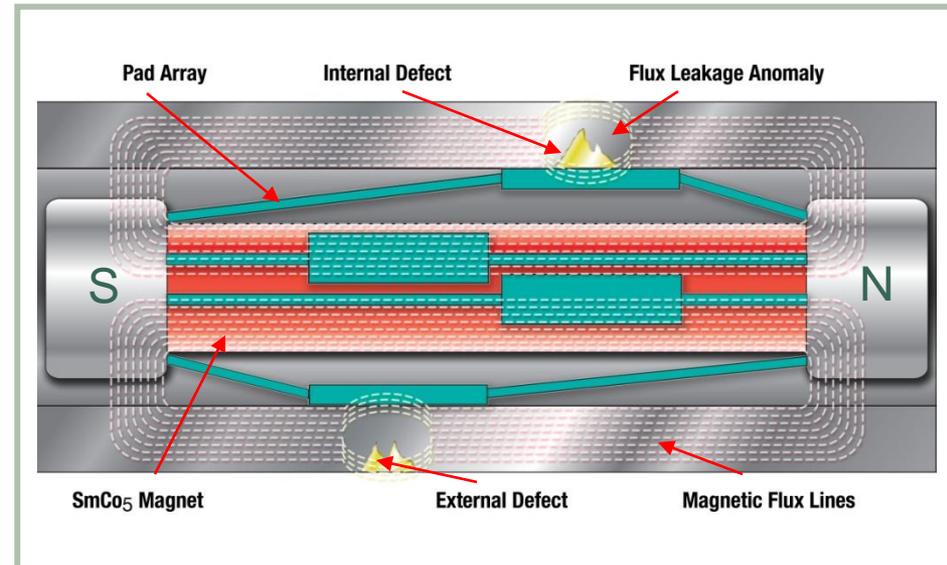


Magnetic Flux Leakage

Defect Identification

Corrosion Sensors

- As the tool moves past a defect, the magnitude of the internal flux leakage is measured by corrosion sensors mounted in each of the CIT's pads.
- The magnitude of the leakage is related to the geometry and severity of the defect.



← Uphole

Downhole →

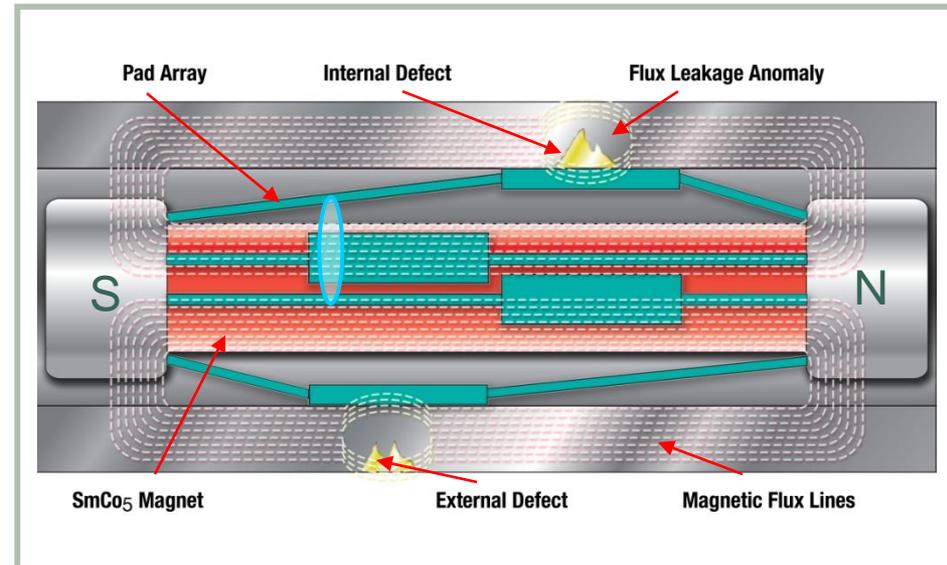


Magnetic Flux Leakage MFL

Defect Identification

Discriminator Sensors

- **Discriminator Sensors** are used to help differentiate between internal and external defects.
- **Discriminator Sensors** are mounted perpendicular to the main field measured by the corrosion sensors.
- Each discriminator sensor is connected to a low power magnet capable of magnetizing only the internal surface of the pipe.
- Changes in the discriminator magnet's field allow us to recognize internal defects.



← Uphole Downhole →



Casing Imaging Tool (CIT)

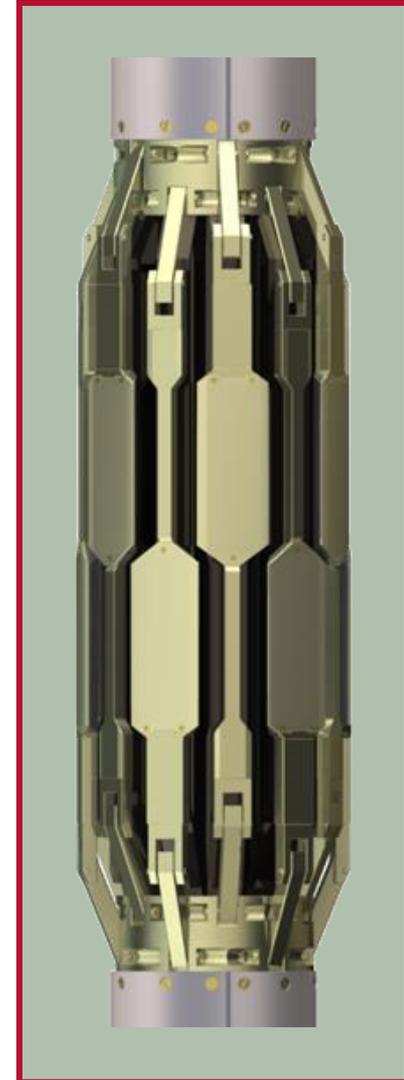
Technical Specifications

Ratings

Temperature	320 F
Pressure	15,000 PSI
Logging Speed	100 ft/min (recommended)
Sampling Rate	122 samples/ft

Tool Model	OD (in)	Length (ft)	Weight (lb)	Casing Range (in)
A	3.88-5.20	18.40	429.2	4.5
B	4.11-5.20	18.40	430.4	5.0-5.5
C	5.13-7.36	18.00	582.8	6.63-7.63
D	7.00-9.35	18.40	889.3	8.63-10.75

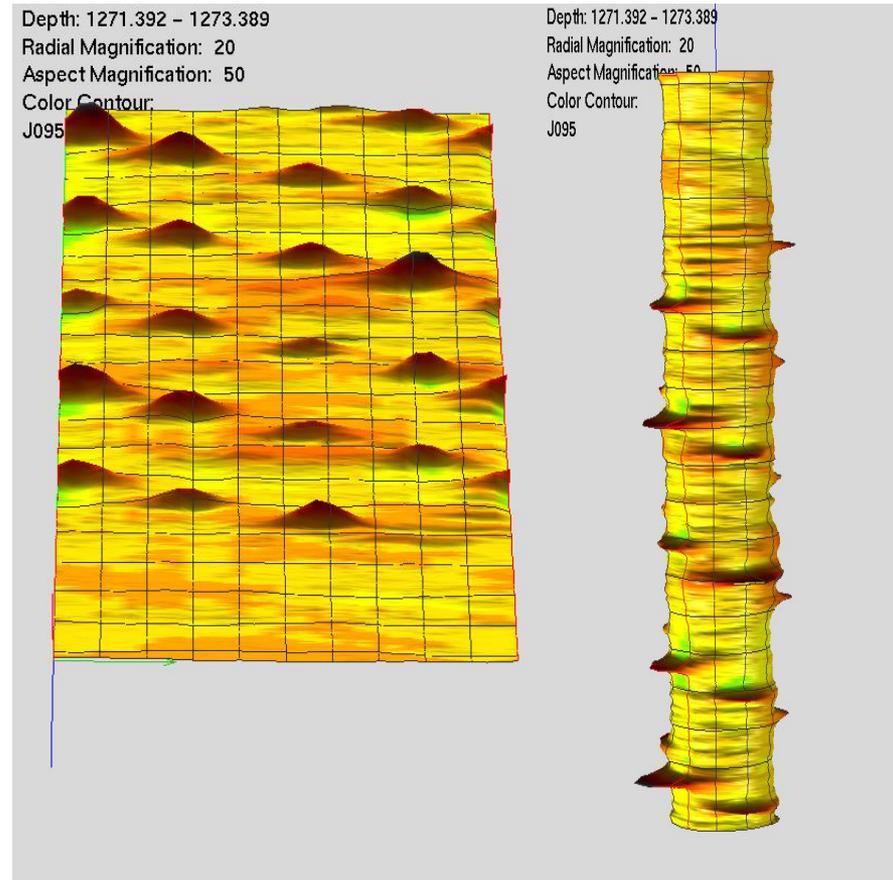
- Ran with Gamma Ray
- Can be run with Multi Sensor Caliper (MSC) and UltraSonic Radial Scanner (URS) all in combination (1 pass)





CITVision Software

- **Uses 3-dimensional images generated from high resolution MFL measurements**
- **Provides clearer picture of the defects within the joint and allows visual analysis and classification of MFL associated with collars, and other hardware**
- **Aids in the determination of the type, distribution, and extent of the casing defect or corrosion**

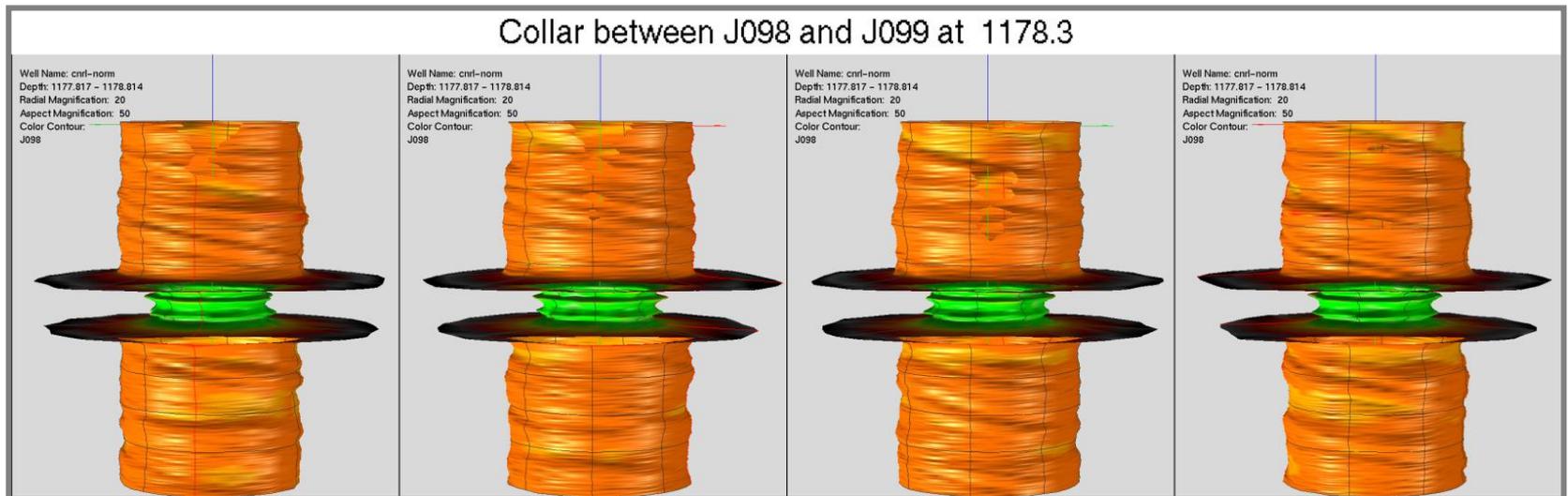




Data Interpretation

Casing Collar

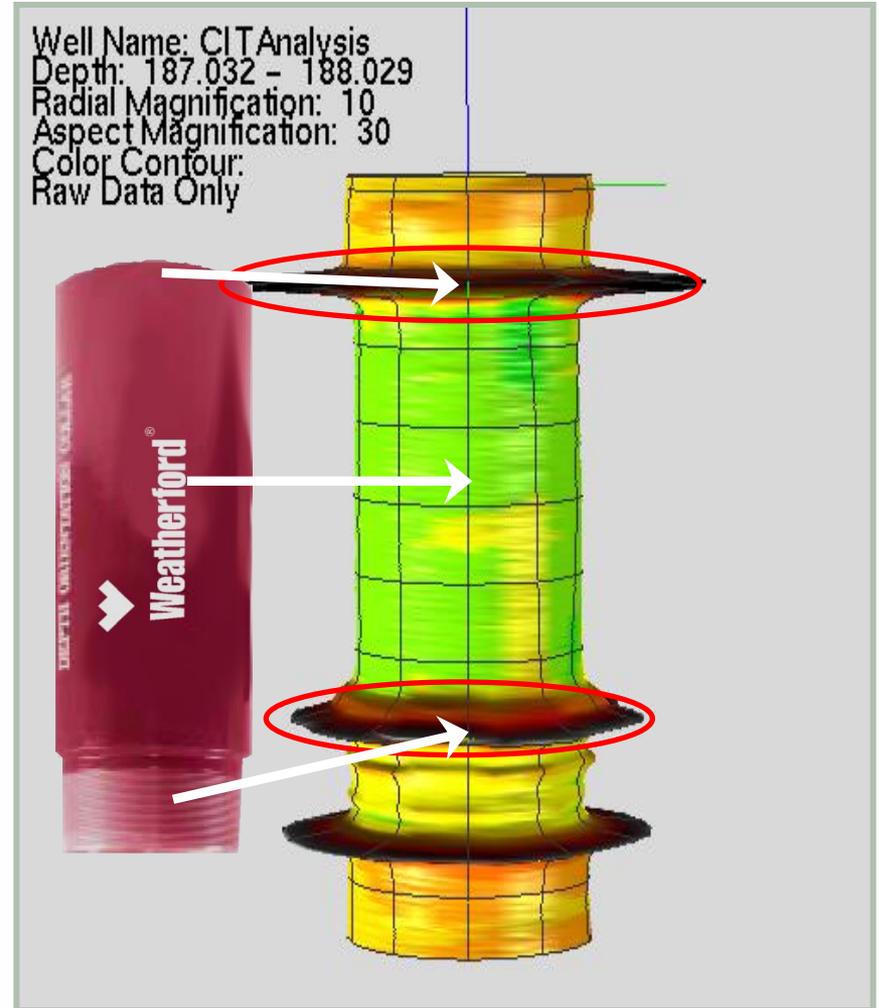
- Processed data display of a collar – 4 views
- Flux suppression in center due to increased mass of collar
- Flux leakage due to threads





CITVision 3D

- **Pipe summary from client indicated this was a Depth Orientation Collar.**





Data Interpretation

Joint Classification

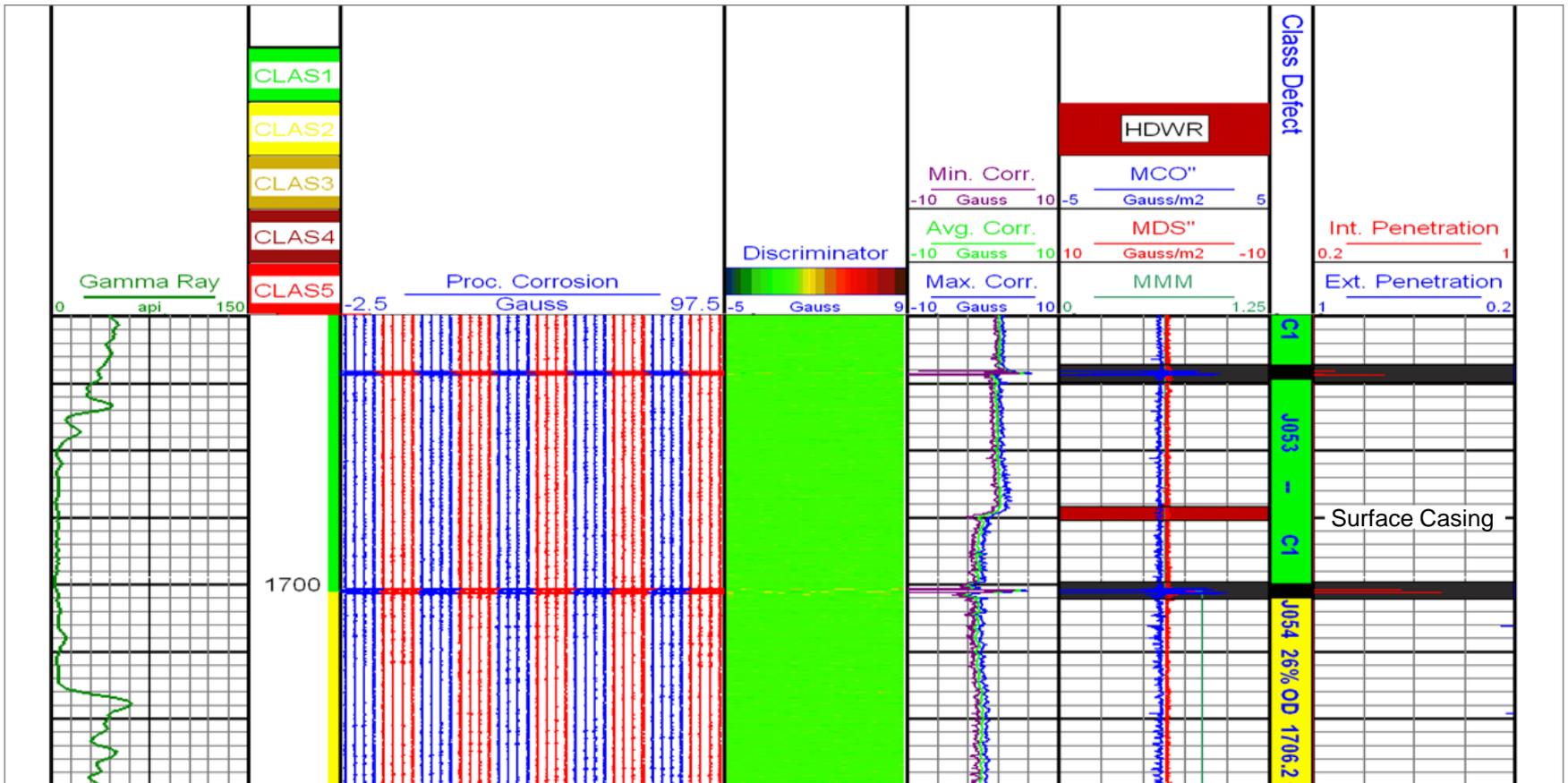
- All anomalies in a joint are analyzed to determine worst case defect and its percent penetration.

Joint Classification		Percent Penetration
Class 1	Green	0 -20%
Class 2	Yellow	21-40%
Class 3	Orange	41-60%
Class 4	Dark Red	61-80%
Class 5	Red	81-100%



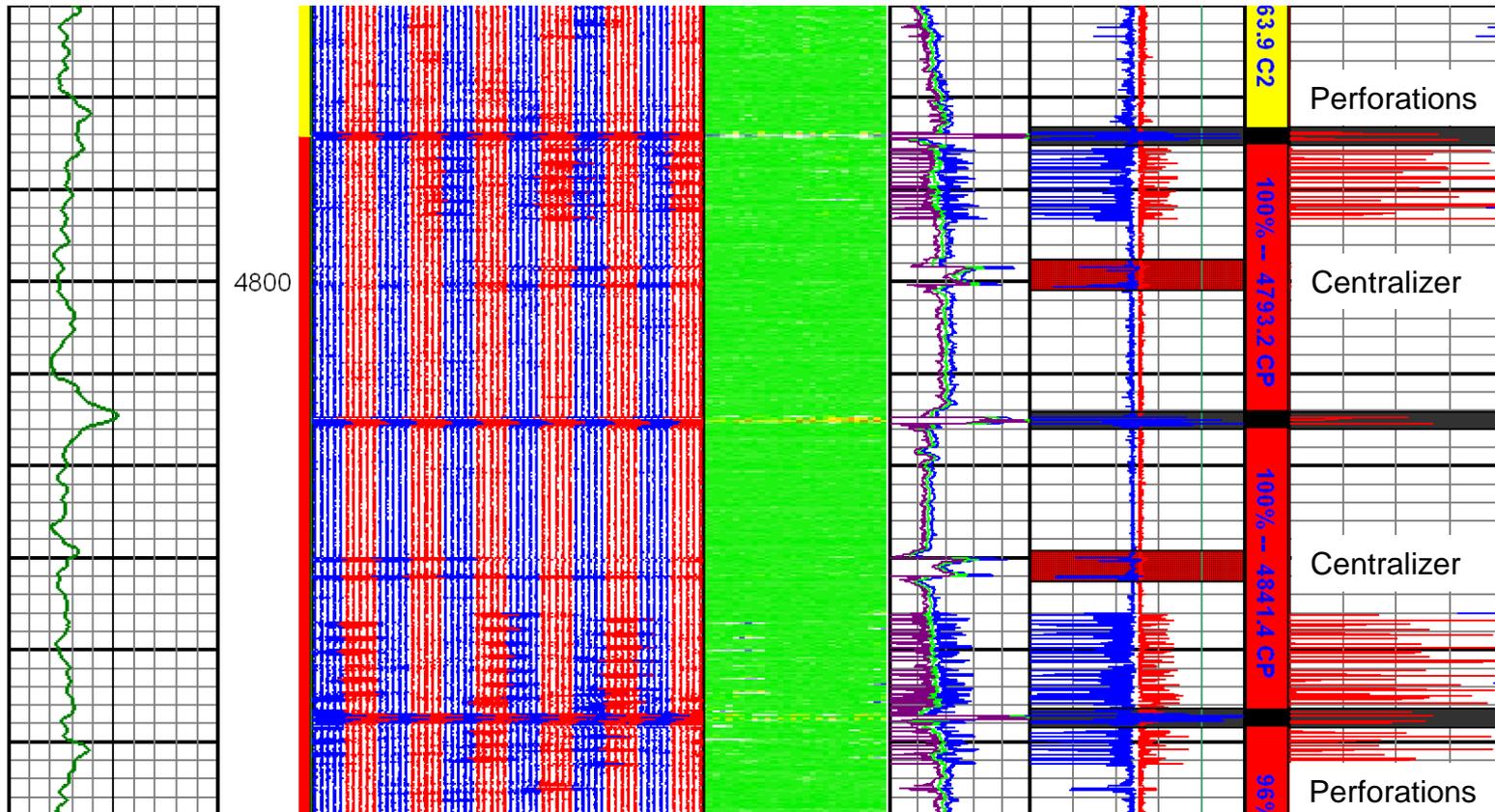
Data Interpretation

Presentation



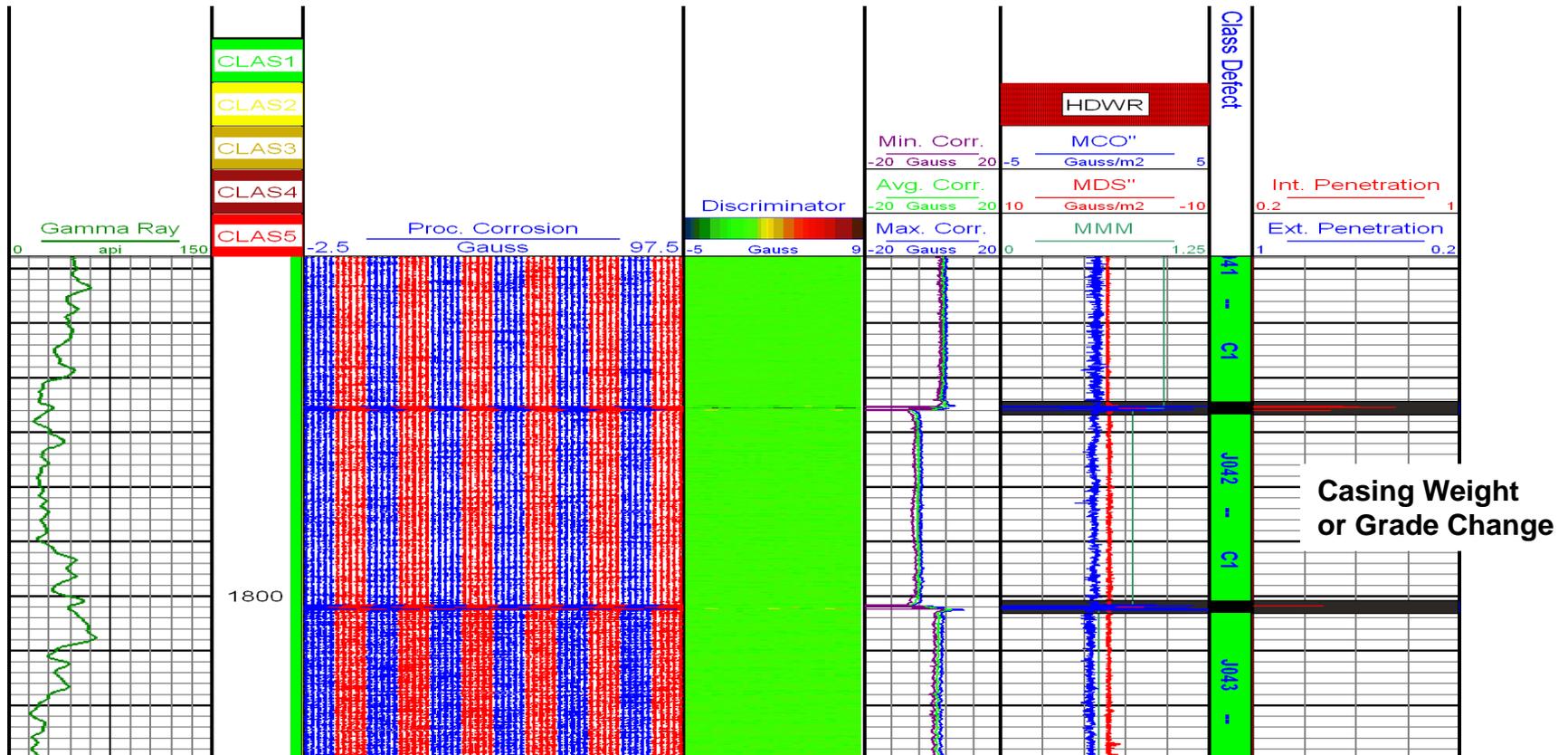


Data Interpretation



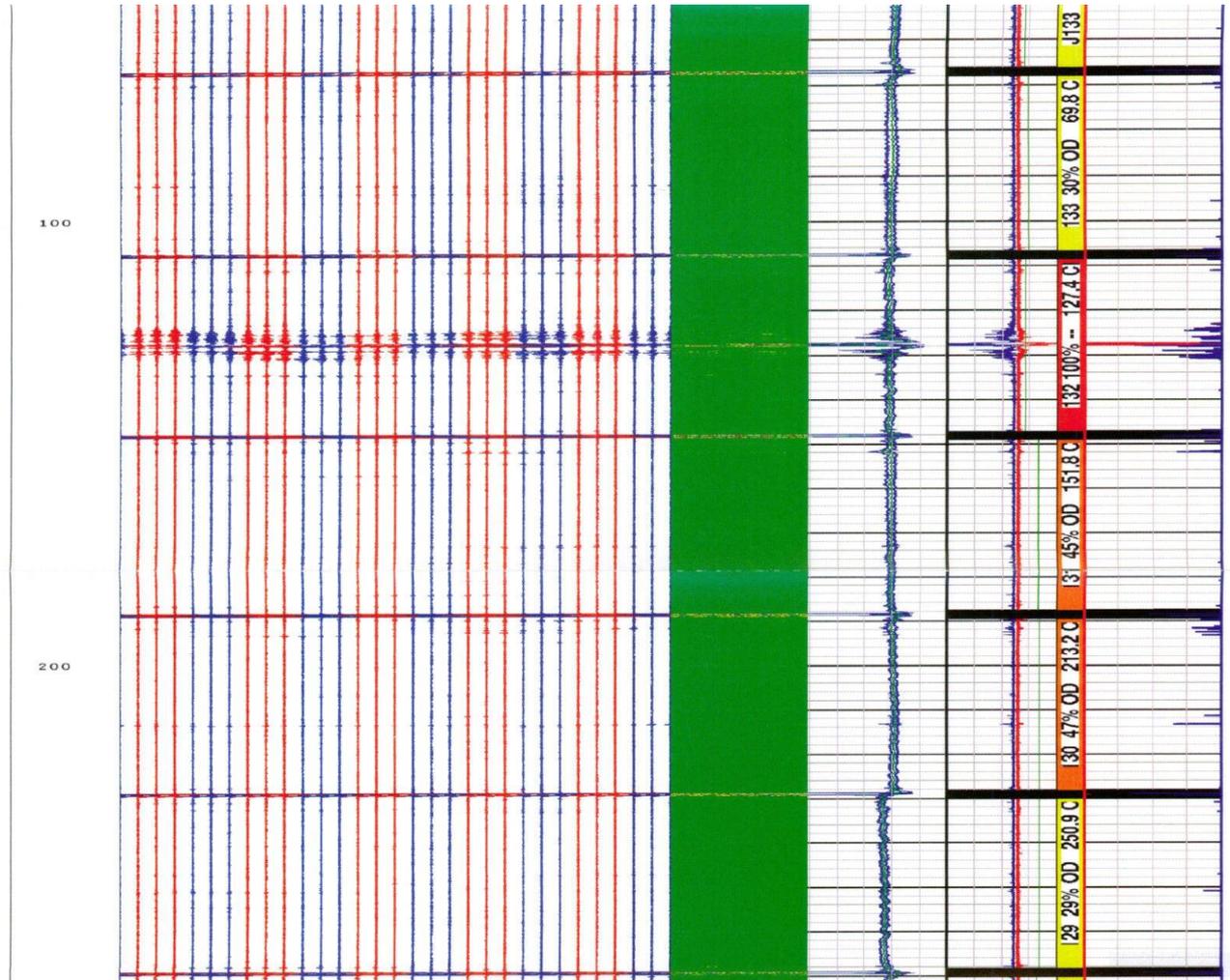


Data Interpretation





Hole with Outside Corrosion





2 Case Studies



Well #1

WFT = <20% ? = 48% Actual = 20.2%





Well #2

WFT = 24% ? = 59% Actual = 29%





New Products

- **Burst Pressure Calculations**
 - Barlow
 - Linear based equation using depth of penetration of worst case defect of each joint
 - Modified B31G (MB31G)
 - Geometry based equation using geometry of defect, and depth of penetration for worst case defect of each joint



Joint Summary Report (word document)

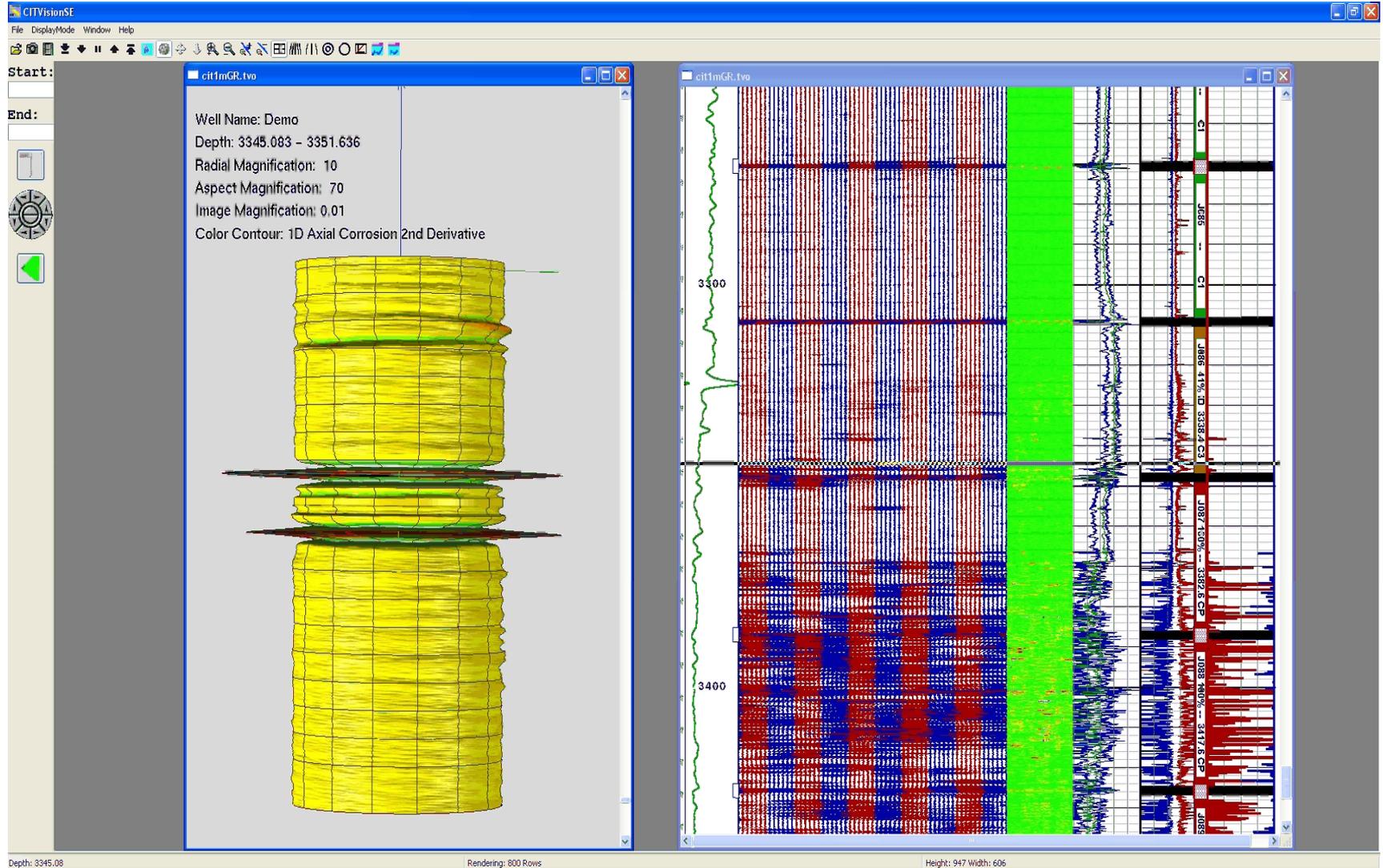
CT-Joint_Summary_Report-Demo.doc [Compatibility Mode] - Microsoft Word

Joint No.	From	To	Length	Max. Pen.	OD/ID	Position	Class	Type	Comments
3	63.85	103.16	39.3	23%	OD	90.0	C2	SIP	
4	103.16	142.13	39.0		--		C1	SIP	
5	142.13	180.17	38.0		--		C1	SIP	
6	180.17	219.37	39.2		--		C1	SIP	
7	219.37	258.25	38.9		--		C1	SIP	
8	258.25	297.43	39.2		--		C1	SIP	
9	297.43	336.66	39.2		--		C1	SIP	
10	336.66	375.66	39.0		--		C1	SIP	
11	375.66	414.74	39.1		--		C1	SIP	
12	414.74	453.84	39.1		--		C1	SIP	
13	453.84	492.43	38.6		--		C1	SIP	
14	492.43	531.66	39.2		--		C1	SIP	
15	531.66	570.83	39.2		--		C1	SIP	
16	570.83	609.99	39.2		--		C1	SIP	
17	609.99	648.78	38.8		--		C1	SIP	
18	648.78	687.35	38.6		--		C1	SIP	
19	687.35	726.55	39.2		--		C1	SIP	
20	726.55	765.43	38.9		--		C1	SIP	
21	765.43	804.01	38.6		--		C1	SIP	
22	804.01	843.23	39.2		--		C1	SIP	
23	843.23	881.63	38.4		--		C1	SIP	
24	881.63	920.84	39.2		--		C1	SIP	
25	920.84	959.72	38.9		--		C1	SIP	
26	959.72	999.00	39.3		--		C1	SIP	
27	999.00	1038.17	39.2		--		C1	SIP	
28	1038.17	1077.44	39.3		--		C1	SIP	
29	1077.44	1118.07	40.6	31%	OD	1091.8	C2	SIP	
30	1118.07	1157.34	39.3		--		C1	SIP	
31	1157.34	1196.49	39.2	22%	OD	1168.8	C2	SIP	
32	1196.49	1235.26	38.8		--		C1	SIP	
33	1235.26	1273.78	38.5	22%	OD	1266.6	C2	SIP	DV Tool
34	1273.78	1316.12	42.3	21%	OD	1304.5	C2	SIP	
35	1316.12	1355.49	39.4		--		C1	SIP	
36	1355.49	1393.16	37.7		--		C1	SIP	
37	1393.16	1432.46	39.3		--		C1	SIP	
38	1432.46	1471.12	38.7		--		C1	SIP	

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CITVision DVD Interactive Product





Final Products

- **Burst Pressure Calculations**
- **Joint-Summary Report**
- **CITVision Interactive DVD**
- **CIT Logplot**



CIT or MSC?

- **When should you use CIT?**

- Looking for Internal or External Corrosion
- Looking for holes
- Looking for Hardware
- Checking for perforation analysis
- Looking for possible collar connection issues

- **When should you use MSC?**

- Looking for internal defects
- Looking for Holes
- Looking for casing deformation (bending, ovality, etc..)
- Looking for casing ID (clearance and drift)
- Looking for estimated wall thickness assuming NOMO (for burst pressure calcs)
- Looking for wear (i.e. drill wear)



Additional Information

- **Analysis and Interpretation will be more in depth and conclusive with multiple Well Integrity Tools run**
- **Casing Integrity Suite includes**
 - Multi Sensor Caliper (MSC) – High and Standard Resolution
 - Casing Imaging Tool (CIT)
 - Ultrasonic Radial Scanner (URS)
- **They can all be run in combination now! Eliminating multiple runs and saving time!**



Questions

Q & A