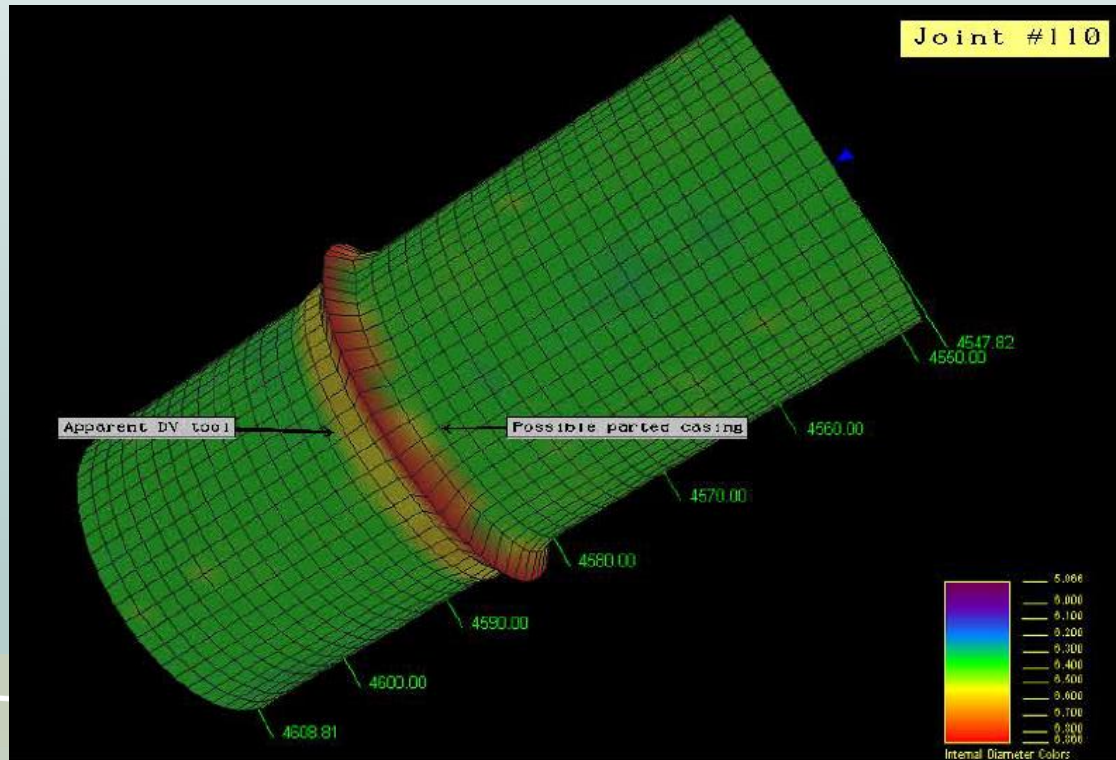


Case Studies:

Evaluating Well Integrity with Multi-Arm Caliper and Magnetic Resonance Logs



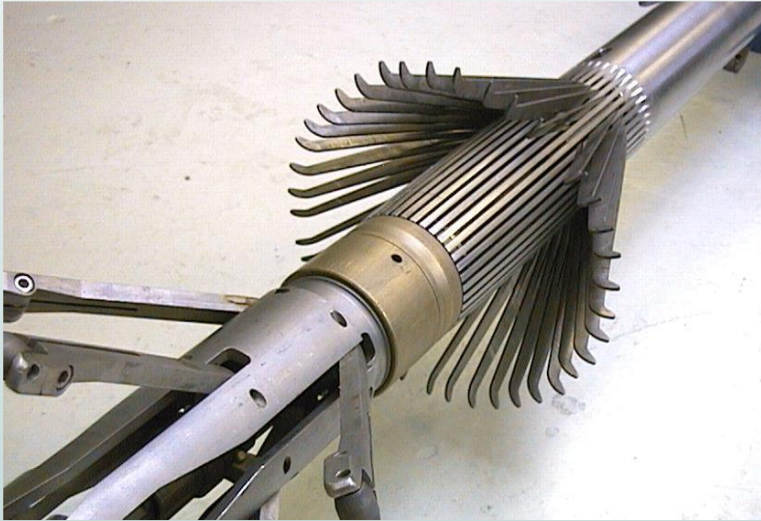
Monte Markley, P.G.
September 29, 2020

Reasons to Evaluate Well Integrity



- Failure of MIT
- Operational Anomalies
- Asset Analysis for CAPEX/OPEX Planning
- Ranking for risk evaluation or workover planning

Multi-Arm Caliper Log

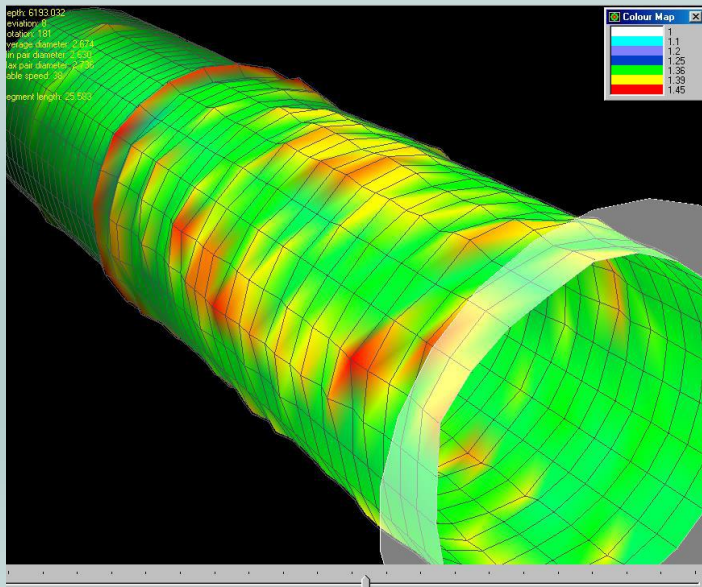


Pros:

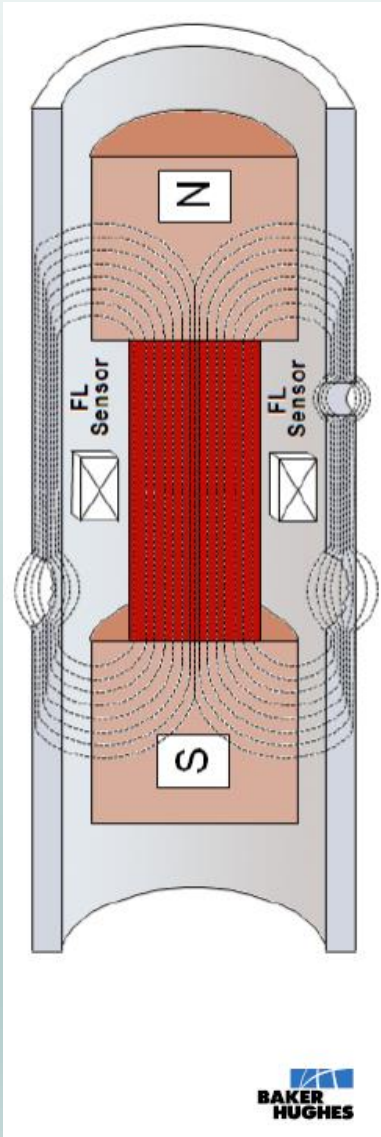
- 40-60 arms give 3-D Image after processing
- Excellent for mechanical damage and deformation
- Reasonable logging speeds

Cons:

- Limited to internal defects
- Scaling in pits can hide defect
- Limited casing sizes < 9 5/8"



Magnetic Flux/Resonance Log



Pros:

- Measures internal & external metal loss
- ID holes, corrosion and defect depth
- Allows geometric measurement of defect for burst calculations
- Can identify external casing strings

Cons:

- Limited to ferrous casings
- Can't detect long axial splits or gradual wear/corrosion

Reference



Wellbore Geometry



Dimensions and Strengths



Tub/Cas/Pipe in Hole



Tub/Cas/Pipe in Casing



Coupling Displacement



Capacity

Calculators

Technical Data

Favorites

HALLIBURTON

Pre-Planning Information

- Tubing/Casing Size & Weight
- ID & Drift Diameter
- Determine pipe wall thickness

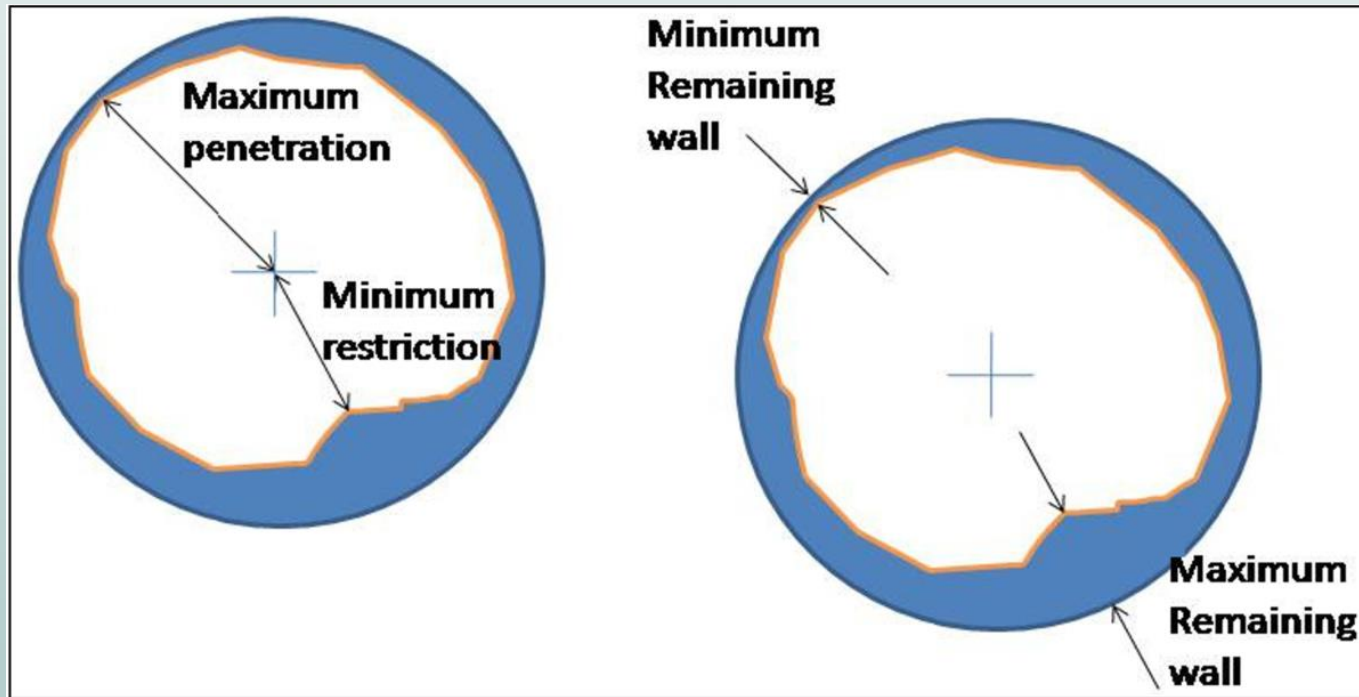
Well Preparation

- Junk Catcher
- Gauge Ring
- Casing Scraper
- Measure maximum well depth and ID to assess casing condition for subsequent runs

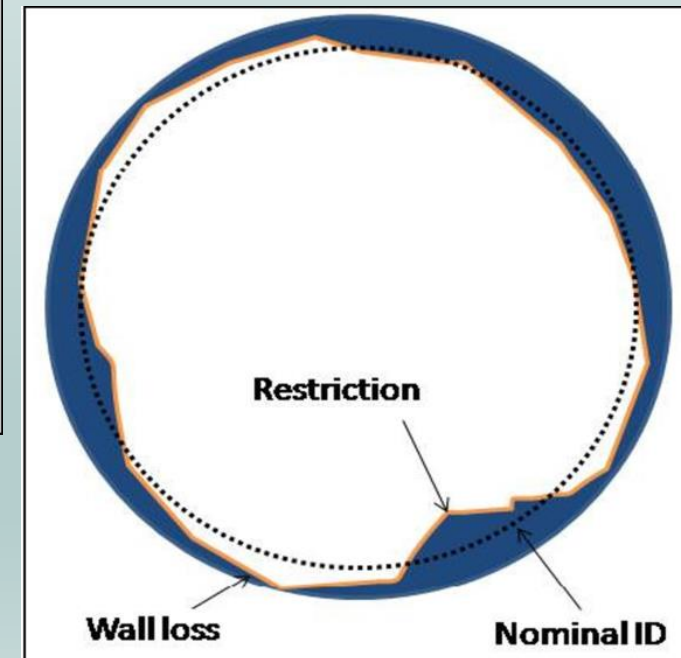


Log Interpretation – Basic Concepts

Maximum Penetration

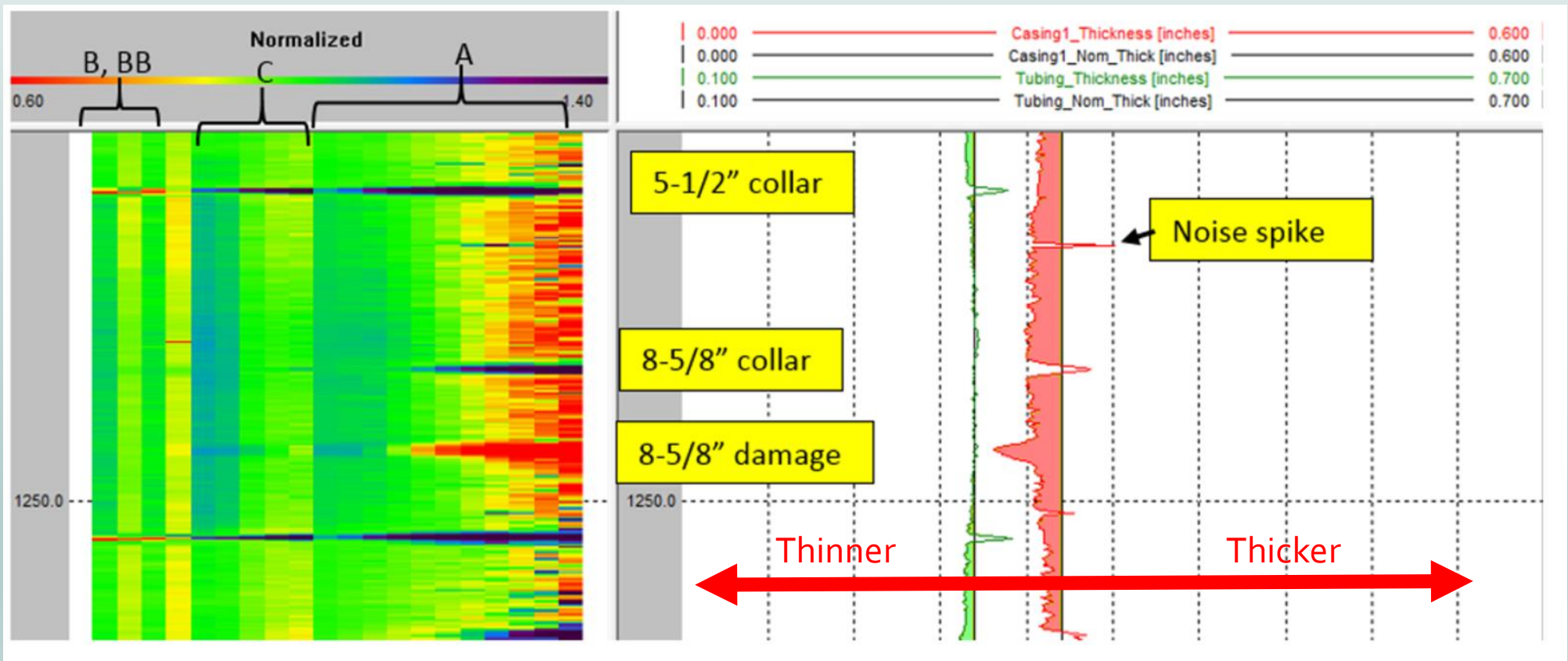


Wall Loss



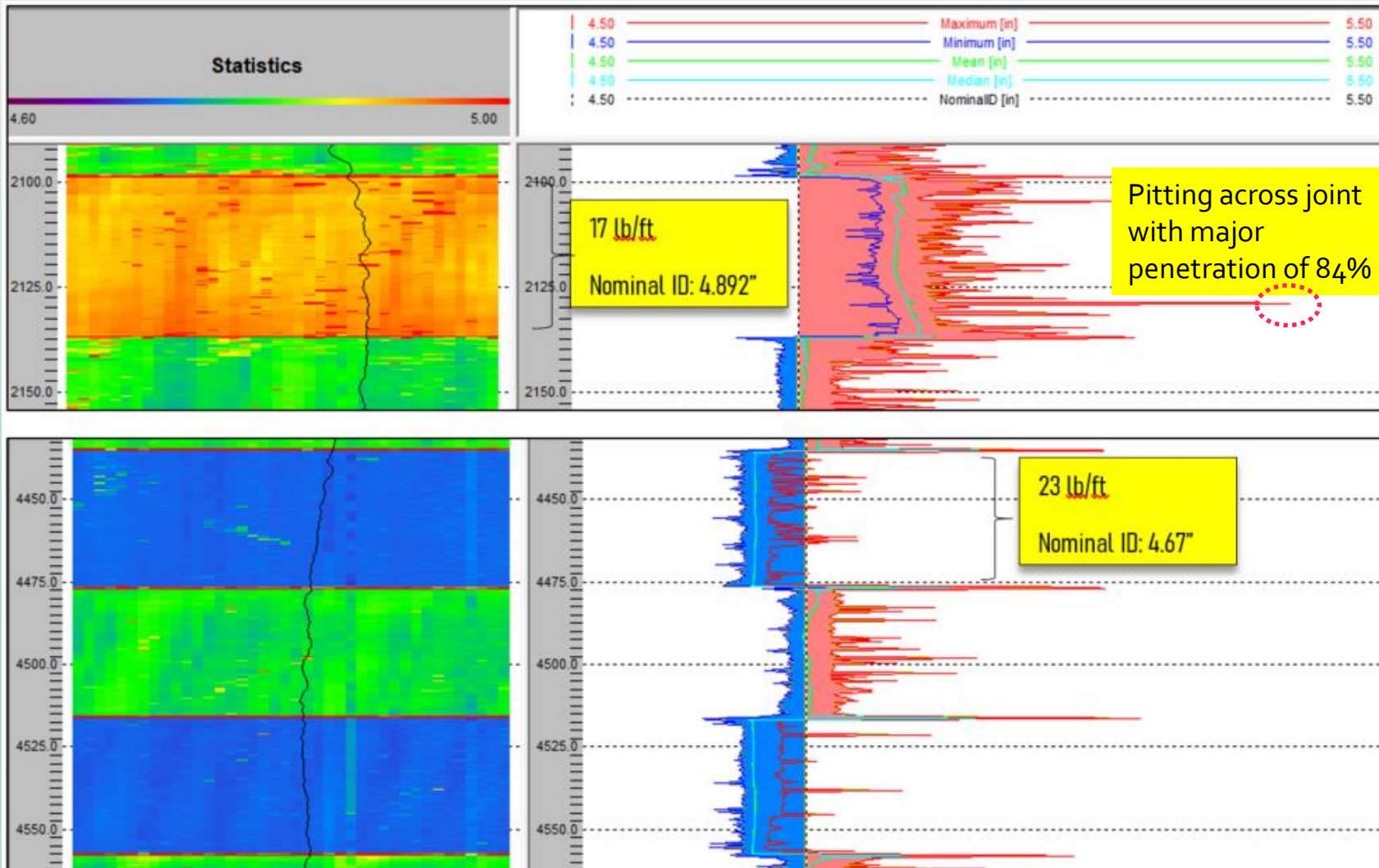
Log Interpretation – Deeper Dive

Magnetic Flux – Metal Thickness



Log Interpretation – Deeper Dive

Multi-Arm Caliper – Maximum Penetration & Pipe Weight

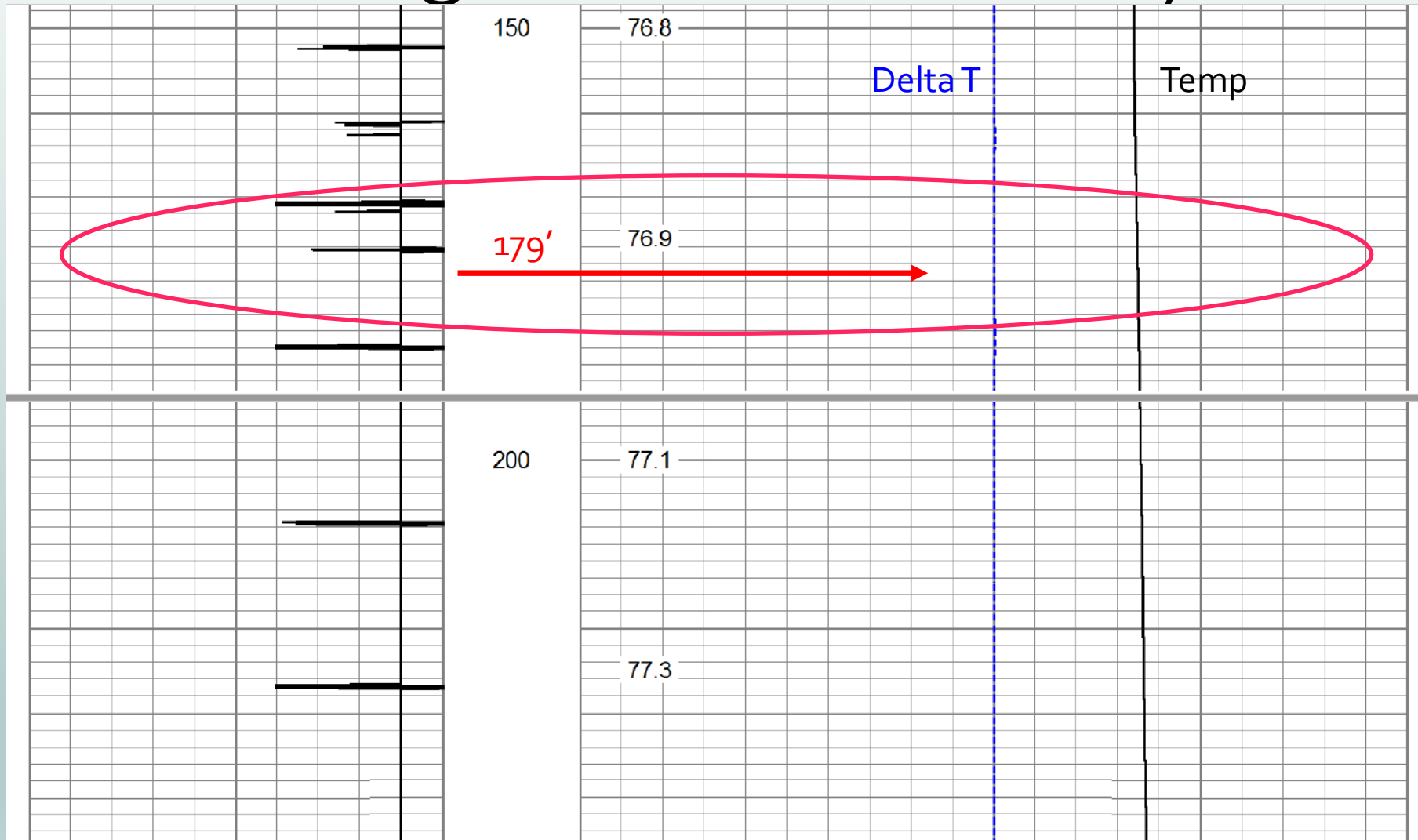


Gas Storage Wells Case Study



- Circa 1940s-1960s
- PHMSA Compliance Driven
- 42 shallow wells
- 450-525 ft. deep
- Compliance requirements similar to Class 1 wells

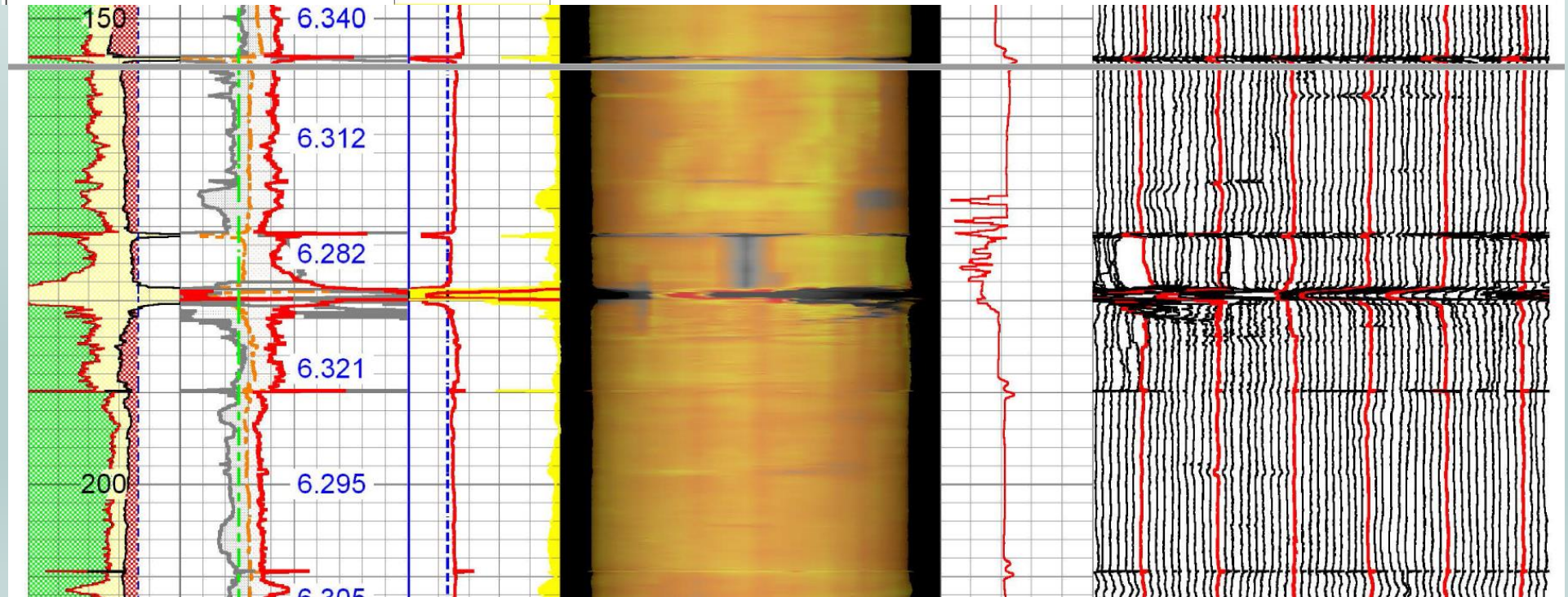
Gas Storage Well Case Study



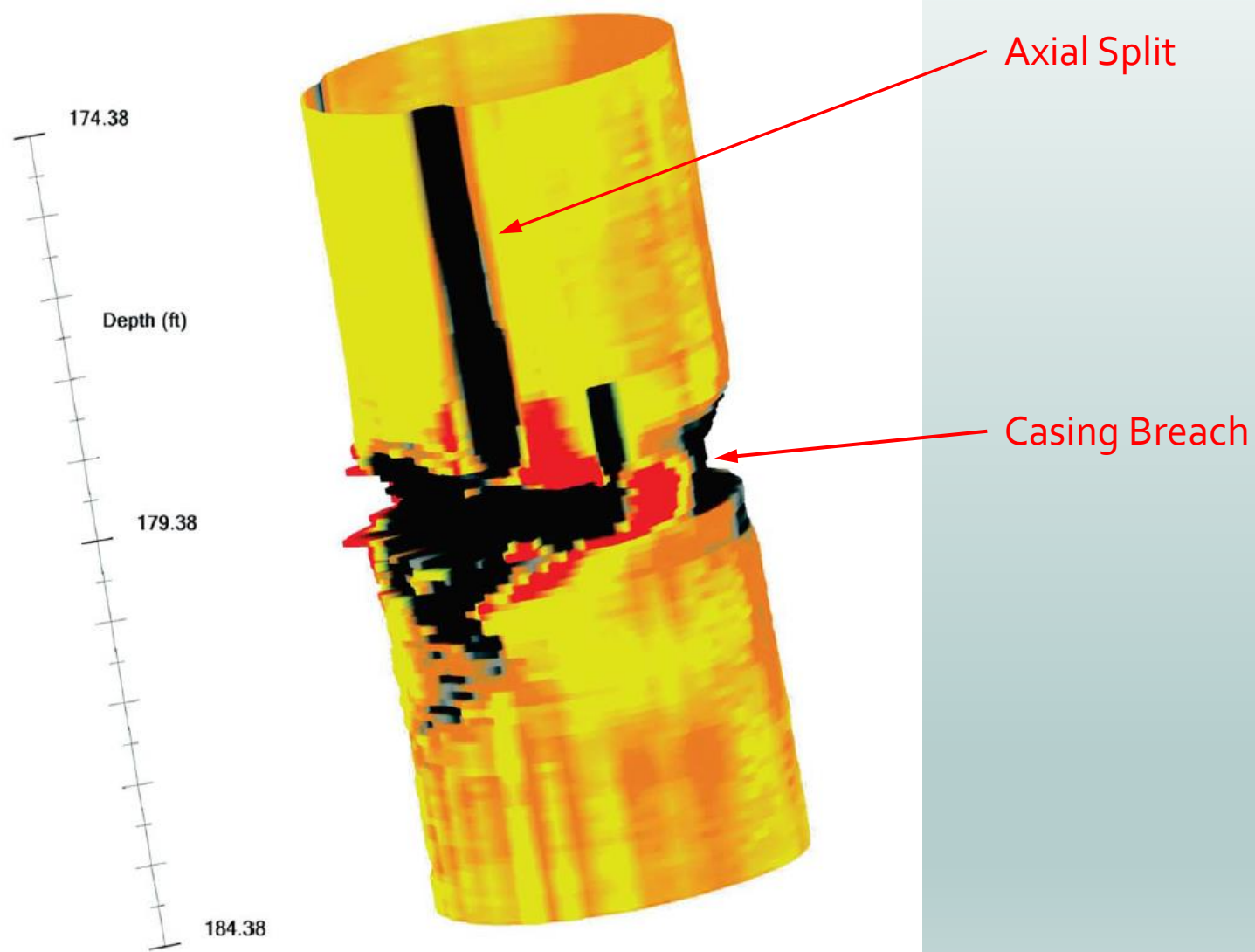
Well Passed Temperature and Pressure MIT's

Gas Storage Wells Case Study

Min RW	6	IDAV (in)	7	CASEID		IMGMAP		Thickness	1.5	R10 (in)	7.5
0 (in)0.25	6	IDMN (in)	7	6 (in) 7	5.895		6.625	0 (in) 0.5	0.5	R20 (in)	6.5
Avg RW	6	IDMX (in)	7	IDAV					-0.5	R30 (in)	5.5
0 (in)0.25	6	CASEID (in)	7	6 (in) 7					-1.5	R40 (in)	4.5
om_Wall_Th		Avg ID (in)		ECCE					-2.5	R50 (in)	3.5
0 (in)0.25				0 (in) 0.5					-3.5	R60 (in)	2.5
				Ovalisation							
				0.5 (in) 0							



Gas Storage Wells Case Study



Conclusions & Recommendations

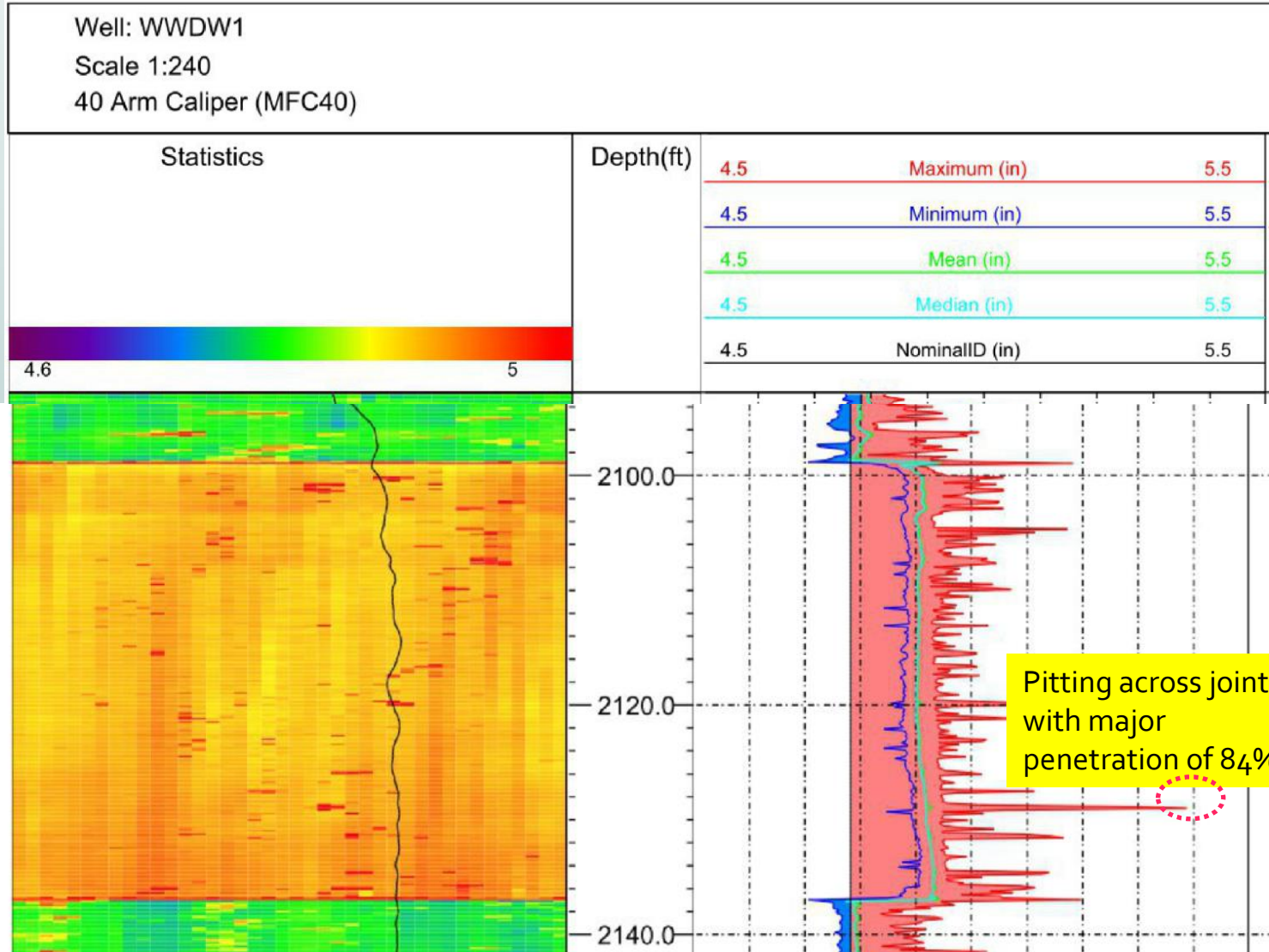
Well Field Assessment Based on Magnetic Flux and Multi Arm Caliper Logging Program											
Well ID	Worst Anomaly			Risk Rank	SCS Eval of CIL	Pipe Joint Analysis Max % Penetration					Well Assessment
	Wall Remaining (inches)	Percent Wall Remaining	Depth (feet)	0-42 (Wells w/Mag Log)	Number of Possible Holes (< 50% Wall Remaining) per casing string	Good	Fair	Bad	Severe	Possible Hole	
1	0.000	0%	179	1	10			2	9	8	Plug
2	0.000	0%	128	2	17			1	6	17	Plug
3	0.032	18%	134	3	18			5	7	11	Plug
4	0.000	0%	95	4	27			3	10	9	Plug
5	0.004	2%	429	5	17			1	8	13	Plug
6	0.008	4%	383	6	16				5	15	Plug
7	0.018	10%	298	8	28			3	8	10	Plug
8	0.043	19%	30	7	4			10	6	5	Plug
39	0.234	85%	422		0	9	1				Good Condition
40	0.234	85%	5		0	10	1				Good Condition
41	0.239	87%	66	30	0	5	5				Good Condition
42	0.249	91%	137	31	0	10					Excellent Condition

Class 1 Injection Well Case Study

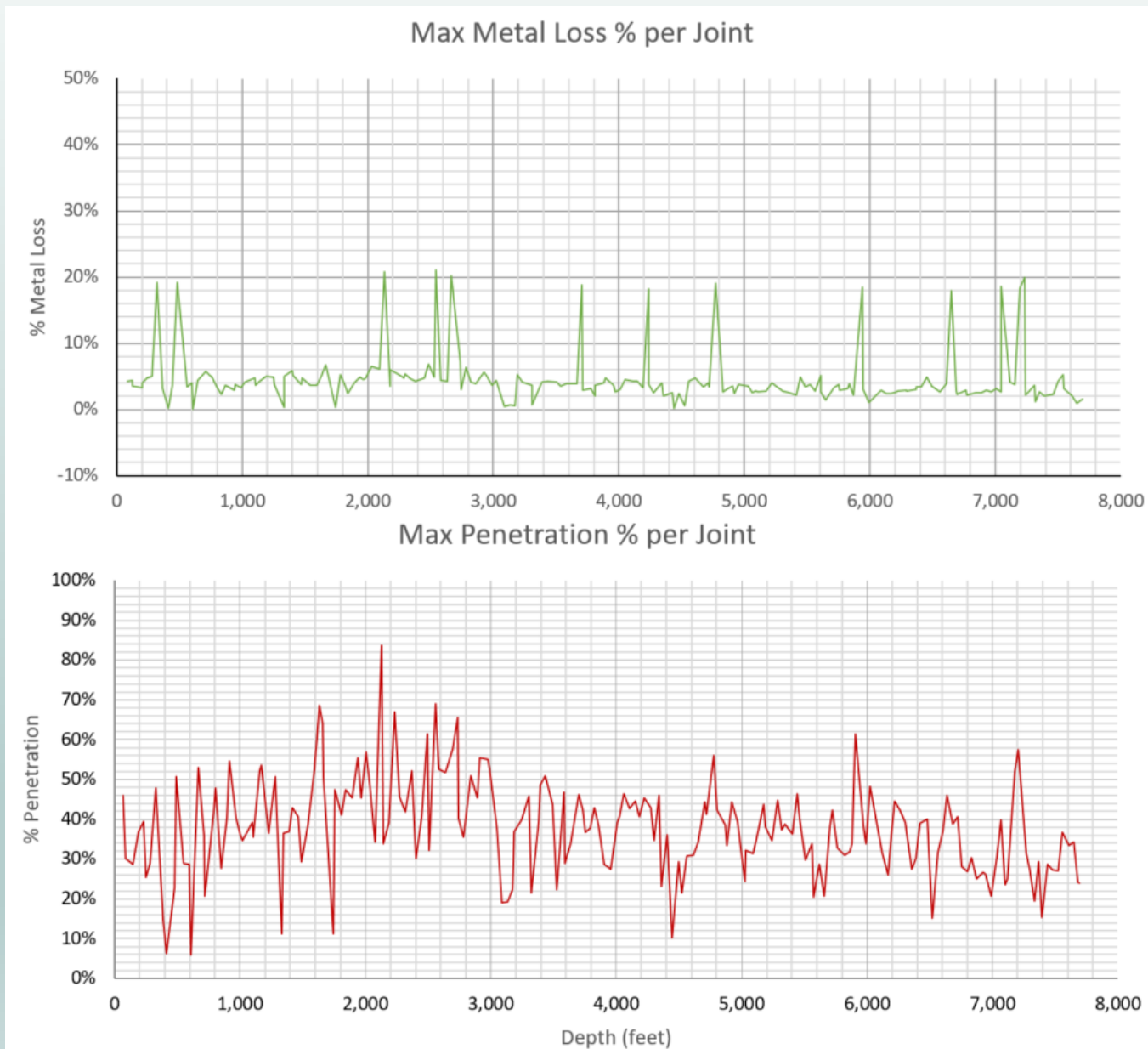


- Suspected small tubing leak
- Evaluated with tubing in well
- 7,850 ft of 5 ½" tubing
- Within 9 5/8" longstring
- Provide owner options

Class 1 Injection Well Case Study

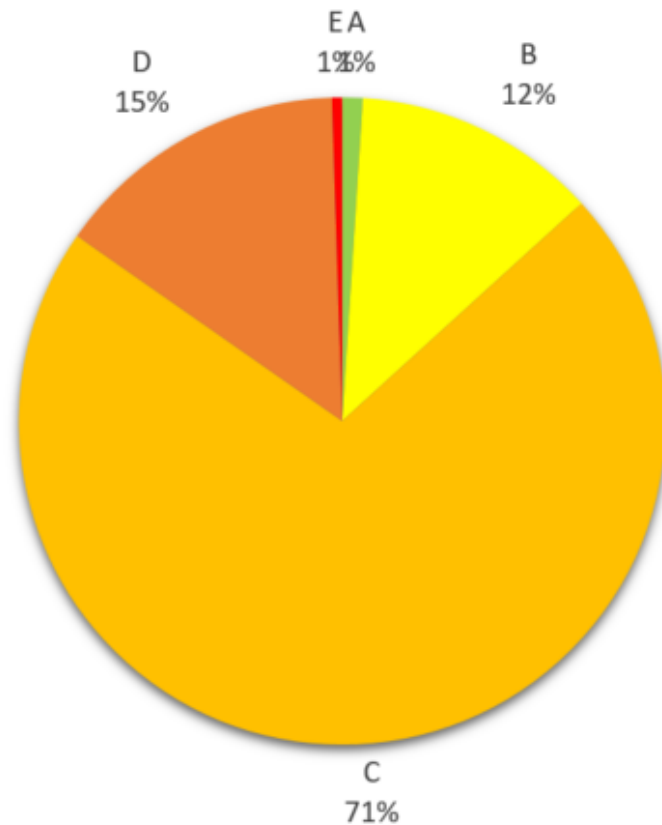


Assessment of Overall Well Condition



Assessment of Overall Well Condition

Max Penetration % Pie Graph



Grade Color	Penetration %	Comment
A	<10%	Very Light
B	10>-25%	Light
C	25>-50%	Moderate
D	50>-75%	Significant
E	>75%	Intensive

Grade	Joints
A	2
B	24
C	140
D	29
E	1

Conclusions & Recommendations

- Only 1 leak in tubing
- Overall, the tubing string in moderate to poor condition
- Patching is only postponing the inevitable
- Replace the entire tubing string
- Longstring casing in good condition

Discussion

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