Reliability of **Drills** and **Drill Stems**

Al Kaye, Reliability - Integrity Engineer

Coking.com®

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Reliability of **Drills** and **Drill Stems**

Recent experiences drove our organization to look closely at the key parameters that influence reliability of drill stems.

Further study revealed that there is a complex mix of the following factors which comprise drill and drill stem performance:

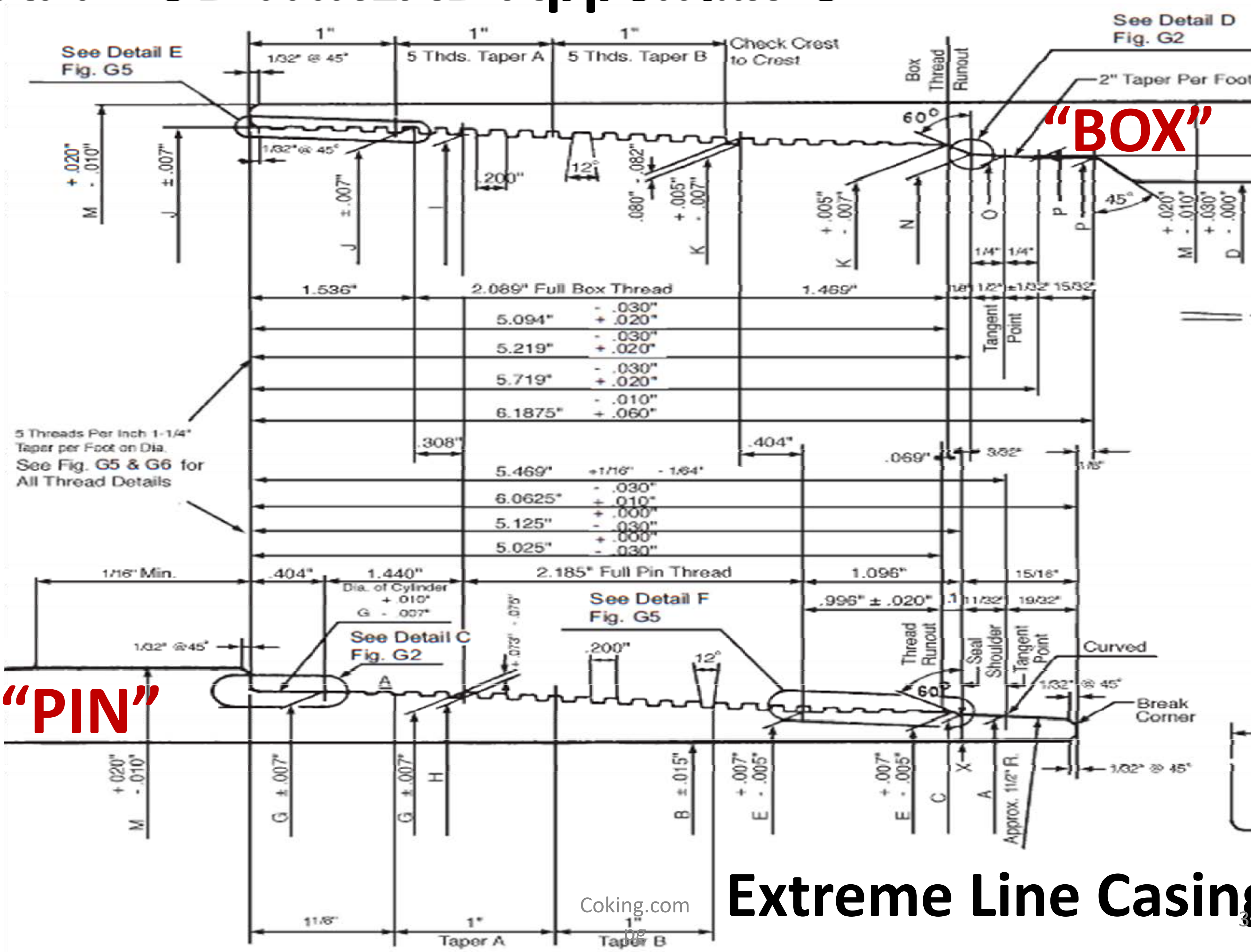
- materials specification, condition and selection
- assembly and hardware design and construction
- drivers and driven hardware
- loading and load factors
- environmental conditions
- process and operating parameters

Sources for guidance on this are very limited and rely almost entirely on in-house experience. One would presume that established knowledge from the conventional drilling industry would be front and centre, but it was found that the characteristics and behaviour of coker drilling and cutting makes the problems unique and at the same time widely variable.

Examining all of the above variables and determining their contribution significance was the only path forward to improve the overall performance and reliability.

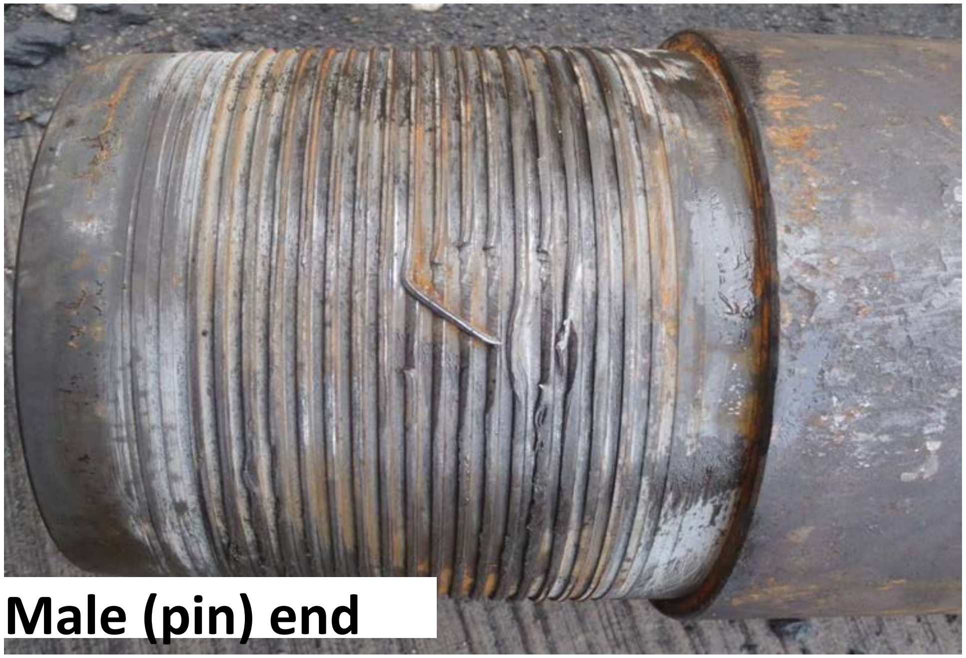
Al Kaye, Reliability - Integrity Engineer

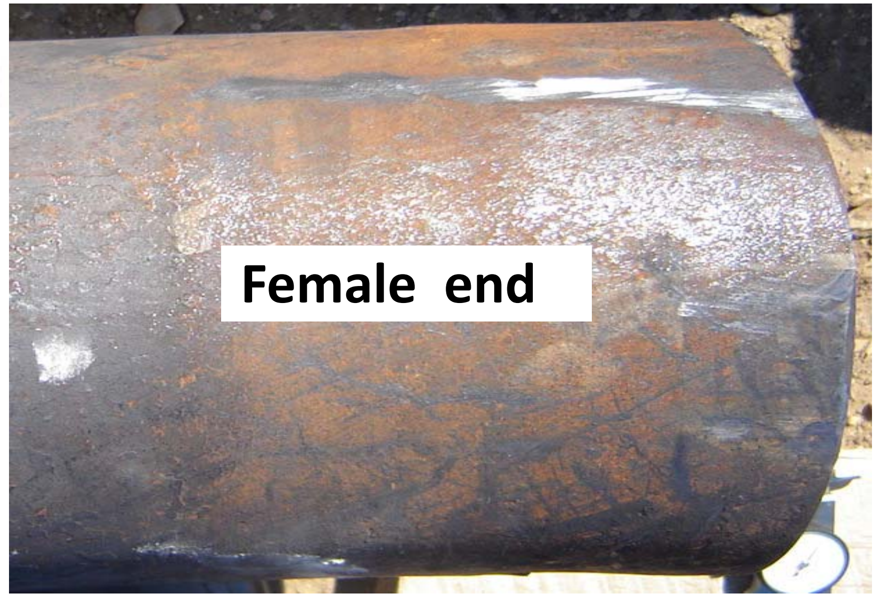
API – 5B THREAD Appendix-G

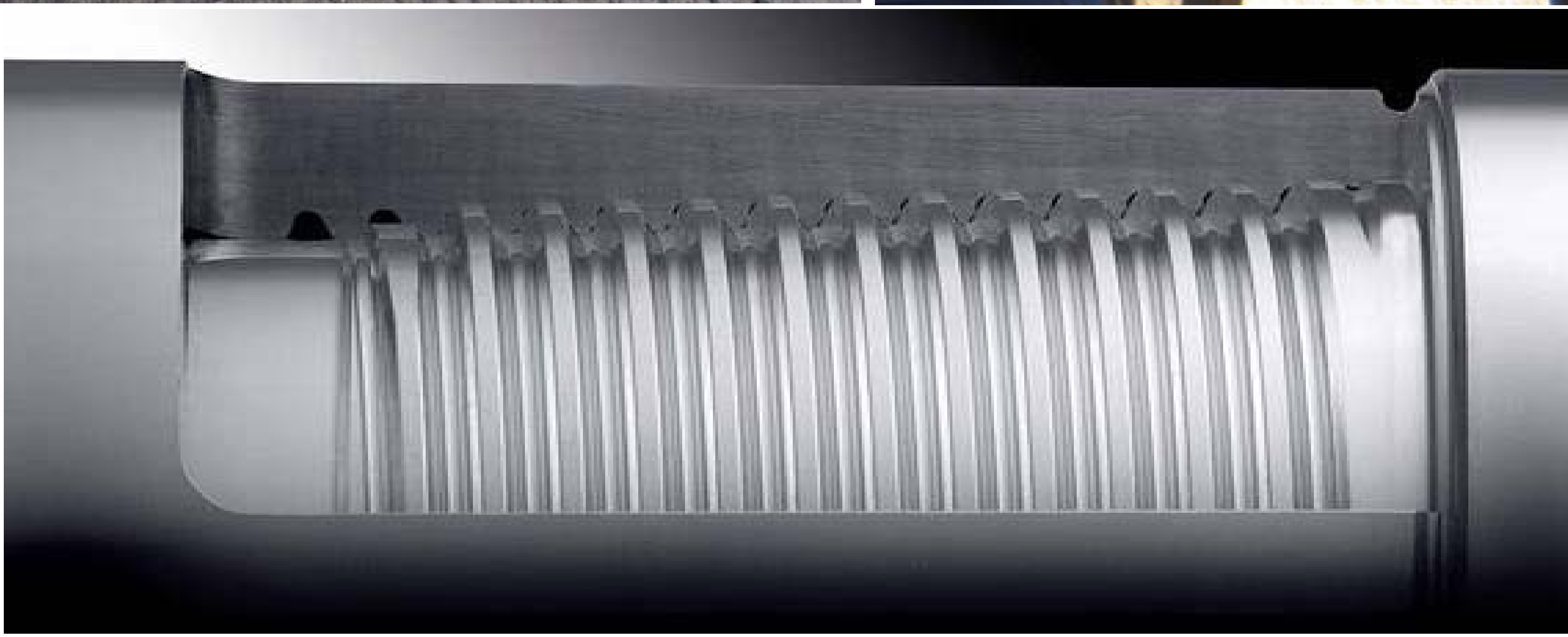


Extreme Line Casing

Threaded Connection







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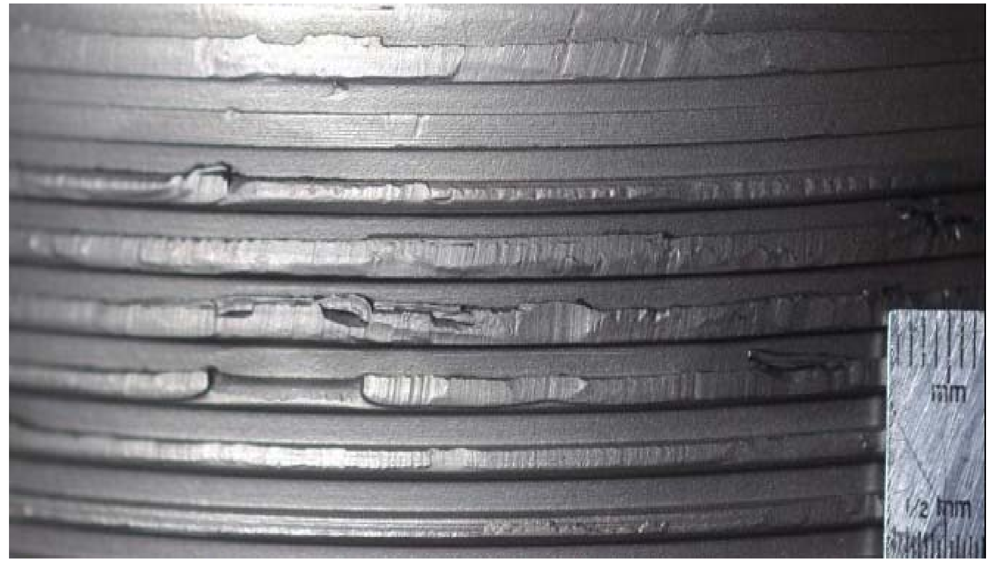
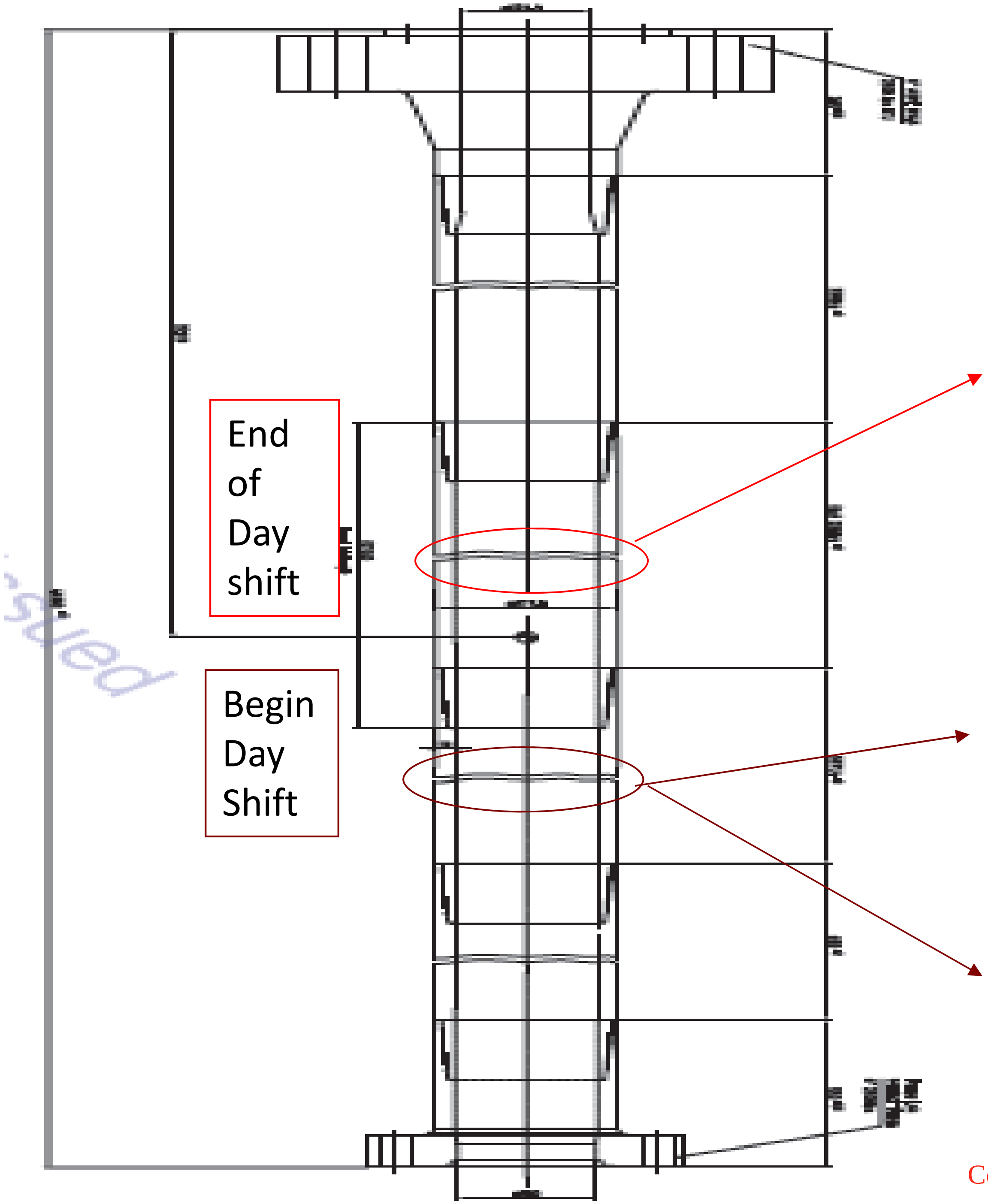
Threaded Connection – (box) female



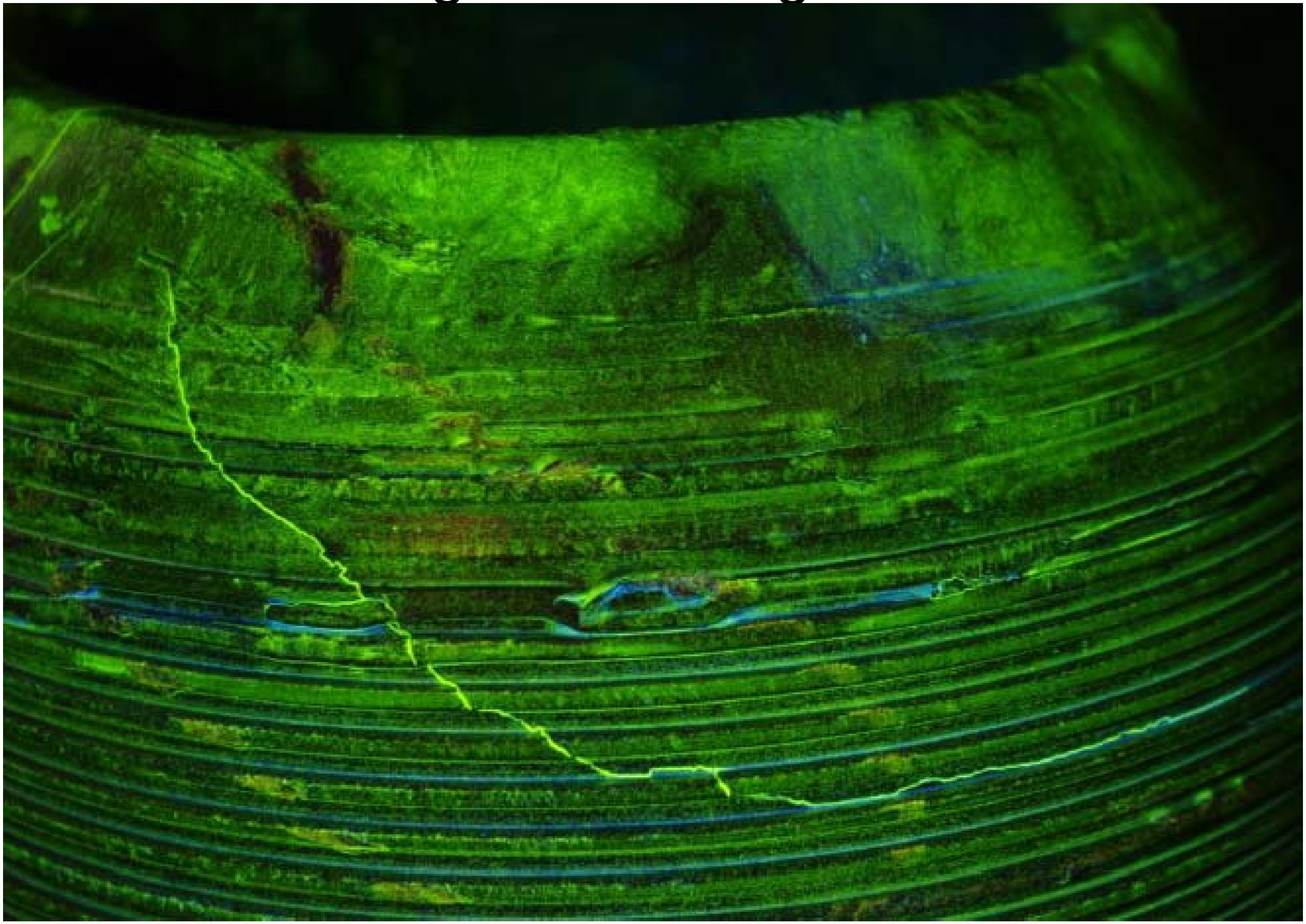
Coker Drill Stems

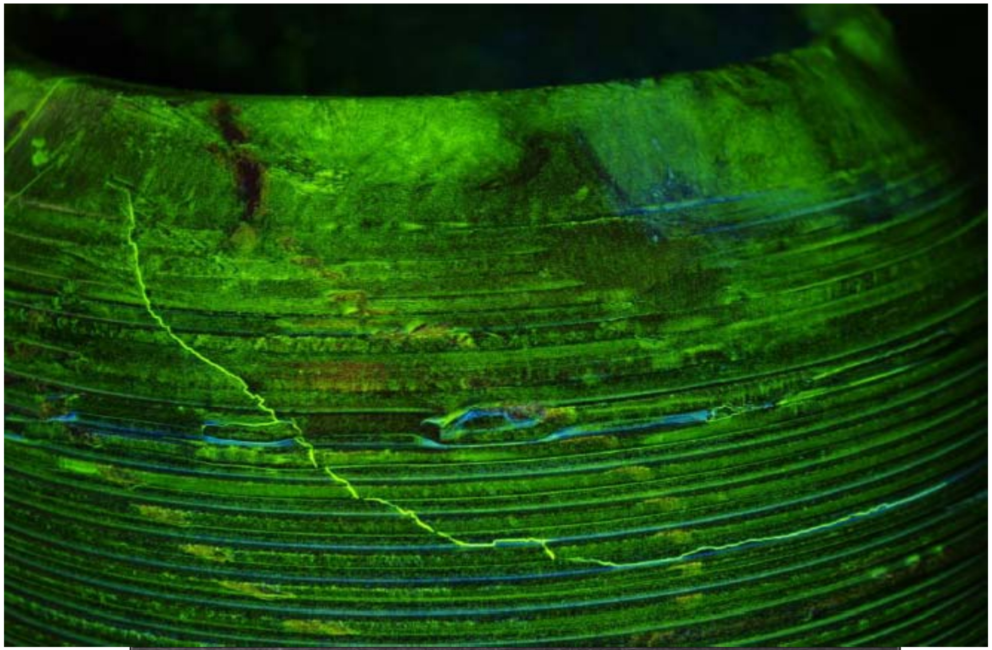


Drill Stems to **Cutting Bit**

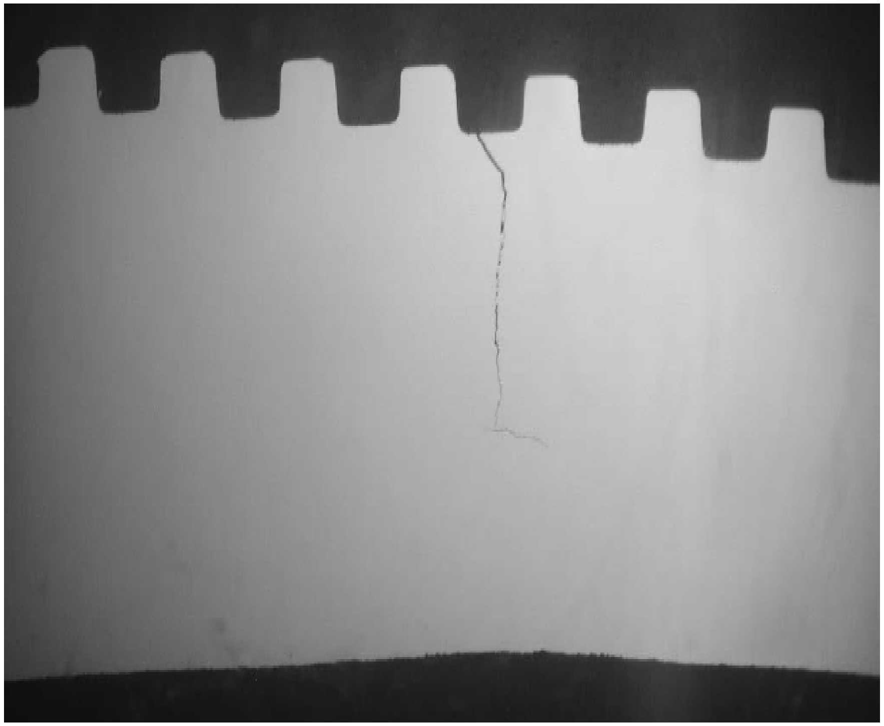
Scarred nut exhibits from unknown source and found loose.

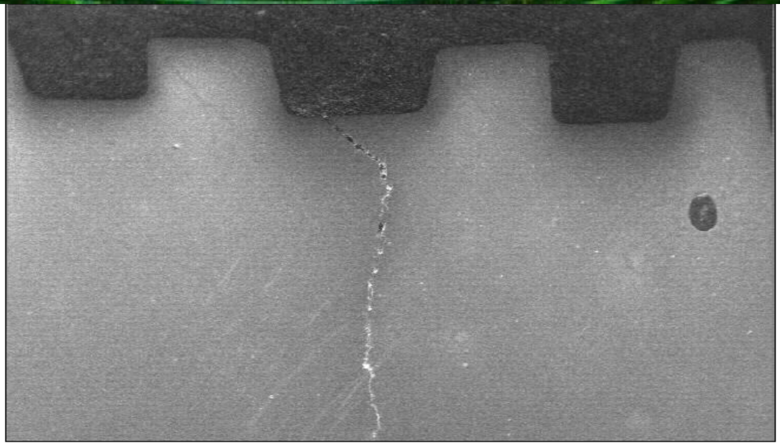
Fatigue Cracking.

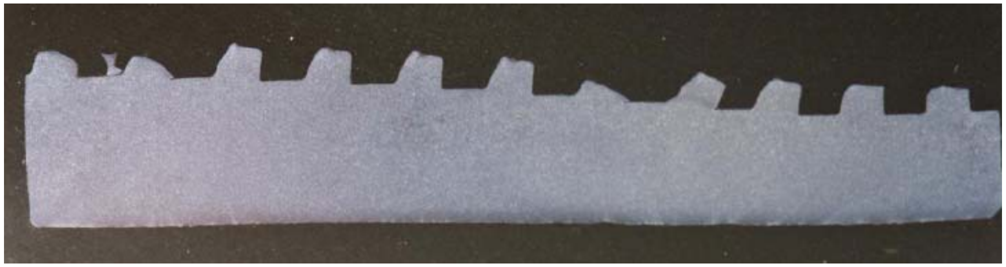




Fatigue Cracking



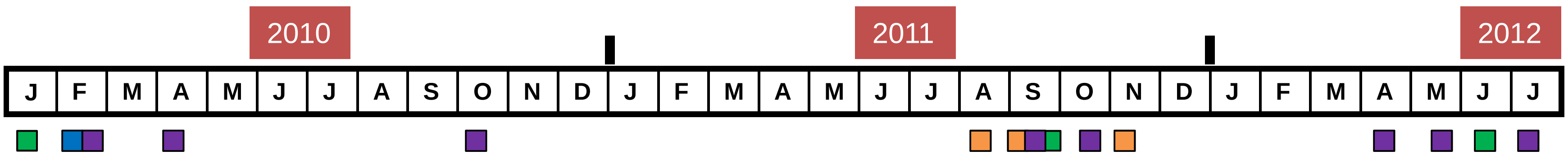




Thread Damage

Experiences ; Timeline of events

Drum 1A	Drum 1B	Drum 2A	Drum 2B
	21-Jan-10	5-apr-10 on night cut WO#272316	1-Feb-10
10-Oct-10	20-Feb-10	20-Aug-11	25-Apr-12
6-Nov-11	5-Sep-11	19-Aug-11	
5-Jul-12	drill mis-align 15feb12	31-Oct-11	
	5-Jul-12	4-May-12 Old piece found in drum WO# 249816	



Coke composition – Cave In (Coke too soft Resulting In Collapse)
Drill Stem Material Compliance
Operator Abuse (Ramming Of Drill Stems Into Coke Bed)
Operator Not Following Procedure
Design Related (Length Design Ration (Flexibility) / Enclosure Supporting Inadequate
Poor Maintenance (Joint Torquing)
Equipment Deficiencies / Failures (Minimum Flow Valves Functioning / Blocked Cutting Tool Nozzles)
Tensile Pull Out With Shear Lip (New)

Failures per year			
2009	2010	2011	2012
4	4	6	4

Failure reasons

Conditions that can cause failures

Coke composition (Coke to soft resulting in collapse)

- Drill stem material compliance (Quality control, certification)

- Operator abuse
  - Ramming of drill stems into Coke bed
- Design related
  - Length diameter ratio (flexibility)
  - Enclosure supporting inadequate
- Poor maintenance (Joint torquing)
- Equipment deficiencies/ failures
  - Minimum flow valves functioning
  - Blocked cutting tool nozzles

•New (8May12) Tensile pull out with shear lip.

Potential Possible **Scenarios**

- Consistency of Pipe material quality?
- What is the initial and in-service thread condition?
- Is the correct thread being used – industry practice?
- Is the setup torque correct initially and thereafter?
- Is unwinding or un-raveling occurring ?
- Bending stresses on the stem during operation?
- Is there bending from jet side load (Nozzle plugging issue)
- Mechanical issues

Confirmed Mechanical Scenarios

- No reverse rotation on the stem.
- In normal mode the torque applied by Kelly drive was with-in range .
- Changing pipe segments lengths, affects flexibility.

Next Steps – **Questions** to be answered

Q1. Review industry practice; threads,materials etc

Q2. Metallurgical testing of the pipe material !

Q3. Is the thread appropriate?

Q4. Confirm on actual torque condition throughout (all drums)!

Q5. Confirm possible blockage on the water nozzle in cutting head (possible side load)?

Q6. What is the stress state?

Q7. Review mechanical condition and parameters!

Answers. What was found. Interesting findings.

A1. Pipe material variations ,wide latitude. Must correctly choose and verify material purchases.

A2. Thread used in a wide variety of drilling. Analysis verified capacity OK if properly tightened. Swage at collar helps.

A3. No bite marks showing from the torque tool (some doubt on torque grip). Validation program successfully implemented.

A4. Actual torque condition ; attention is important. Requires power tightening with suitable thread compound.

A5. Bending stresses substantial. “Snugged” into shoulder stop is essential to engage the proper interference fit.

A6a. Blockage in water-jet nozzles not sufficient to cause deformation (although side loads can be substantial).

A6b. Drum alignment critical ;no compelling issues found.

A6c. Rub marks on drill stems suggested item 6 relevant.

A1.Drill Stem Tubulars; **Material Condition**

ASTM A516- 4140

ASTM A-519 Heat Treated Conditions Gr.4140	Ultimate Strength (ksi)	UTS (MPa)	Yield Strength (ksi)	YS (MPa)	Elongation (%) ,2in.	Hardness Rockwell (B scale)	Heat Treat (Temp+Soak)
Hot Rolled	120	855	100	621	15	100	Temper10min 500-740C
Stress Reliev'd	120	855	100	689	10	100	30K<Tempering temp.
Annealed	80	552	60	414	25	85	840-900C No soaking
Normalz'd	120	855	90	621	20	100	840-900C No soaking
Oil -Water Quench			>100	>700	<8	>240	Temper 10min 500-740C

A1.DrillPipe ; 4140 Material Properties

Grade 4140	Wall 't' mm(in)	Heat Treat Condtn	Yield Strength Mpa (ksi) min /max	Tensile Strength Mpa (ksi)	Elongation long-transv	Hardness Properties Method	min	max
Type 1	{Types 5-9 not ASTM categorization}	SR	758 (110) min	855 (120)	10	HB	100	200
Type 2		N	758 (110) min	855 (120)	20	HB	100	200
Type 3		A	414 (60) min	552 (80)	25	HB	85	200
Type 4	50.8 (2)	Q	552 (80) / 665 (95)	655 (95)	18-16	HRC		22
Type 5	50.8 (2)	Q	655 (95) / 758 (110)	724 (105)	16.5-14.5	HRC		28
Type 6	50.8 (2)	Q	758 (110) / 965 (140)	862 (125)	14-11	HRC	28	36
Type 7	50.8 (2)	Q	758 (110) min	862 (125)	14-11	HRC		36
Type 8	38 (1.5)	Q	862 (125) / 1034 (150)	931 (135)	12.5-10	HRC		38
Type 9	38 (1.5)	Q	862 (125) min	965 (140)	12.5-10	HRC	30	38

SR=Stress Reliev'd N=Normalized Q=Quench+tempered

A1.Drill Stem Tubulars; **Material Condition**

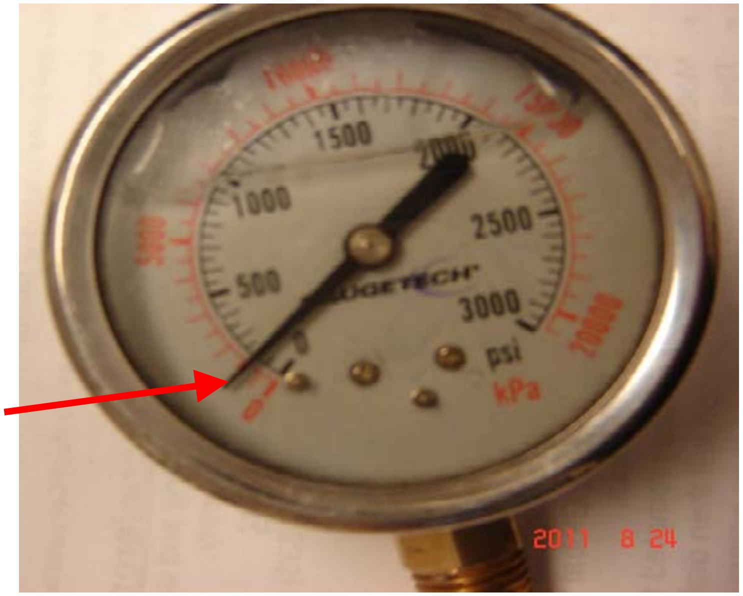
ASTM A516- 4140

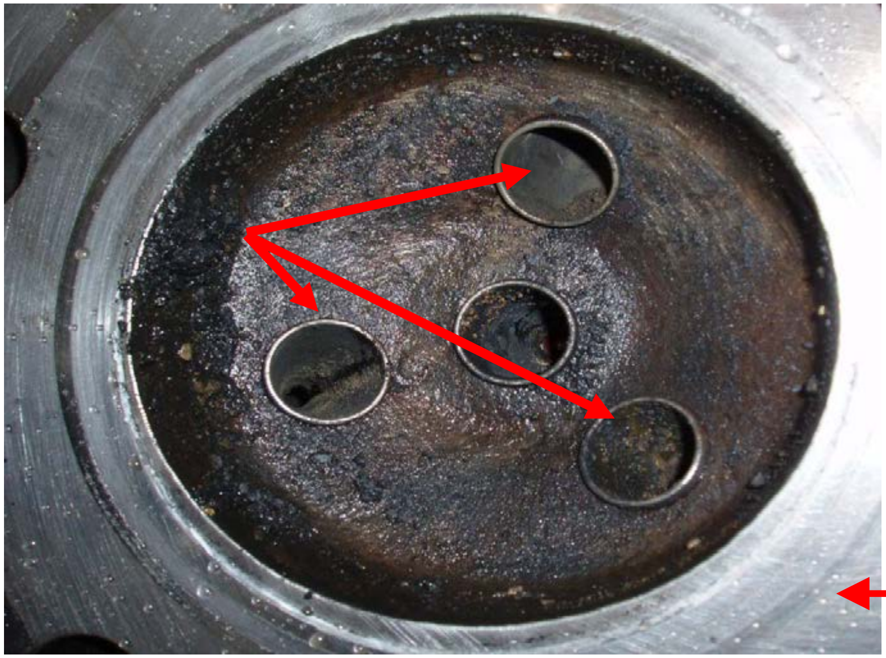
Grade	Carbon	Manganese	Phos & Sulphur	**Chromium**	**Nickel**	Molybdenum
4140	0.38 -0.43	0.75 -1	0.04	0.8-1.1	max 0.25	0.15 -0.25
EN/DIN (42CrMo4)	0.38 -0.43	0.75 -1	max 0.25	0.9 -1.1	max 0.25	0.15 -0.25

Grade	Wall 't' mm (in)	**Heat Treat** Condtn	**Charpy (average) Impact Ave of 3 Specimens**	**Charpy (individual) Impact**
Type4	50.8 (2)	Q	50 J (37 ft-lb)	35 J (26 ft-lb)
Type5	50.8(2)	Q	40 J (30 ft-lb)	28 J (21 ft-lb)
Type6	50.8(2)	Q	27 J (20 ft-lb)	19 J (14 ft-lb)

Path forward – A4. Contd. **Torque**

Hydraulic Torque Gauges need to be zero, calibrated regularly and reading the correct end of the hydraulic cylinder.





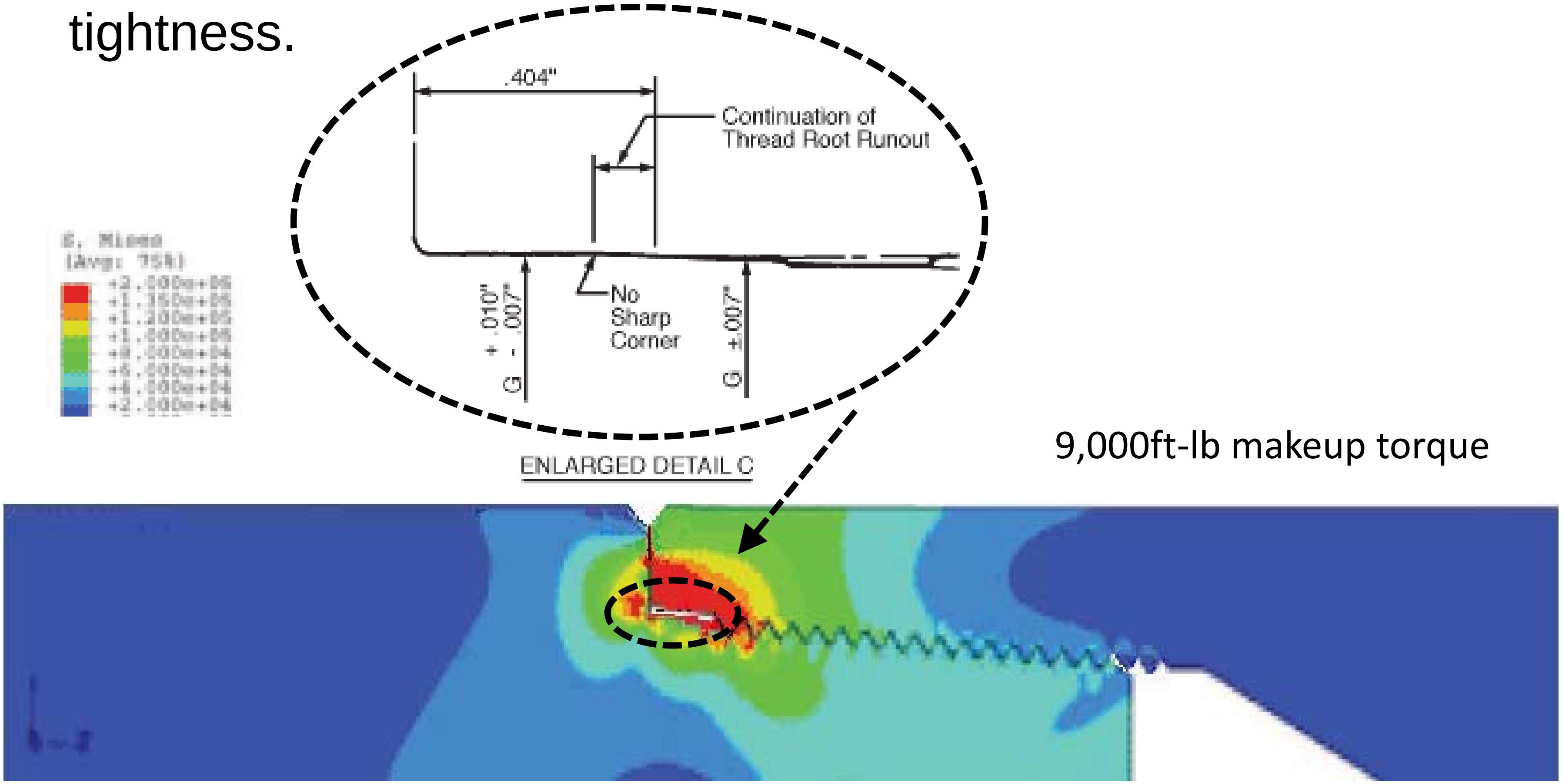
Path forward – A5.

Nozzle-Jet Blockage

Side cutting nozzles were not plugged ; confirmed by opening the drill bits.

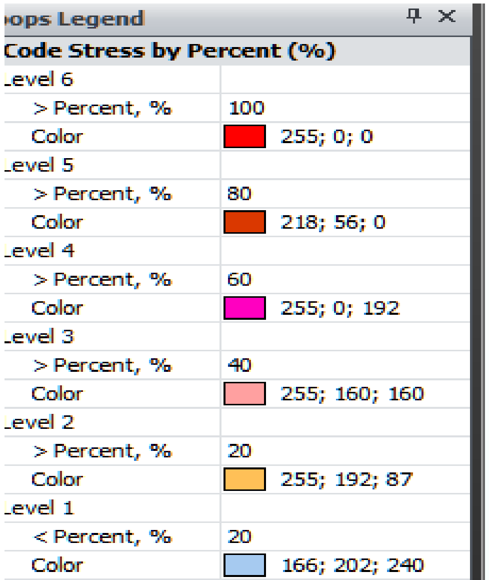
Path forward – A6. **Stress**

- Strength & load carrying comes from the closing shoulder stop.
- Full torque completion is essential.
- “Snugged” into shoulder; essential to engage proper joint tightness.

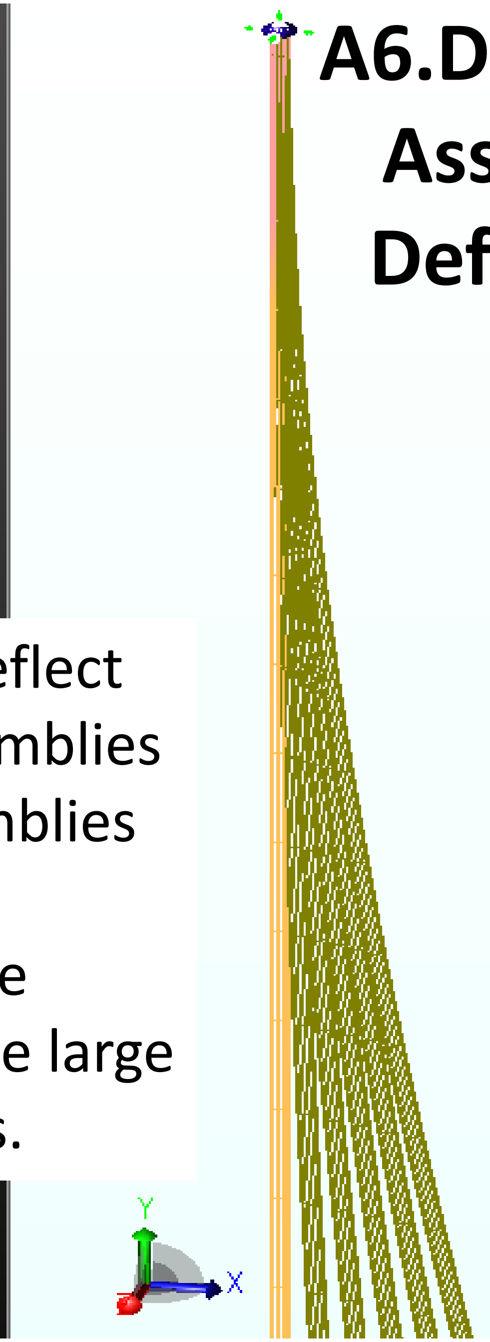


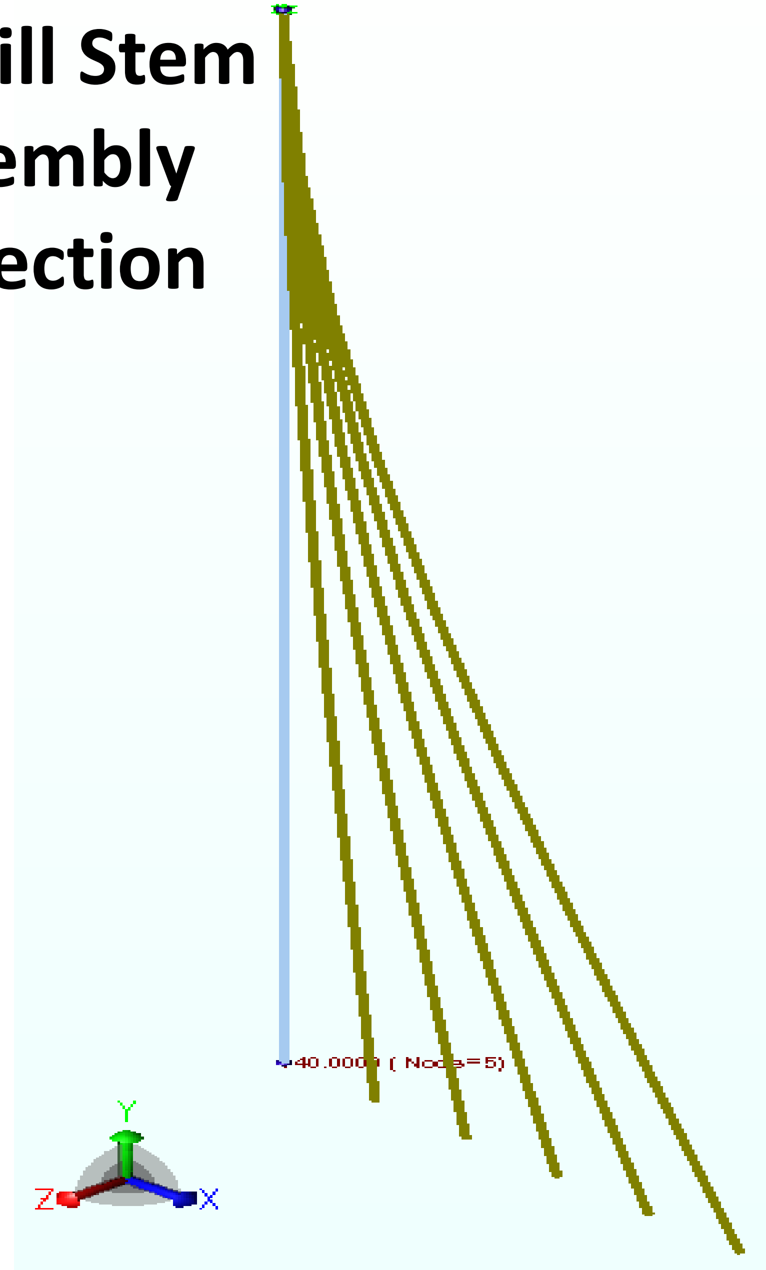
9,000ft-lb makeup torque

A6.Drill Stem Assembly Deflection



ops Legend	
Code Stress by Percent (%)	
Level 6	
> Percent, %	100
Color	255; 0; 0
Level 5	
> Percent, %	80
Color	218; 56; 0
Level 4	
> Percent, %	60
Color	255; 0; 192
Level 3	
> Percent, %	40
Color	255; 160; 160
Level 2	
> Percent, %	20
Color	255; 192; 87
Level 1	
< Percent, %	20
Color	166; 202; 240



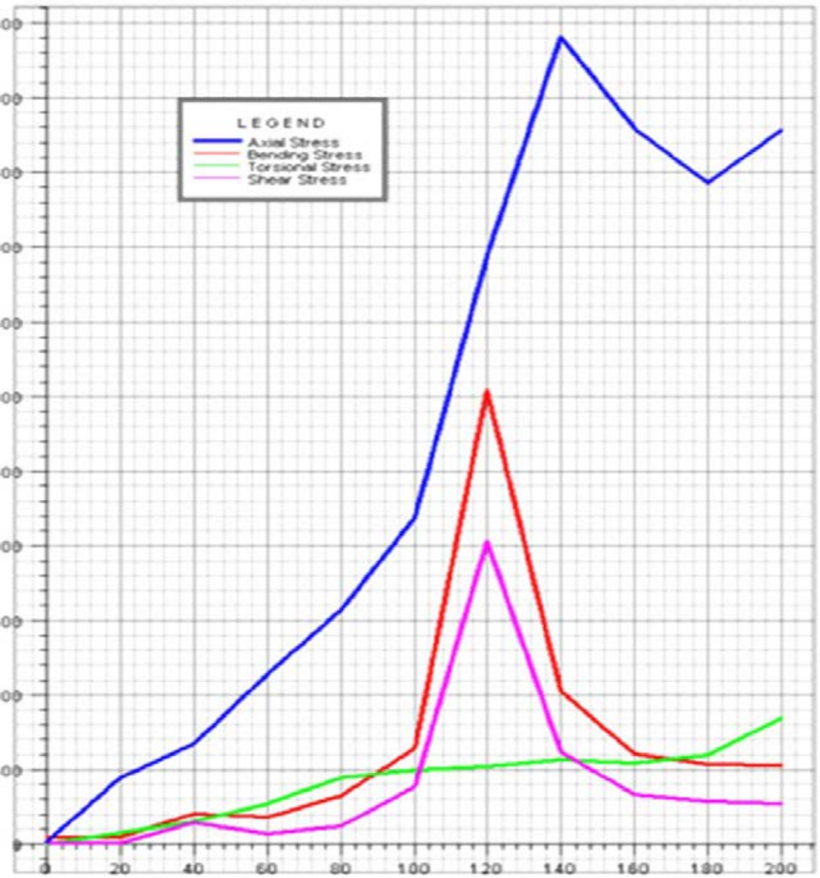


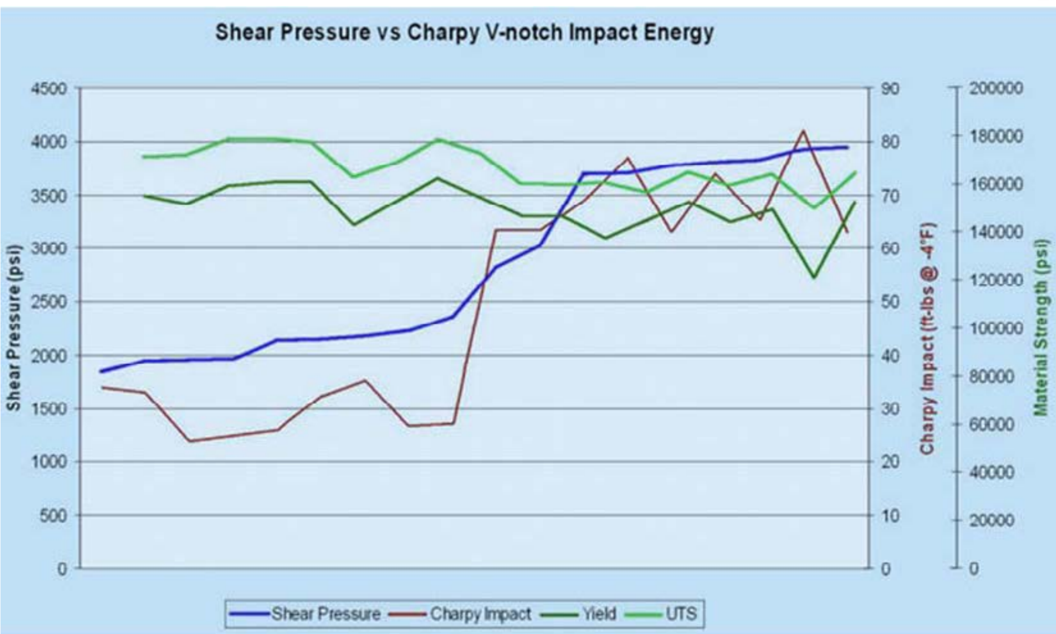
- Small loads can deflect long drill stem assemblies
- Short stiffer assemblies are harder to bend
- Very large loads are required to generate large bending deflections.

A6 Contd. Stress

Rotational speed

- Stress increases with speed up to peak value.
- A critical speed is readily defined.
- All stresses are affected by increased speed with Torsional Stress being *least* affected.

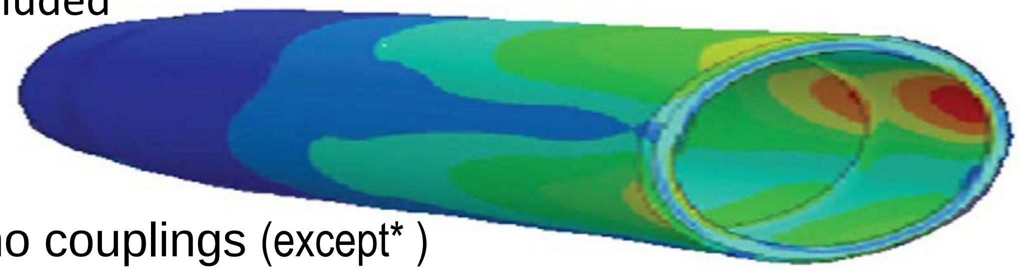




Shear strength; Impact Strength governs over Material Strength.

Path forward – A6 Contd. **Stress**

Basic Cylinders-no stress raisers included



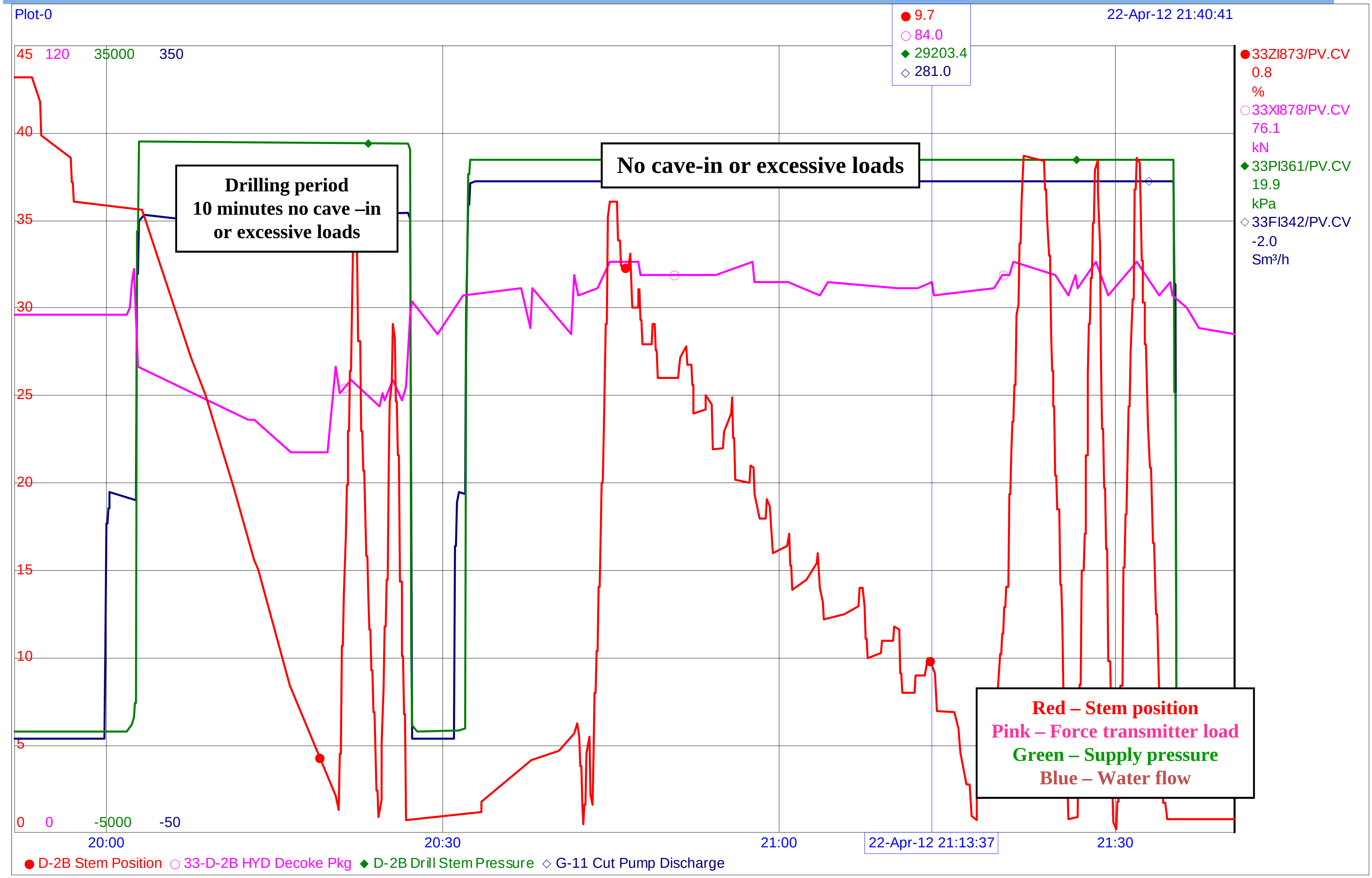
Min.Bending Force = 10 lb (0.04kN)

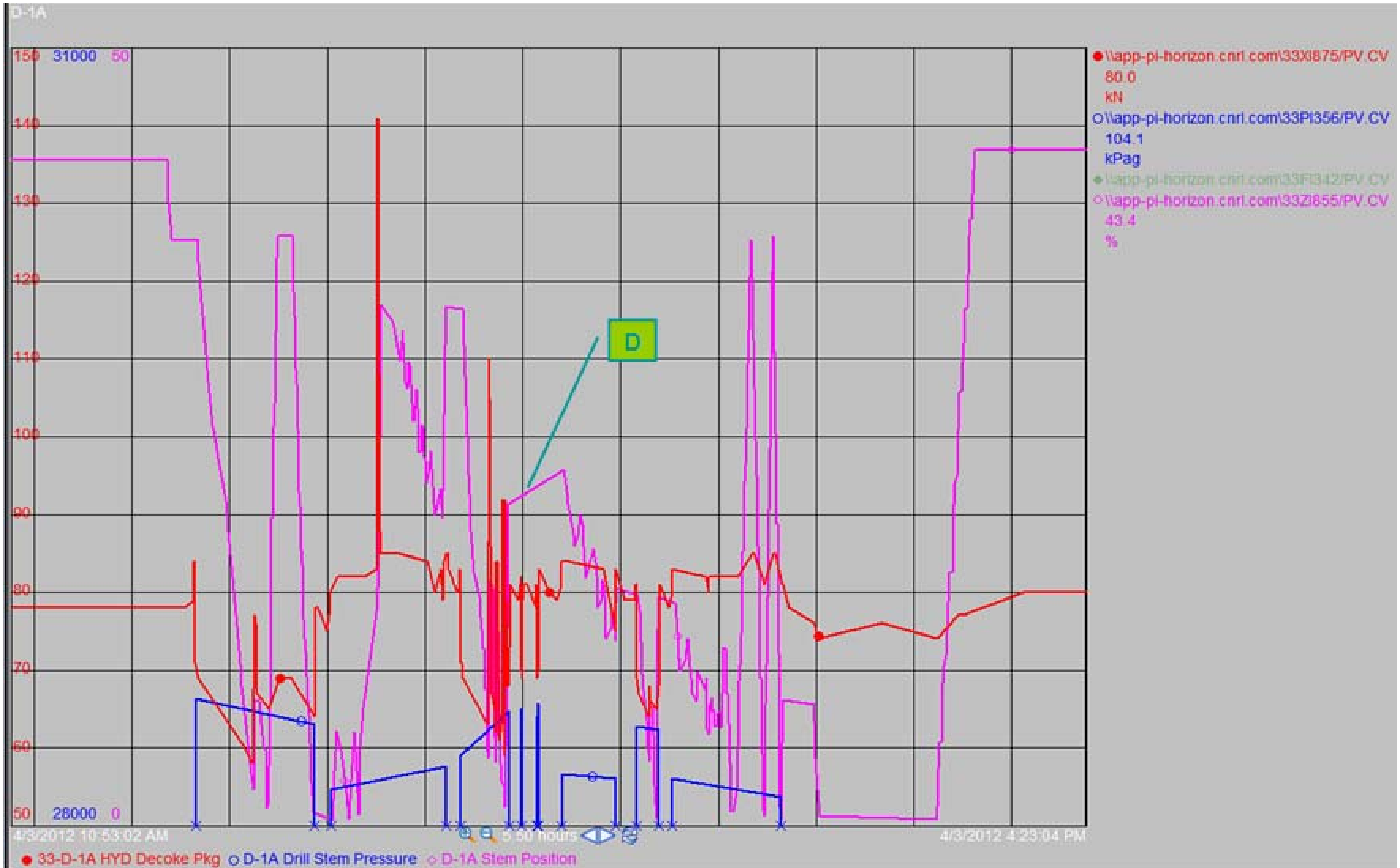
Min.Vertical Force = 9400 lb (42 kN)

Lateral structural stiffness; Pipe; no couplings (except*)

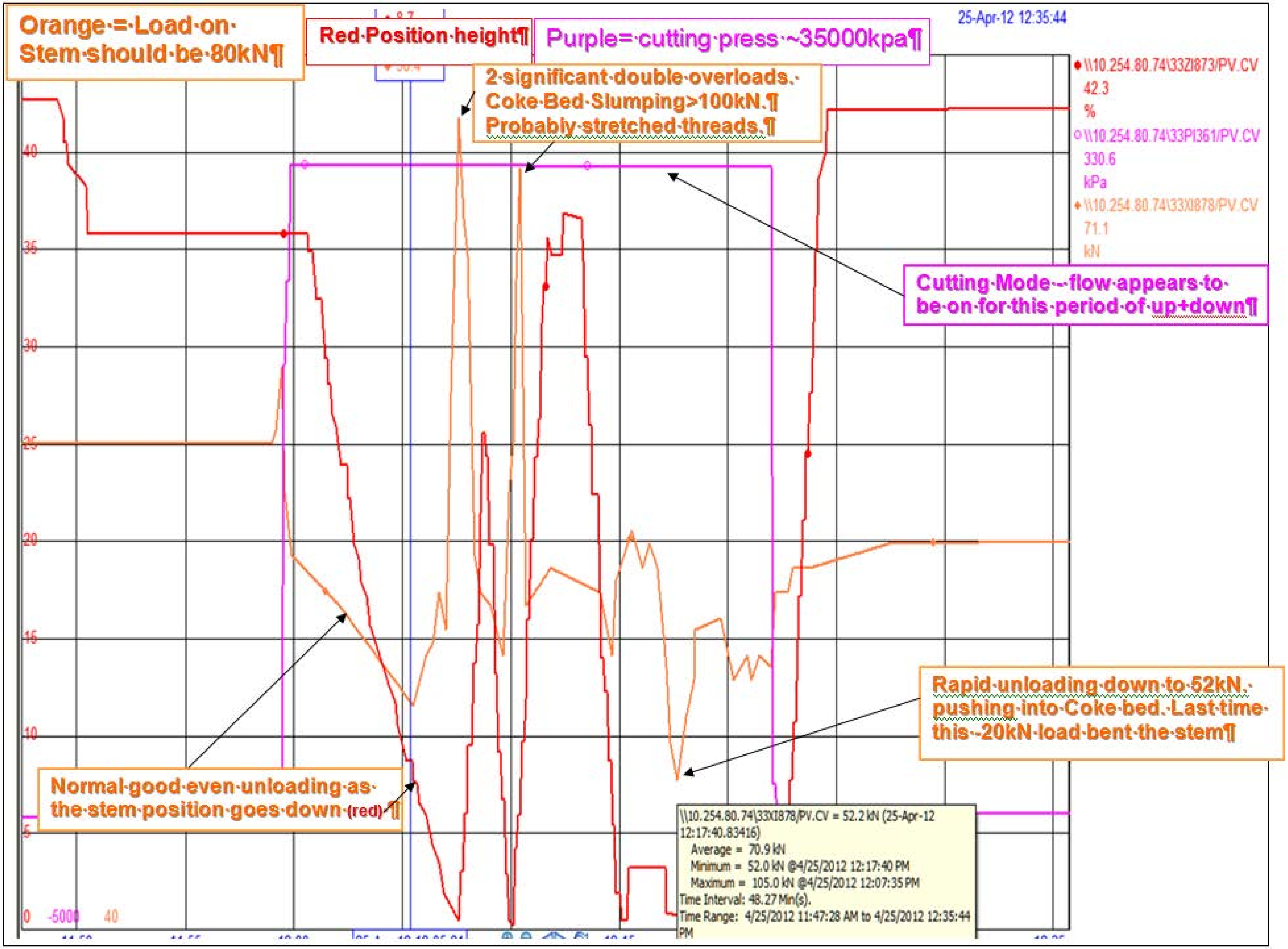
	Bending Moment ft-lb (kNm)	Bending Stress psi (MPa)	Operating Hoop Stress psi (MPa)	Basic Vertical Axial Stress psi (Mpa)	Von Mises 3D Stress Intensity psi (MPa)
Minimal bend'g ≤1"	155 ft-lb 0.21 kNm	90 psi (0.62 Mpa)	7,500 psi (52 MPa)	3,900 psi (27 MPa)	10,400 psi (71.7 MPa)
Normal bend'g ≤6"	1,000 ft-lb 29.2 kNm	525 psi (3.62 Mpa)	7,500 psi (52 MPa)	3,900 psi (27 MPa)	10,500 psi (72.4 Mpa)
Bend'g. to VessIR =130"	21,520 ft-lb 29.2 kNm	13,000 psi (90 MPa)	7,500 psi (52 MPa)	3,900 psi (27 Mpa)	16,000 psi (110.3 MPa)
1stub length Bnd'g. to VessCone =60" with Couplings *	252000 ft-lb 342 kNm	130,000psi (896 MPa)	7,500 psi (52 MPa)	3,900 psi (27 Mpa)	162,500 psi (1120 MPa)

The ideal cut



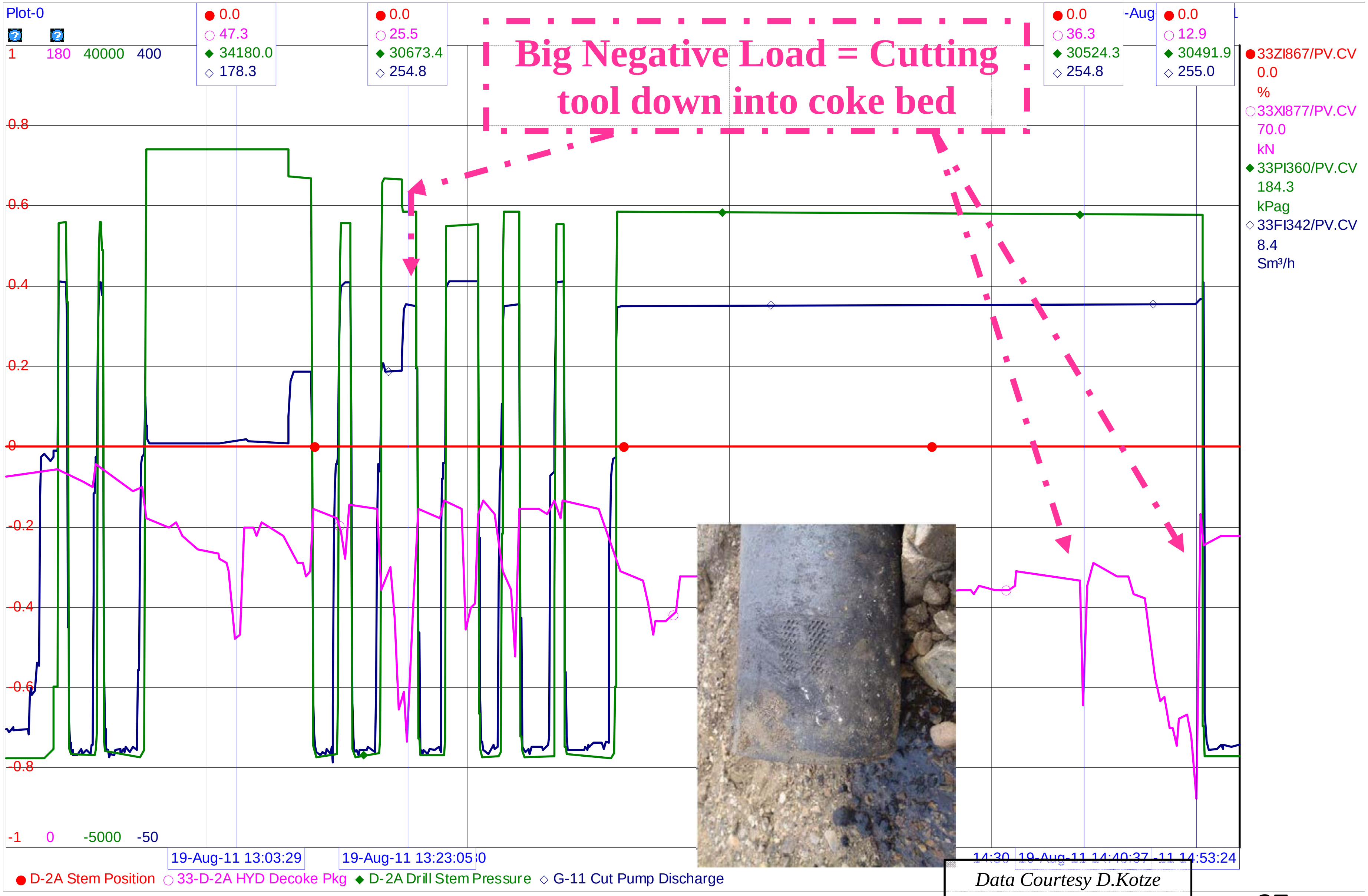


- D = After clearing the pilot hole, the bit was raise to nearly the previous level of the top of the bed. So the tool was in a warm spot for 18 min (1:24-1:42). Unlikely to be as hot as leaving the tool in the cone for an extended period of time. If the tool had be +5m higher, it would have been in a "cool-er" zone.


Orange = Load on Stem should be 80kN
Red Position height
Purple= cutting press ~35000kpa
25-Apr-12 12:35:44
2 significant double overloads. Coke Bed Slumping>100kN. Probably stretched threads.
\\10.254.80.74\33ZI873/PV.CV
42.3
%
\\10.254.80.74\33PI361/PV.CV
330.6
kPa
\\10.254.80.74\33XI878/PV.CV
71.1
kN
Cutting Mode - flow appears to be on for this period of up+down
Rapid unloading down to 52kN. pushing into Coke bed. Last time this -20kN load bent the stem
Normal good even unloading as the stem position goes down (red)
\\10.254.80.74\33XI878/PV.CV = 52.2 kN (25-Apr-12 12:17:40.83416)
Average = 70.9 kN
Minimum = 52.0 kN @4/25/2012 12:17:40 PM
Maximum = 105.0 kN @4/25/2012 12:07:35 PM
Time Interval: 48.27 Min(s).
Time Range: 4/25/2012 11:47:28 AM to 4/25/2012 12:35:44 PM
40
35
30
25
20
15
10
5
0
-5000
40

Example; Stem Failure Drum 2A (Oct 2011)

Example. Stem failure Drum 2A (Au 2011)



Validations Already Performed

Addressed

- Connections are weak compared to pipe body.
- Material evaluation… Thorough material specification issued.
- It is normal to estimate point stresses in drill string components with Finite Element Analysis.
- Investigated drill stem support vs. length. Failure limit analysis. The infinite variety of stress concentrations and load conditions in a drill string make this extremely complex.
- "Snugged" into shoulder stop is essential to engage the proper interference fit.
- Requires power tightening with suitable thread compound.
- Reviewed industry practice; threads, materials etc
- No bite marks showing from the torque tool (some doubt on previous torque grip). Validation program successfully implemented.
- Thread checking & stem condition checked regularly. Avoid galling.

Validations Being Performed.

<u>Options to be addressed</u>

- Drill stem (flexibility & support) Investigate possibility to increase diameter to 8”
  - Consider Installing new 30% stronger joints
  - Install longer sections of drill stem
  - Increase drill stem diameter (evaluate considerable load increase)

- Material sampling and analysis
  - Sent material to Lab top verify strength and composition

- Coker cone inspection (check for deflection related contact)
  - Send cutting tool for material analysis to check for “cone contamination”

- Review maximum load settings (Limiting of drill stem loading in logic)

- Review Coke consistency and Coker operational parameters

- Consider Installation of acoustic monitoring devices in the chute. Works for some.

- PLC controlled drilling cycles

- Modify Coker enclosure to support maintenance effort

Path Forward

Pre-2009 drill stem failures

Addressed

- Evidence inconclusive, many theories
- Operator problems noted
    - Coke bed contact (auto cutting tool erosion)
    - Drill stem patterns erratic (procedures not followed)
- Maintenance previously needed attention
    - Drill stem torquing analyzed and confirmed
    - Drill stem torquing procedure not followed
    - Drill stem procedure inadequate

Changes after 2009

- Thermo-couples on feed heaters 33-F-1/2 (Top row installation)
- Installation of Coker enclosure with guide device at elevated position
- Installation of advanced cutting tools

Post-2009 related failures

- Operator procedures – considerably improved with training provided and monitoring on PI Process Control.
- Reviewed industry practice; threads, materials etc
- Cave-ins due to product consistency**……? To be worked on. Universal problem to Drum Hardware reliability.**

Conclusions & Path Forward

1. Ongoing state of the art & industry practice
2. Options for thread arrangements.☞ under review.
3. Fit-up & abutting (shoulder seating) is critical.
4. Ongoing QA is paramount, Operator Practices, Material ordering and receiving etc.
5. Ongoing Monitoring of Operating Parameters (PI etc)
6. Care in drilling and cutting technique is critical.
7. New KEY initiative;Upgrading Continuous Improvement.
8. Coke bed slumping & hardness – difficult to manage.
9. Lower API will create more cutting problems.