T&D Mini-Series – Session 8, Wrap Up

2/28/2023

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Agenda

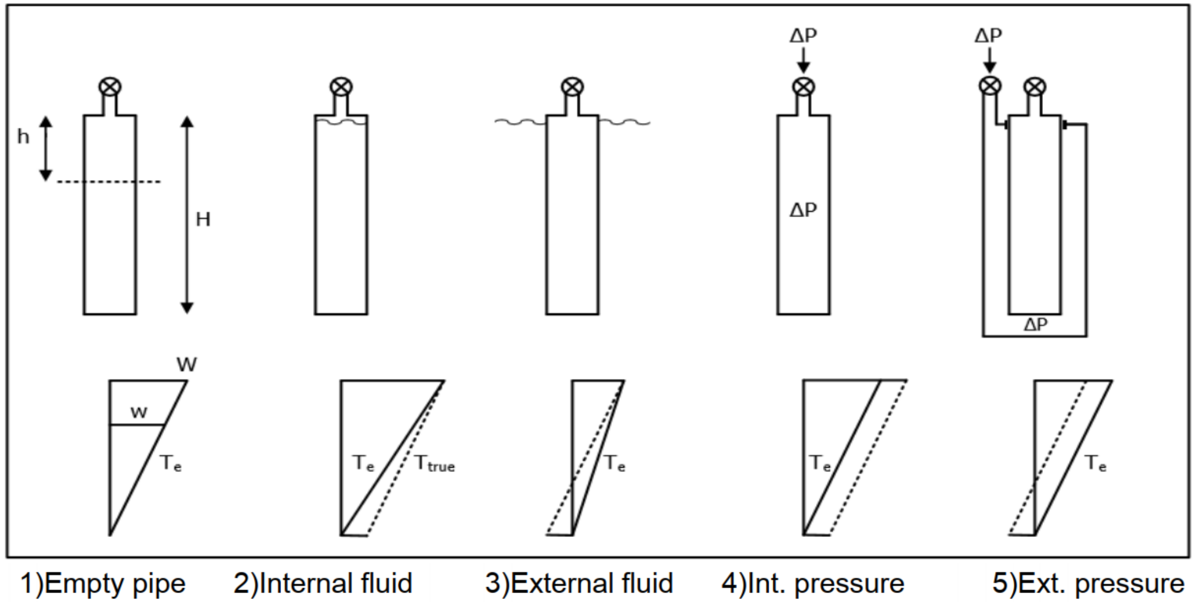
- Recap
- Real vs. Effective Tension
- How to determine max tension and torque (practical exercise)
- Q&A

T&D Mini-Series Recap

- Session 1 – Brandon Foster – Intro: Slides Video
- Session 2 – Truls Larsen – Ancillary Applications: Slides Video
- Session 3 – Dr. Catalin Teodoriu – Basic Physics: Slides Video
- Session 4 – Dr. Stephane Menand – Soft vs. Stiff String: Slides Video
- Session 5 – Neil Armstrong – Model Techniques and Applications: Slides Video
- Session 6 – Mitch Abahusayn – Special Operations: Slides Video
- Session 7 – Devi Subramaniam – Realtime Operations: Slides Video

"What is "True" vs. Effective Tension?"

- $T_e = T_{true} - P_i A_i + P_e A_e$
- T_e=Effective tension, lbs
- T_{true}= True tension, lbs
- P_i=Internal pressure, psi
- A_i= Internal cross-sectional area, in^2
- P_e= External pressure, psi
- A_e= External cross-sectional area, in^2



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- Effective tension is what matters when we are calculating T&D and evaluating buckling
- "True" tension is what we would read on a strain gauge. That does not mean the effective tension isn't "real".
- "True" tension is the starting point of the calculation and then we take internal and external pressured into account

"What Is the Maximum Allowable Tension / Torque?"

- Who? – Who are we talking to? Engineer, Company Man, Driller, Grandma?
- What? – Limited by what? The drill pipe, BHA, top drive, or *current emotional state*?
- When? – Near TD, at 16:00 on Friday, in the middle of the night, or after we got stuck?
- Where? – Assuming we have a weak point in the string, where is it currently located?
- Why? – Why have we accepted our current limits as statement of fact?

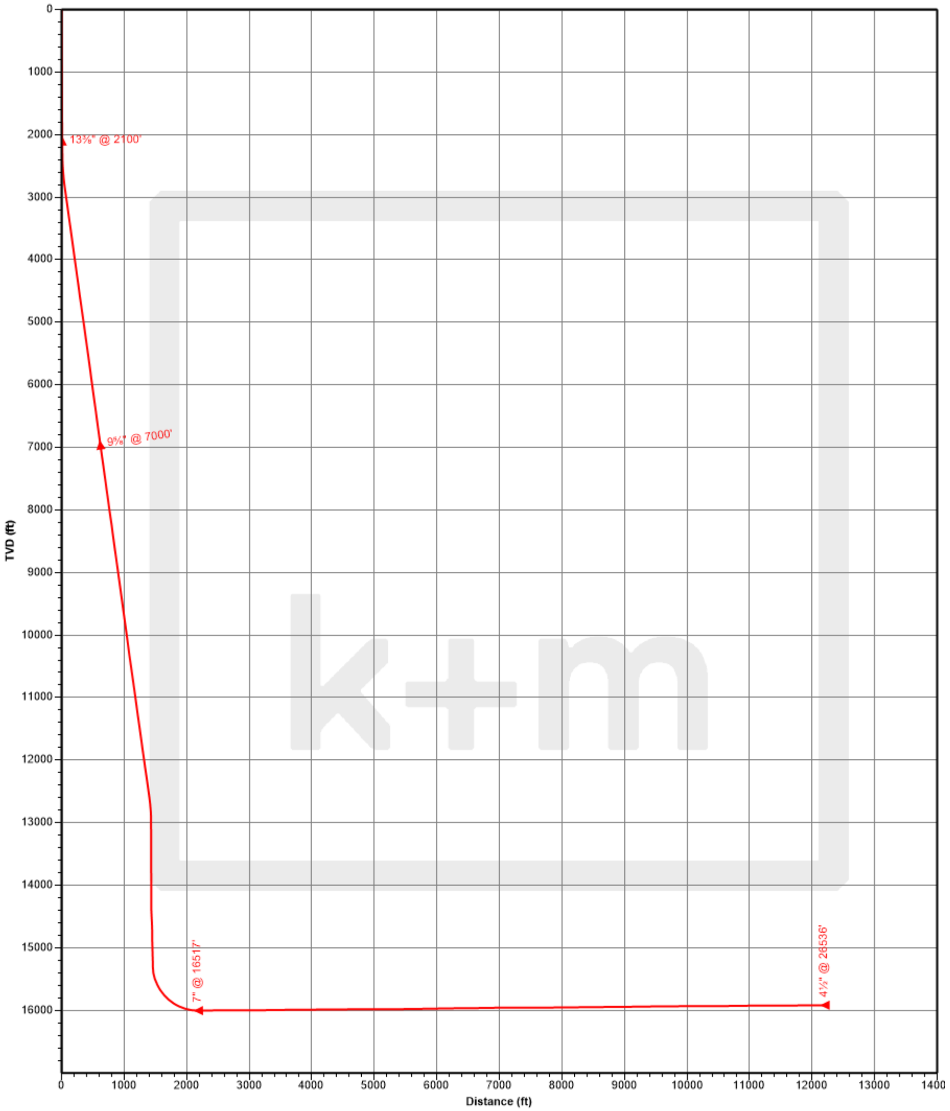
- *HOW* do we figure all this out?

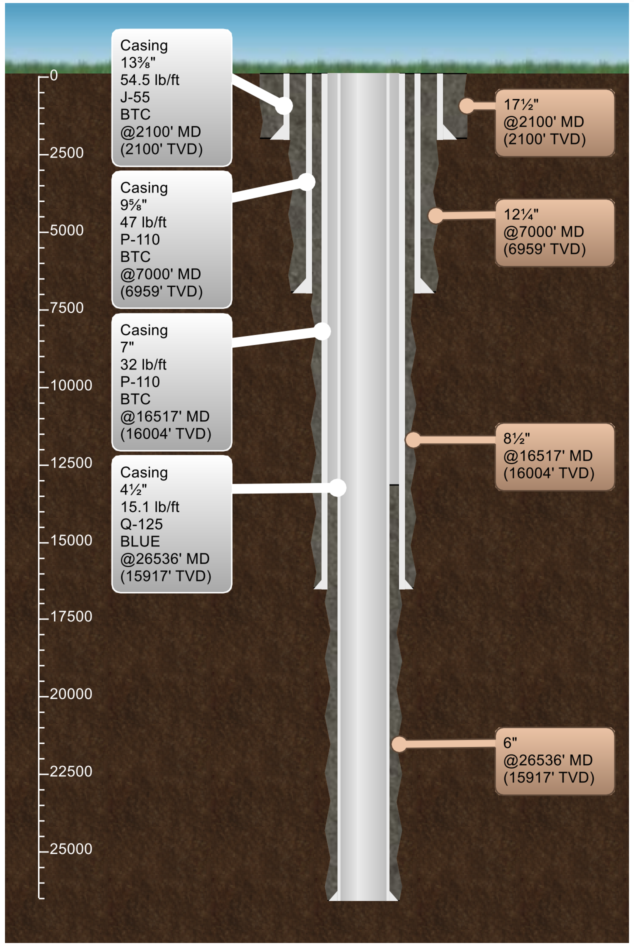
Wellpath

- Deep TVD – 16,000’
- 1,500’ Stepout
- 2-Mile Lateral
- 1.5°/100’ Nudge
- 8°/100’ BUR
- 4-String Design
  - Casing points based on offset vertical wells
- Sandstone target interval
  - Hard, abrasive, 25 drilling days
- 13,000 psi multistage frac completion

“Just like a Bakken well”

“XYZ company is drilling 3-mile laterals – we can do this, no problem”





Drill Pipe Spec

- We are renting 4" 14# S135 XT39
- Spec Sheet says for Premium (80% remaining body wall thickness):
  - *Tube Tension = 403,500 lbs*
  - *Tube Torque = 32,800 ft-lbs*
  - *Max makeup = 22,300 ft-lbs*
- We need to apply a Design Factor to ensure that we don't exceed ratings and allow for some wear while drilling.
- Typically we us 80% / 1.25 DF for the tube
  - *Tube Tension = 322,800 lbs*
  - *Tube Torque = 26,240 ft-lbs*
- *Some Operators also limit torque to 90% of MUT. Not uncommon to go to 100%*
  - *Max Torque = 20,000 ft-lbs*

FOR REFERENCE ONLY

GRANTPRIDECO™

Drill Pipe Performance Characteristics ©

Pipe Size and Weight: 4" 14.00 IU
Pipe Grade: S-135
Range: 3
Tool Joint: 4.875 X 2.563 XT39

Pipe

	New	Premium		New	Premium
OD (in)	4.000	3.868	Torsional strength (ft-lbs)	41,900	32,800
Wall thickness (in)	0.330	0.264	Tensile strength (lbs)	513,600	403,500
ID (in)	3.340	3.340			
Calculated plain end weight (lbs/ft)	12.921	10.151	80% Torsional strength (ft-lbs)	33,500	26,200
Cross sectional area pipe body (in²)	3.805	2.989	Pressure capacity (psi)	19,491	18,428
Cross sectional area OD (in²)	12.566	11.751	Collapse capacity (psi)	20,141	13,836
Cross sectional area ID (in²)	8.762	8.762			
Section modulus (in³)	3.229	2.523			
Polar section modulus (in³)	6.458	5.046			

Note: Premium properties are calculated based on uniform OD and wall thickness.

Tool Joint (120000psi material Yield Strength)
XT39

OD (in)	**4.875**
ID (in)	**2.563**
Pin tong length (in)	**10.0**
Box tong length (in)	**15.0**
Torsional Strength (ft-lbs)	**37,100**
Max Recommended Make-up Torque (ft-lbs)	**22,300**
Min Recommended Make-up Torque (ft-lbs)	**12,500**
Balance OD (in)	4.992
Tensile strength (lbs)	729,700
Tool joint/Drill pipe torsional ratio (New pipe)	0.89
Tool joint/Drill pipe torsional ratio (Prem pipe)	1.13
Min OD for premium class (in)	4.531

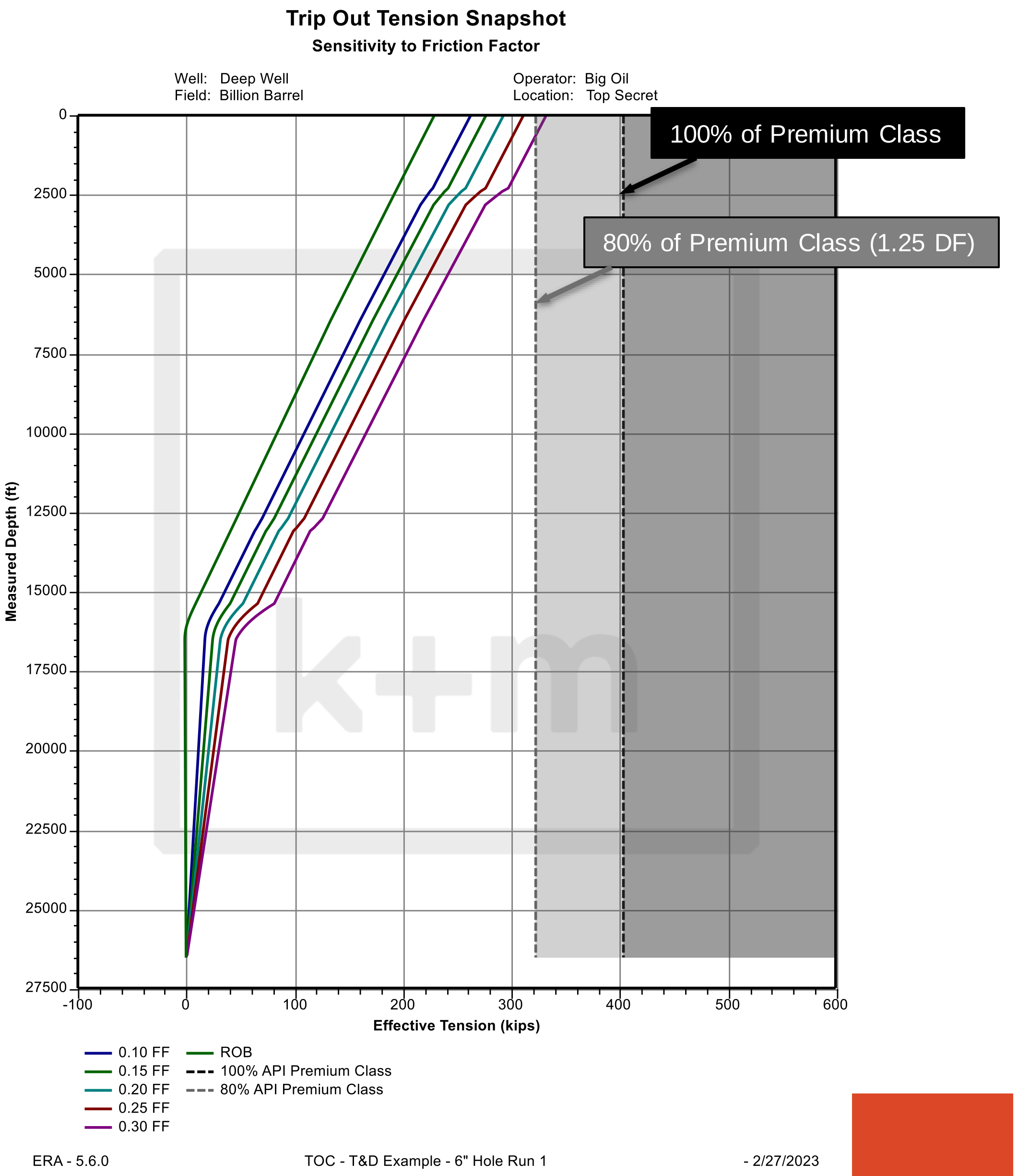
Minimum make-up is based on shoulder separation caused by bending.

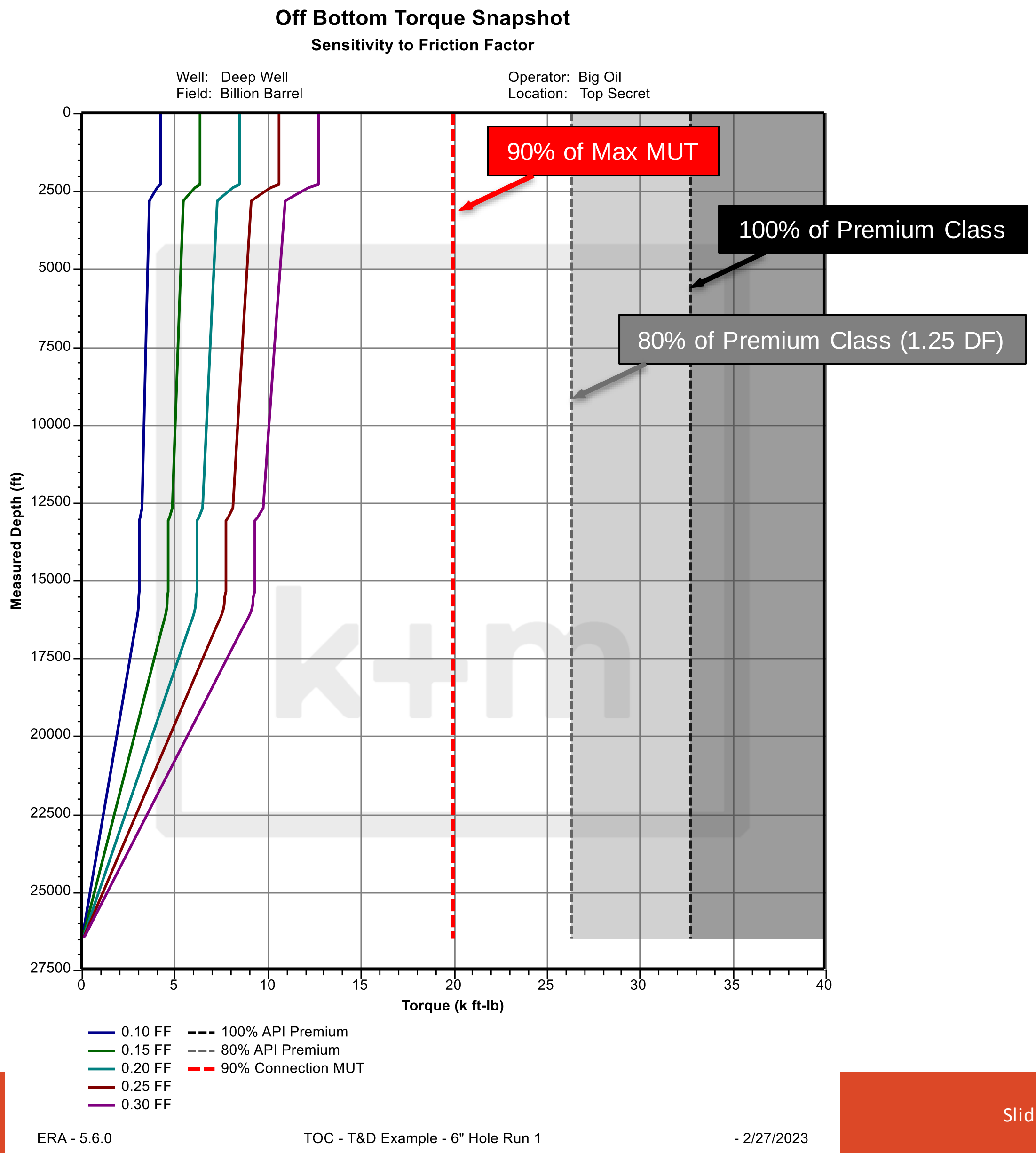
Drill pipe assembly with Grant Prideco XT39 eXtreme™ Torque Connection

Adjusted weight (lbs/ft)	14.91
Approximate length (ft)	43.71
Fluid displacement (gal/ft)	0.228
Fluid capacity (gal/ft)	0.446
Drift size (in)	2.438

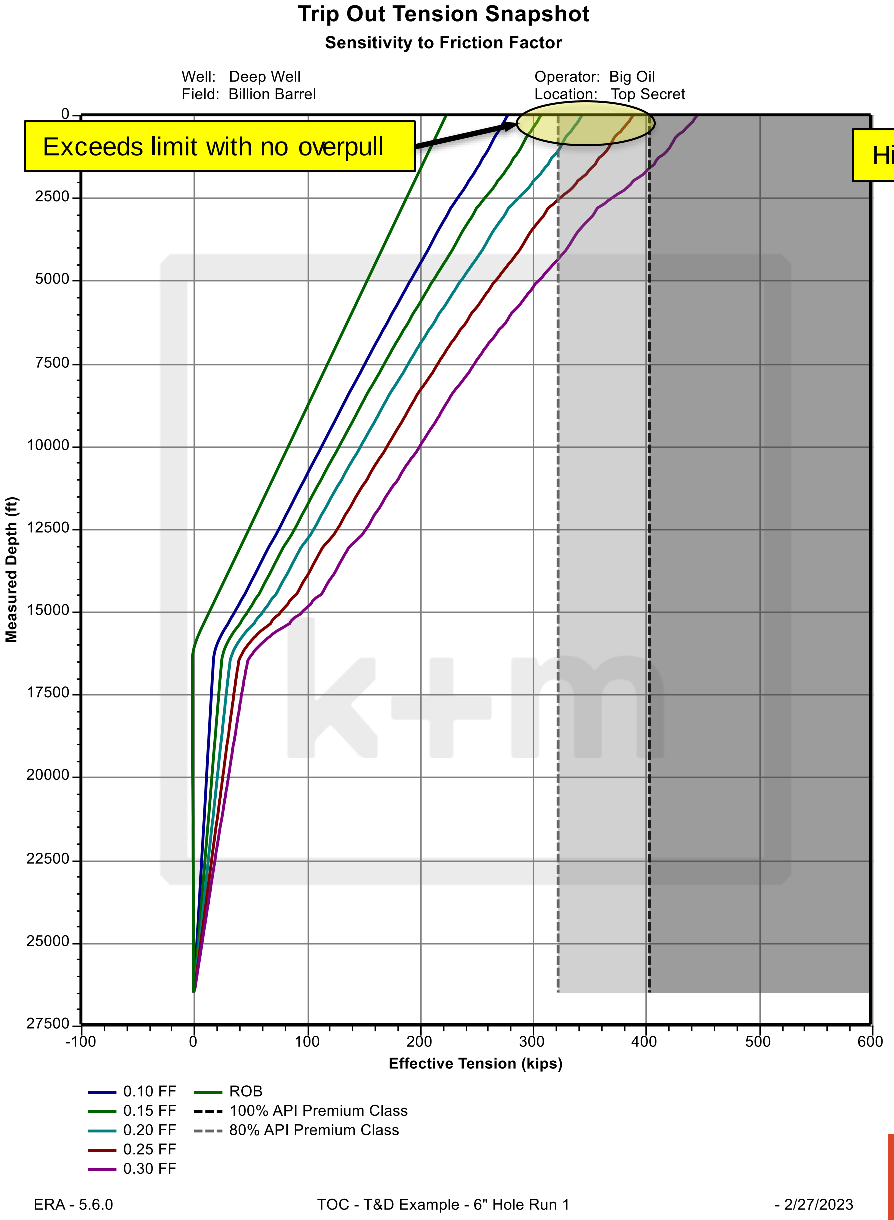
Brian Christen 4/22/2002

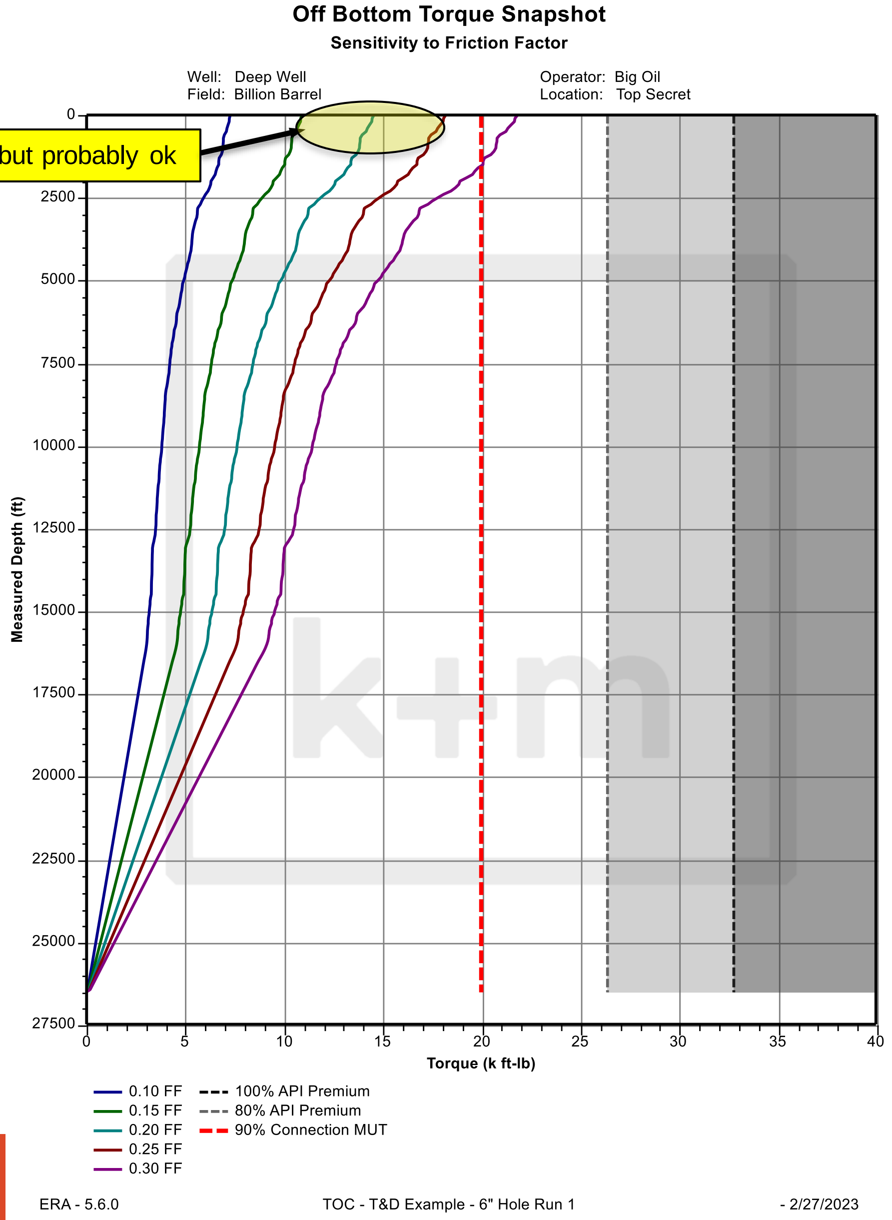
4” 14# Drill Pipe, No Tortuosity, Uniaxial Limits





4” 14# Drill Pipe, Tortuosity, Uniaxial Limits





Combined Loading (aka, VME or Triaxial Loading)

$$VME = \sqrt{\sigma_r^2 + \sigma_\theta^2 + \sigma_z^2 - \sigma_r\sigma_\theta - \sigma_r\sigma_z - \sigma_\theta\sigma_z + 3\tau^2}$$

- Converts stress in multiple directions to one “equivalent” direction
- The equivalent stress is then compared to yield strength of material
- *Can also re-arrange the equation to solve for tension, torque, etc.*

σ_r= Radial stress

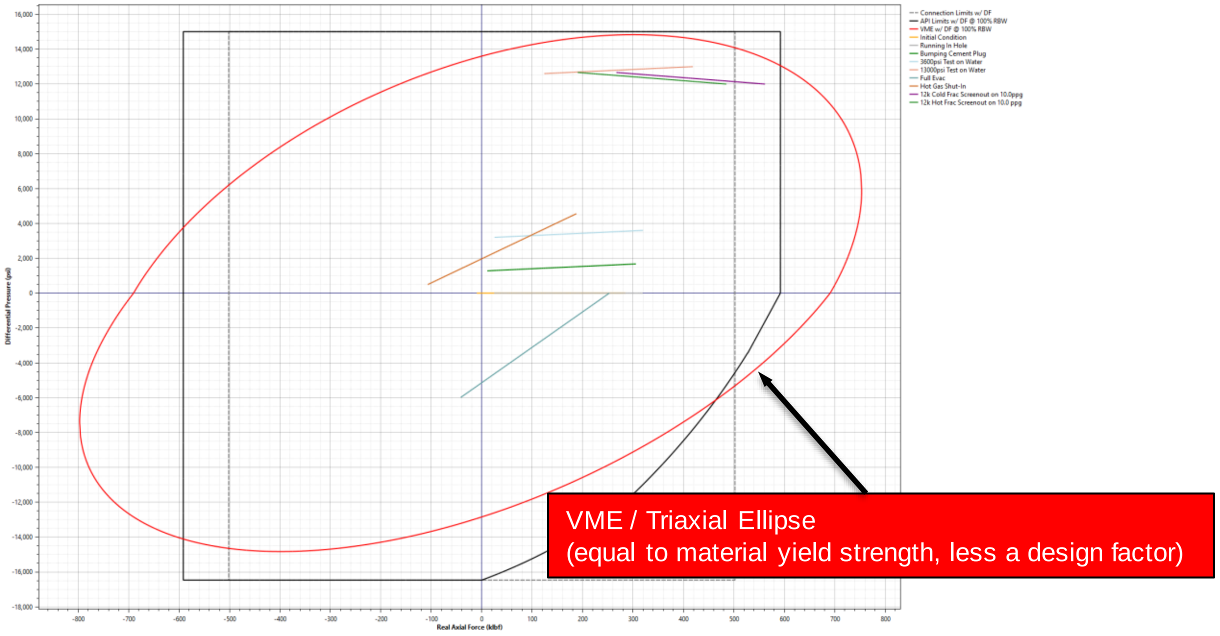
σ_θ= Hoop stress

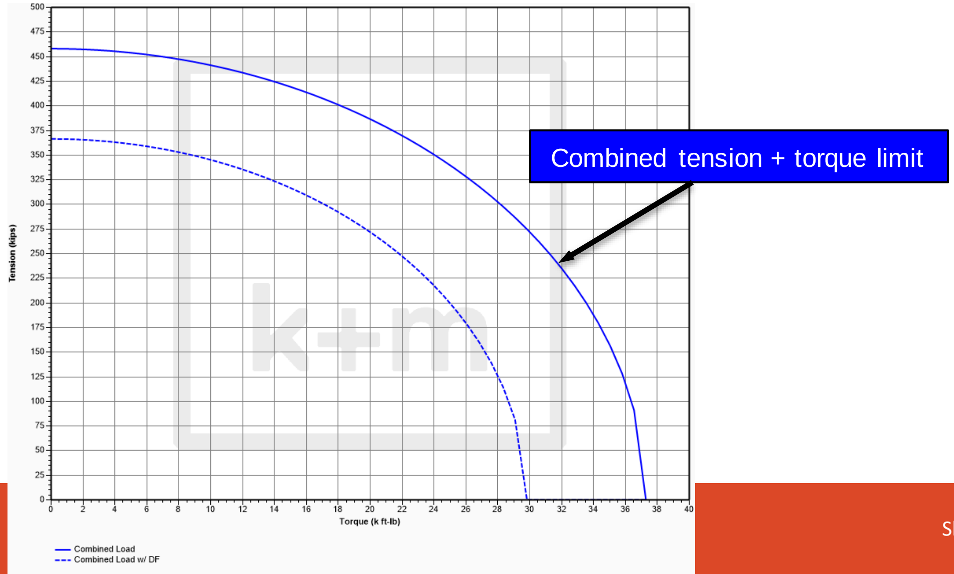
σ_z= Effective axial stress (σ_a + σ_b)

σ_a= Axial stress

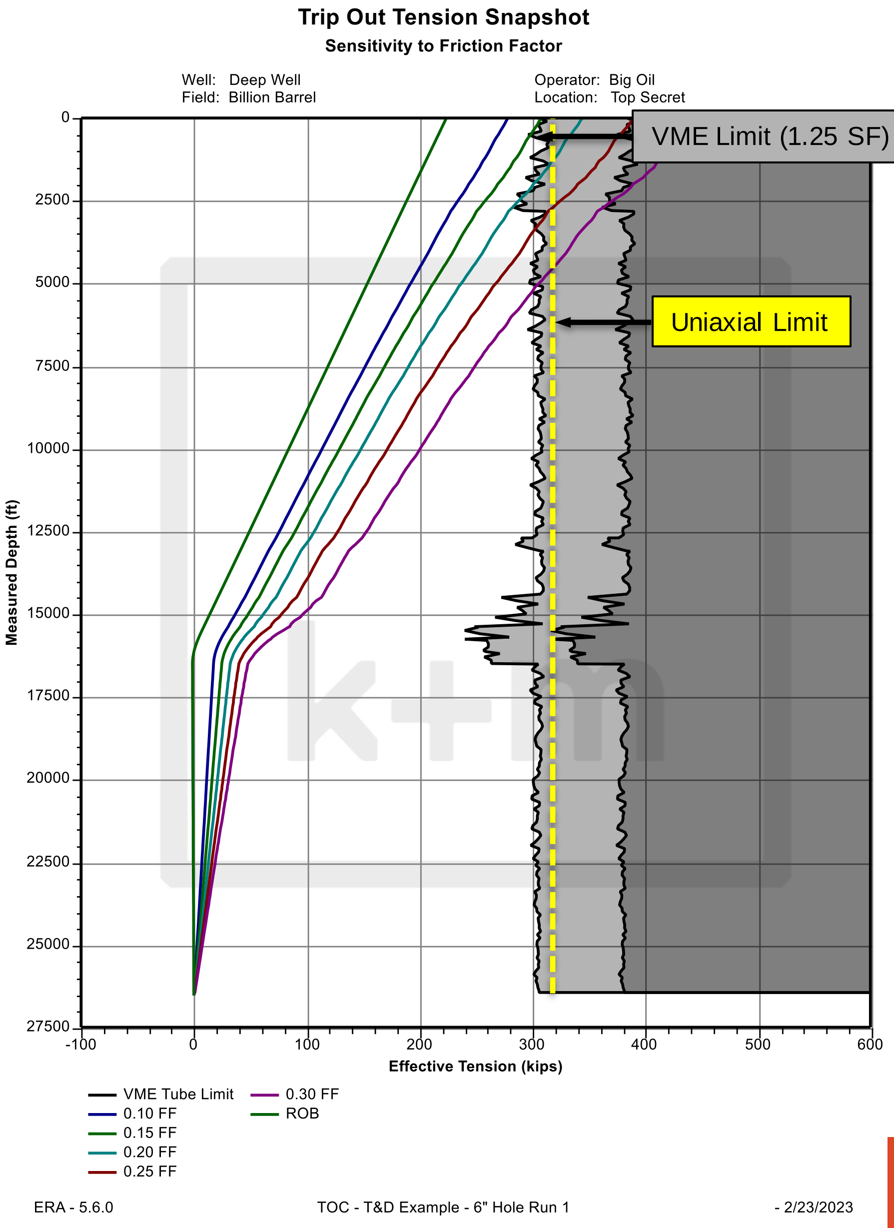
σ_b= Bending stress

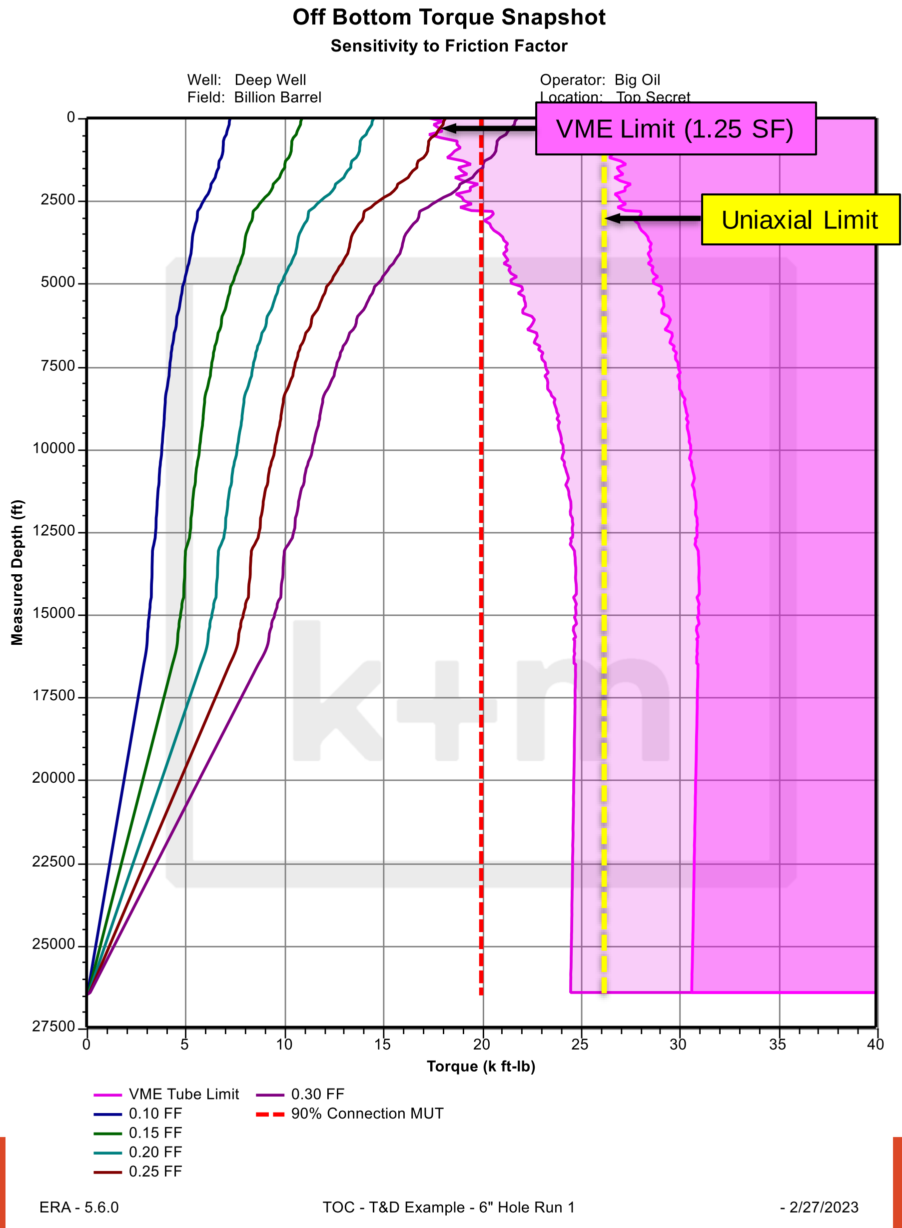
τ= Shear stress



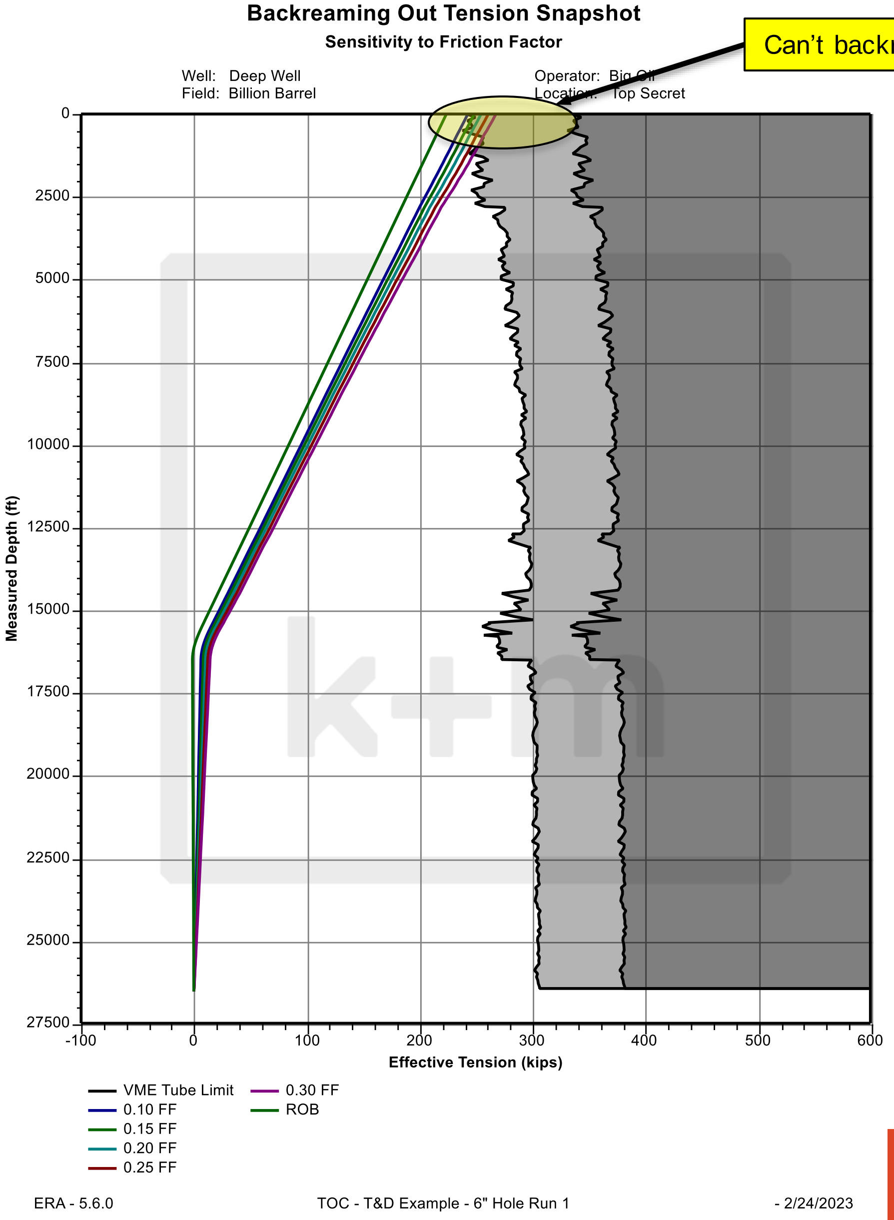


4” 14# Drill Pipe, Tortuosity, VME Limits

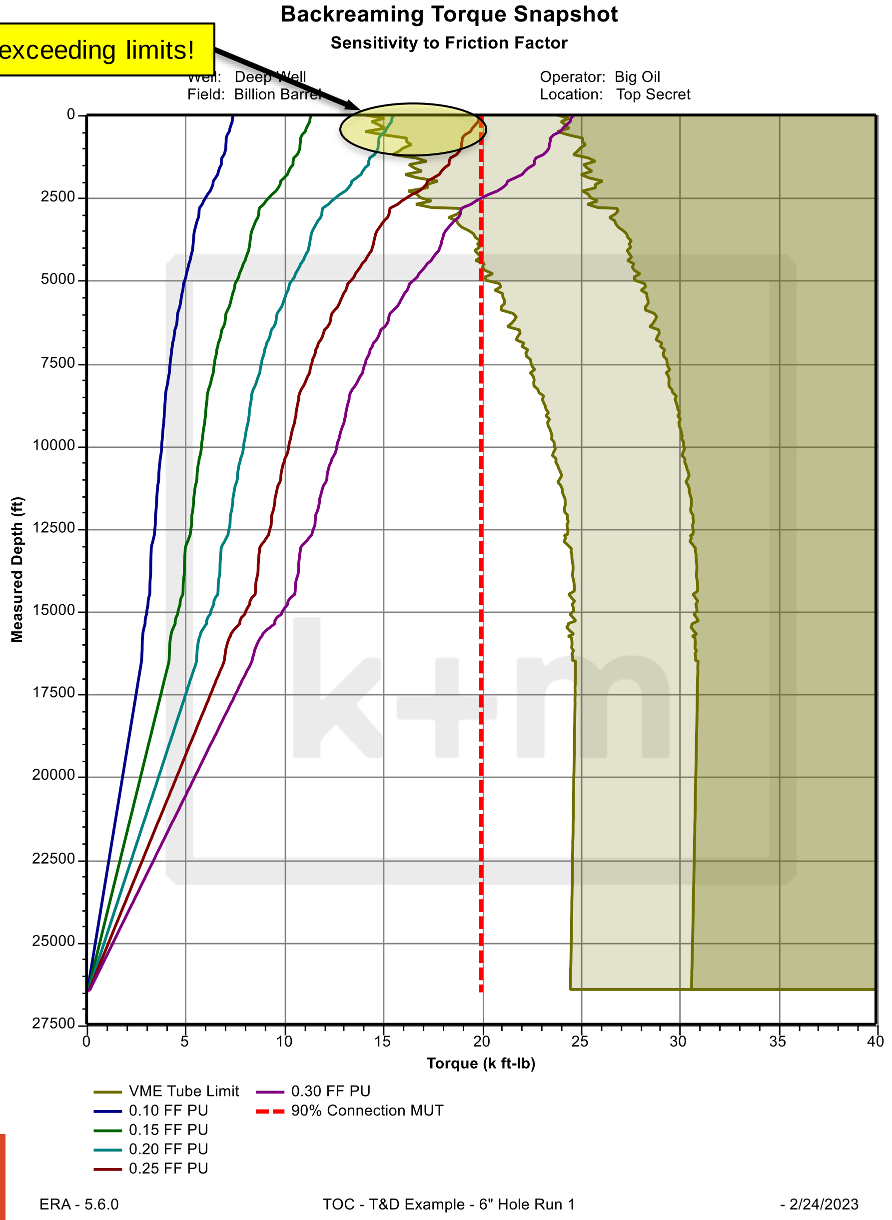




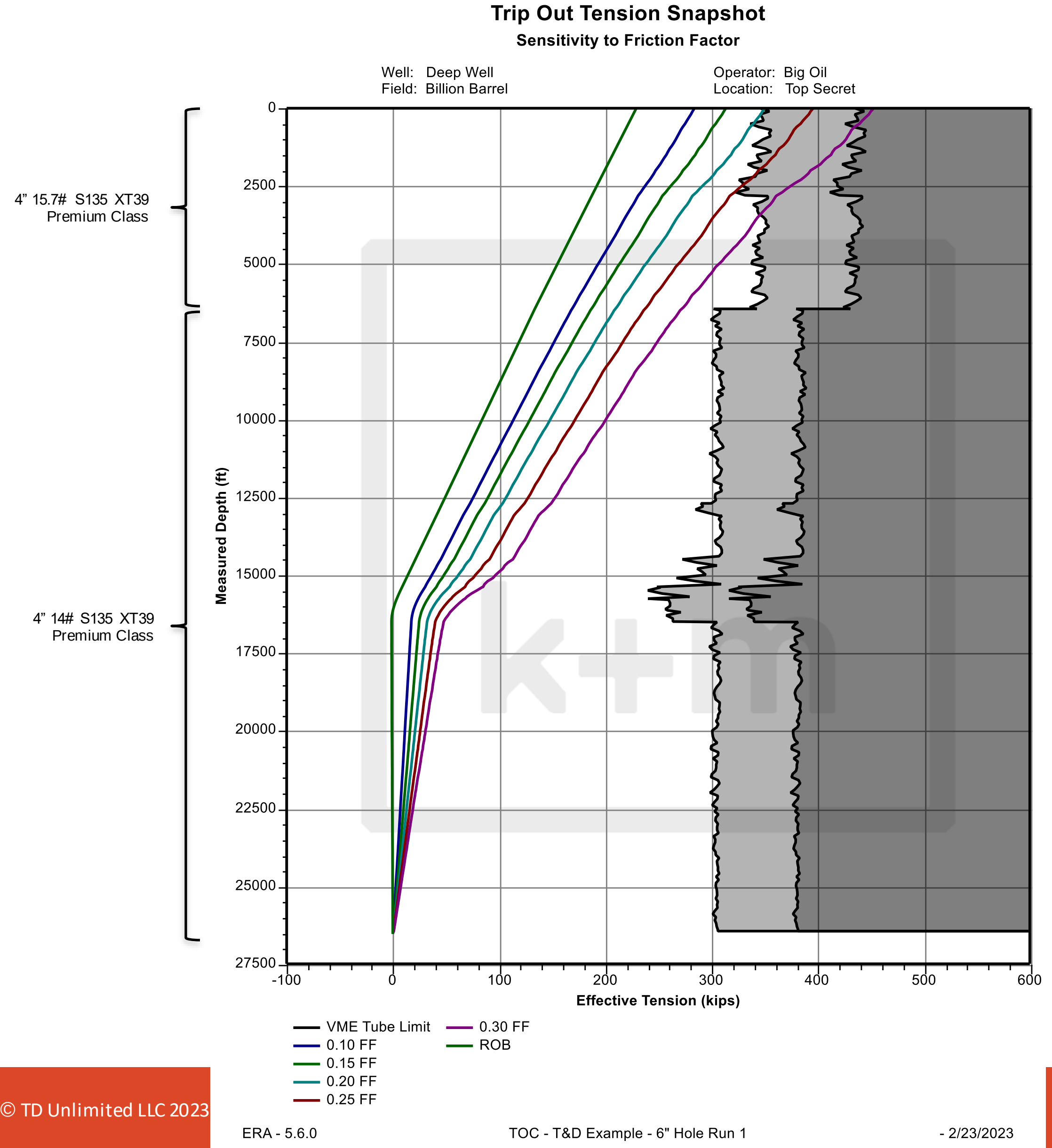
4” 14# Drill Pipe, Tortuosity, VME Limits - Backreaming

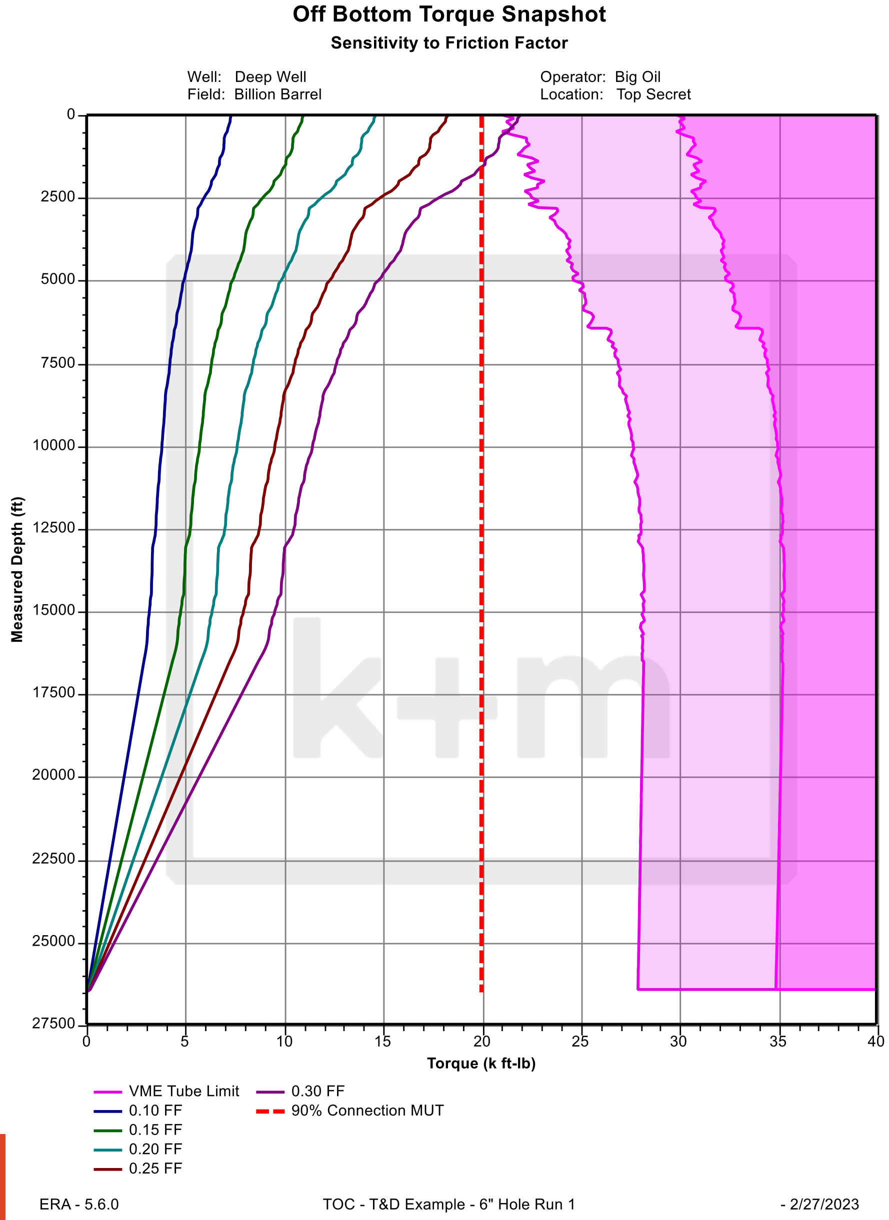


Can’t backream without exceeding limits!

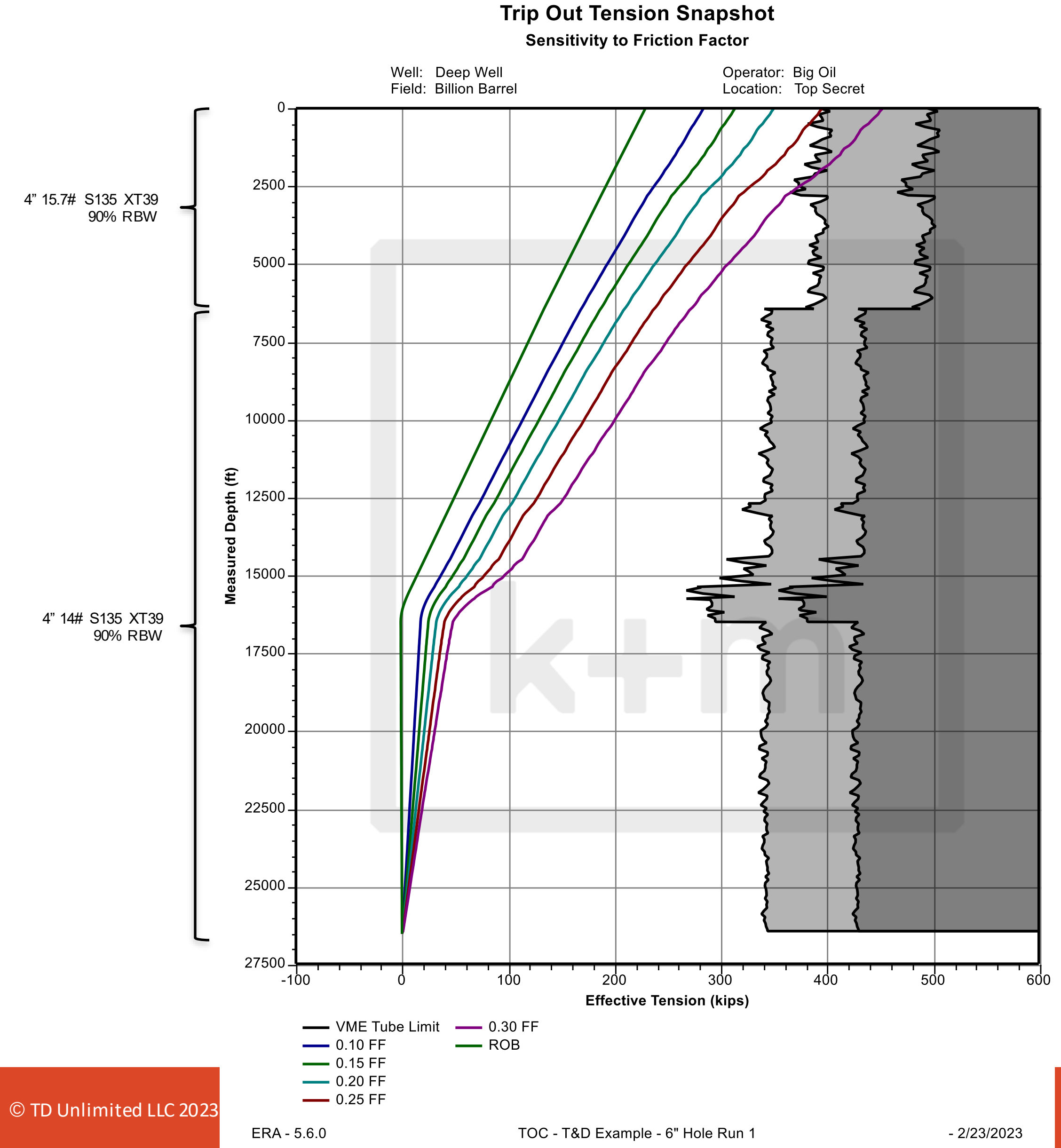


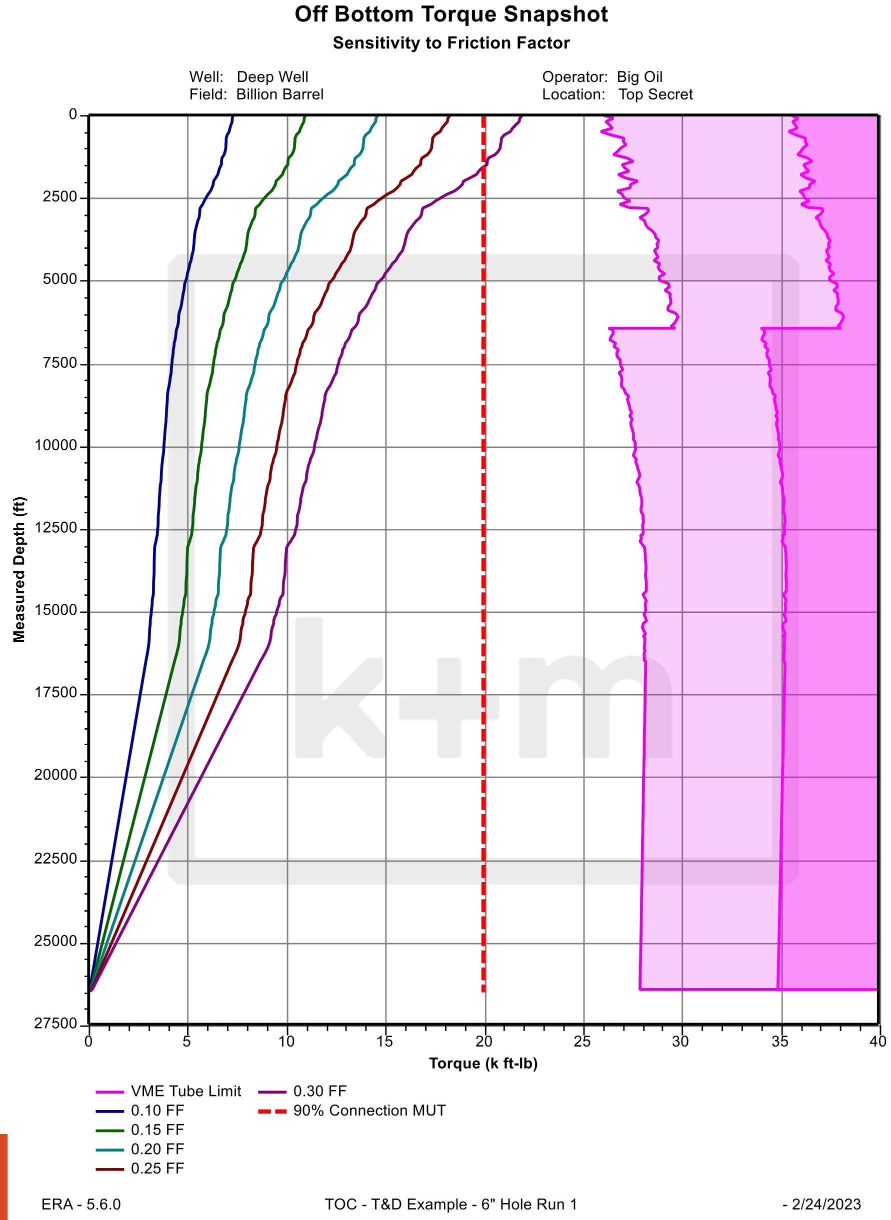
4” 14# x15.7# Drill Pipe, Tortuosity, VME Limits





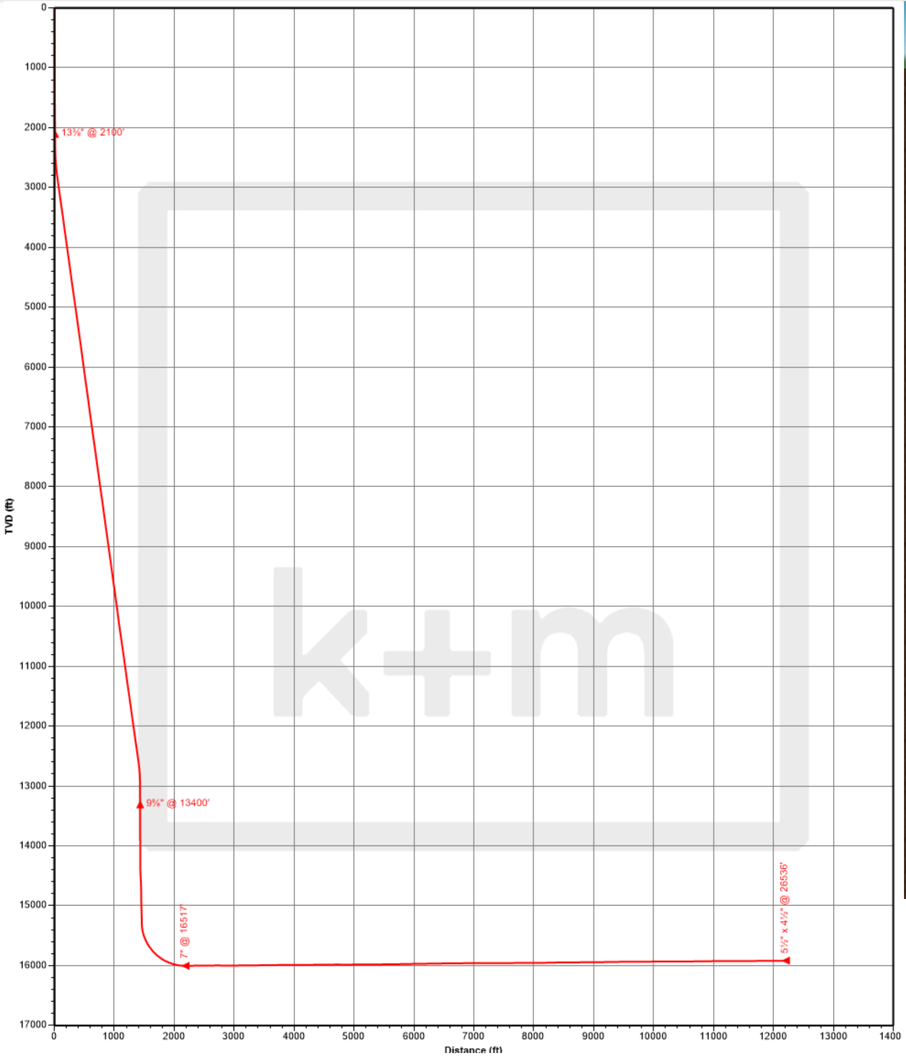
4” 14# x15.7#, 90% RBW Tortuosity, VME Limits

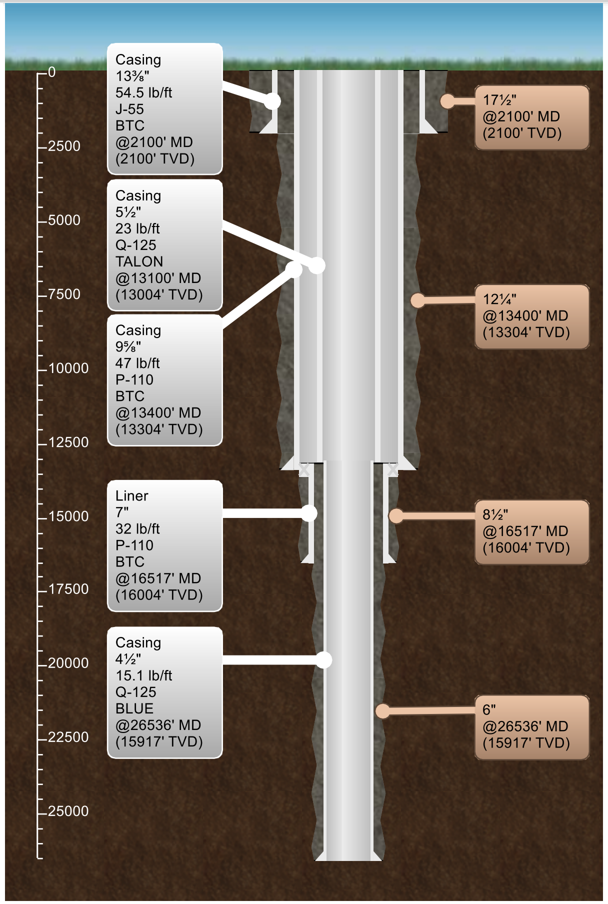




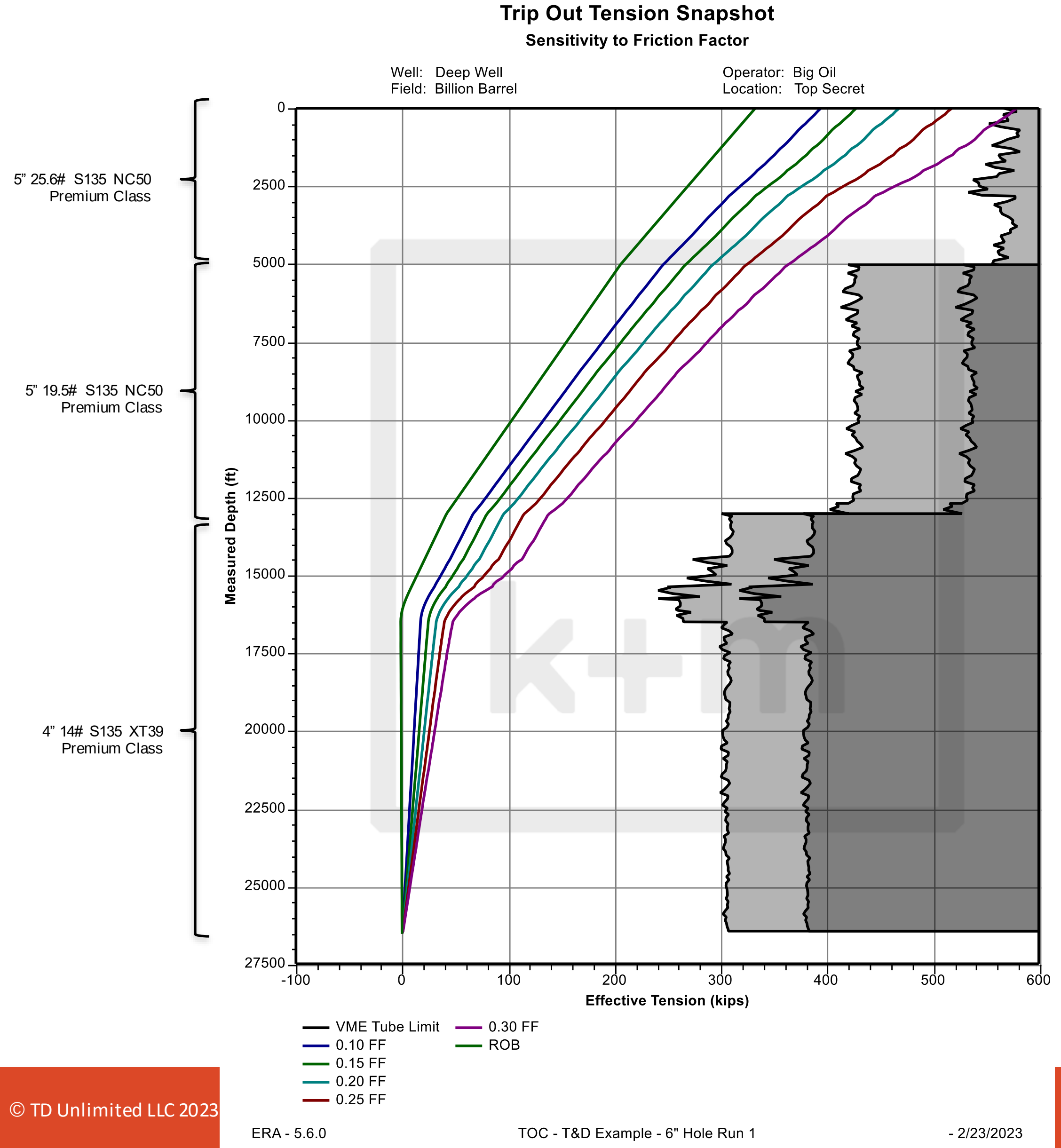
Design Change!

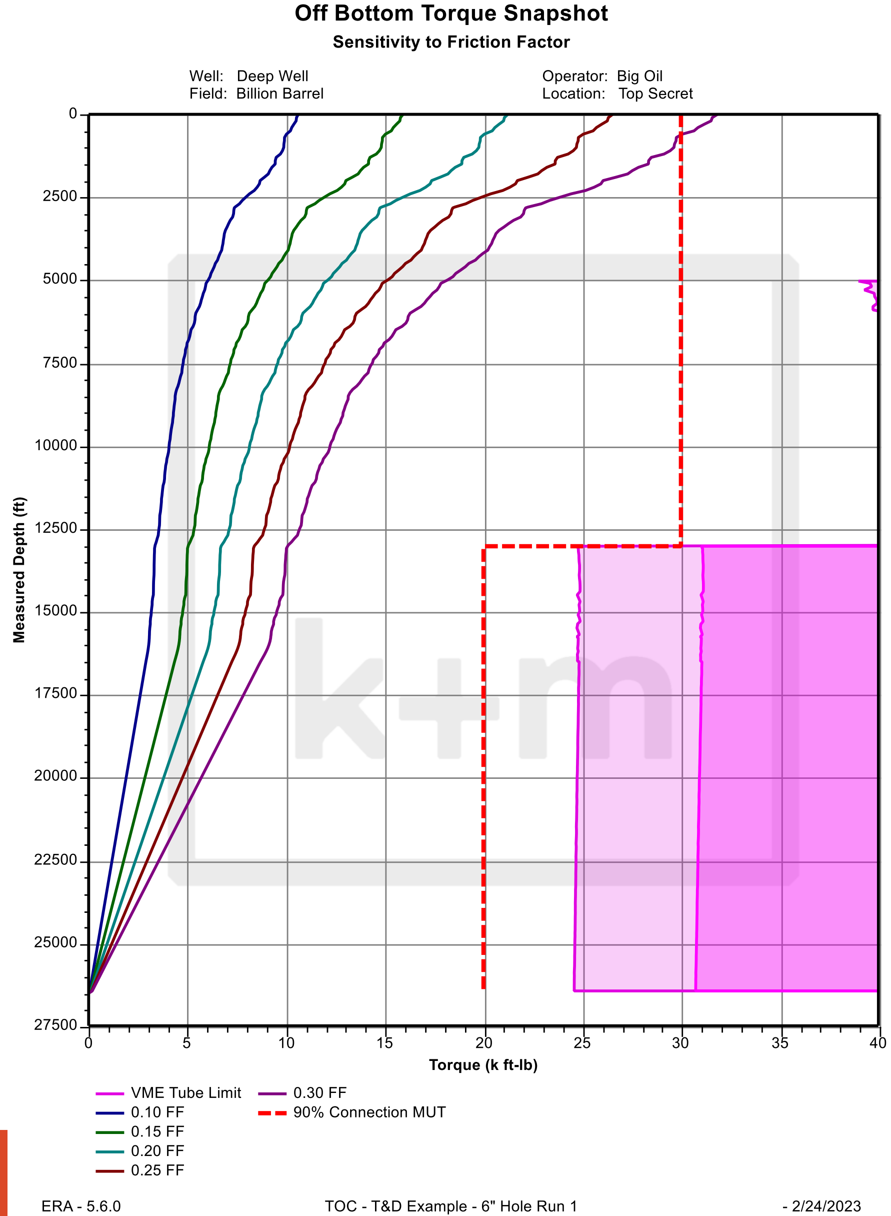
- Why are we setting 9⅝” so shallow?
  - That’s what the vertical offsets wells did 40 years ago
  - Offsets all used WBM and rock bits
  - All the offsets used the same mud weight from 2000’-13000’
- What if we extend 12¼” to 13,000’ and run 7” as a liner rather than a long string?
  - Large annulus above the 7” liner top allows us to use a tapered string to drill the lateral
  - Also allows for tapered production casing



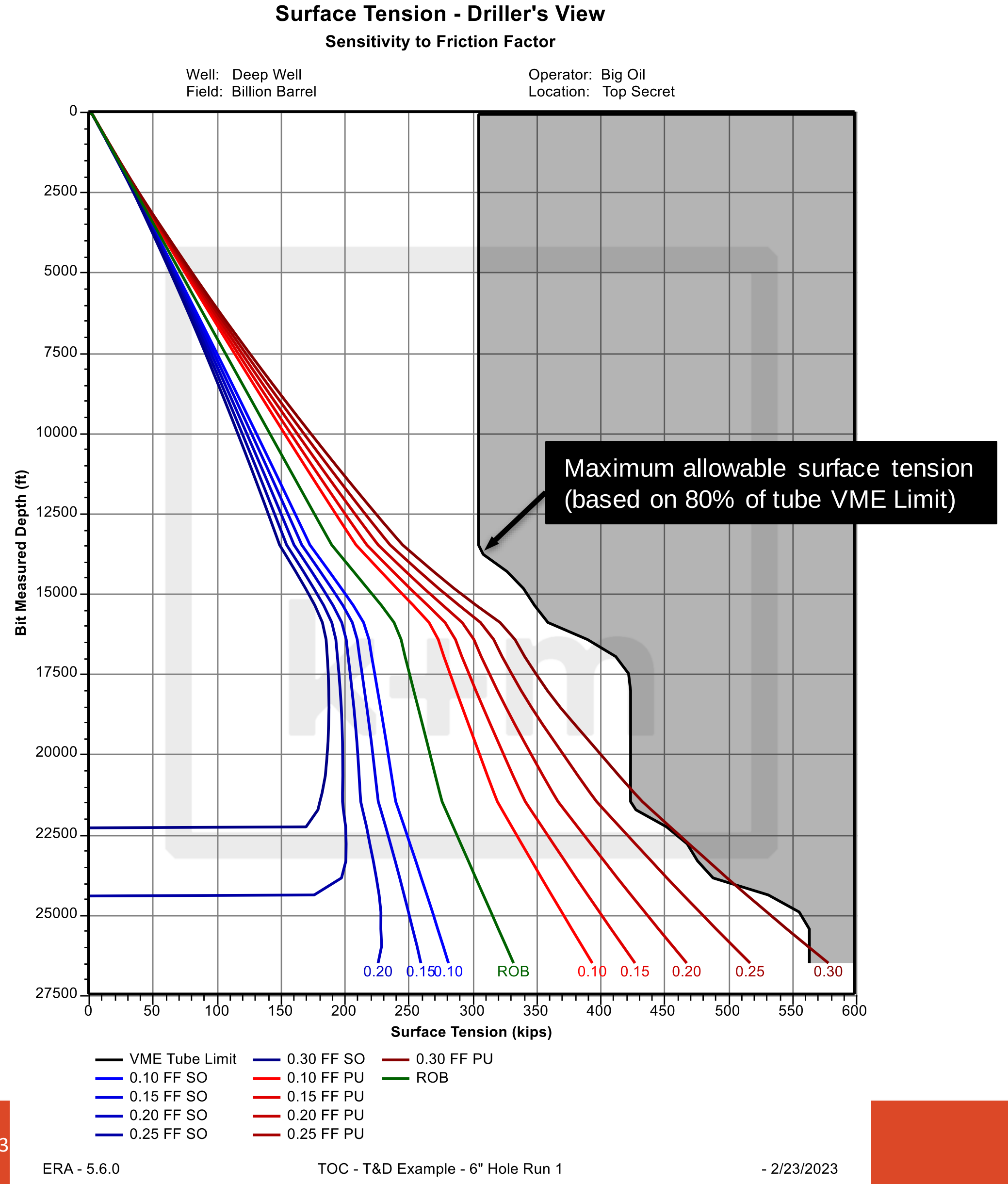


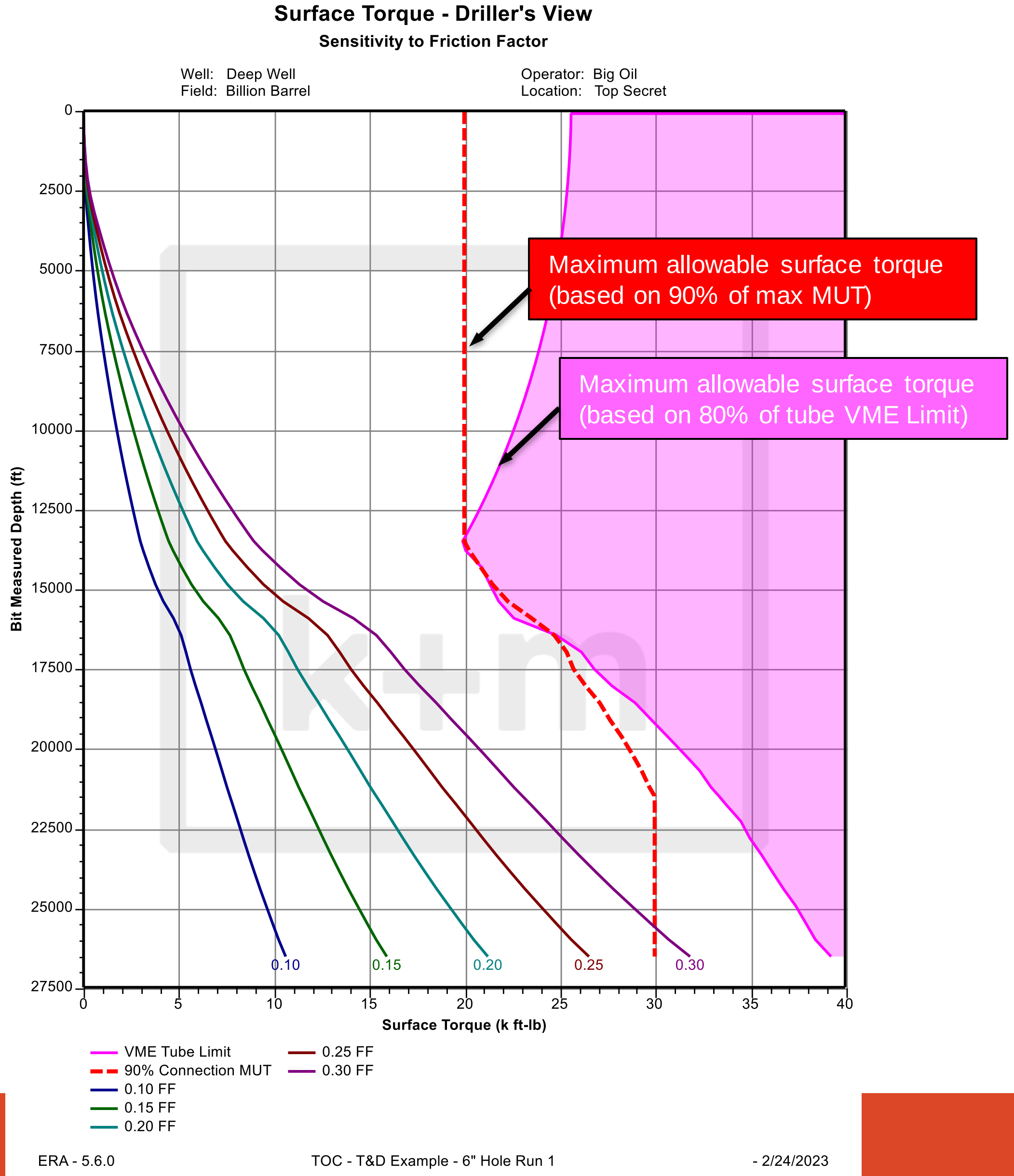
5”x4”, Tortuosity, VME Limits





Driller’s View





Benefits of Design Change

- Adequate torque and tension margins drilling the lateral
- Save $1MM on casing
- Accommodates 5½”x4½” production casing rather than 4½” liner or 4½” long string
  - Frac down 4½” long string severely limits rate due to friction pressure
  - Running 4½” as a liner and frac down 7” is risky due to wear on 7”, and liner top integrity
- Better hydraulics, ECD, and swab/surge drilling and running/cementing casing
- Frac cleanout with 2⅞”x2⅜” work string (wouldn’t have been possible with all 2⅜”)

Recommended Process

1. Verify pipe condition (New, 90% RBW, Premium)
2. Agree upon minimum design factors
   – 1.20-1.25 is typical for VME or Tension
   – 1.0-1.25 is typical for Tool Joint Makeup Torque
3. Apply artificial tortuousity to planned wellpath (based on offsets)
4. Calculate VME limit for tube tension and torque
5. Base FF assumptions on offsets / analogs
6. Make allowances for torque at bit and overpull

Q&A