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CT String Design Methodology for Extended Reach Applications

ICoTA Canada Round Table
Hotel Arts – October 29th, 2014

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Outline

- Considerations
- CT size, Length, Grade, Minimum Wall Thickness.
- Wall thickness sections (transitions points)
- Pre-Job Modeling
- CT Force Matching
- CT Extended Reach Design Methodology
- Example 1 – 2-7/8” Ultra-Long Lateral Well
- Example 1 – Field Success
- Example 2 – 2-3/8” vs 2-5/8”
- Conclusions

CT String Design Methodology

Basic techniques:

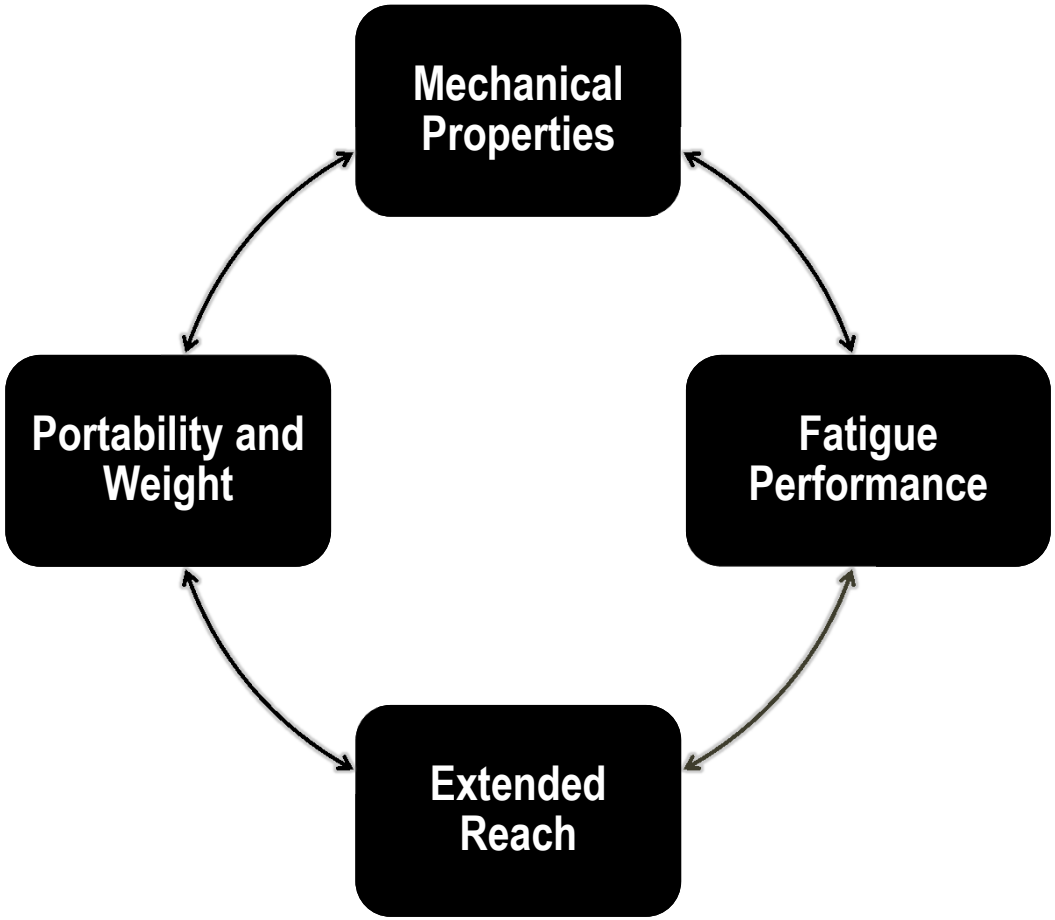
- VME Safety Factor
- Consistent Overpull Value

TENSILE STRENGTH BASED

More sophisticated methods were created for **HIGH PRESSURE** and **EXTENDED REACH** applications that considers:

- Burst and Collapse predictions models for oval tubing under axial loads,
- The effect of diametrical growth, elongation and wall thinning,
- Tubing forces and lock-up behavior.

General Considerations



Extended Reach CT Designs Considerations

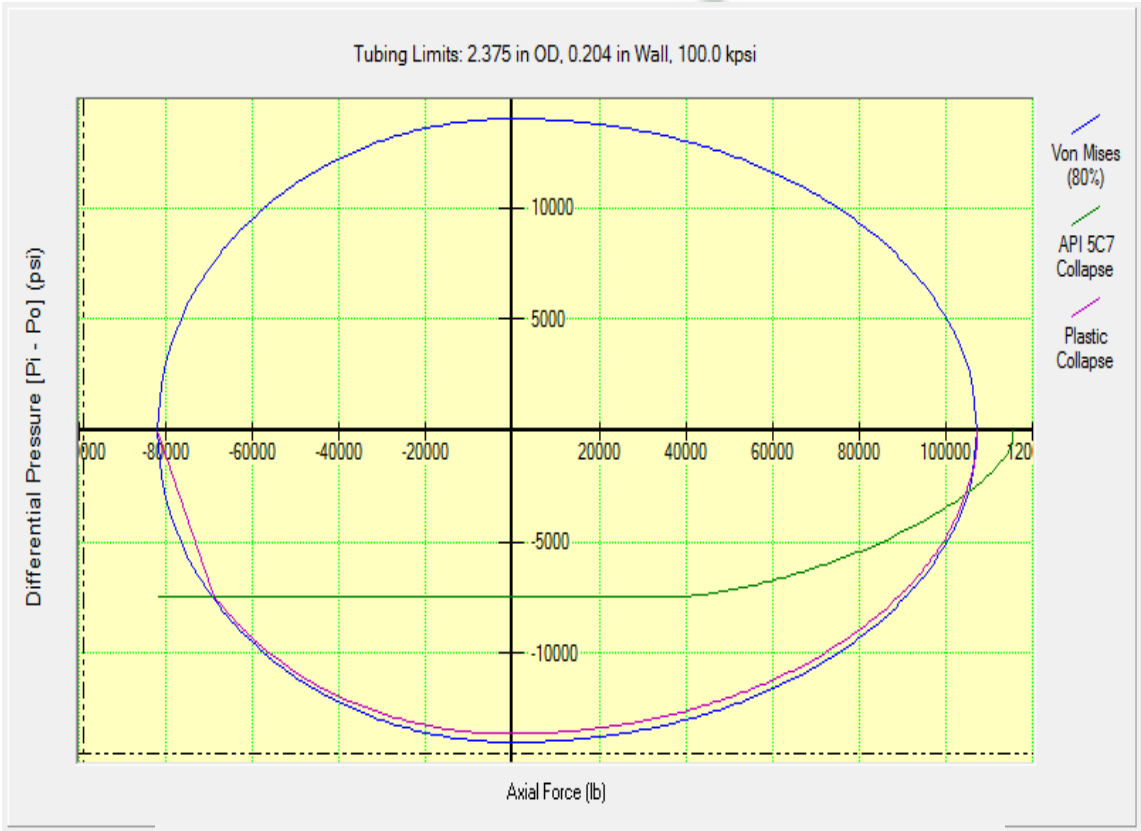
Wellbore Features	Operation Challenges	Extended Reach Tools	Fluid Additives
• Completion size • Restrictions • Kick off depth • Build up rate • Dogleg severity	• Max. Working Pressures • CT flow Rates • Annular Velocities • Min. WOB • BHA	• Tractors • Agitators • Water Hammers • etc.	• Metal to Metal • Beads • Friction Reducers

Great impact on the well friction coefficient reduction

Steps to design a CT string:

1. OD size
2. Length
3. Grade
4. Minimum Wall Thickness
5. Wall Thickness Sections

Von Mises Combined Stress
(tri-axial stresses: axial, tangential and radial)

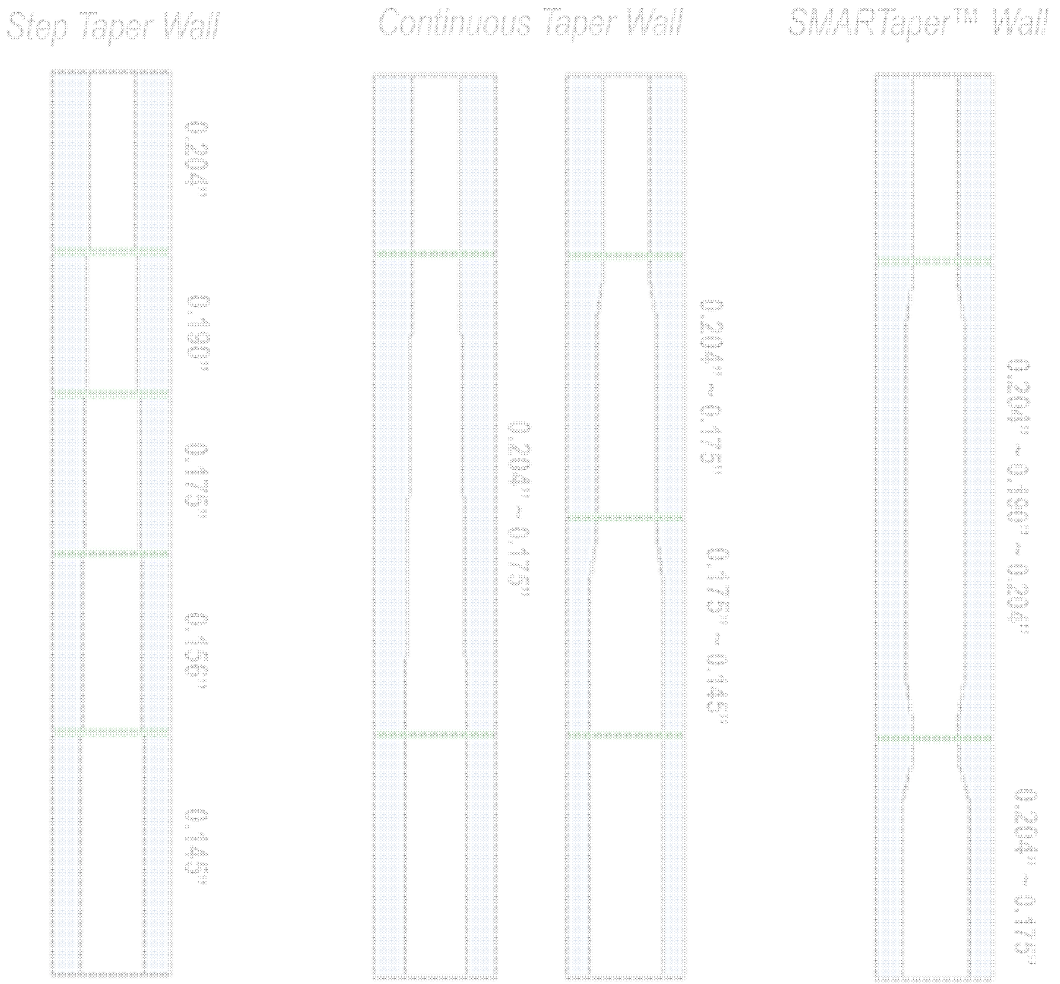


The limits must be larger by a safety factor than the forces expected in any job of the string.

Wall thickness sections (transitions points)

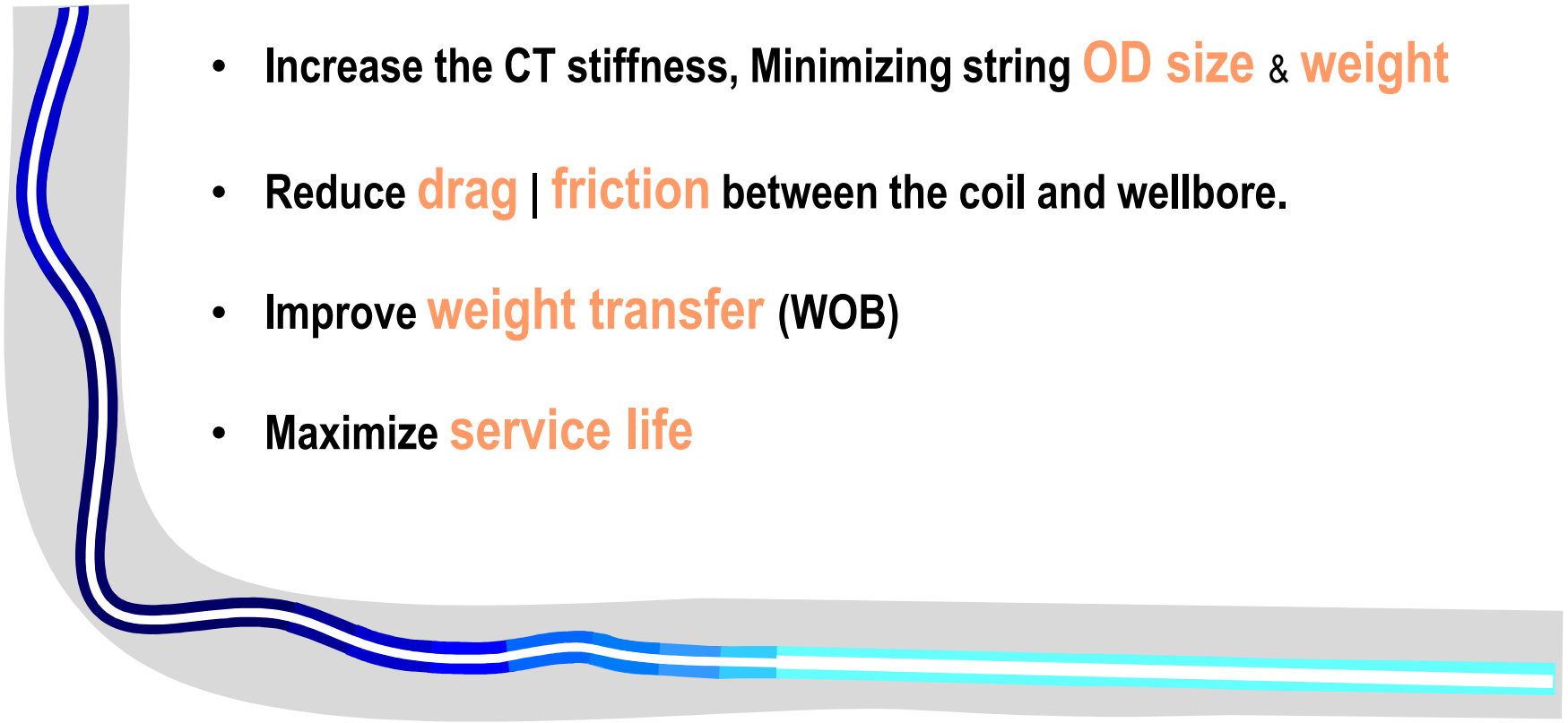
It depends on:

- The strength/stiffness needed along the length of the tubing, for OVERPULL and REACH.
- The weight restrictions (to reduce transportation logistics)
- and whether optimizing string life is essential.



CT String Design Methodology

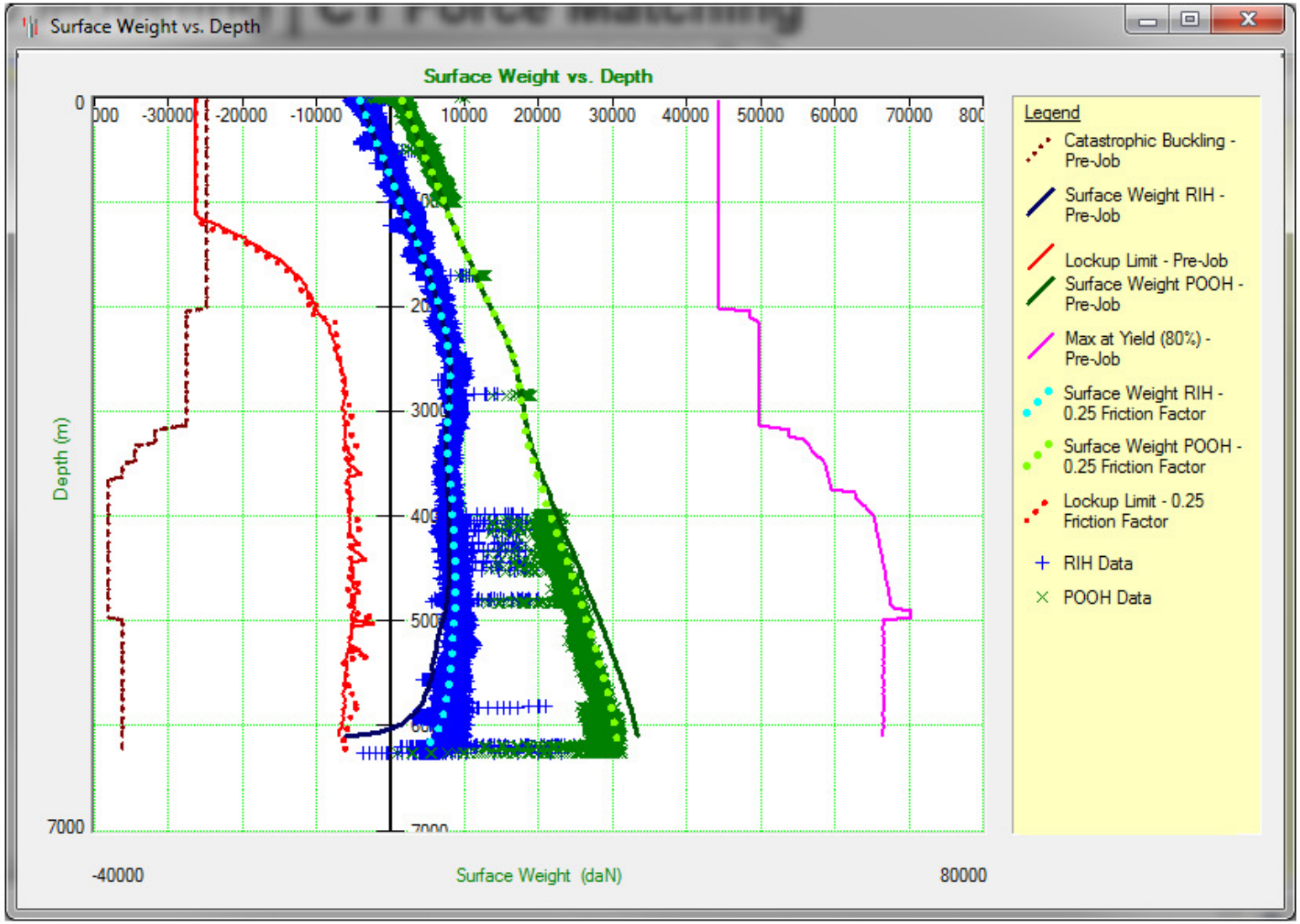
Extended Reach CT Designs



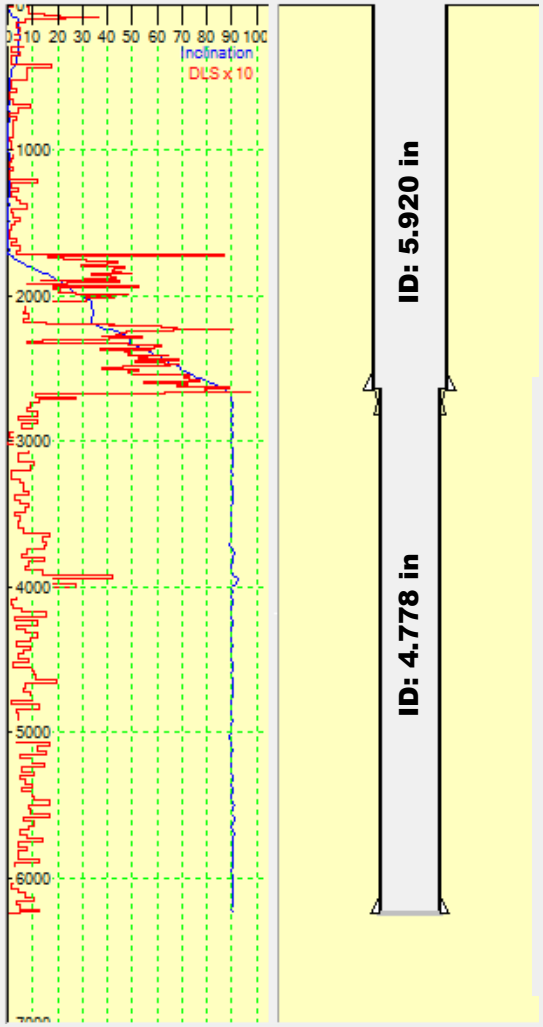
- Increase the CT stiffness, Minimizing string OD size & weight
- Reduce drag | friction between the coil and wellbore.
- Improve weight transfer (WOB)
- Maximize service life

Pre-job Modeling | CT Force Matching

Increase Predictability of CT operations

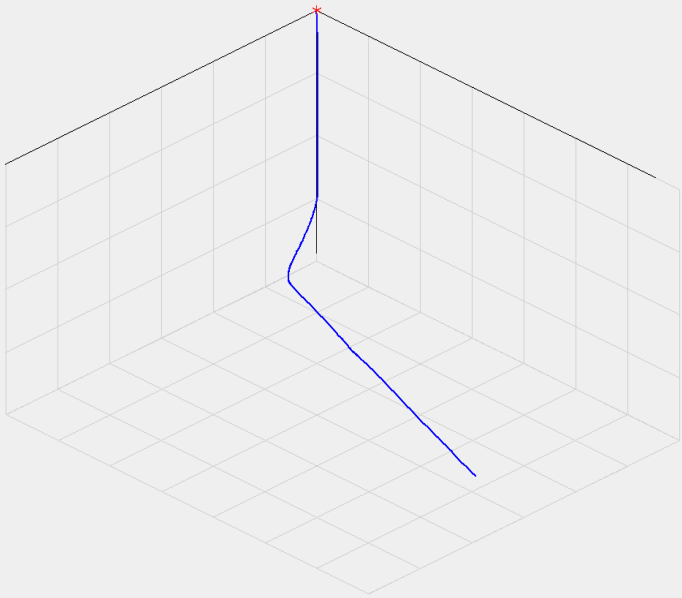


Extended Reach CT Designs – Example 1



Ultra-long lateral wells from the Western Canadian Sedimentary Basin with up to 2.65 depth ratio.

As per the model, a 2⅞" (73.33mm) CT with 0.250" max wall thickness will reach bottom and have sufficient set-down force for the milling operations.



Total Depth: 6,245 m
TVD: 2,352 m
Min Diameter: 4.778 in
Max. inclination: 93 deg
Max. dogleg: 9.731 °/30m

~3, 600m Lateral

Cerberus Suit v11.5.17 for Coiled Tubing

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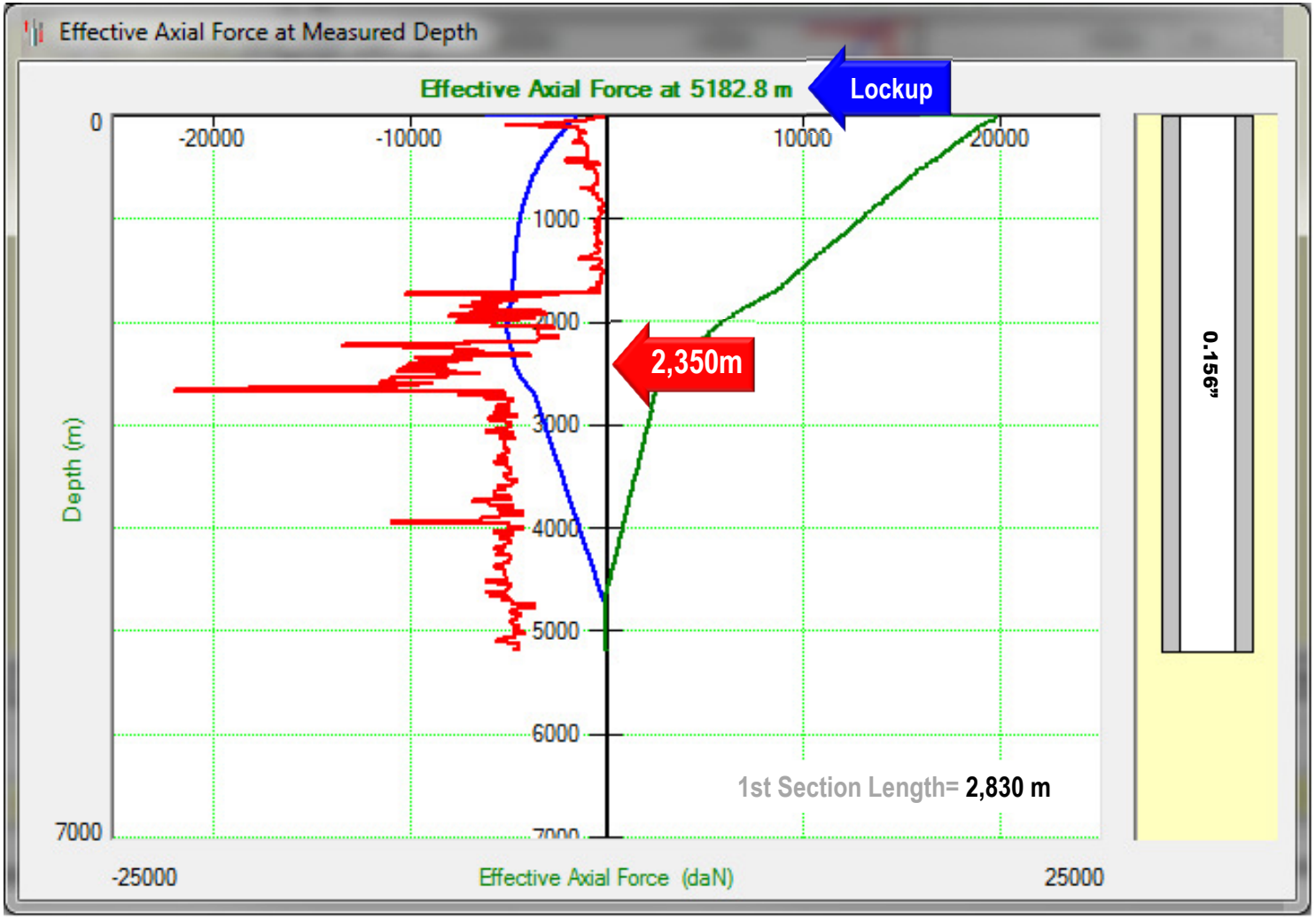
Extended Reach CT Designs - Process

MD 6,245m
TVD 2,352m

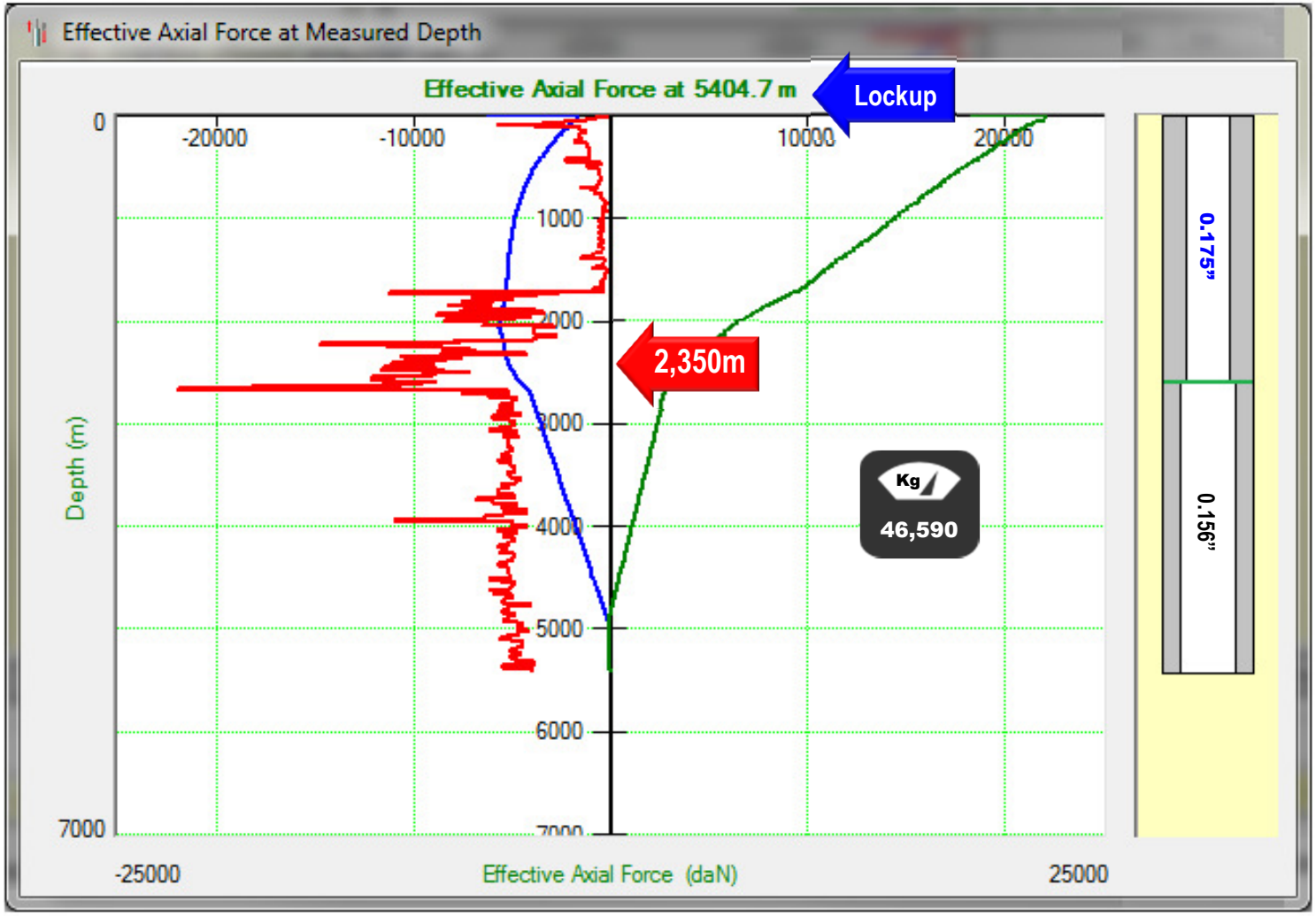


Eff Force RIH
Eff Force POOH
Helical Buckling

Cerberus Suit v11.5.17 for Coiled Tubing

Extended Reach CT Designs - Process

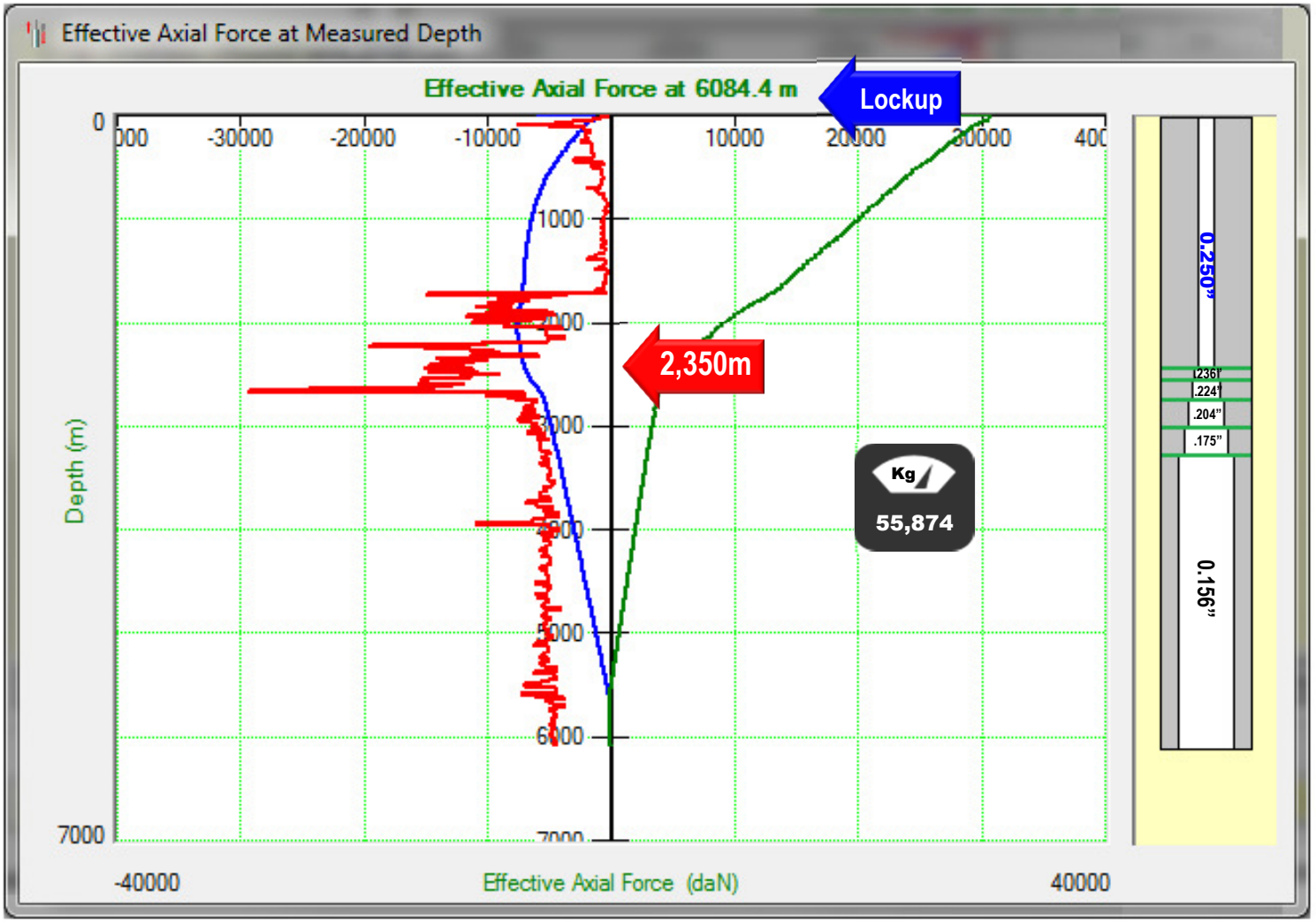
MD 6,245m
TVD 2,352m



Cerberus Suit v11.5.17 for Coiled Tubing

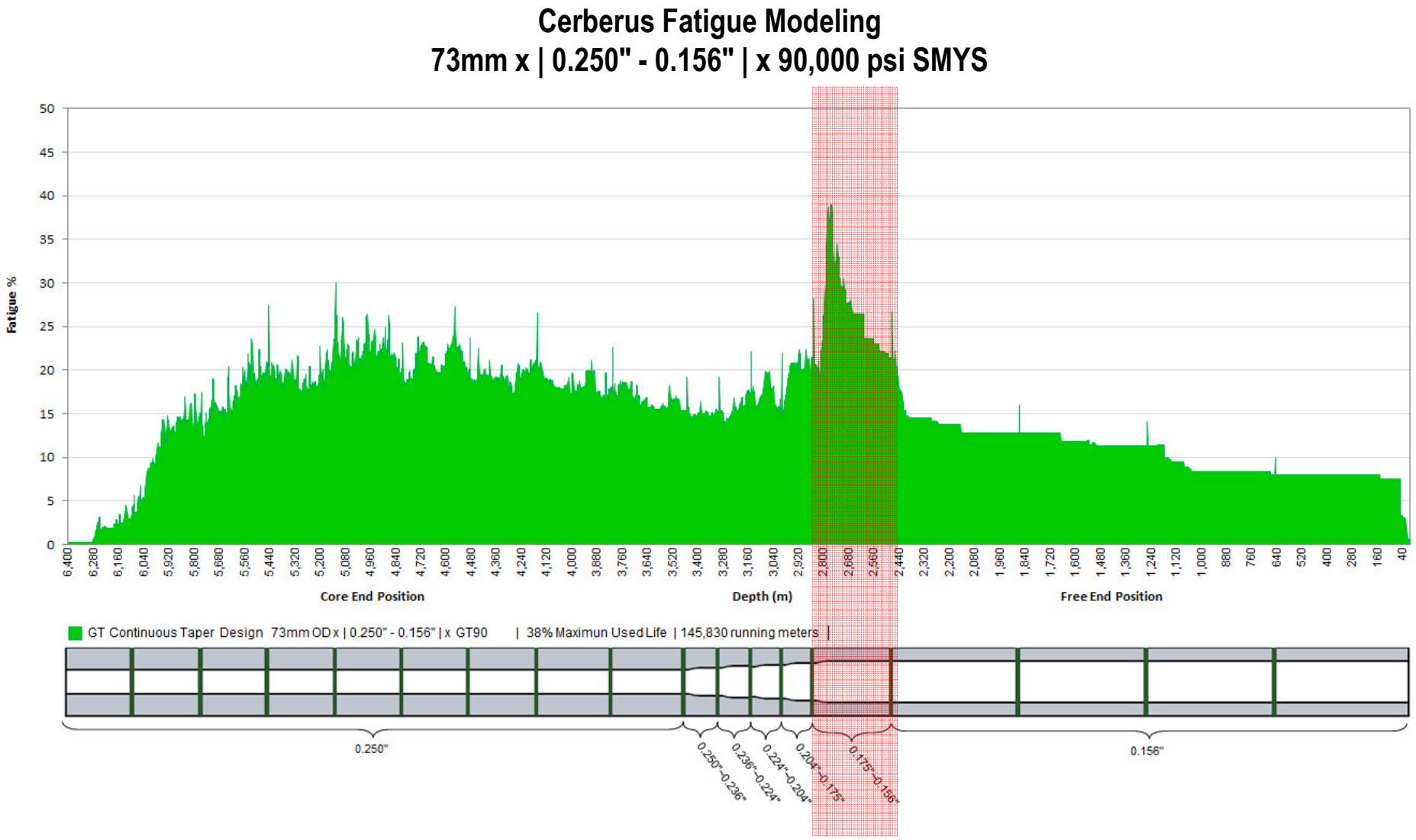
Extended Reach CT Designs - Process

MD 6,245m
TVD 2,352m



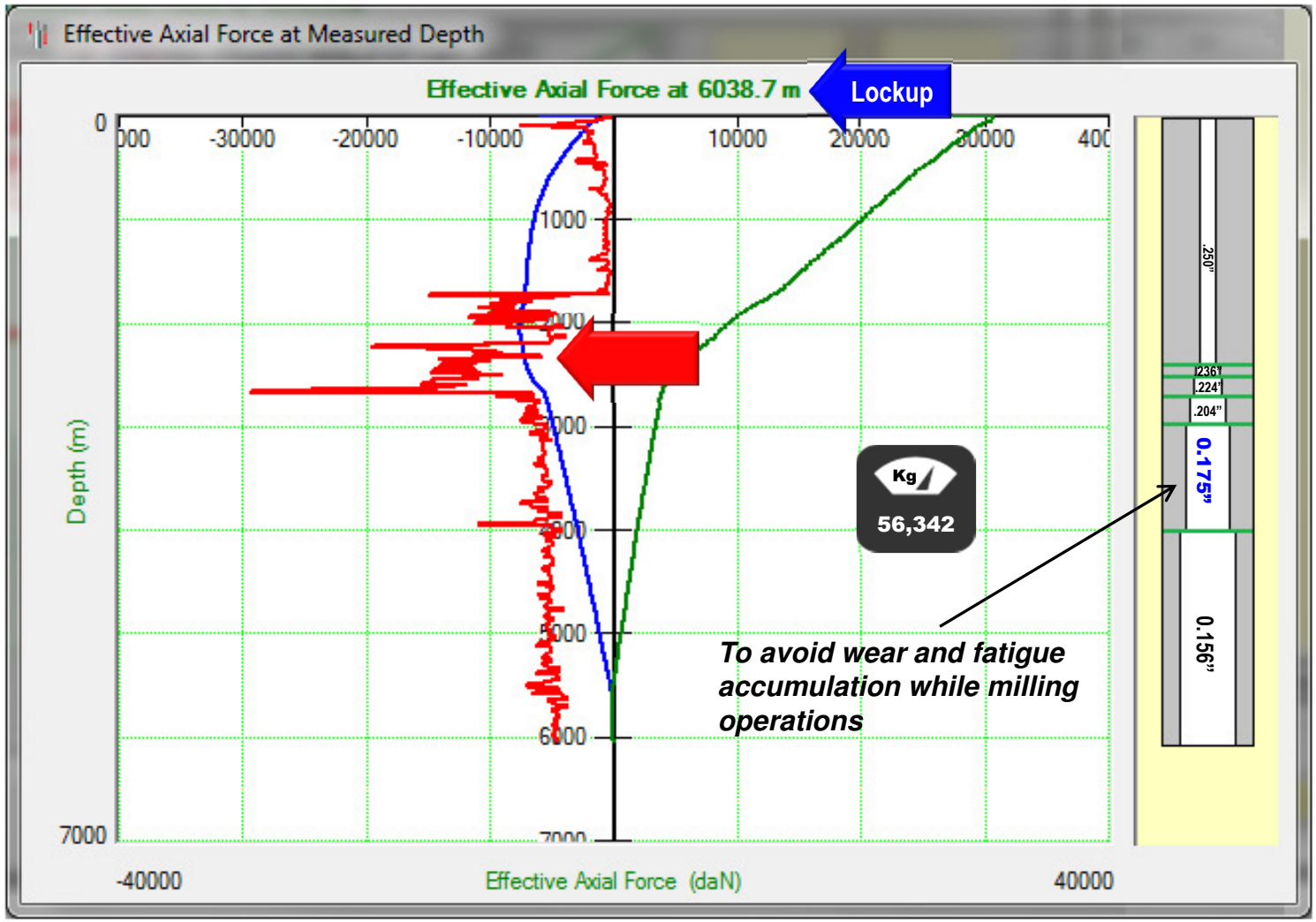
Cerberus Suit v11.5.17 for Coiled Tubing

Extended Reach CT Designs - Process



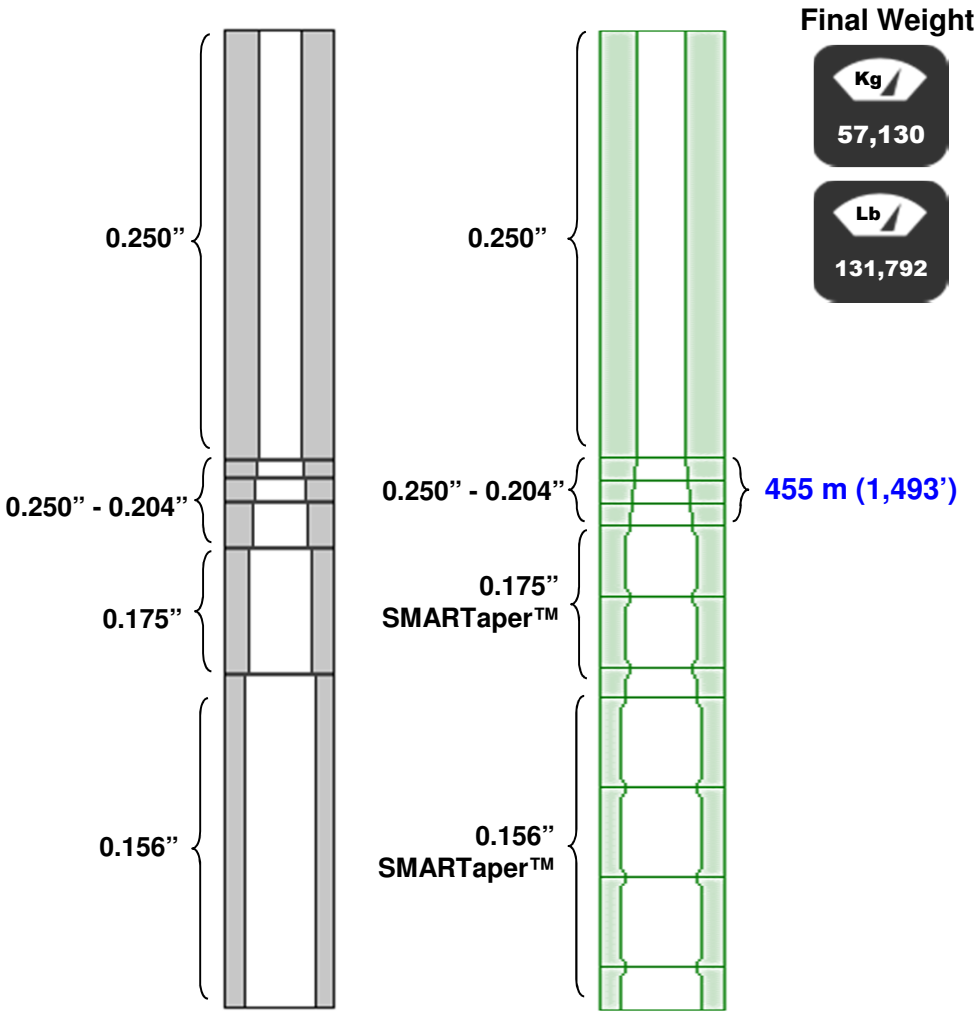
Extended Reach CT Designs - Process

MD 6,245m
TVD 2,352m
KOP ~2,000m



Cerberus Suit v11.5.17 for Coiled Tubing

Extended Reach CT Designs – Example 1



The SMARTaper™ technology was used to **quickly vary the wall thickness** along the length of the string without adding tapered bias welds.

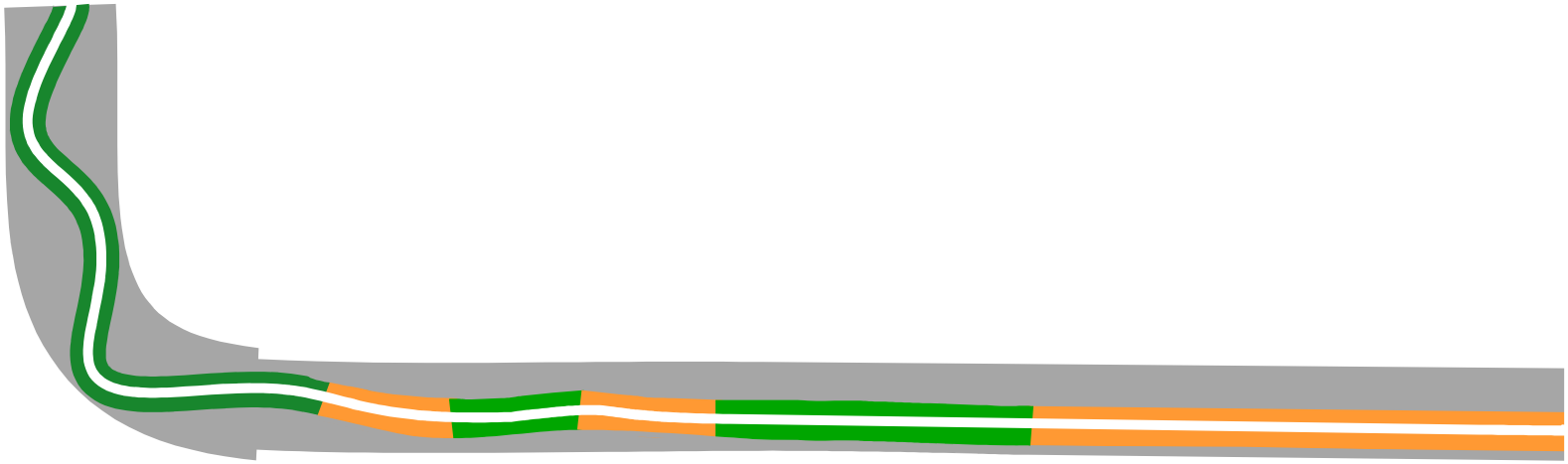
Benefit:

Increase tubing **strength in the bias welds** of the **thinnest sections** to reduce bending fatigue and maximize operational safety at the well-site.

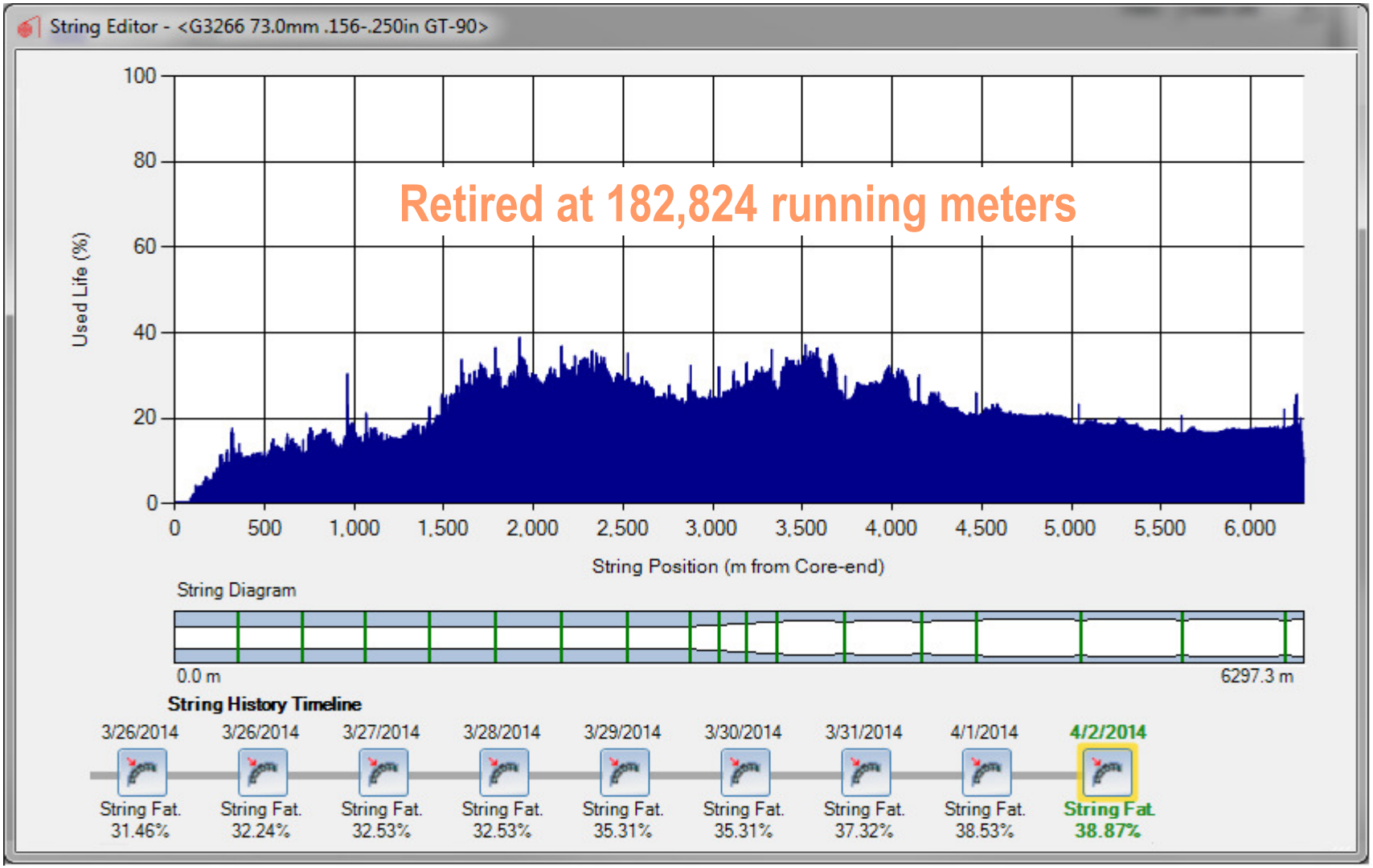
Extended Reach CT Designs – Example 1

Success Results

- Utilizing a custom SMARTaper™ 2-7/8” coiled tubing string, the service company successfully milled up to 18 plugs per well and reached a maximum depth of ~6,275 m (20,587 ft).

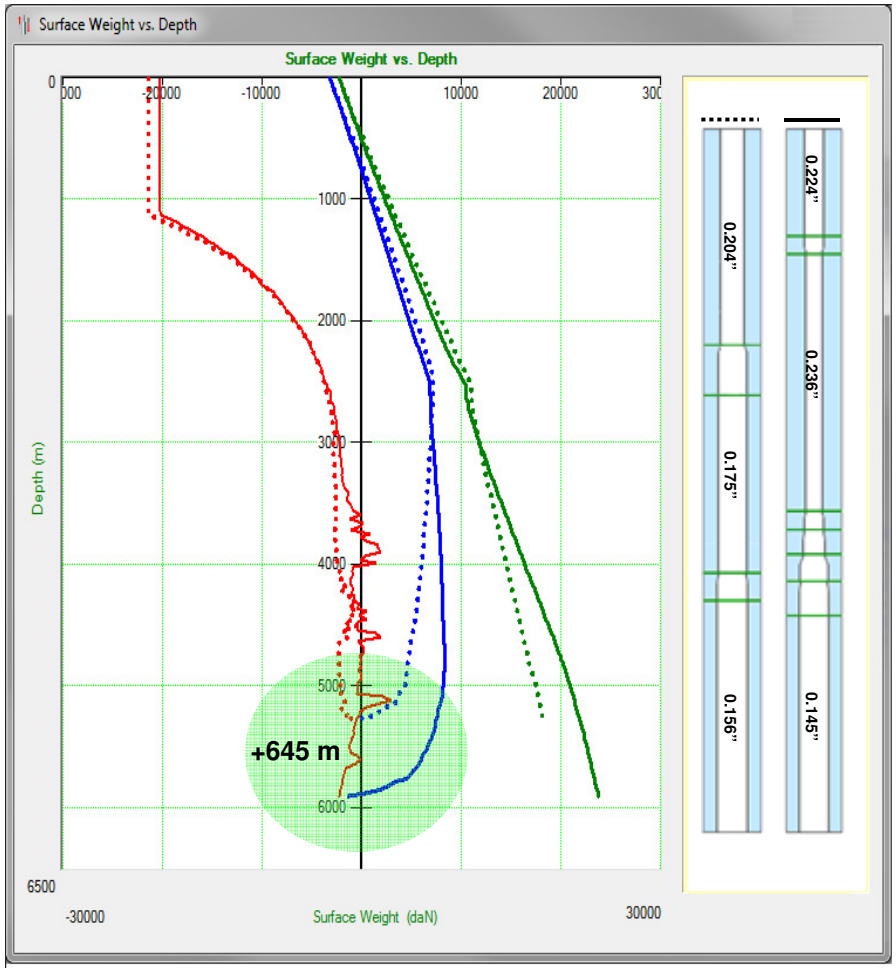


Extended Reach CT Designs – Example 1

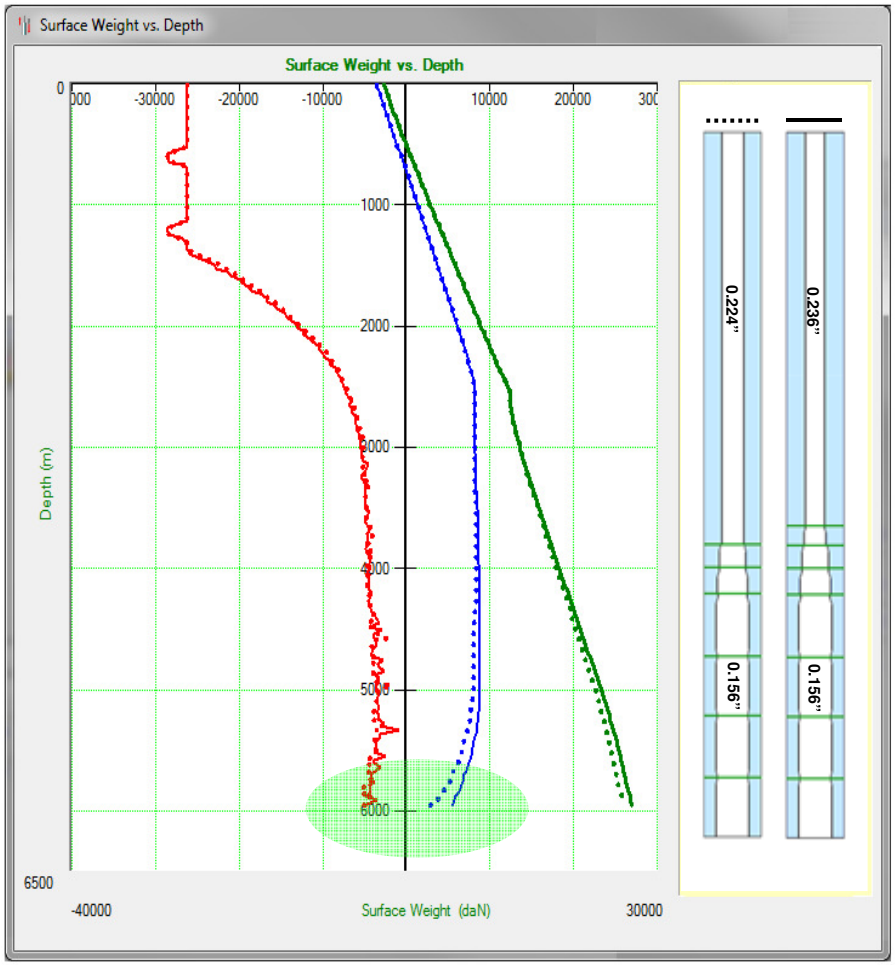


Extended Reach CT Designs – Example 2

2 ⅜” (63.33mm)



2 ⅝” (66.6mm)



Cerberus Suit v11.5.17 for Coiled Tubing

TD: 5,957m **TVD: 2,520**m **Lateral: 3,437**m Min. diameter: 4.778“ (121.36mm) Max. inclination: 93° Max. dogleg: 18.269 °/100ft /30m **FR** 0.25 RIH 0.25 POOH

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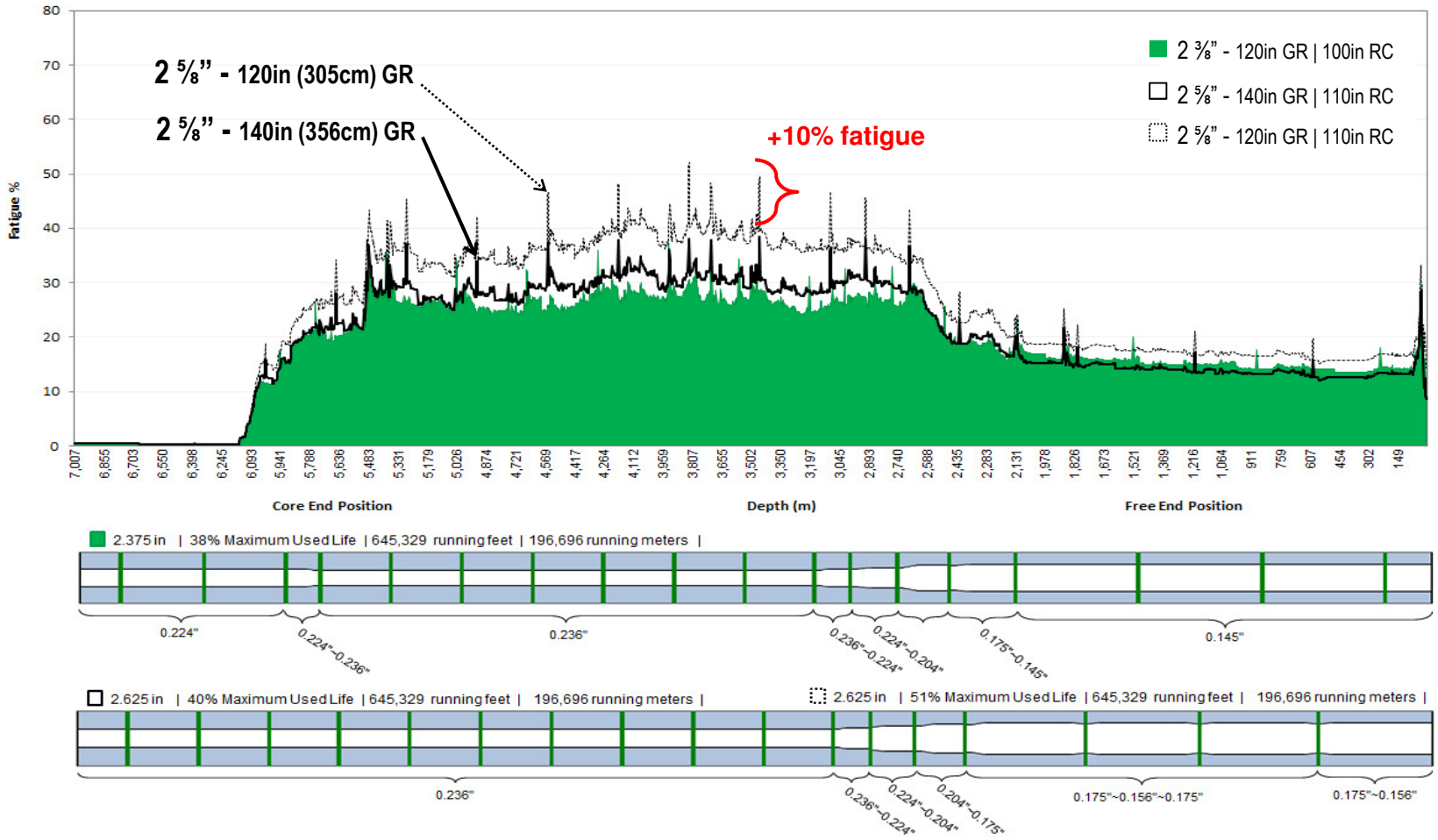
Extended Reach CT Designs – Example 2

Fatigue Comparison

Cerberus® Fatigue Modeling

2 ⅜" vs 2 ⅝



Conclusions

Extended Reach CT designs are an Iterative optimization based on:

- ✓ **The interrelation of the CT use limitations**
- ✓ **Pre-job modeling**
- ✓ **Selection of the optimal wall thickness and transition points**
- ✓ **CT manufacturer capabilities**

Questions?

Thanks to ICoTA Canada for the opportunity to present today.

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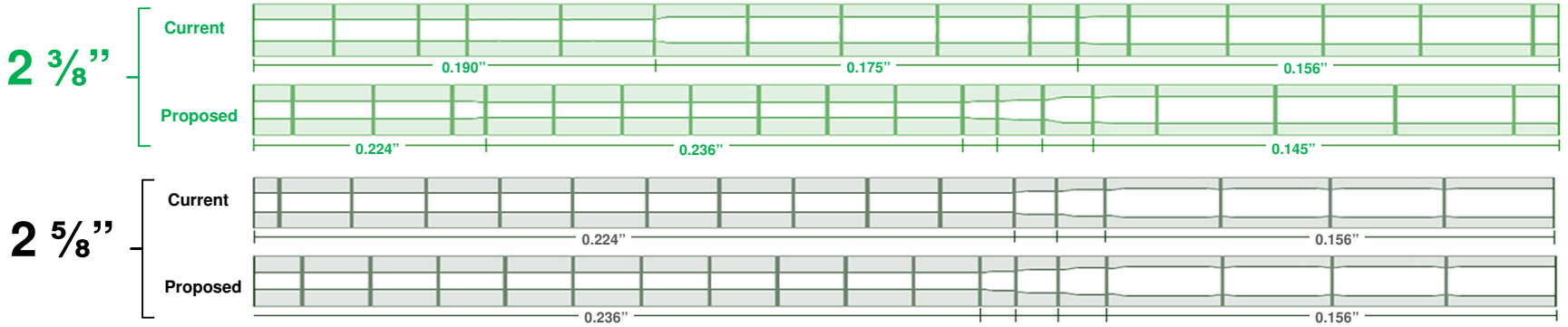
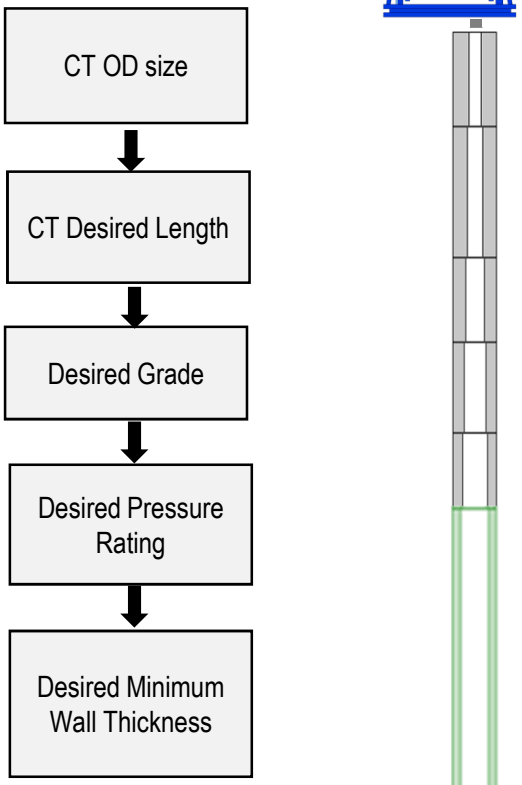
Extended Reach CT Designs – Example 2

Reach Comparison

	2 ⅜" CT		2 ⅝" CT	
	ACTUAL DESIGN | 0.190" ~ 0.156" |	Proposed Design | 0.236" ~ 0.145" |	Option 1 | 0.224" ~ 0.156" |	Option 2 | 0.224" ~ 0.156" |
Nominal Weight	94,743 lbs 42,975 kg	105,982 lbs 48,073 kg	118,694 lbs 53,839 kg	122,318 lbs 55,483 kg
Burst Internal Yield Pressure 80% (Mpa)	75	70	68	68
Collapse Pressure 80% (Mpa)	-32	-28	-26	-26
Maximum Fatigue Life % Aplication Factor 1	46%	38%	46%	40%
Running Meters	196,696	196,696	196,696	196,696
Reach (m)	5,273	5,916	No Lock-Up	No Lock-Up
Weight on Bit (daN)			-249	-469
Maximun Pick up Force (daN) Based on 80% of yield strength	9,554	10,907	12,422	13,109
Pump Pressure (Mpa)	32.3 at 400 L/min	33.5 at 400 L/min	29.6 at 400 L/min	29.8 at 400 L/min
Annular velocity (m/min)	45	45	49	49
Grade	100,000 psi SMYS	100,000 psi SMYS	100,000 psi SMYS	100,000 psi SMYS



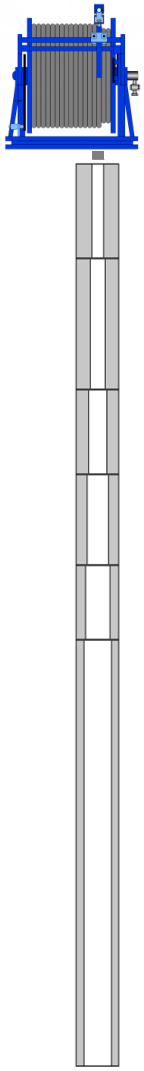
String Design Basic Techniques



- **Consistent Overpull Capacity**
- **Uniform Stress σ_a / σ_y**

Rule:
Design the string to have the minimum overpull towards the upper end.

String Design Basic Techniques - Examples



2⅜” x |0.134”-0.204”| x 18,000 ft (~5,500m)

Uniform Stress σ_a / σ_y

σy	O.D.	Top Wall Nominal	Length	Section Weight	Cummulative Weight	Yield Load at 100%	Overpull at 100%	Overpull at 80%	σa/ σy
psi	in	in	ft	lb	lb	lb	lb	lb	%
90,000	2.375	0.134	13,100	42,120	42,120	84,910	42,790	25,808	50%
90,000	2.375	0.145	900	3,120	45,240	91,430	46,190	27,904	50%
90,000	2.375	0.156	900	3,340	48,580	97,880	49,300	29,724	50%
90,000	2.375	0.175	1,300	5,360	53,940	108,860	54,920	33,148	50%
90,000	2.375	0.19	1,000	4,440	58,380	117,380	59,000	35,524	50%
90,000	2.375	0.204	800	3,790	62,170	125,220	63,050	38,006	50%

Consistent Overpull Capacity

σy	O.D.	Top Wall Nominal	Length	Section Weight	Cummulative Weight	Yield Load at 100%	Overpull at 100%	Overpull at 80%	σa/ σy
psi	in	in	ft	lb	lb	lb	lb	lb	%
90,000	2.375	0.134	8,100	26,040	26,040	84,910	58,870	41,888	31%
90,000	2.375	0.145	1,900	6,580	32,620	91,430	58,810	40,524	36%
90,000	2.375	0.156	1,700	6,300	38,920	97,880	58,960	39,384	40%
90,000	2.375	0.175	2,700	11,130	50,050	108,860	58,810	37,038	46%
90,000	2.375	0.19	1,900	8,450	58,500	117,380	58,880	35,404	50%
90,000	2.375	0.204	1,700	8,060	66,560	125,220	58,660	33,616	53%