Casing Design Optimization in the Acordionero and Costayaco Fields in Colombia

Autor(es): W. Suek, C. Cogollo, D. Torres, J. Diago; Gran Tierra Energy C. Espinosa, C. Romero; Tenaris

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Abstract

Due to high torque requirements while installing the 7" production casing in Acordionero and Costayaco fields different connections and casing specifications have been tested, in some cases leading to overshooting specifications. The scope of this work is to present the evolution of the casing design to obtain the optimized specifications for the injector and production wells in these two fields.

With more demanding well trajectories and deeper wells, the operative torques tended to increase while installing the 7" production casing in Acordionero and Costayaco fields. Therefore, premium connections were used in some cases and in others a higher pipe specification with an API type connection to obtain higher operating torques, increasing the well´s cost. To optimize the casing specification two processes took place. The first one, was the design of a semi-premium connection that offered the operating torque required and the second one was the casing design considering proprietary grades that complied with the load cases, considering wall thickness reduction due to corrosion.

The casing manufacturer designed a 7" semi premium connection that offered a high operating torque regardless of the weight or the grade of the pipe, enabling the optimization of the casing specification. Besides the higher toque offered by the connection, the casing installation was 2 hours faster for a 9,000 ft string due to its design with a deeper stabbing and less threads per inch than an API Buttress type connection.

To optimize the 7" casing specification an engineering analysis was performed considering the well type (producer or injector), the corrosion rate in each case and the load cases that the casing will be submitted to. The resulting specification for the wells in Acordionero field was a standardized mix string with 7,000 ft of 7" 23 ppf P110 Improved Collapse and Yield (ICY) and 2,000 ft of 7" 26 ppf P110 ICY. This combination could be further optimized by using only a 7" 26# P110 in the last 2,000 ft in the producer wells, but logistically is preferable to have a standardized design. On the other hand, in Costayaco field the optimized specification was a 7" 26 ppf P110 ICY casing.

Since 2020 more than 15 wells wave been drilled in these fields with the new specifications, reaching operating torques up to 40,000 lb-ft during installation and cementing operations, saving more than $200,000 USD.

The use of a high torque semi-premium connection enabled the possibility to optimize the casing design, generating savings in the casing cost and in rig time.

Acordionero and Costayaco Fields

Gran Tierra Energy is developing the Acordionero and Costayaco Fields drilling multiple well pads. This strategy significantly reduces the surface footprint of the operations while maximizing the contact with the reservoirs and recovery.

However, this decision at the same time brings challenges for well construction. To reach the objectives from the same location traduces in challenging trajectories with ever increasing lateral displacement.

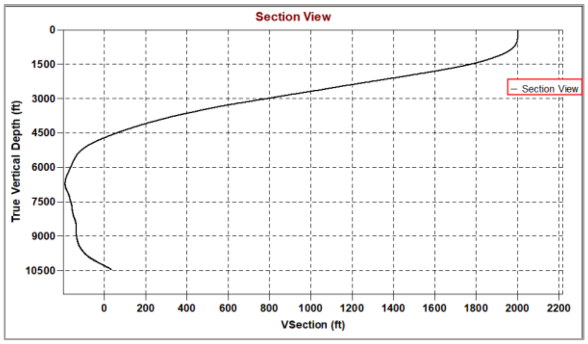


Figure 1.Section View Ac31i

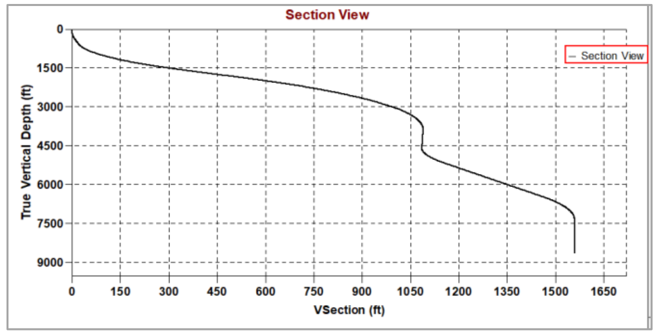


Figure 2.Section View CYC 25D

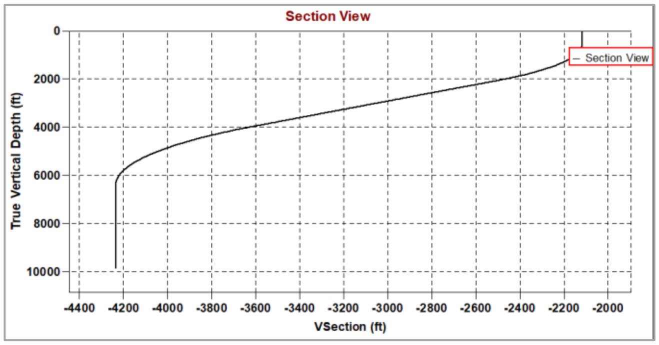


Figure 3. Section View Ac 58

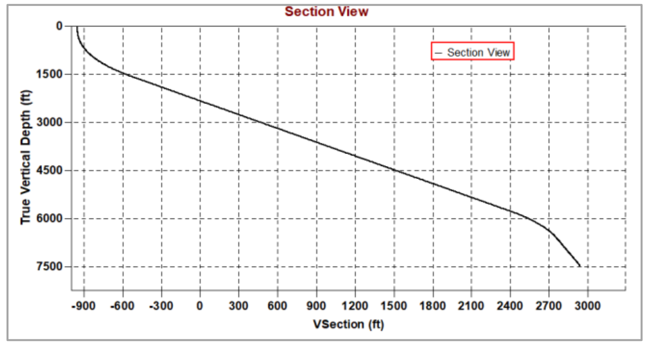


Figure 4. Section View Ac 93i

The Torque Challenge

The highly deviated trajectories resulted in even-increasing torques for casing connections while rotating and cementing. The following chart shows the evolution of torque in a casing string during running with rotation and during cementing.

Figure 5. Torque vs depth while running the casing

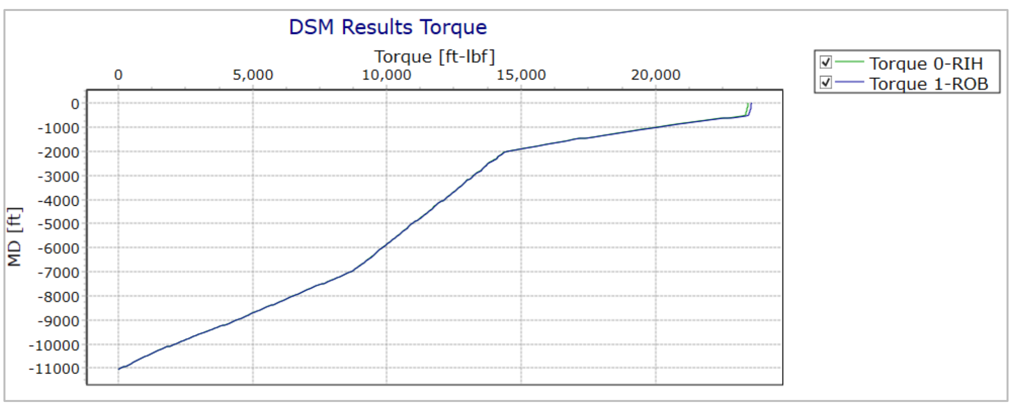
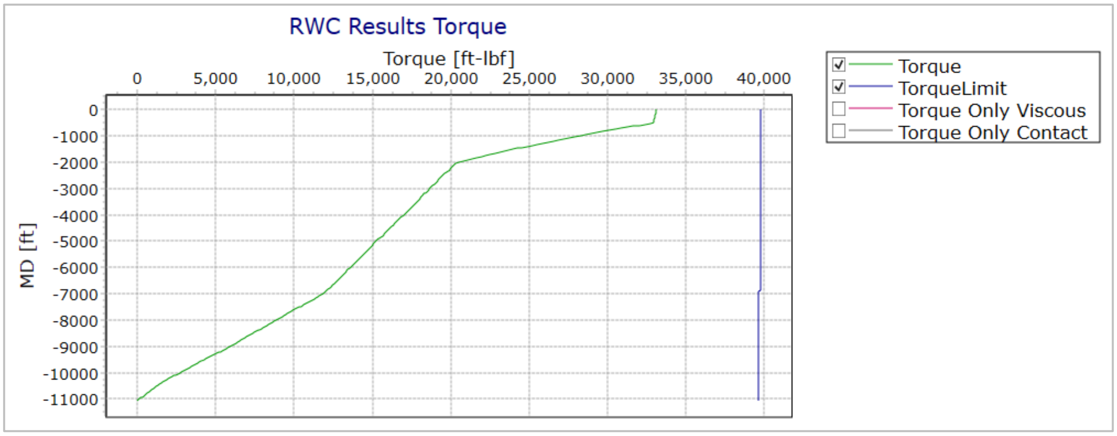


Figure 6.Torque vs depth while cementing the casing



The operative torque in shouldered connections is limited to the contact area of the torque shoulder and the yield strength of the steel. The following image shows the torque shoulder of a shouldered connection and the area in contact during torque transmission. In this order of ideas, reducing the linear weight of the casing, would have resulted in a derating of the operative torque offered by the connection.

Figure 7: Shouldered connection

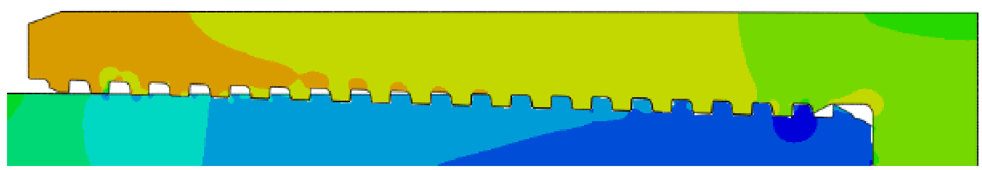


Figure 8: Stresses in a shouldered connection - Applying Torque

As a result, the casing design of the Acordionero and Costayaco fields consisted of the following strings for the casing design:

Table 1: Original Casing Strings - Acordionero and Costayaco Fields

Acordionero	Costayaco
7 26# P110 TXP BTC	7 29# P110 TXP BTC

Wedge Type Casing Connection

The casing manufacturer developed a different concept for high torque connections based in the Wedge concept developed in the 80s. The concept focuses in a continuously variable thread that works as an elliptical wedge. Additionally, with the proper design of the tolerances, the connection allows a pin-pin contact that adds a “torque shoulder” to further increase torque capabilities of the connection.

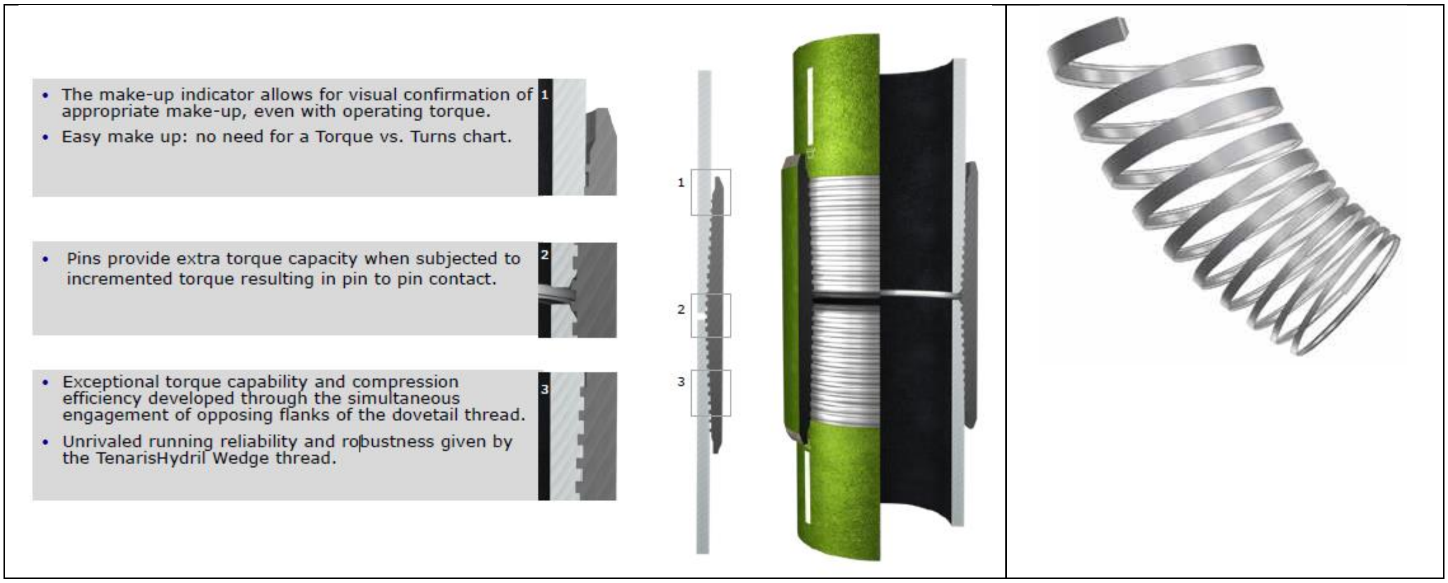


Figure 9: WEDGE 461 design concept

Even though the concept was very promising it required full scale testing to validate the results. Those tests allowed the release of the connection design for 7”. The following table lists the testing applied to the 7” connection.

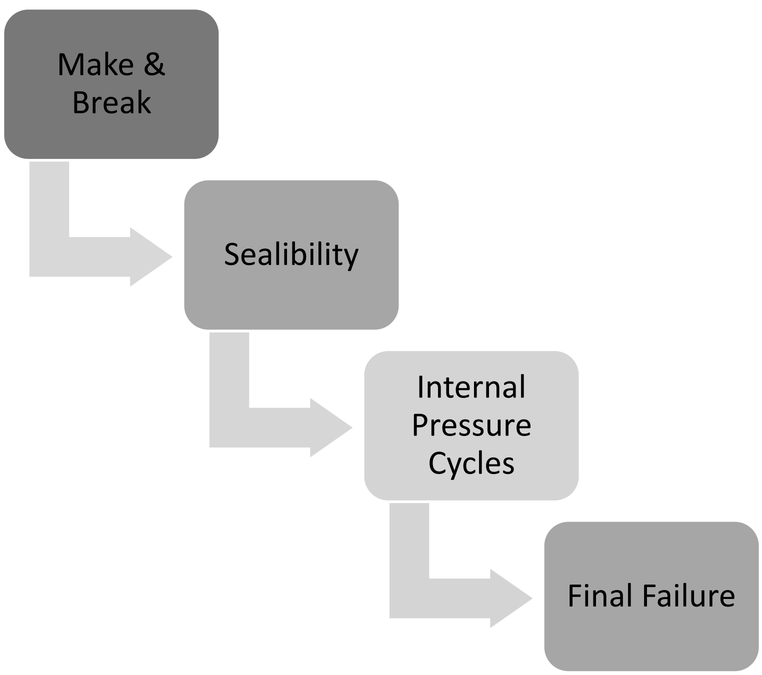


Figure 10: Testing for WEDGE 461

Originally, this connection allowed installing casing in more demanding trajectories. However, the authors soon realized that this concept of connection separates the torque capabilities from the weight and wall thickness, and therefore there was room for further optimization. See how little the operative torque changes for different grades and wall thickness in the following picture.

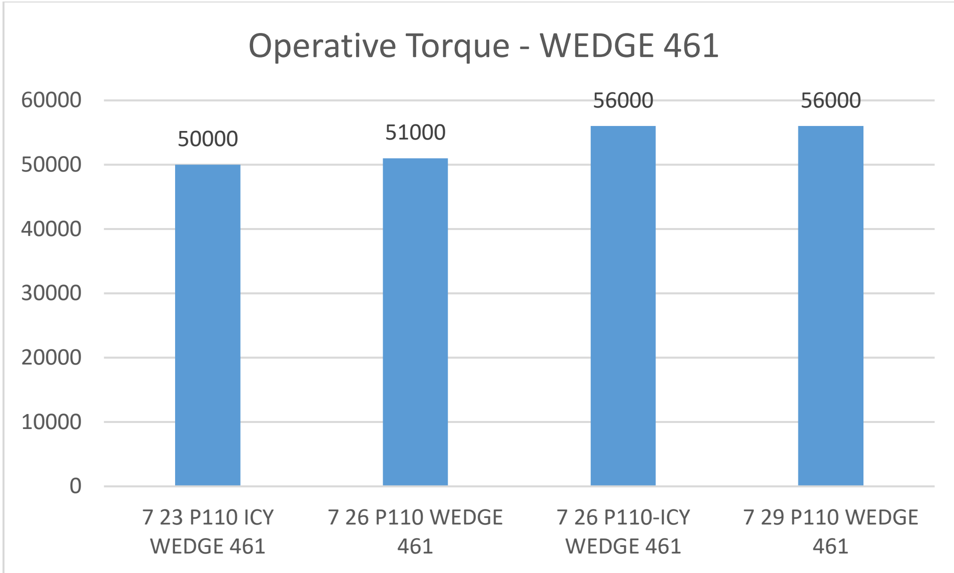


Figure 11: Operative Torque WEDGE 461

Design Optimization

Every casing design shall consider a set of loads and compare them to the resistance of the pipe. The relation between resistance and load is the design factor and should be above 1 to have a safe design.

The wells at the Acordionero and Costayaco fields include producer and injectors wells. The following loads were considered for the 7" production casing section.

Table 2: Load Cases Injector Wells

String	Load case	Loading mode	Internal Pressure Profile	External Pressure Profile	Temperature Profile
Injector Wells Production Casing	Installed load	Base case	Running mud weight (10 ppg)	MW (10 ppg) to TOC and cement slurry density	Static (as cemented)
	Full evacuation-static	Collapse	Null	Drilling MW (10 ppg) of this section	Static
	Injecting through casing	Burst	Well head injection pressure (5,000 psi) over injection fluid (8.4 ppg)	Pore pressure	Static

Table 3: Load Cases - Producer Well

String	Load case	Loading mode	Internal Pressure Profile	External Pressure Profile	Temperature Profile
Producer Wells Production Casing	Installed load	Base case	Running mud weight (9.3 ppg)	MW (10/11 ppg) to TOC and cement slurry density	Static (as cemented)
	Full evacuation-static	Collapse	Null	Drilling MW (10/11 ppg) of this section	Static
	Partial evacuation-static	Collapse	Null to 7,800 ft and production fluid (7.5 ppg) to TD	Drilling MW (10/11 ppg) of this section	Static

Then, using casing design software the design factors were calculated for each well type with the current casing design.

Table 4: Acordionero initial design factors

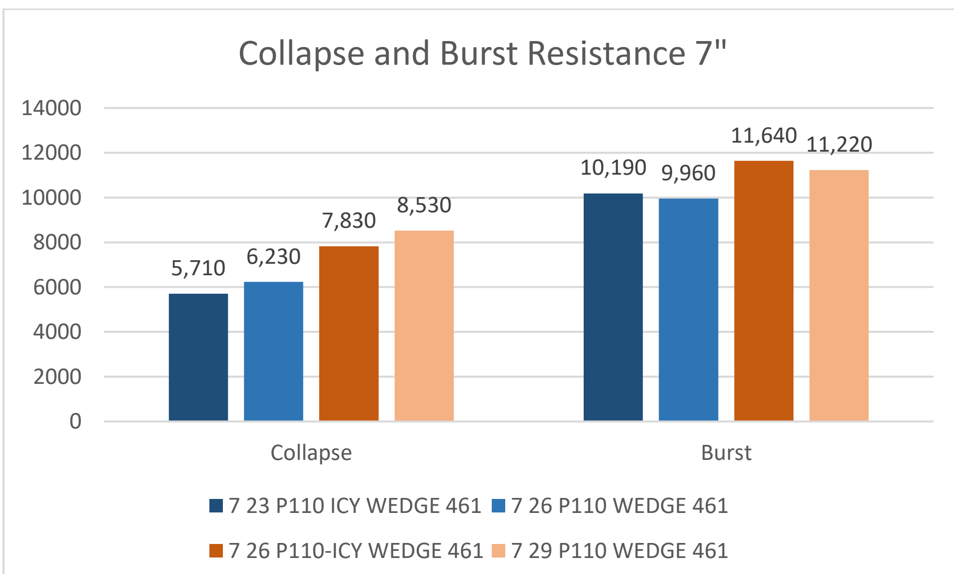
Acordionero	Burst	Collapse	Tension	VME
7 26 P110 TXP BTC	1.98	1.04	2.13	2.00

Table 5: Costayaco initial design factors

Costayaco	Burst	Collapse	Tension	VME
7 29 P110 TXP BTC	2.48	1.41	2.66	2.22

As seen in tables above, the calculated design factors were above the minimum design factors. This presented the opportunity to optimize design in two ways:

- Minimizing the wall thickness according to static design. Eliminate the need to use higher grades and wall thickness to comply with required torque.
- Replace standard casing grades with Improved Collapse and Yield Grades. The casing manufacturer developed special steel grades that increase the collapse and burst resistance compared to standard grades. The following chart shows the collapse and burst resistance of different wall thickness for 7" casing.



To take one key alternative, the 7 23 P110 ICY vs 7 26 P110 has 13% reduction in wall thickness (and weight). However, burst increases 3%, while collapse only reduces 9%. The total steel weight influences heavily the cost, therefore reducing it will report savings while using special grades allows the engineer to comply with the design factors.

Effect Of Corrosion

Gran Tierra Energy has conducted studies to evaluate the reduction of wall thickness of pipe from corrosion and erosion in producers and injectors. At least at this moment, the wall thickness reduction in casing is uniform with fixed corrosion rates of 1.7 MPY.

The static design was adapted to compensate the corrosion rate. The challenge was to reflect that corrosion rate effect in the collapse resistance of ICY grades. The product engineering from the casing manufacturer evaluated the derating of collapse resistance for different uniform wall thickness reduction.

Table 6: Collapse resistance reduction due to wall thickness reduction

Year	Accumulated Wall Thickness Loss (%)	Collapse Load (psi)	Collapse Resistance (psi)	Design Factor
0	0	0	7,830	
1	0.47%	5,954	7,612	1.27
24	11.28%	3,414	5,330	1.56
35	16.45%	3,414	4,270	1.25
47	22.09%	3,414	3,414	1.00

The design considered the reduction of wall thickness in the process of selecting the casing.

Final Casing Design

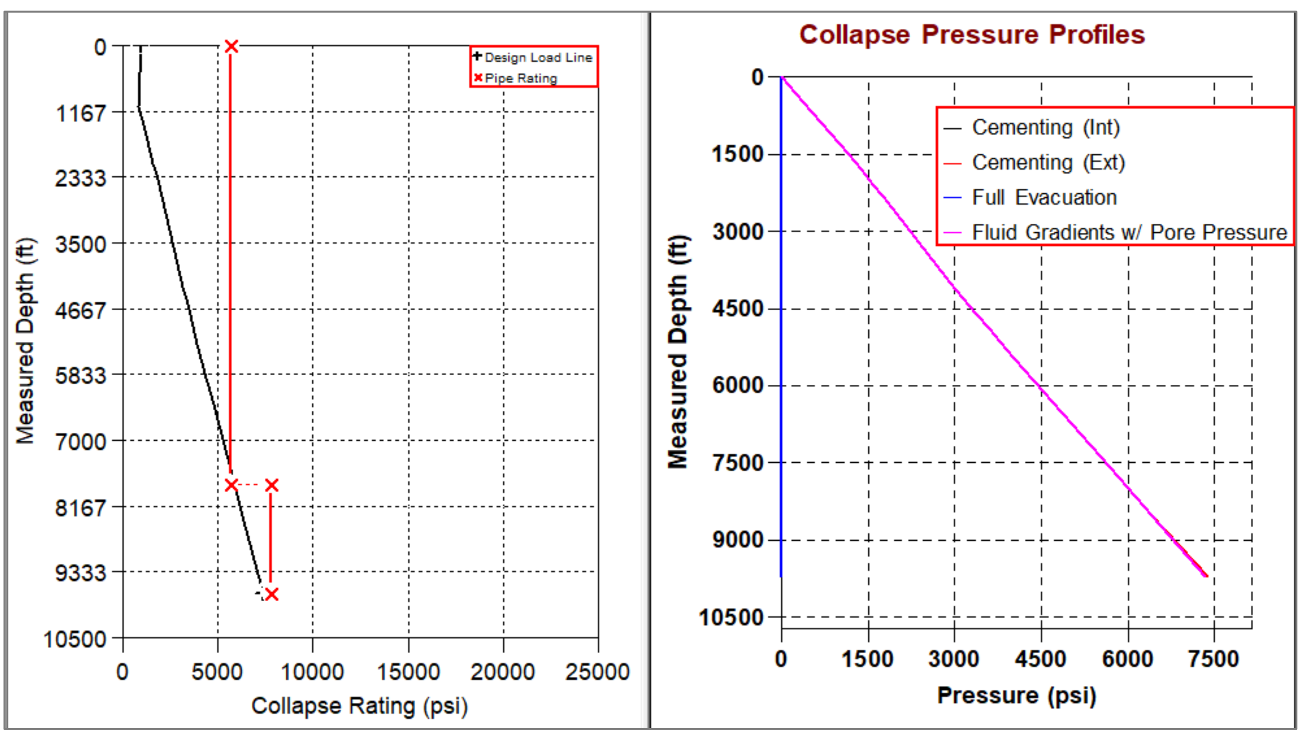
Acordionero

After considering, the loads mentioned previously and corrosion rates for the field the casing design resulted in:

Table 7: Acordionero Final Design

Specification	Depth (ft)
7 23 ppf P110 ICY WEDGE 461	0 – 7,000
7 26 ppf P110 ICY WEDGE 461	7,000 – 9,726

In this case, more than 7,000 ft or 23 ppf casing could have been considered leading allowing more savings per well, however limited completion tool availability results in having to use 7” 26 ppf or higher weight casing across the producing zones.



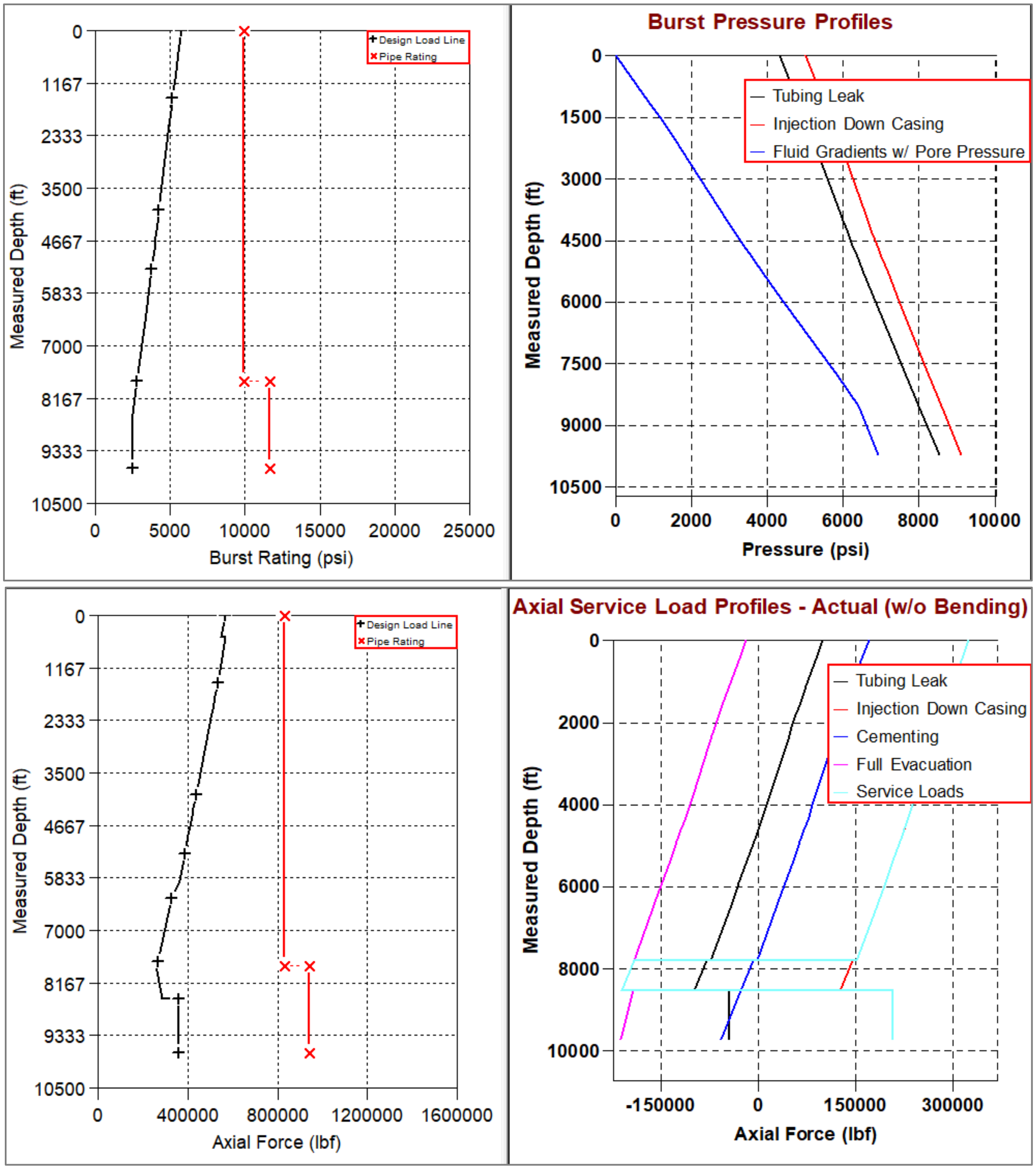


Figure 12: Acordionero Final Design Charts

The resulting design factors were:

Table 8: Acordionero Final Design Factors

Minimum Design Factors				
Burst	Collapse	Axial	Triaxial	Specification
1.97 B6	1.33 C5	4.11 C2	2.41 B6	7" 23 ppf P110-ICY TSH WEDGE 461
2.76 B6	1.33 C5	(8.97) B6	2.74 C1	7" 26 ppf P110-ICY TSH WEDGE 461

B6	Tubing Leak
C1	Full/Partial Evacuation
C2	Cementing
C5	Full Evacuation Production
( )	Compression

The final validation of the design required the Torque & Drag analysis:

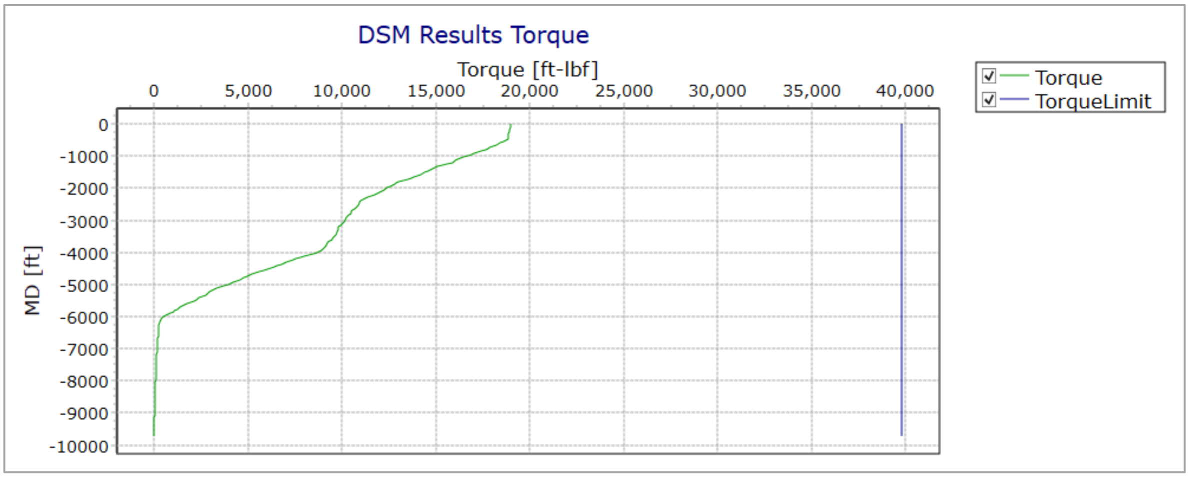


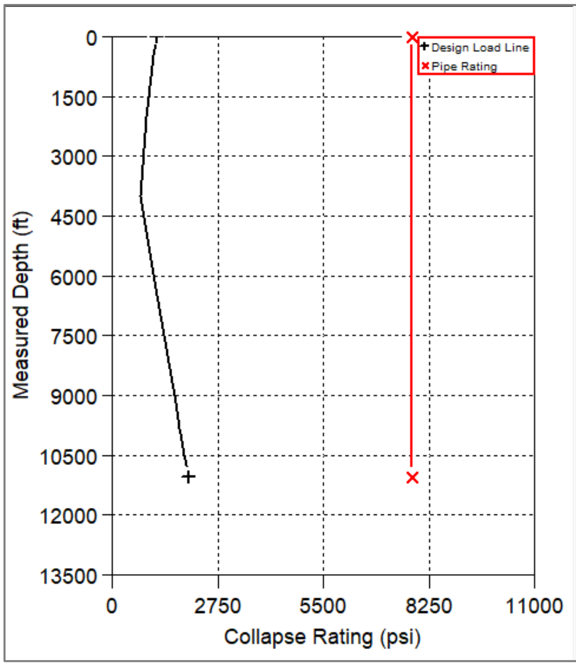
Figure 13: Acordionero Final T&D

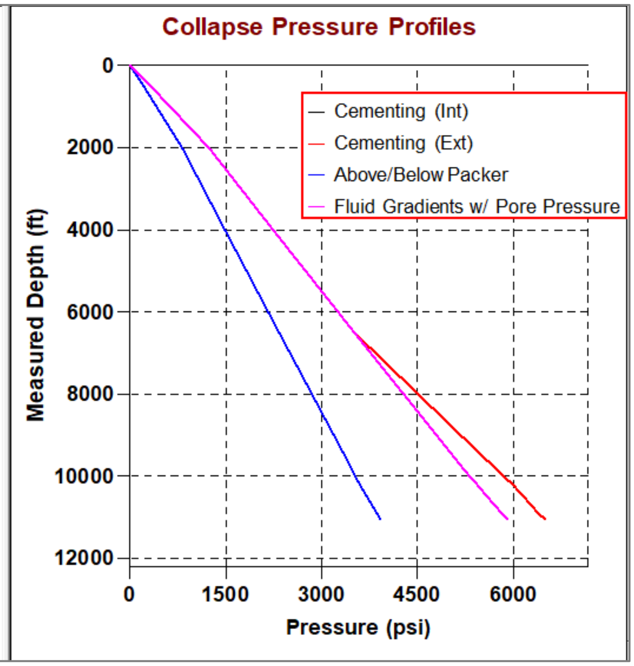
Costayaco

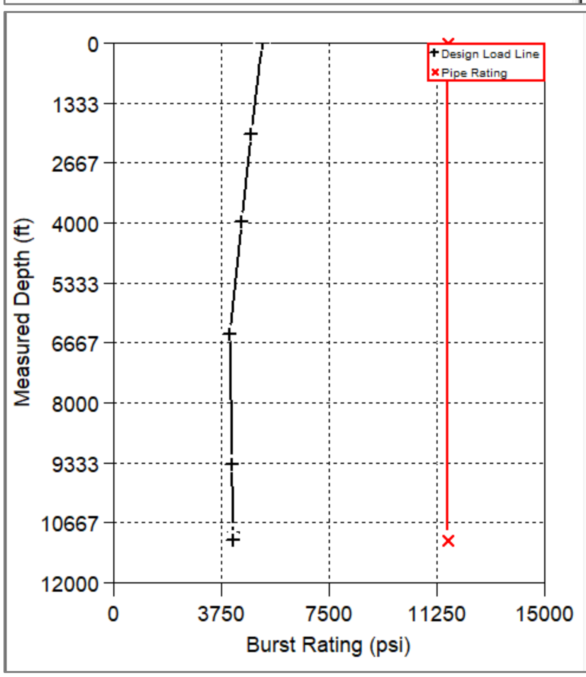
As for Acordionero, the authors validated and optimized casing design for the Costayaco wells.

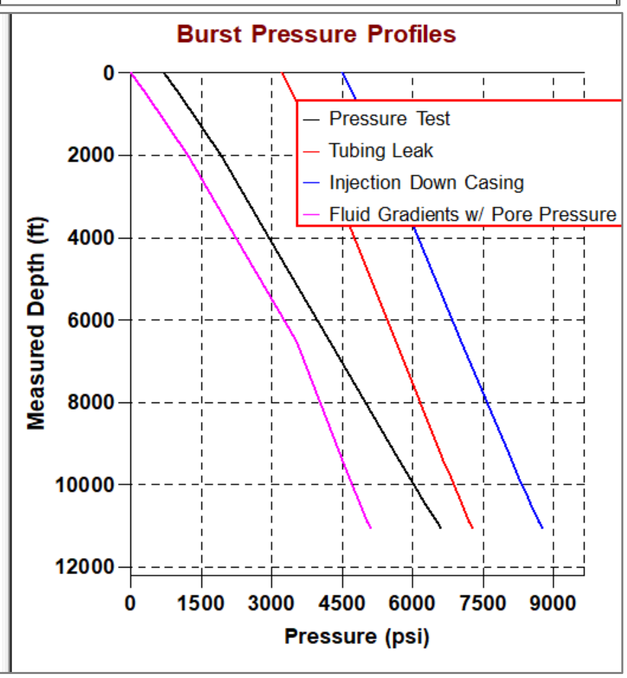
Table 9: Costayaco Final Design

Specification	Depth (ft)
7 26 ppf P110 ICY WEDGE 461	0 - 11071


Design Load Line
Pipe Rating
Measured Depth (ft)
0
1500
3000
4500
6000
7500
9000
10500
12000
13500
0
2750
5500
8250
11000
Collapse Rating (psi)


Collapse Pressure Profiles
Cementing (Int)
Cementing (Ext)
Above/Below Packer
Fluid Gradients w/ Pore Pressure
Measured Depth (ft)
0
2000
4000
6000
8000
10000
12000
0
1500
3000
4500
6000
Pressure (psi)


Design Load Line
Pipe Rating
Measured Depth (ft)
0
1333
2667
4000
5333
6667
8000
9333
10667
12000
0
3750
7500
11250
15000
Burst Rating (psi)


Burst Pressure Profiles
Pressure Test
Tubing Leak
Injection Down Casing
Fluid Gradients w/ Pore Pressure
Measured Depth (ft)
0
2000
4000
6000
8000
10000
12000
0
1500
3000
4500
6000
7500
9000
Pressure (psi)

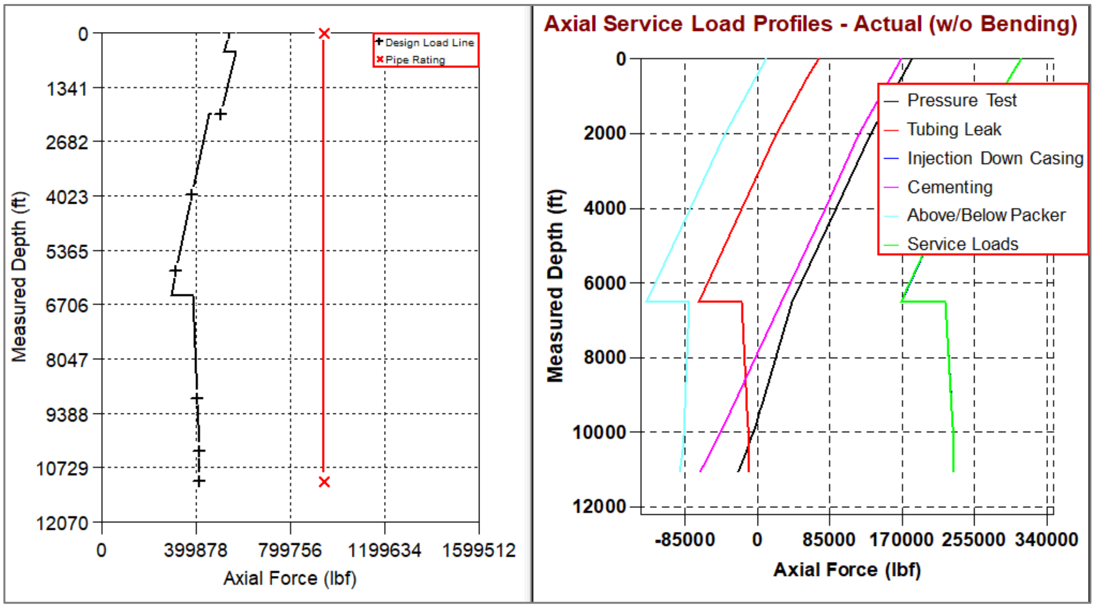


Figure 14: Costayaco Final Design Charts

Obtaining the following design factors (Table 10):

Table 10: Costayaco Final Design Factors

Minimum Design Factors				
Burst	Collapse	Axial	Triaxial	Specification
2.26 B8	1.31 C5	2.93 B8	2.51 B8	7" 26 ppf P110-ICY TSH WEDGE 461

B6 Tubing Leak
C1 Full/Partial Evacuation
C2 Cementing
C5 Full Evacuation Production
( ) Compression

The final validation of Torque and Drag for running and rotating while cement show a healthy 1.64 design factor for torque.

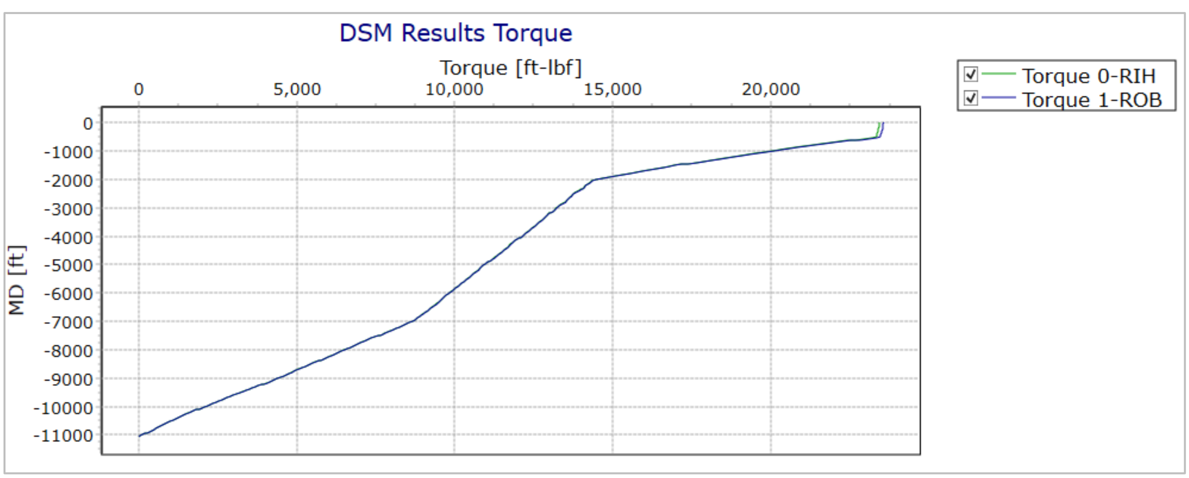


Figure 15: Costayaco Final T&D - Running in Hole

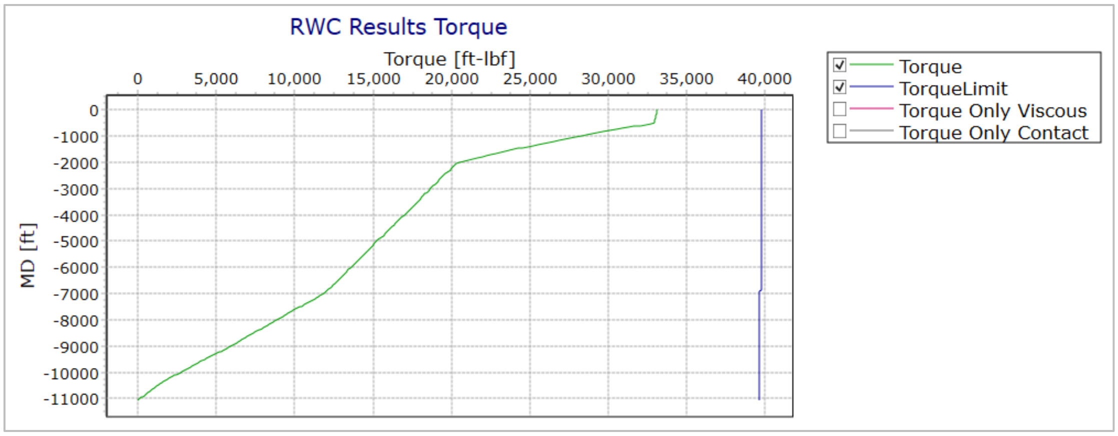


Figure 16: Costayaco Final T&D - Rotating while Cement

Additional Benefits

Improved Running Speed

TSH WEDGE 461 connection has two advantages compared to BTC compatible connections:

- Lower thread per inch (TPI), requires less turns to reach final position.
- Deeper stabbing, the make-up starts earlier. See picture below.

Figure 17: Stabbing TXP BTC

Figure 18 Stabbing WEDGE 461

Typically, TSH WEDGE 461 connection runs 20% faster than BTC type connections. For 9000/10000 ft wells constructed by Gran Tierra Energy, this faster speed reduces 2 hours of casing running time. The following figure shows the compared running speed for several wells.

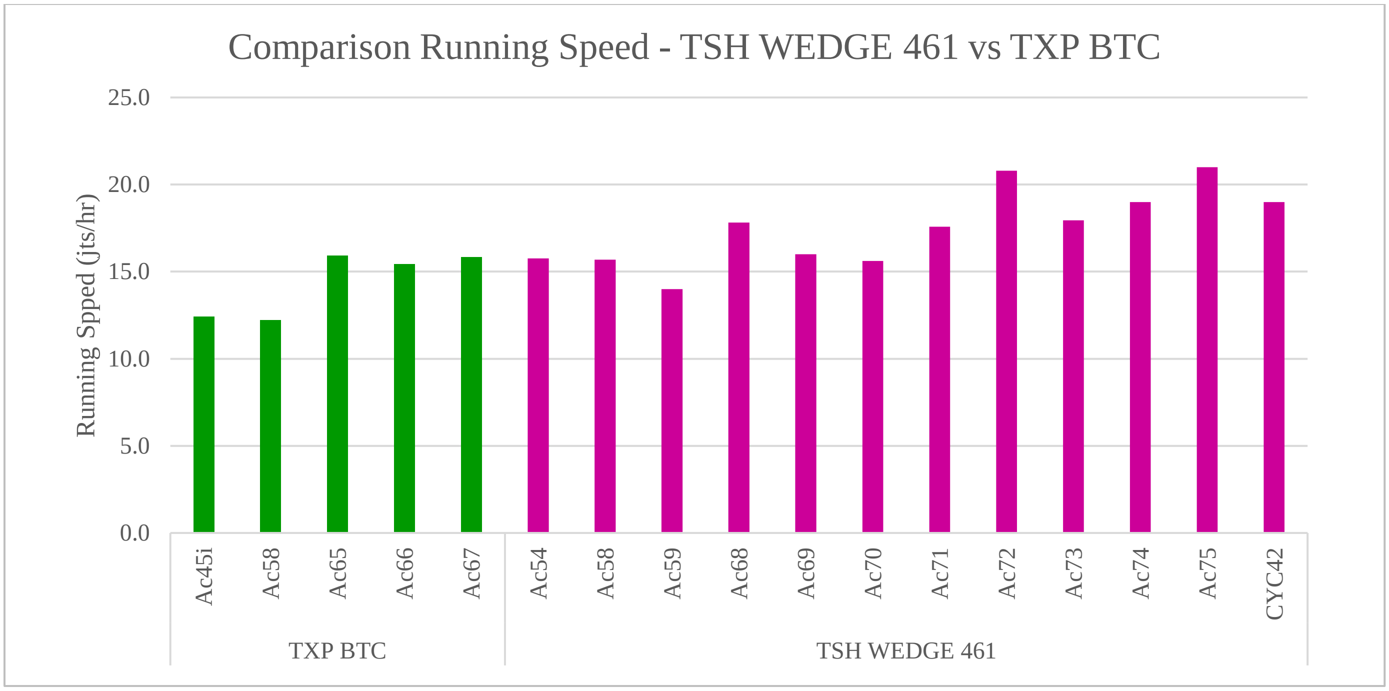


Figure 19: Running Speed Comparison

These results are consistent with the use of this connection in shale wells in US and highly deviated wells in Colombia (Romero & Alvarez, 2020).

Standardization

The use of two specifications for both fields gave Gran Tierra Energy better flexibility to drilling plan.

Conclusions

Casing design for deviated wells shall consider static loads, torque requirements and the effects of corrosion rates.

The use of high torque wedge type connections allows the design engineer to separate static loads from torque requirements.

The use of Improved Collapse and Yield steel grades allows the design engineer to reduce total steel weight while maintaining safe design factors. This action results in direct cost reduction.

Gran Tierra Energy applied the concepts mentioned above in more than 15 wells in Acordionero and Costayaco fields and changed the design standard for those fields. The results saved more than 200,00 USD while improving the design factors for static design and torque during rotation.

References

Romero, C., & Alvarez, J. (2020). Optimization of Casing Design for Wells Drilled in Llanos Region in Colombia. A Technical Analysis of the Problematic and the AdoptedSolutions. *SPE Latin American and Caribbean Petroleum Engineering Conference.* Bogota: SPE.