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A Comprehensive Evaluation of Drill Pipe Insulation for Downhole Temperature Management Using Physics-Based Models

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ABSTRACT

High bottom-hole temperature is a leading cause of downhole tool failure in geothermal wells, with the potential to significantly increase well construction costs. While investment is being made in the development of high-temperature tools, an alternative solution is presented by drill pipe insulation, which can help manage downhole temperatures effectively. This would allow continued use of existing tools developed primarily for the oil and gas industry. Various approaches to insulating drill pipes exist, each with its own advantages and drawbacks. This paper systematically reviews these approaches and evaluates their effects on drillstring hydraulics and dynamics using high-fidelity physics-based models, providing guidance on selecting the most appropriate insulation method for well construction.

The insulation methods analyzed in this study include: (i) internally coated or lined drill pipes, (ii) drill pipes with external coatings, and (iii) dual-wall drill pipes with vacuum or insulating material between the walls. The study examines how these insulation methods impact temperature control and fluid behavior within geothermal wells, considering both full and partial insulation coverage. Two well configurations are considered: a deep (~8.5 km TVD) vertical well and a horizontal well of the same TVD but also having a 2 km lateral section.

A comprehensive thermo-hydraulic model is used to analyze heat transfer between the drilling fluid and the surrounding rock formation, and the hydraulic implications of using insulated drill pipe, which typically have a smaller internal diameter or larger outer diameter when compared to conventional pipes. The insulation leads to higher pressure drops at equivalent flow rates. Additionally, the study explores the effects of insulated pipes on drillstring dynamics using a multi-degree-of-freedom lumped parameter model.

This analysis aims to provide quantitative insights into the trade-offs of various drill pipe insulation methods, offering practical recommendations for their future application in geothermal well construction.

1. INTRODUCTION

Geothermal wells are generally divided into 3 categories based on their temperature: low-temperature wells, which operate at less than 150°C; medium-temperature wells, with temperatures ranging from 150°C to 200°C; and high-temperature wells, exceeding 200°C (Kruszewski and Wittig, 2018). For large-scale commercial applications and effective energy production, accessing high enthalpy geothermal wells with temperatures exceeding 300°C is crucial (Fallah et al., 2021; Khaled et al., 2023; Khaled et al., 2023). Beyond the locations where high temperature is close to the surface due to volcanic settings, high enthalpy-engineered geothermal wells are generally expected to be between 7 km – 10 km deep (although in areas with low geothermal gradients they may exceed 10 km depth) and are characterized by high temperature and potentially also high pressure (HPHT) conditions (van Oort et al., 2021). Drilling these deeper wells presents several challenges, including tool failures caused by extreme temperatures. The majority of downhole tools currently available are designed to operate at temperatures up to 150°C, with high-temperature tools generally rated for use up to 175°C and only a limited number capable of functioning at temperatures as high as 300°C (Khaled et al., 2023). Thermal degradation of drilling fluids presents a significant challenge when drilling supercritical geothermal wells, where temperatures exceed 374°C and pressures surpass 221 bar for pure water (Dobson et al., 2017). Geothermal reservoirs are commonly composed of formation rocks such as volcanic rocks, granite, quartzite, granodiorite, and greywacke. These rock types are characterized by their hardness and abrasiveness, which accelerate drill bit wear and reduce their lifespan, especially at high temperatures (Mohamed et al., 2021; Vollmar et al., 2013). Therefore, the use of proper cooling strategies to reduce the bottom hole circulating temperature (BHCT) can help mitigate these issues and save costs.

Several numerical models have been built over the past years to analyze and simulate BHCT behavior in the wellbore (Al Saedi et al., 2018; Corre et al., 1984; Fallah et al., 2021; Kabir et al., 1996). Trichel and Fabian (2011) conducted a sensitivity analysis to understand the effects of different drilling parameters on the BHCT in the horizontal sections of high-temperature wells. They concluded that the bottom hole assembly (BHA) pressure drop had a major impact on BHCT by limiting achievable flow rates. They recommended minimizing BHA pressure drop as much as possible while considering trade-offs, especially with a steerable motor BHA. Steps recommended included minimizing mud weight and increasing flow rate while considering its impact on motor performance, ROP, and hole cleaning. Moreover, using water-based mud (WBM) and optimizing bit design to use the largest total flow area (TFA) proved effective in reducing the BHCT. Zhang et al., 2024 explored BHCT in a deep horizontal shale well and found out that for horizontal sections shorter than 1000 m, reducing the inlet temperature proves to be an effective method for cooling the bottom hole. However, when the horizontal section exceeds 1500 m, the influence of inlet temperature becomes progressively reduced, and alternatives need to be explored.

An effective cooling strategy involves the use of insulated drill pipes (IDPs), which help maintain lower downhole temperatures by delivering drilling fluids to the bottom hole at significantly cooler temperatures compared to conventional drill pipes (CDPs) (Finger et al., 2000). Table 1 below provides a summary of various IDP types found in the literature, highlighting their advantages, disadvantages, and applications.

Table 1: Applications of different types of IDPs with their advantages and disadvantages.

IDP Type	Advantages	Disadvantages	Application
IDP with internal coating	▪ Light weight ▪ Insulation protected from abrasion wear ▪ Minimum erosion from cuttings	▪ Failed insulation could plug bit or downhole motor ▪ Hard to install and repair	Adams & Fard, 2023 demonstrated the impact of using IDP with internal coating in drilling formations at temperatures of 150 °C to 300 °C on cooling the wellbore. Two geothermal test wells were drilled one in New Mexico and another in Utah (FORGE). In the New Mexico well drilled at temperatures up to 250°C, the IDP kept the mud temperature below 95°C, well under the target of 120°C to prevent BHA damage. Similar positive results were observed in the Utah FORGE well.
IDP with external coating	▪ Light weight ▪ Easy installation ▪ Insulation failure would not have serious effect on circulation	▪ Insulation has high risk of erosion	Vetsak et al., 2024 developed and field-tested a new insulated drill pipe (IDP) with an external coating. In formations with temperatures exceeding 150°C, the use of this IDP reduced the bottom-hole circulation temperature (BHCT) from 107°C to 65°C.
Dual wall drill pipe	▪ Reliable protection for insulation ▪ Insulation materials are readily available (i.e., fiberglass, polyurethane foam, etc.)	▪ Pipe is heavy ▪ Fabrication and material are expensive ▪ Reduced inside diameter affects hydraulics	Xiao et al., 2022 studied the impact of 3 different types of IDPs including dual wall IDP, single wall IDP and a composite-material IDP on BHCT in a deep shale gas horizontal well (BHCT of the horizontal section ranges between 135°C and 155° C). The results of this study indicated that all insulated drill pipes exhibited good wellbore cooling effects. BHCT was reduced from 148.2 ◦C to 79.35 ◦C using the dual-wall insulated drill pipe.

In the following, the results of a simulation study into the cooling effects of IDP vs CDP are presented, showing not only the implications and effectiveness of IDP use on downhole cooling, but also its effect on hydraulics and drillstring dynamics.

2. METHODOLOGY

The advanced thermo-hydraulic model developed by Fallah et al. (2021), Gu et al. (2022), Ma et al. (2016) is employed to simulate the BHCT and hydraulics in geothermal wells. The transient behavior of drilling fluid hydraulics using different kinds of IDPs is evaluated to study the impact of insulated technology on two well configurations: deep vertical wells and long lateral wells. The well configurations are based on representative wells drilled in West Texas. The path of the well with lateral section is divided into three major sections: a vertical section, a 400 m curve section, and a horizontal lateral section (90° inclination) with 2 km length. Figure 1 illustrates the well configurations studied in this paper. For the base case, the drilling fluid flow rate is 136 m^3/h (600 gal/min) with 40°C (104°F) mud inlet temperature. Simulation time is set to 1500 minutes to ensure the BHCT reaches the steady-state condition. Table 2 summarizes the properties and geometry of the wells. Table 3 and 4 present the casing and BHA setups, respectively.

Table 2: Two well configurations modified from the well drilled in Delaware and Val-Verde Basins of West Texas.

	Vertical well	Horizontal well
Geometry		
Hole size	0.22 m (8.67 inches)	0.22 m (8.67 inches)
True vertical depth	8,600 m (28,215 ft)	8,600 m (28,215 ft)
Wellbore inclination	0°	90°
Lateral section length	0 m (0 ft)	2,000 m (6,562 ft)
Drilling fluid properties		
Mud type	Water-based mud	Water-based mud
Density	1,078 kg/m^3 (9.0 ppg)	1,078 kg/m^3 (9.0 ppg)
Plastic viscosity	14 mPa·s	14 mPa·s
Specific heat capacity	3,750 J/kg·K	3,750 J/kg·K
Thermal conductivity	0.75 W/m·K	0.75 W/m·K
Formation and Geothermal Properties		
Formation surface temperature	17°C (62.6°F)	17°C(62.6°F)
Formation gradient	24°C/km (1.32°F/100ft)	24°C/km (1.32°F/100ft)
Rock density	2,800 kg/m^3 (23.4 ppg)	2,800 kg/m^3 (23.4 ppg)
Specific heat capacity	930 J/kg·K	930 J/kg·K
Thermal conductivity	2.31 W/m·K	2.31 W/m·K
Operational factors		
Fluid flow rate	136 m^3/h (600 gal/min)	136 m^3/h (600 gal/min)
Mud inlet temperature	40°C (104°F)	40°C (104°F)

Table 3: Well design.

Parameters	ID	OD	Length	Thermal conductivity
Conductor casing	0.48 m (19.9 in)	0.51 m (20.1 in)	100 m (328 ft)	45 W/m·K
Surface casing	0.32 m (12.6 in)	0.34 m (13.4 in)	1000 m (3281 ft)	45 W/m·K
Intermediate casing	0.22 m (8.7 in)	0.24 m (9.4 in)	4000 m (13123 ft)	45 W/m·K
Open hole	-	0.22 m (8.7 in)	4600 m (15092 ft)	45 W/m·K

Table 4: Drill string configuration used in the study.

Parameters	ID	OD	Length	Thermal conductivity
Drill pipe (DP)	0.121 m (4.8 in)	0.14 m (5.5 in)	8224 m (26982 ft)	45 W/m·K
Heavy weight DP	0.083 m (3.3 in)	0.14 m (5.5 in)	223 m (732 ft)	45 W/m·K
Drill collar	0.073 m (2.9 in)	0.17 m (6.7 in)	143 m (469 ft)	45 W/m·K
Drill bit	-	0.22 m (8.7 in)	0.8 m (3 ft)	45 W/m·K

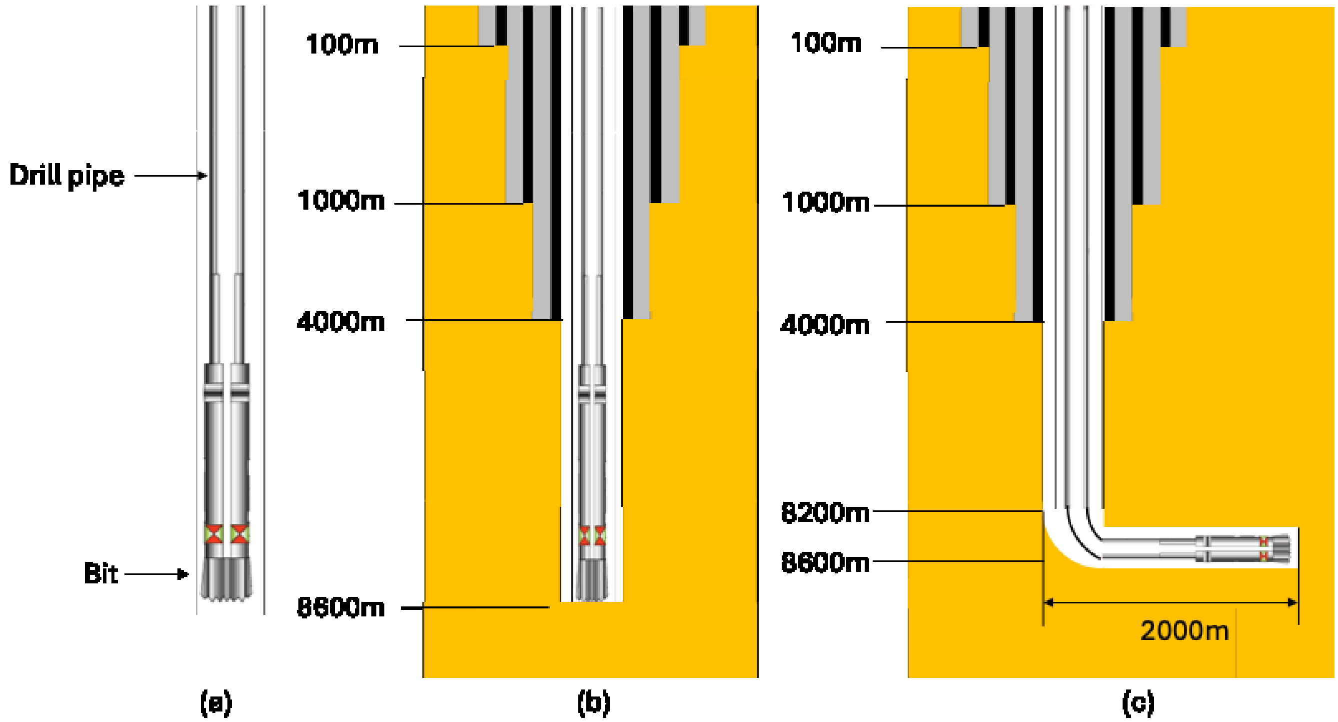

Figure 1: a) Drill string, b) vertical well, c) horizontal well configurations used in this study.

3. RESULTS

The primary aim of this study is to assess the impact of IDPs on BHCT, standpipe pressure (SPP), and drilling dynamics within geothermal wells. Simulations were conducted for both full and partial insulation coverage, as well as for vertical and horizontal well configurations, to offer insights into choosing the most suitable insulation method for well construction. CDP and internal, external, and dual-wall IDPs under various flow rates and geothermal gradients are tested. Table 5 presents the details of four drill pipes investigated in the study. For the coated IDPs, a composite fiber-resin coating with 1 mm thickness applied to the internal and external surfaces of the drill pipes, respectively, was assumed, resulting in thermal conductivities of 0.47 W/m·K and 1.31 W/m·K. For the dual-wall IDP, phenolic resin was taken to be the filling material with an internal diameter of 80 mm, achieving a thermal conductivity of 0.092 W/m·K. The behavior of full IDP coverage is compared to partial IDP coverage, the latter with 70% of drill pipe covered by the insulation technologies either from the surface (top), at the midpoint (middle), or at the end (bottom) of the drillstring.

Table 5: CDP, internal, external, and dual-wall IDPs investigated in the study.

Type of DP	Insulated materials	ID	OD	Coating thickness	Thermal conductivity	Weight	Reference
CDP	-	121.4 mm (4.8 in)	139.7 mm (5.5 in)	-	45 W/m·K	32.6 kg/m (235.8 lb/ft)	Xiao et al., 2024
IDP with internal coating	A composite fiber-resin coating	119.4 mm (4.7 in)	139.7 mm (5.5 in)	1 mm	0.470 W/m·K	32.6 kg/m (235.8 lb/ft)	Vetsak et al., 2024
IDP with external coating		121.4 mm (4.8 in)	141.7 mm (5.6 in)	1 mm	1.310 W/m·K	32.6 kg/m (235.8 lb/ft)	Vetsak et al., 2024
Dual-wall drill pipe	Phenolic resin	80.0 mm (3.1 in)	139.7 mm (5.5 in)	-	0.092 W/m·K	38.7 kg/m * (279.9 lb/ft)	Xiao et al., 2022

* The weight of the dual-wall drill pipe is from Drill Pipe specs.

3.1. Influence of Coating on BHCT

This section examines the effects of different insulation deployment patterns, including full and partial coatings. Partial coating assumes coverage of 70% of the drill pipe with insulation. The study tests internal, external, and dual-wall IDPs under various flow rates and geothermal gradients.

3.1.1. Full Coating Scenarios for Different IDPs

Figure 2 illustrates the effects of three types of IDPs on the BHCT in the analyzed vertical and horizontal wells. The BHCT in the horizontal well is higher than in the vertical well, regardless of insulation methods, due to its extended lateral section and associated larger formation contact area. Among the options, dual-wall IDPs offer the best insulation, leading to the lowest BHCT, followed by internal and external IDPs. Notably, the BHCT reaches 153°C with the external IDP in the horizontal well, which slightly exceeds the maximum 150°C designed temperature for downhole tools.

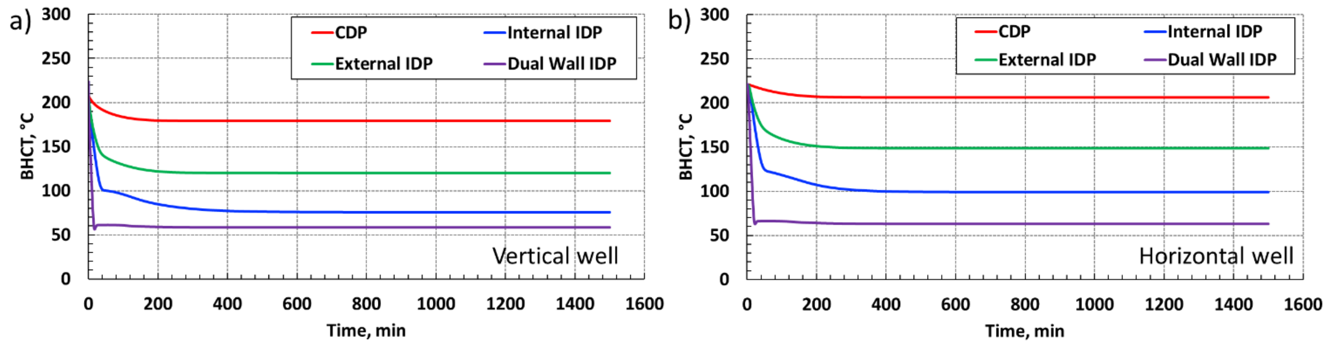

Figure 2: Impact of internal, external, and dual-wall IDP on BHCT in a) vertical and b) horizontal geothermal wells.

3.1.2. Partial Coating Scenarios for Different IDPs

As shown in Figure 2, insulating the drill pipe can lead to significant temperature reductions. Utilizing partial insulation can help lower the operational costs of the IDP and so they are considered here as well. Figures 3 illustrate the thermal behaviors of the vertical geothermal well with partial IDPs placed at different locations. Due to the inhomogeneous material of DP resulting in the change of heat transfer rate of the internal and dual-wall IDPs (70% of IDP and 30% of CDP), fluctuations in BHCT are observed at the start of circulation. These fluctuations are most pronounced at the bottom isolation scenario, followed by the middle and top scenarios. The BHCTs recorded in the vertical well with partial internal IDPs are 146°C, 123°C, and 121°C for the top, middle, and bottom placement scenarios, respectively. By contrast, the partial external IDP does not manage to reduce the temperature below 150°C with 70% insulation. However, dual-wall IDPs successfully maintain temperature in a safe range of 131°C to 141°C. Overall, positioning the insulation at the bottom of the drill pipe is more advantageous than placing it at the top or middle.

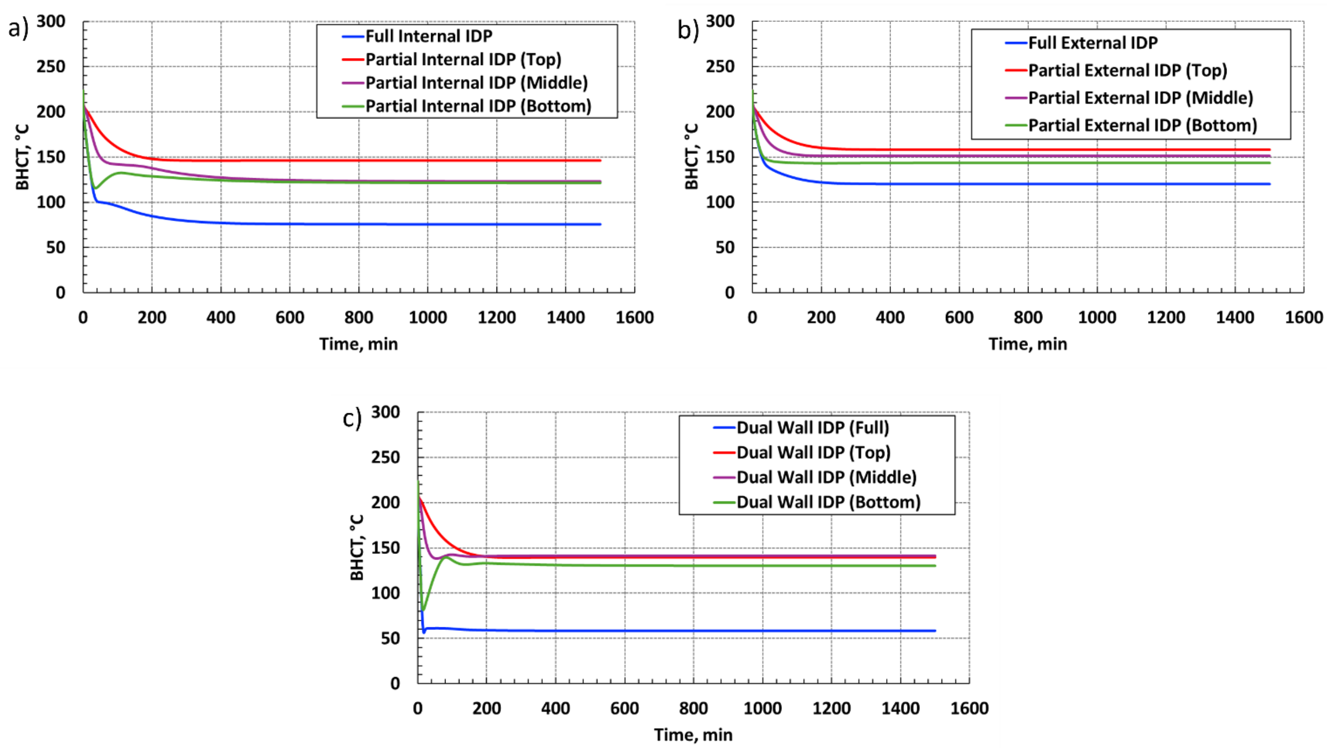

Figure 3: Impact of the location of a) partial internal IDP, a) partial external IDP, and a) partial dual-wall IDP on BHCT in vertical geothermal wells.

Figure 4 depicts the thermal behavior of horizontal geothermal wells with partial insulation. Generally, Bottom Hole Circulation Temperature (BHCT) in horizontal wells is higher than in vertical wells. The use of full internal IDPs lowers the BHCT to 100°C and a range of 150°C - 170°C with partial internal IDPs. Similarly, full external IDPs reduce the BHCT to 150°C and between 170°C and 185°C with partial external IDPs. For dual-wall IDPs, the BHCT decreases to 65°C with full dual-wall IDPs and between 155°C and 160°C with partial dual-wall IDPs. Among the studied partial IDPs, positioning the insulation at the bottom yields a lower BHCT compared to placing them at the top or middle locations.

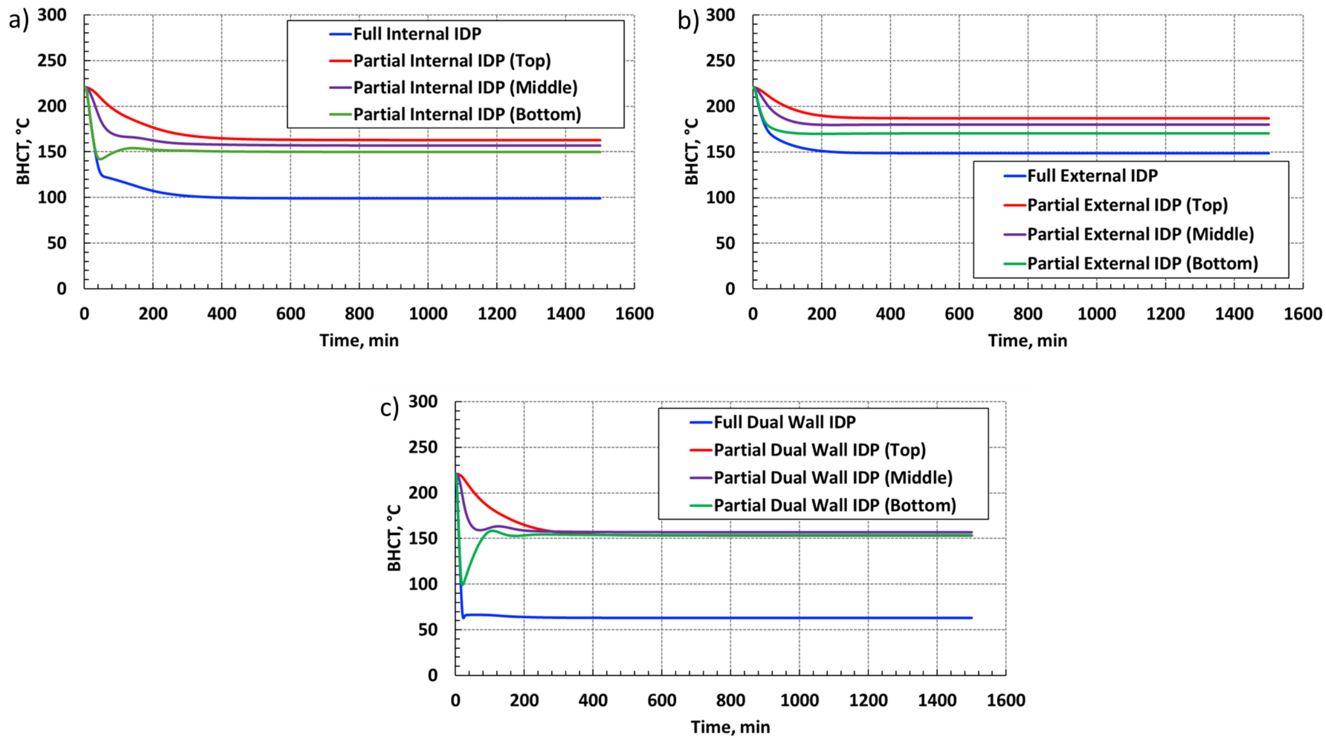

Figure 4: Impact of the location of a) partial internal IDP, a) partial external IDP, and a) partial dual-wall IDP on BHCT in horizontal geothermal wells.

3.1.3. Influence of Geothermal Gradients

Figure 5 illustrates the impact of BHCT in vertical and horizontal wells with variation of the reservoir temperature from 200°C to 400°C. Table 6 lists the reservoir temperatures along with the corresponding geothermal gradients analyzed in this section.

Table 6: Reservoir temperatures along with the corresponding geothermal gradients analyzed in this section.

Geothermal gradient	Reservoir temperature
21.3°C/km (1.17°F/100ft)	200°C (392°F)
27.1°C/km (1.49°F/100ft)	250°C (482°F)
32.9°C/km (1.81°F/100ft)	300°C (572°F)
38.7°C/km (2.12°F/100ft)	350°C (662°F)
44.5°C/km (2.44°F/100ft)	400°C (752°F)

In the vertical well (Figure 5a), both dual-wall and internal insulation deployment patterns (IDPs) successfully maintain safe temperature levels. Specifically, the BHCT for the internal IDP increases from 71°C to 107°C as reservoir temperatures rise, while the BHCT for the dual-wall pipe remains steady at 59°C. Conversely, for external IDPs, the BHCT exceeds 150°C once the reservoir temperature surpasses 350°C. Figure 5b shows similar trends in horizontal wells, where the external IDP fails to effectively lower the BHCT beyond a reservoir temperature of 250°C. The coating thickness studied is 1mm, and increasing this thickness could potentially reduce thermal conductivity, thereby lowering the BHCT. The effective temperature management exhibited by both internal and dual-wall IDPs underscores their suitability for superhot formations, where reservoir temperatures reach or exceed 400°C.

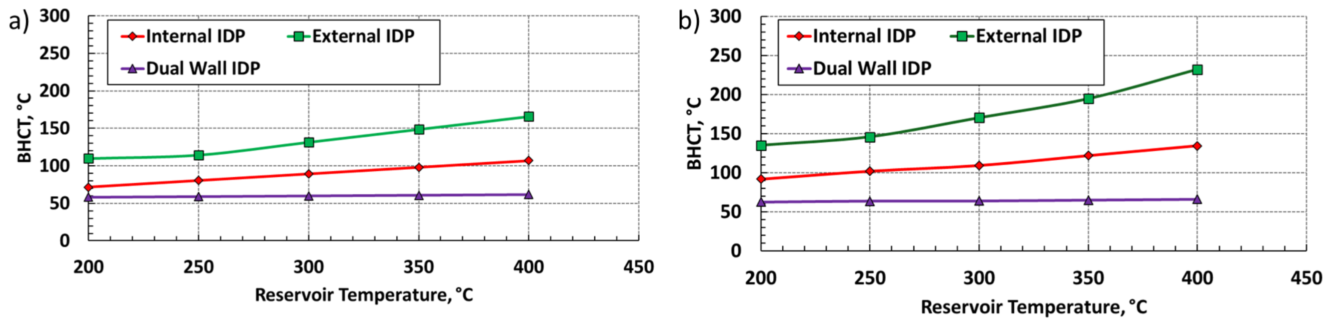

Figure 5: Impact of reservoir temperature on BHCT in a) vertical and b) horizontal wells with different types of IDPs.

3.1.4. Influence of Flow Rates for Both Full and Partial Coating

The previous findings indicate that managing temperature in reservoirs with high temperatures poses significant challenges. To address this, Figure 6 depicts the BHCT for different IDPs when the reservoir temperature is set at 400°C. It is evident that an increased flow rate helps to lower the BHCT in both vertical and horizontal wells. For vertical wells, internal and dual-wall IDPs can effectively manage temperature at flow rates ranging from 400 to 800 gal/min. Conversely, the external IDP requires a flow rate exceeding 700 gal/min to function adequately. In horizontal wells, the dual-wall IDP can be utilized at a lower flow rate, while the internal IDP necessitates a flow rate greater than 600 gal/min. However, the external IDP (with 1 mm coating) is not an effective method for temperature management in these scenarios.

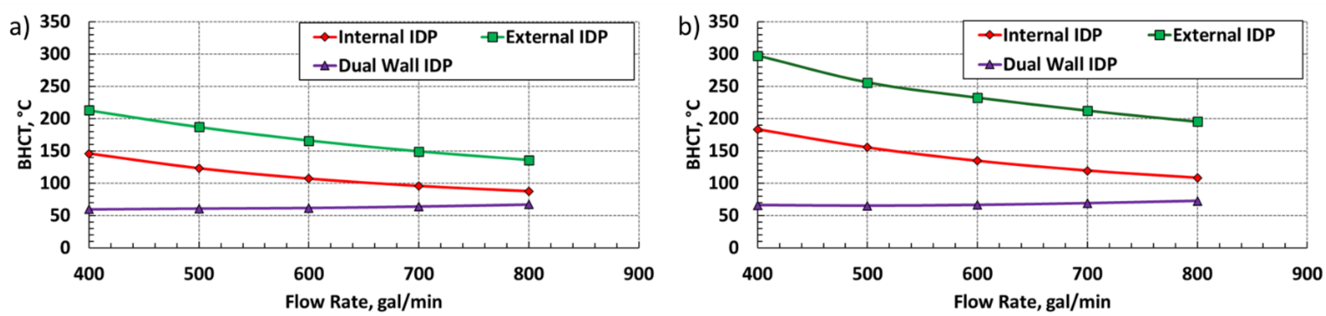

Figure 6: Impact of flow rate on BHCT in a) vertical and b) horizontal wells with different types of IDPs.

3.2. Influence of Coating on SPP

Understanding the impact of insulation coatings on SPP is vital for managing hydraulics during deep geothermal drilling. If the SPP is excessively high, the pumps may struggle to deliver sufficient power. This section examines how various insulation deployment patterns affect SPP under different conditions, including both full and partial coatings. A maximum standpipe pressure capacity of 7,500 psi (51,700 kPa) is assumed (DrillWell, 2025).

3.2.1. Full and Partial Coating Scenarios for Different IDPs

Figure 7 provides a detailed representation of the SPP observed in the vertical well, specifically highlighting the effects of insulation positioned at different locations along the drill pipe. In the case of the coated IDP, the geometry of the drill pipe is only changed slightly, which results in only minor increases in the SPP. Very high SPP values are observed for full dual wall IDP due to its reduced ID, which in fact exceed the aforementioned SPP limitations. The partial dual-wall IDP scenarios exhibit a significant reduction in the pressure, with a decrease of 22% when compared to the full dual-wall IDP configuration. This notable drop in SPP indicates that the partial dual-wall insulation is more effective in managing pressure dynamics within the well. Such a reduction is crucial as it not only reflects on the efficiency of the insulation but also enhances the overall feasibility and practicality of employing dual-wall insulation technology in geothermal drilling operations.

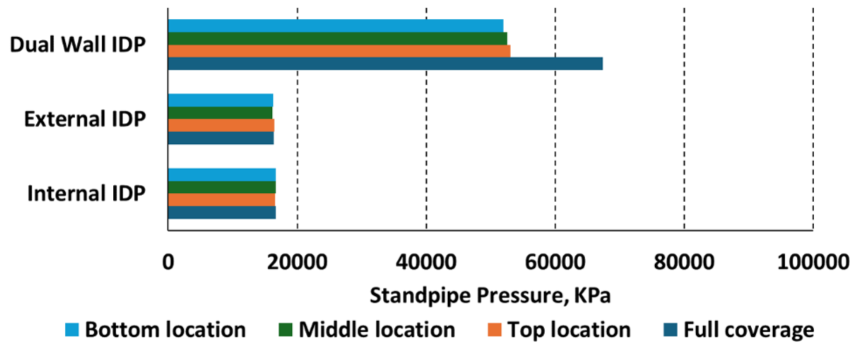

Figure 7: Impact of the location of partial internal, external, and dual-wall IDPs on SPP in vertical geothermal wells.

Figure 8 shows the SPP in the horizontal well with partial IDPs at various locations. The pressure in the horizontal well is notably higher than in the vertical well. No significant difference in SPP is observed between full and partial IDPs using internal and external configurations. Full coverage dual-wall IDP yields pressure that exceed the standpipe limitation, but in this case the partial coverage scenarios also exceed this limitation despite the 21% drop in pressure compared to the full coverage scenario. This may limit therefore the applicability of dual pipe in directional/horizontal wells with long reservoir exposure sections.

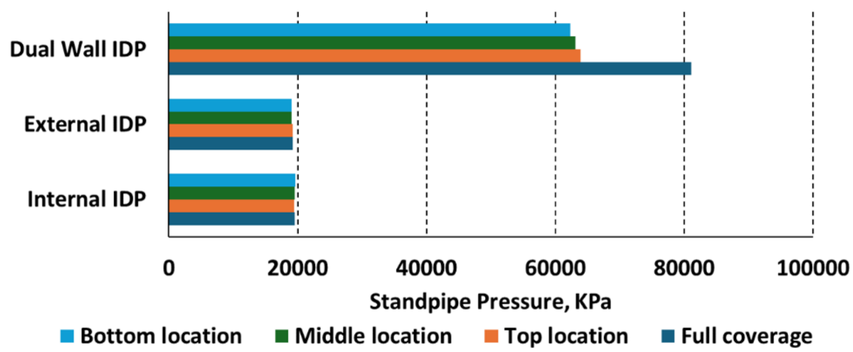

Figure 8: Impact of the location of partial internal, external, and dual-wall IDPs on SPP in horizontal geothermal wells.

3.2.2. Influence of Flow Rates for Both Full and Partial Coating

Figure 9 illustrates the effect of flow rate on SPP in vertical and horizontal wells with various insulation deployment patterns (IDPs). In the vertical well (Figure 9a), the SPP for internal and external IDPs remains below the limit within the flow rate range of 400 to 800 gal/min. However, the SPP for dual-wall IDPs exceeds the standpipe limit (51,700 KPa) when the flow rate exceeds 500 gal/min. In the horizontal well (Figure 9b), the SPP for internal and external IDPs also stays below the limit across the same flow rate range of 400 to 800 gal/min. For dual-wall IDPs, the SPP surpasses the standpipe limit when the flow rate exceeds 400 gal/min.

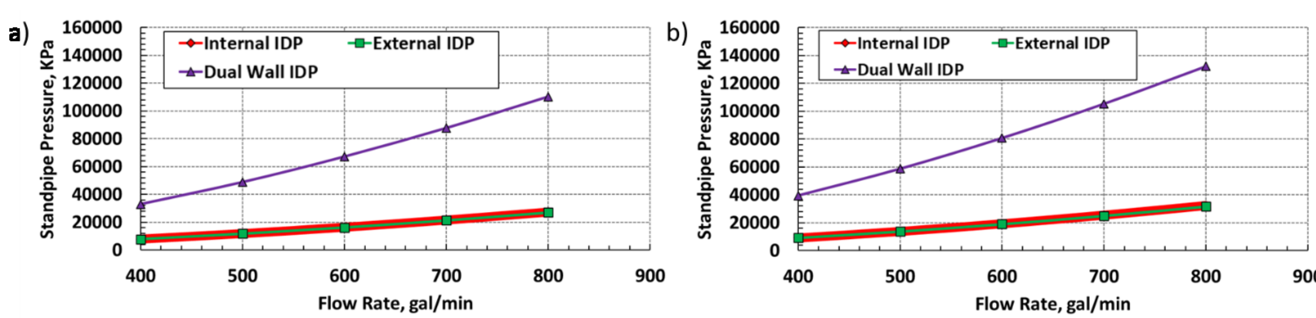

Figure 9: Impact of flow rate on standpipe pressure in a) vertical and b) horizontal wells with different types of IDPs.

3.3. Influence of Different Types of IDPs on Drilling Mechanics

The main difference in mechanics between CDPs and IDPs is caused by the internal diameter, which affects the DP stiffness and weight. Since the cross-sections of internal and external IDP are close to that of the CDP (coating thickness is 1 mm, see Table 5), the stiffness and weight are assumed to be equivalent. Thus, the discussion in this section is focused solely on dual-wall IDPs and CDPs.

Torque and drag analysis was conducted for the horizontal well case with CDP, 100% dual-wall IDP, and 70% dual-wall IDP. A stiff string model was adopted to calculate the tripping in/out hookload and the off-bottom rotation hookload/torque. The results are reported in Table 7. Due to the heavier weight of the dual-wall IDP, the increase in tripping in/out hookload ranges from 11.9% to 19.6%. Hookload is smaller when dual-wall IDPs are deployed at the bottom of the drillstring as they are laterally supported by the horizontal wellbore. Such increased wellbore contacts also result in a larger off-bottom rotation torque compared with the top/middle dual-wall IDPs.

Table 7: Drilling mechanics difference between dual wall IDP and CDP.

Drilling Mechanics		CDP	Dual wall IDP			
			Full	Top 70%	Middle 70%	Bottom 70%
Tripping out hookload, kN		2972	3519 (+18.4%)	3411 (+14.8%)	3397 (+14.3%)	3335 (+12.2%)
Tripping in hookload, kN		2401	2871 (+19.6%)	2829 (+17.8%)	2809 (+17.0%)	2687 (+11.9%)
Off-bottom rotation	Hookload, kN	2704	3209 (+18.7%)	3132 (+15.8%)	3118 (+15.3%)	3026 (+11.9%)
	Torque, kNm	16.02	17.91 (+11.8%)	16.06 (+0.2%)	16.48 (+2.9%)	17.91 (+11.8%)
Stick-Slip 40 RPM 111kN	Frequency, Hz	0.0732	0.0991 (+35.4%)	0.0896 (+22.4%)	0.0860 (+17.5%)	0.0856 (+16.9%)
	ROP, m/hr	22.14	21.06 (-4.9%)	19.34 (-12.6%)	19.35 (-12.6%)	20.81 (-6.0%)

Based on the model coupled drillstring dynamics using 3D field-consistent corotational beam elements, we also conducted simulations to investigate the dynamic responses of dual-wall IDPs. As discussed above, the dual-wall IDP has a smaller ID, lower average density, and higher torsional stiffness when compared with CDP. In the simulation, the surface drilling parameters are maintained constant and set as 40 RPM @ 111 kN WOB. The drilling boundary conditions and bit-rock interactions are adopted from coupled drillstring dynamics modeling using 3D field-consistent corotational beam elements. Stick-slip torsional vibration behavior is observed with all different drillstring configurations, and the stick-slip frequency and ROP are reported in Table 7. In Figure 10, the drillstring RPMs at different measured depths (MD) are illustrated. The propagation of the torsional mechanical wave in the drillstring can be clearly observed, and the stick-slip frequency difference can also be noted. Dual-wall IDP leads to a higher frequency in stick-slip when compared to CDP, but the downhole stick-slip bit RPM values are smaller than those observed with CDP. This means that the stiffer dual-wall IDP drill string offers some mitigation of stick-slip severity when it occurs compared to CDP. This benefits hole-making ability by offering better drillstring stabilization, less damage of bits and downhole tools, and associated with these a higher rate of penetration.

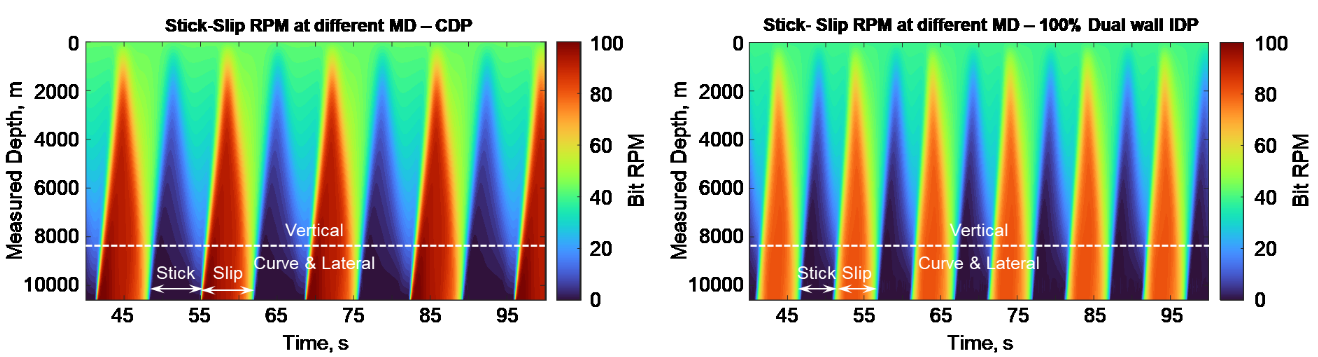

Figure 10: The drillstring RPM at different MD with stick-slip. Surface drilling parameters: 40 RPM, 111 kN WOB.

4 CONCLUSIONS

This study highlights the effects of various types of IDPs on BHCT, hydraulics and drill string mechanical behavior in both deep vertical and horizontal geothermal wells, assuming a ~8.5 km TVD well depth and, in case of the horizontal well, a 2 km lateral length. The analysis of full and partial coverage/insulation scenarios for IDPs configurations reveals that dual-wall IDPs consistently provide superior insulation and temperature management in both vertical and horizontal geothermal wells. Their ability to maintain lower BHCTs under varying conditions, such as insulation placement, geothermal gradients, and flow rates, demonstrates efficacy, particularly in very high-temperature environments. Partial insulation can reduce operational costs, with placement at the bottom of the drill pipe yielding the more significant thermal benefits than placement at the top or middle of the drillstring.

The BHCT results, however, have to be looked at also from the perspective of potential hydraulic limitations. The analysis of the influence of insulation coatings on standpipe pressure (SPP) reveals that partial dual-wall IDPs reduces SPP by as much as 22% when compared to full dual wall configurations. This brings expected standpipe pressures below that SPP limit for the vertical well scenario, but will still exceed this limit for the horizontal well scenario. This may limit the use of dual wall IDP in long deviated/horizontal well scenarios. By contrast, internal and external IDPs allow SPP values to be maintained below the operational SPP limit for various flow rates in both vertical and horizontal well scenarios, but are of course less effective in reducing BHCT than dual-walled IDP.

The comparative drillstring dynamics analysis of CDP and dual-wall IDP configurations shows a significant impact of drill string ID on drilling mechanics. The findings reveal that the increased weight of dual-wall IDPs results in higher tripping hookloads, with increases ranging from 10.0% to 22.3%. However, strategic IDP deployment at the bottom of the drillstring effectively reduces hookload, e.g., due to lateral support from the wellbore in horizontal well scenarios. Simulations using a coupled drillstring dynamics model demonstrate that dual-wall IDPs, characterized by a smaller ID and higher torsional stiffness, are less prone to stick-slip than CDP, which may help drilling stability and enhance rate of penetration.

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