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Tubing Impossible: Rig-Less Casing Repair In A Geothermal Well With Coiled Tubing

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ABSTRACT

Maintaining casing integrity is crucial for the long-term reliability and safety of geothermal wells. This paper presents a successful rig-less intervention using high-capacity coiled tubing (HCCTU) technology to clean out and restore a compromised geothermal well. Conducted in mid-2025, the operation achieved two primary objectives: the removal of wellbore obstructions at approximately 219 m and 731 m measured depth (MD), and, most importantly, the restoration of casing integrity by installing and cementing a 6-5/8-in casing string from the surface to 461 m MD. This intervention marks the first application of HCCTU on a geothermal well of this configuration in New Zealand, demonstrating a viable alternative to conventional rig-based workovers. The paper provides an overview of the engineering design, including the selection of tools and materials, as well as the operational execution, detailing the step-by-step process of the intervention. It also addresses technical challenges, including tool wear, thermal management, and real-time diagnostics. The methodology provides a scalable, low-impact approach for geothermal interventions that require a minimized surface footprint and improved operational efficiency. This paper aims to demonstrate the viability of rig-less casing repairs of geothermal wells and offer insight into future applications of HCCTU in the geothermal industry.

1 INTRODUCTION

In conventional practice, remediation of compromised casing typically requires a drilling rig, which introduces significant mobilization costs, surface footprint, and operational risks. Failures in casing not only compromise well productivity and safety but also increase operational costs through unplanned interventions and workovers (Alsubaih et al., 2025). These challenges are amplified in geothermal fields, where high temperatures, scaling, and complex geology place unique stresses on casing systems (Sarmiento & Björnsson, 2007).

Recent efforts across the geothermal sector have emphasized the need for more cost-effective and lower-impact solutions for well interventions (Reinsch et al., 2017). While coiled tubing (CT) technology is widely used in oil and gas operations for cleanouts, stimulations, and casing repairs, its application in geothermal wells has remained limited. The primary barriers include thermal stability of tools, equipment availability, and the absence of field-proven case studies.

1.1 Background

Coiled tubing has a well-established track record in the oil and gas industry, where it is valued for its ability to conduct rig-less interventions such as milling, cleanouts, acid stimulations, and cementing (Bourgoyne et al., 1991). The technology enables continuous tubing to be inserted into the wellbore under pressure, allowing for live-well operations and reducing downtime.

In geothermal applications, CT adoption has been slower due to unique technical hurdles:

- High temperatures can degrade elastomer seals, limit tool life, and challenge real-time diagnostics (Rufford et al., 2015).
- Scaling and debris from silica and mineral deposition often obstruct geothermal wells, requiring aggressive cleanout strategies (Gallup, 2009).
- Well architecture in geothermal fields, with large diameters and variable casing strings, complicates tool design and deployment (Reinsch et al., 2017).

Despite these challenges, the potential benefits of CT for geothermal are substantial. Rig-less interventions reduce mobilization time, surface footprint, and overall project costs compared to rig-based workovers. Moreover, the flexibility of CT allows for innovative solutions such as section milling, zonal isolation, and casing

repairs, which are increasingly relevant as geothermal operators seek to extend the lifespan of aging fields and develop Enhanced Geothermal Systems (EGS) (Sarmiento & Björnsson, 2007).

Western Energy has recently expanded its geothermal intervention capability through the acquisition of a dedicated high-capacity coiled tubing (HCCTU) spread. The package comprises a purpose-built casing running floor (CRF), a quintuplex pumping system capable of sustained high-rate circulation, and a 2-7/8-in coiled tubing unit designed for long-duration operations. This well's workover represented the first significant deployment of this equipment in a geothermal application, where it was utilized for casing milling, cement placement, and subsequent shoe track cleanout. Performance during the campaign confirmed that the spread could deliver circulation rates of up to 8 bpm at pressures exceeding 4,000 psi, while also enabling rig-less casing installation and cementing operations. This investment not only broadens Western Energy's service offering but also demonstrates the technical feasibility of using HCCTU spreads to execute complex geothermal well repairs without the support of a conventional drilling rig.

2 METHODOLOGY

2.1 Well Overview

The Tauhara field is recognized as one of New Zealand's principal geothermal resources, characterized by the coexistence of deep high-enthalpy geothermal systems and shallow low-temperature hydrothermal features (Curtis, 1988). The subject of this intervention is a geothermal monitoring well located in the Tauhara field, which was originally drilled in 1967 as a standard-diameter vertical well. The well has played a critical role in long-term reservoir surveillance and regulatory compliance for the field. Since at least 2012, the well has been equipped with 1/8-in pressure monitoring tubing, which has provided continuous data for field management and consent obligations.

Concerns regarding casing condition were first raised in 2003, when a casing integrity survey indicated potential metal loss at approximately 219.6 meters from Rotary Table (mRT). In the years following, routine gauge ring and HTXY surveys repeatedly confirmed restrictions in the internal diameter at this depth, suggesting progressive damage. Despite this, the well remained in service for monitoring purposes.

Although originally drilled as a non-artesian well, the casing break has altered the well's behaviour. A shallow steam and gas cap has developed, and ammonium carbonate residues have been observed at the surface, indicating chemical ingress through the compromised interval. During the shut-in period, this well tends to develop a gas cap, which requires repetitive bleed-off. Some precautions noted during the program discussion were that this tendency to develop gas caps will require adequate contingencies in well control situations.

Air cap testing, first implemented in 2019, initially suggested the casing system remained competent. However, by 2024, a marked deterioration was observed: tests indicated a leak at 219.6 mRT that communicated directly with a pressurized formation. The results showed that above a threshold of 14 barg, outflow occurred from the damaged interval, confirming that the casing no longer provided reliable isolation.

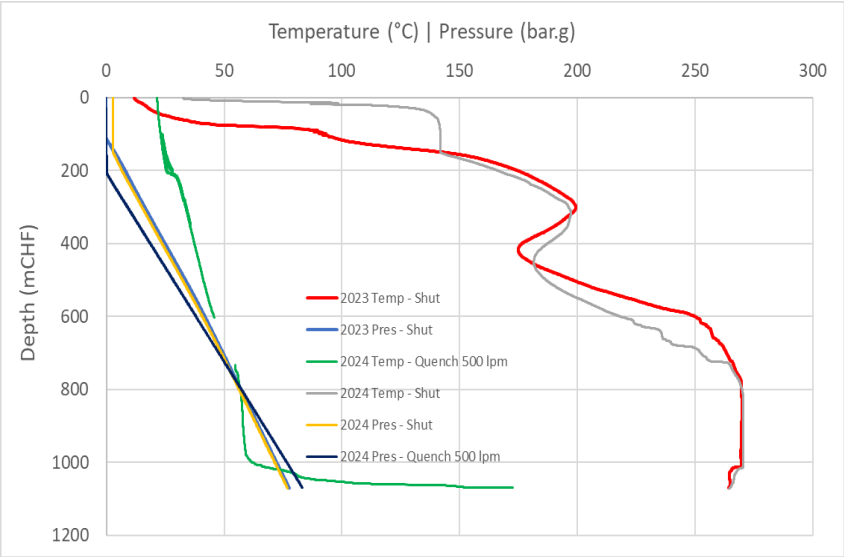


Figure 1. Well pressure & temperature profile in 2023- 2024

In preparation for intervention, a comprehensive suite of wireline-based diagnostics was performed in December 2024. This included a high-temperature XY calliper survey (HTXY), memory pressure–temperature–spinner (PTS) logging, and a downhole camera survey conducted under quench conditions. The diagnostics provided conclusive evidence of two primary issues: (i) a casing break at 219.6 mRT with an internal diameter reduced to 4.16-in, and (ii) scale deposition at 730.6 mRT, reducing the available diameter to approximately 3-in.

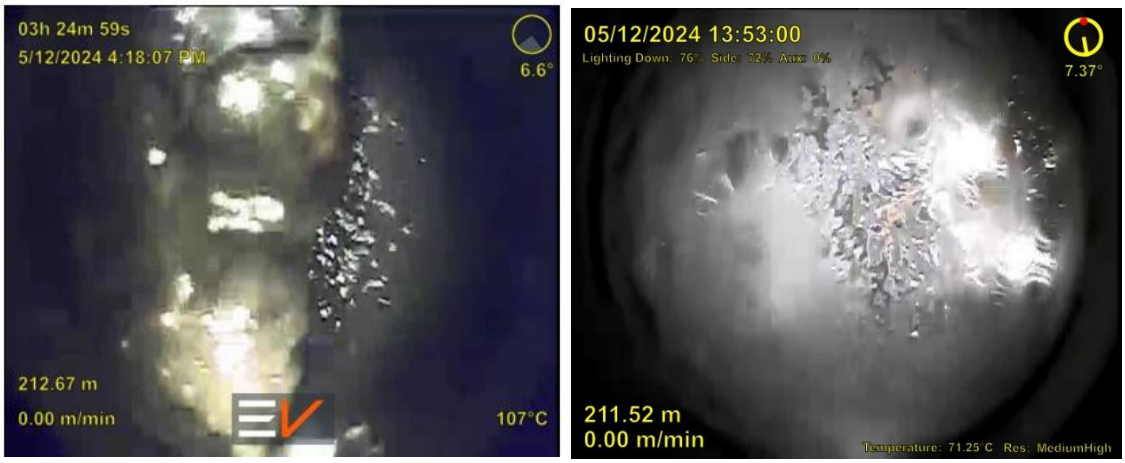


Figure 2. Side views of 210-212 mCHF of casing damage that appears to be a folded casing (left) and inflow of water and steam (right).

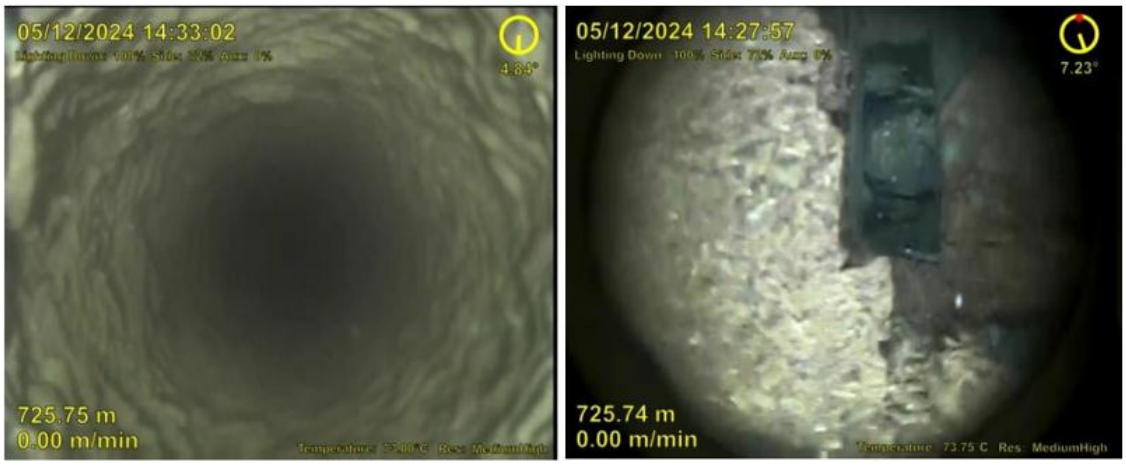


Figure 3. Down view of scale deposition at 717.4 mRT / 725mCHF (left) and side view of liner slot (right).

Against this backdrop, the objective of this workover was to restore compromised casing integrity and thereby secure the long-term operability of the asset. By employing a high-capacity coiled tubing unit (HCCTU), the project aimed to demonstrate the feasibility of performing complex geothermal well repairs without the need for a conventional drilling rig to be mobilized. This approach aimed to reduce overall project costs, minimize surface footprint, and provide a scalable model for future well interventions across New Zealand's geothermal sector.

2.2 Surface Equipment

The surface spread for the intervention was designed to accommodate the requirements of an HCCTU in a geothermal environment. It included the HCCTU reel and injector system, capable of handling long-duration runs, coupled with a dual-ram and annular BOP stack to provide redundancy and well control. An 11-in lubricator string was used to facilitate safe deployment of downhole tools. At the same time, twin pumper units and a dedicated batch mixing system ensured consistent delivery of cement slurries and circulation fluids throughout the workover.

A range of bottom-hole assemblies (BHAs) was mobilized to address the specific challenges anticipated in the well. These included tapered mills of 5.88-in and 7.5-in OD for progressive obstruction removal, tricone bits (IADC 117 and 217) for dressing cement and hard debris, concave junk mills for handling elastomeric or irregular

materials, and wash nozzles for debris cleanout and fluid conditioning. Wireline services were fully integrated into the operation, providing both diagnostic capabilities via downhole cameras and calliper tools, as well as functional support, such as bridge plug setting and verification.

Equally critical to the success of the workover was the data acquisition system. Real-time monitoring and a robust modelling framework enabled accurate tracking of depth, pressure, circulation rates, and motor performance. This allowed the operations team to capture key events as they occurred, optimize milling practices, and establish a reliable reference for future geothermal CT interventions.

2.3 Intervention Workflow

The workover was inherently complex, with multiple possible scenarios and decision points anticipated throughout execution. Given the uncertain well conditions and the potential for unexpected events, the programme was designed to be dynamic rather than prescriptive. Operational procedures were intentionally structured to allow regular review, discussion, and adjustment as new downhole information became available.

Instead of a rigid step-by-step plan, the programme served as an overarching framework for how the intervention was expected to unfold. Flexibility was embedded by supporting the main programme with a series of "work instructions" tailored to each run-in-hole (RIH). These work instructions contained the detailed operational notes, including updated bottom-hole assembly (BHA) schematics, pressure control equipment (PCE) configurations, and contingency measures relevant to the planned run.

To ensure alignment across the team, each work instruction was reviewed, discussed, and acknowledged by the HCCTU crew before commencing the associated run. This process provided the opportunity to incorporate the latest well observations, validate decision-making in real-time, and confirm that operational practices remained both safe and effective.

An initial set of work instructions was prepared in advance of the campaign, covering expected operations such as obstruction milling, cement plug placement, casing installation, and shoe track cleanout. However, the programme also anticipated that additional instructions might be required as conditions evolved, ensuring that the intervention remained adaptable to actual well performance.

2.3.1 Milling Casing

The milling operation was strategized to have two sequential runs in the section, with each run designed to enlarge the restriction and verify access progressively. Prior to the run, a set of downhole tools was installed to connect to the CT using a 5.88-in tapered mill. After function-testing the motor and confirming expected circulating pressures, the CT was run to 214 mRT, approximately 5 m above the casing break. At this point, the pumps were stopped, while quench circulation was maintained at 800 lpm on the backside. The CT was then advanced carefully to tag the obstruction, picked up, and re-engaged with the Coiled Tubing Motor (CTM) at the milling pump rate. Differential pressure and torque were applied until the obstruction was gradually broken down. Throughout this process, the pump crew was briefed on stall limits and procedures to ensure safe operation of the motor. Once milling progress was confirmed, the string was reciprocated across the obstruction interval to clean up the break zone until smooth passage of the taper mill was achieved.

Following this, the bottom-hole assembly was changed out for a 7.5-in OD milling BHA, allowing for a larger-diameter cleanout of the same interval. The downhole conditions were verified using a camera run to confirm the effectiveness of the milling. The cycle of milling, reciprocating, and verification was repeated until the restriction was cleared, and a 7.5-in ID was consistently achieved through the section.

2.3.2 Camera Run and Setting Bridge Plug

Following the completion of milling operations, a downhole camera survey was conducted using the wireline unit. This step was critical for visually confirming the effectiveness of the milling, ensuring that the section was not only free of obstructions but also sufficiently smooth to allow for subsequent casing installation and cement placement. The camera inspection also provided an opportunity to assess the condition of the wellbore walls and verify that no additional structural damage had occurred during the intervention.

In preparation for cementing, a bridge plug was deployed via wireline and set below the casing break. The plug served two essential purposes: first, to provide a foundation for cement placement by preventing slurry losses into the lower open section of the well; and second, to temporarily isolate the deeper zone during the workover, thereby maintaining well control and enhancing the integrity of the repair. This combination of post-milling

diagnostics and strategic placement of a bridge plug was a key enabler in ensuring that the subsequent cementing stage could be carried out effectively and with minimal risk of failure.

2.3.3 CT Cement Plug

The cement plug was specifically designed and laboratory-tested under simulated circulation temperatures to verify thickening time and placement behaviour. Given the relatively small volume requirement of less than 5 bbls, the slurry was formulated with a density of 14.2 ppg, balancing sufficient compressive strength with the ability to be easily drilled out once the casing string was in place. During the planning phase, consideration was given to the use of a cement wiper dart, particularly considering the larger equipment size (2-7/8-in CT) being deployed. The wiper dart would have provided an additional safeguard against contamination during the placement of such a small cement volume. However, after evaluation, it was concluded that the standard cement placement methodology remained effective and reliable for the scope of this operation.

Following the placement of the cement plug and prior to running the new casing, a dressing run was performed. This step was essential to remove any residual cement irregularities and to ensure that the plug surface was sufficiently smooth and unobstructed. By doing so, the risk of the casing string becoming stuck, dragged, or encountering excessive resistance during installation was mitigated, thereby improving the efficiency and safety of the subsequent casing placement operation.

2.3.4 Casing Installation

The casing installation phase involved running 39 joints of 6-5/8-in × 28 lb/ft casing to a final depth of 461 m. As this represented the first rig-less casing running operation undertaken by Western Energy personnel, a pre-deployment simulation was conducted in the yard. This exercise was crucial in providing the crew with familiarity and confidence in handling the new equipment, as well as ensuring that operational roles and procedures were well understood prior to execution in the field.

Cementing was subsequently performed using 90 bbl of 15.6 ppg slurry, displaced with 48.3 bbl of fresh water. Given the well's operational history of experiencing both gas kicks and migration, careful consideration was given to the design of gas-tight cement. A series of laboratory tests was carried out during the planning stage to refine the slurry composition and develop a reliable "recipe design" that would deliver the necessary compressive strength, thickening time, and gas-migration control under geothermal temperature conditions.

Both top and bottom cementing plugs were deployed as part of the displacement sequence, ensuring proper separation of fluids and improved placement efficiency. Full cement returns were observed at the surface, confirming that the annulus had been successfully filled and zonal isolation had been achieved. Following cement placement, the BOP stack was reassembled and pressure-tested to 1,000 psi against the newly installed casing, verifying well integrity prior to proceeding with subsequent operations.

2.3.5 Tubing Guide Installation

Following the installation and cutting of the casing, an operational challenge was encountered with the tubing guide. The original design, which incorporated square edges, restricted the passage of the coiled tubing and prevented the bottom-hole assembly (BHA) from entering the wellbore. As a result, a modification to the tubing guide was required. The removal, adjustment, and reinstallation of the guide extended the operational schedule by approximately 24 hours, representing a notable period of non-productive time (NPT).

Once the tubing guide was modified to eliminate the sharp transitions, the obstruction was resolved, and five subsequent coiled tubing runs were successfully deployed without incident. This experience highlighted a key design consideration for future interventions: tubing guides should be manufactured with smoother geometries to reduce the likelihood of tool hang-ups and unnecessary delays.

Despite the setback, the incident also provided a positive outcome. The Western Energy crew refined and streamlined their blowout preventer (BOP) removal and reinstallation procedure during the modification process. These procedural improvements are expected to enhance operational efficiency in future geothermal coiled tubing workover campaigns.

2.3.6 Milling Shoe Track

The final phase of the intervention focused on shoe track milling and cleanout operations to re-establish full well access below the newly installed casing. A total of four milling runs and one wash run were conducted, utilizing a combination of tricones, junk mills, and wash nozzles. These operations successfully extended drift to

approximately 908 m, restoring access to the deeper sections of the well and confirming the effectiveness of the casing and cement placement.

To support these downhole activities, careful attention was given to circulation and water management. Returns from the well were directed to the pond where water from the well first being held before pumped to the shale shaker and solids were separated. The fluid then pumped to pass through two twin filter pods for secondary filtration, ensuring that clean water was consistently available for pumping. This two-stage filtration system was critical for preventing debris from re-entering the wellbore and obstructing the BHA during milling as well as conserve the water and avoiding the overflow of the pond during mill out, thereby enhancing operational efficiency and reducing the risk of tool damage.

2.4 Operational Adjustments

2.4.1 Master Valve Change

During the operation, residual cement was discovered in the well's master valve, necessitating an unplanned replacement of the valve. While this adjustment represented only a minor modification to the programme, it nonetheless introduced additional time and cost to the overall workover. Such unplanned scope changes, even when relatively small, highlight the importance of preventive measures to reduce avoidable downtime and expenditure.

Two lessons were identified to minimize the likelihood of similar issues in future campaigns: (i) the implementation of more comprehensive post-cementing wash-up procedures to ensure that cement residues are fully cleared from the wellhead equipment, and (ii) inspection and cleaning of the master valve prior to tubing guide installation to verify that all sealing surfaces and internal components are free from debris. By integrating these measures into standard practice, the risk of valve-related delays can be significantly reduced.

2.4.2 Coil Fatigue

A general rule of thumb in coiled tubing operations is that when fatigue accumulates repeatedly at the same location on the coil, the affected section should be removed and the fatigue point relocated. This is typically applied when the fatigue level reaches approximately 15% at a single spot, in order to prevent localized weakening that could compromise coil integrity. In this intervention, however, the coiled tubing string was relatively new, and the 15% fatigue threshold was assessed as tolerable without requiring cut-and-slip.

It is important to distinguish this from cases where the coil approaches higher fatigue levels, on the order of 80% of the maximum allowable yield limit. At such elevated fatigue levels, continued operation is not acceptable, as the probability of coil failure becomes unacceptably high. In those situations, cutting the coil and relocating the fatigue point, or retiring the string altogether, becomes mandatory to maintain safe operating margins.

3 LESSON LEARNT

The planning effort required for this project was extensive, totalling more than 900 preparation hours. In New Zealand, manpower resources are typically calculated on an hourly basis for specific projects, which highlights the significant level of investment required in this case. While future operations of a similar nature are unlikely to demand such extensive planning, the incorporation of lessons learnt from this campaign will streamline the process. Measures such as holding biweekly coordination meetings and maintaining a shared action tracker proved highly effective in keeping the project on schedule and ensuring accountability across teams.

This workover also marked the first full-scale deployment of Western Energy’s newly invested equipment spread, including the high-capacity coiled tubing unit (HCCTU). As expected, the crew required additional time to familiarize themselves with the sequence of operations, particularly the rig-up of the coiled tubing system. Mobilization was budgeted at three days, but the actual requirement extended to four and a half days due to the learning curve and site-specific constraints.



Figure 4. The above picture shows the actual layout of the spread with the cement pumping unit and bulker onsite.

A key improvement identified to enhance future rig-up efficiency is the use of dedicated transport baskets for equipment, as well as transporting the BOP directly within the CRF substructure. Furthermore, it was noted that mobilization should prioritize moving the CRF to the site in the early stages, rather than bringing all equipment simultaneously. By staggering the mobilization sequence in this way, delays can be minimized and rig-up operations made more efficient.

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