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Coiled Tubing Hammer Live Well Cleanouts: Journey from Experimental to Proven Routine Maintenance Technology

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ABSTRACT

Wellbore scaling remains a persistent challenge in geothermal operations, often leading to reduced well productivity and costly interventions. Traditionally, small workover rigs were deployed to mechanically remove wellbore scales, but this approach incurred significant downtime, higher operational risk and expense. In response, Contact Energy Limited (CEL), in collaboration with Western Energy Services (WES), initiated an experimental program in 2016 to adapt coiled tubing (CT), commonly used in oil and gas, for geothermal well interventions. A key innovation was the refinement of the Live Well Cleanout (LWC) technology and the development of Coiled Tubing Hammer (CTH) - a percussive downhole tool designed to operate under high-temperature and live-flowing conditions. From 2016 to first half of 2025, CEL & WES transitioned from trial-based applications to the routine implementation of LWCs, completing a total 71 operations with the CTH tool used in 66 operations. This paper reviews the evolution of CT interventions, evaluates performance data, and demonstrates how this approach has become a cost-effective, low-downtime and routine solution for maintaining geothermal well productivity.

1 INTRODUCTION

Mineral scaling within the wellbore causes flow impairment, and production/reinjection capacity decline, directly impeding the ability to sustain targeted megawatt (MWe) generation levels. For production wells, the flashing of superheated water to steam and cooling of hot water causes calcium carbonate, more commonly known as Calcite, to be formed and deposited. For reinjection wells, the cooling of brine when injected downhole causes silica scales to be formed and deposited. The scales commonly encountered in geothermal wells are calcite, amorphous silica, quartz, and traces of sulphides and clay-based minerals. If left unmanaged, scaling can restrict flow paths, reduce well output, and ultimately lead to premature well failure. Table 1 presents an actual composition of a scale obtained from a geothermal reinjection well tested using X-ray diffraction (XRD).

Table 1. Quantitative XRD Analysis report on mineral percentage for a scale sample obtained from a production well in New Zealand.

Chemical Formula	Common name	Abundance
$CaCO_3$	Calcite	99%
SiO_2	Quartz	1%

Until the early 1990's, geothermal wells had been worked over using drilling rigs. However, the increasing cost of such operations, coupled with the associated lost production downtime, has rendered some wells uneconomical to clean. Consequently, such wells are left idle or operated at minimal production levels. Due to this challenge, Contact Energy (CEL) and Western Energy (WES) have researched, developed, trialled, and implemented wireline and intervention techniques to reduce if not remove calcite scale in the wellbore (Wilson et al., 2015). This Paper reviews the development and implementation of a multi-phase experimental approach aimed at restoring and maintaining well productivity in the Ohaaki and Wairakei geothermal fields.

2 EXPERIMENTAL PHASE (2013 – 2016)

The experimental programme, conducted between 2013 and 2016, was structured into distinct phases to evaluate and optimise various scale removal techniques. Each phase built upon the lessons of the previous, advancing from mechanical wireline broaching to more robust and versatile coiled tubing cleanouts.

2.1 Phase 1: Wireline Broaching

Broaching is a mechanical wellbore cleaning technique traditionally used in the oil and gas industry to remove soft debris, wax, or fill material from production tubing or casing. The technique involves running a series of specially designed broach tools using wireline (slickline) to mechanically loosen and remove deposits inside a wellbore. Typically, broaching starts with small diameter tools then transitions to bigger diameter tools compatible with the internal diameter of the casing. Its simplicity, cost effectiveness, and capability in cleaning localized obstructions made it a preferred approach in well interventions.

In geothermal applications, broaching has been adapted to address mineral scale deposits due to high-temperature and silica-rich fluids. It has been historically performed in Yangbajing and Lihir. The earliest attempt by CEL and WES to trial broaching was at a well in the Ohaaki geothermal field in the early 2000's.

In 2013, CEL and WES enhanced broaching technology through modifying it for application in high-temperature, larger-casing geothermal wells. Figure 1 shows the net generation at Ohaaki before and after the first three successful broaching jobs in May 2013.

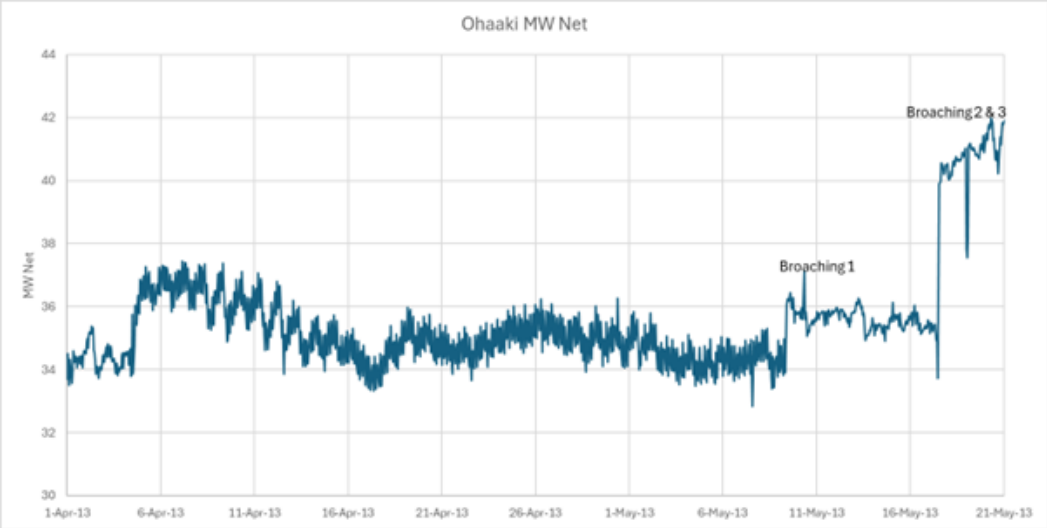


Figure 1: Increase in Ohaaki Net Generation after Three Broaching Jobs in 2013.

CEL and WES have successfully applied broaching to 14 wells with total production recovery of over 22 MWe at less than half the cost of conventional drill rig-based workover. The most significant advantage of broaching was its ability to reinstate wells that would otherwise be financially impractical to workover using a drill rig.

In addition, broaching is a better wellbore gauge tool to use instead of running typical go-devils since it has jarring capabilities. When a blockage is tagged, a jarring motion can be applied and pass through the obstruction if it is soft scale. It has been used as a routine diagnostic tool to run prior to coiled tubing and rig-based interventions.

However, broaching has limitations that affect its overall effectiveness and cost efficiency. Since the well must be shut during the operation, it results in production downtime and associated opportunity costs, especially for high-output wells. The process also relies on mechanical weight and gravity for debris removal, meaning not all scale debris materials are lifted out. Residual debris may settle in lower sections of the well, restricting flow and reducing the long-term benefit of the intervention.

Broaching is most effective when performed regularly on newly formed or soft scale deposits. Once the scale hardens, such as in the case of old silica or calcite buildup, the tool's scraping capability becomes limited, requiring repeated interventions to maintain well performance. For wells that are completely blocked or contain thick, hardened deposits, broaching is often ineffective or impractical, as there is a high risk of tool sticking or cable damage.

Furthermore, broaching does not guarantee complete cleaning of the scaled interval. The tool may only reach specific sections of the wellbore, leaving behind scale residues that can serve as nucleation sites for new deposits. These limitations make broaching suitable mainly as a short-term or preventative maintenance option rather than a comprehensive well productivity recovery technique.

While broaching has proven to be a valuable and cost-effective method for restoring partial well productivity, its limitations - in dealing with hardened or extensive scale deposits - highlight the need for more robust intervention techniques. To address wells with more severe blockages or where broaching is ineffective, CEL and WES progressed to the next stage of development: coiled tubing cleanouts.

2.2 Phase 2: Coiled Tubing Cleanout

Coiled tubing (CT) is a continuous, small-diameter steel pipe, typically between 1.00 to 3.25 inches in outer diameter, wound onto a large spool for deployment. First introduced in the oil and gas industry in the 1960s, CT offered a flexible, cost-effective alternative to conventional jointed pipes. Traditionally, CT was used for well interventions such as acid stimulation, nitrogen lifting and wax/paraffin cleanouts without requiring the well to be shut.

Over time, coiled tubing has evolved to support more complex operations such as milling, drilling, and hydraulic fracturing, driven by industrial improvements in metallurgy, surface equipment, and downhole tools. These developments have made CT a critical tool for modern oil and gas interventions.

In the geothermal context, CEL first explored coiled tubing cleanout technology in the early 1990s, adapting a jet washing technique originally developed for the Salton Sea geothermal field (McClatchie & Verity, 2000). However, early trials in New Zealand yielded mixed results, and since rig-based cleanouts remained relatively cost-effective at the time, the approach did not gain lasting adoption.

Compared to broaching, coiled tubing cleanout offers greater mechanical force, fluid circulation, and flexibility, making it more suitable for more complex well conditions. These attributes made CT particularly suitable for wells with hardened or extensive scale deposits that could not be effectively addressed through broaching alone. The following sections detail the evolution of CEL and WES's coiled tubing cleanouts history, beginning with early field trials, followed by validation and optimisation efforts, and culminating in the integration of CT cleanouts into routine well maintenance strategies.

3 EARLY TRIALS (2016 - 2017)

The earliest known documentation of live well cleanouts in geothermal within the past three decades was presented by Molina (1995), who reported that the method has been developed in Iceland over a period of 25 years. The method utilised a drill rig with jointed pipes to mechanically remove scale deposits while the well remained flowing to the silencer. According to Molina (1995), scale removal under flowing conditions proved more effective than when the well was kept quenched through cold-water injection. Subsequent papers by Thorhallsson (2003) and Pereira (2014) further supported the advantages of performing wellbore cleaning operations under flowing conditions. Thorhallsson (2003) concluded that "the best way to extend the life of geothermal wells and minimise maintenance and costly repairs is to allow the wells to flow continuously, thereby avoiding thermal cycling."

Drawing on the success of coiled tubing (CT) in oil and gas operations, its potential for geothermal applications became more reasonable. However, adapting CT for geothermal environments required overcoming significant technical challenges, particularly those associated with high-temperature, high mass flows, and tool durability. The following section details the various CT downhole tools trialled in CEL well interventions:

3.1 Variable Vane Type Motor (MacDrill)

The first downhole tool identified to be used for WES coiled tubing interventions on CEL wells is a variable vane type motor called the MacDrill. During that time, it was the only available tool that can handle >260 °C temperatures for mechanical clearing of wellbore scales. Based on Wilson & Anderson 2021, there were in total 6 wells were worked-over (one well twice) with the MacDrill, and there was complete success in 2, partial success in 3, and 1 was a complete failure.

Although successful in multiple wells with apparent soft scale, the limited motor life resulted in inadequate performance for harder scale and extended milling operations. Despite partial success in total of 6 well operations, both CEL and WES retained a clear appetite for innovation, fuelling a path to broader thinking and

design alterations. The technology has been utilised to clean out production and reinjection wells to a diameter of 14.5" ID (16" casing) and depths of up to 3000m.

3.2 High Temperature Motor (CTM)

The next tool identified was a high temperature motor from an international supplier. These motors are specialized downhole tools designed to operate reliably in the thermal environment of geothermal wells.

Conventional motors designed for oil and gas applications typically fail at temperatures above 175°C due to elastomer degradation and loss of mechanical strength in stator materials. In contrast, geothermal-grade motors are constructed using high-temperature elastomers and metal-to-metal stator configurations to withstand continuous exposure to hot, corrosive brines.

These CTMs function by converting hydraulic energy from the circulating fluid into rotational motion that mechanically removes mineral scale deposits from wellbore casings and liners.

3.3 Coiled Tubing Hammer (CTH)

Percussion drills are successfully used for drilling hard rock, the same principle is used with the CTH tool. The CTH (coil tubing hammer) was developed to crack or shatter the hard abrasive well bore scale. Rather than a rotary scraping, cutting method, that can damage the valuable well bore casing.

Inside the motor body of the CTH, is an oscillating piston that when engaged strikes a cutting bit. The face of the bit has various designs of cutting structure for different types of well bore scale. In operation, compressed gas is pumped down the work string. Upon reaching the hammer, the gas drives the piston into rapid oscillation. Each downward stroke of the piston strikes the bit, transferring percussive energy to the scale below. This action fractures the material by exceeding its tensile strength while preserving its crystal structure. Once broken into smaller fragments, the material is transported to the surface by the upward annular well flow between the external of the coiled tubing string and the internal of the wellbore.

From July 2016 to December 2017, WES and CEL successfully implemented the CTM on 5 wells and CTH on 8 wells. These interventions recovered a total of 16 MWe of generation output.

4 VALIDATION AND OPTIMISATION (2018 - 2019)

From 2018 to 2019 marked the validation and optimisation phase on the implementation of coiled tubing live well cleanouts on CEL wells. Driven by the early trials' challenges and lessons learned about the downhole tools (CTM and CTH) and wellbore conditions (depth, temperature, pressure), WES and CEL were able to undertake improvements in the overall job planning and execution. These enabled a creation of structured approach to well intervention projects including:

- Strong technical collaboration between Operator and Contractor in engineering planning:
    - Well data review and technology assessment: reviewing of well data and operational history to determine the root cause of performance decline and attribution to mineral scaling, suitability of live well cleanout and performing coiled tubing simulations.
    - Surface facilities engineering: reviewing of wellhead condition, cellar, steamfield pipe and facilities and flowback systems such as atmospheric flash tank "silencer".
- Wireline diagnostics: to gather more data about the wellbore.
- Bottom Hole Assembly (BHA): selecting a BHA with appropriate hammer and bit size for the wellbore and its conditions.
- Execution: implementation of the cleanout program. Includes real-time monitoring of coil speed, pressures, and weights; flowback monitoring where applicable.
- Post-job evaluation: comparing pre- and post-cleanout performance metrics. Post-cleanout performance data includes determination of scale column length and % recovery in terms of total mass flow.

From May 2018 to July 2019, CEL successfully cleaned out 1 reinjection and 9 production wells using the CTH, and gained back 48.2 MWe of generation at only a fraction of the cost of a traditional rig-based workover. These

successful cleanouts demonstrated the technical and economic viability of coiled tubing interventions, setting the stage for their broader adoption across CEL's geothermal operations.

5 INTEGRATION INTO WELL MAINTENANCE PRACTICE (2020 - PRESENT)

Since 2020, Coiled Tubing (CT) live well cleanouts have become a core component of CEL's routine well maintenance strategy, guided by clear planning and informed decision-making. The process begins with regular reviews of available geothermal fuel and generation forecasts, which help establish a baseline for expected output (Figure 2). These reviews are aligned with financial year planning to anticipate the number of interventions works required, to maximise station fuelling.

A preliminary schedule of anticipated CT works is developed annually providing a forward view of expected activity across the field. This schedule helps align resources, both from CEL and WES, well in advance.

By forecasting generation targets, CEL can proactively identify wells that may need CT intervention to maintain performance. Early analysis is carried out to assess production and injection trends across the field, focusing on wells showing signs of decline. This includes evaluating historical performance, blockage growth, and the time since the last intervention. Wells showing initial signs of significant scaling in the wellbore are flagged for potential CT work, with the goal of sustaining optimal production within operational limits.

This forward-looking planning helps ensure CT work is proactive rather than reactive, and is well coordinated with WES to align activities across both companies.

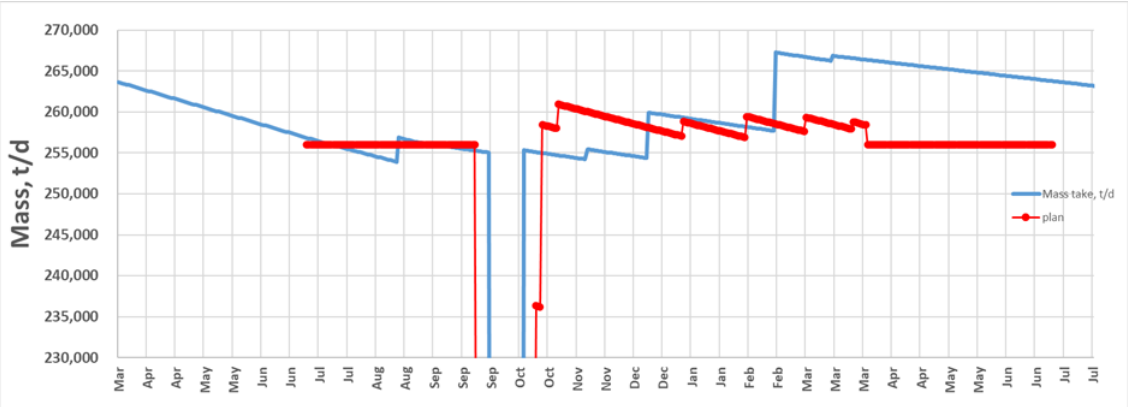


Figure 2: Generation Plan and Fuel Forecast.

Once candidate wells are identified, CEL conducts a detailed technical assessment to define the scope and method of intervention. This includes evaluating the nature of the blockage and outcomes from previous cleanings. Wells with soft scale or minor obstructions may be scheduled for broaching, while those with more severe or recurring issues may require a live well cleanout using CTH. Each intervention is tailored to the well's condition to ensure efficient use of resources and minimize downtime.

CT activities are also coordinated with drilling, steamfield operations and WES to optimize resource utilization. Post-intervention performance is tracked to validate the effectiveness of the cleaning method and inform future planning. Lessons learned from each CT job are captured in CEL's maintenance database, strengthening predictive capabilities for future interventions.

Over time, this systematic and proactive approach has proven effective in sustaining generation levels and improving overall field reliability.

5.1 Iterative Planning and Adaptive Scheduling

CEL's approach to CT live well cleanouts planning is iterative, allowing for adjustments as new information becomes available. Figure 2 is a living document that evolve throughout the year. This flexibility ensures that CEL can respond effectively to changing operational and market conditions.

Electricity prices directly influence generation targets, and the prioritization of intervention works. If market prices shift significantly, the generation forecast (Figure 2) is recalibrated to reflect revised output expectations. This, in turn, affects which wells are prioritized for CT intervention.

Unplanned outages and resource constraints also play a critical role. For example, delays in steamfield availability, drilling personnel, or Western Energy Services manpower and/or equipment may require rescheduling or re-sequencing of planned CT works. These constraints are continuously monitored, and the intervention scheduling is updated to reflect the most current understanding of field readiness and resource alignment.

To support this dynamic planning process, Figure 3 illustrates CEL's adaptive CT intervention cycle. It shows how inputs such as market signals, operational disruptions, and resource availability feed into ongoing updates to both the generation forecast and intervention schedule. This iterative approach has enabled CEL to embed CT interventions into its long-term well maintenance strategy, ensuring sustained generation and improved fuel reliability.

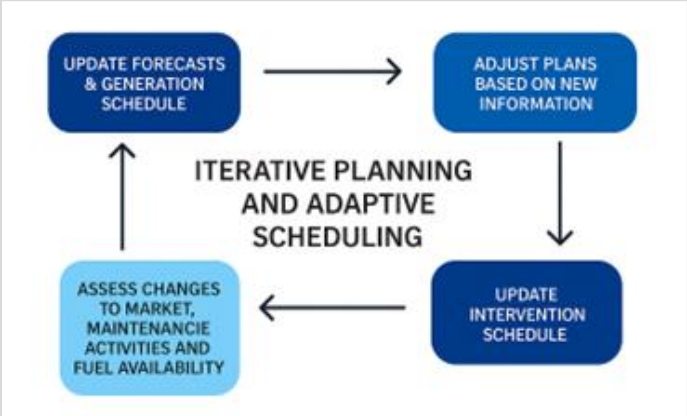


Figure 3: Planning and Scheduling Workflow.

6 RESULTS AND IMPACT

Between July 2016 to June 2025, CEL and WES completed 71 live well cleanouts. The field results are summarised in Table 2. The analysis of Live Well Cleanout (LWC) interventions from 2016 to the second half of 2025 reveals a clear progression in both strategy and effectiveness. Figure 4 shows that in the early years, specifically 2016 and 2017, MWe gains were relatively low. This is consistent with the exploratory and trial nature of interventions during this period, where the primary focus was on testing tools, refining techniques, and understanding the scaling challenges specific to each well. These foundational efforts laid the groundwork for more impactful interventions in subsequent years.

A significant turning point occurred in 2018, where MWe gain peaked. This illustrates that by this stage, CEL and WES had successfully validated and optimised their coiled tubing cleanout techniques. The high return on fewer interventions in 2019 indicates improved targeting, better understanding of well conditions, and more effective execution. Years 2018 to 2019 served as a benchmark, demonstrating how well-planned and technically sound interventions can achieve significant generation recovery.

From 2020 onwards, the data shows a sustained level of MWe gain, even as the number of interventions varied year by year. This trend reflects a shift from reactive to proactive maintenance, where interventions were not only technically refined but also strategically timed. The consistent gains suggest that CEL and WES developed a reliable intervention framework, allowing them to anticipate well decline and act before severe scaling or blockages occurred. This proactive approach helped maintain generation capacity and reduced the risk of wells becoming fully nonproductive before intervention could be performed.

Figure 5 overlays MWe gain with electricity price trends, underscoring the importance of timing. Interventions that coincided with higher electricity prices - such as those in early 2022 and late 2024 - delivered greater economic value. By avoiding prolonged periods where wells contributed zero output, and aligning cleanouts with favourable market conditions, CEL managed to maximise revenue while minimising opportunity costs. A key opportunity cost saving is the avoidance of rig workover-based quenching and heat-up, which typically incurs between 5 to 21 days of downtime when a production well is cut-out from system.

Finally, the data suggests that anticipating well decline is critical for maintaining output and reducing the duration and cost of outages. Wells that are allowed to fully scale over or block require longer, more complex interventions - often with diminishing returns. In contrast, timely interventions preserve well integrity and reduce

the need for extensive cleanouts. This balance between MWe gain and downtime cost is essential for sustaining geothermal generation in a cost-effective and operationally efficient manner.

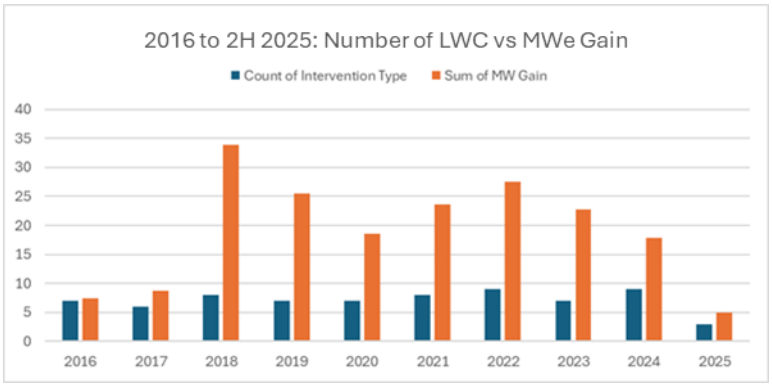


Figure 4: Total Number of LWC per year vs Total MWe gained from 2016 to 2H 2025.

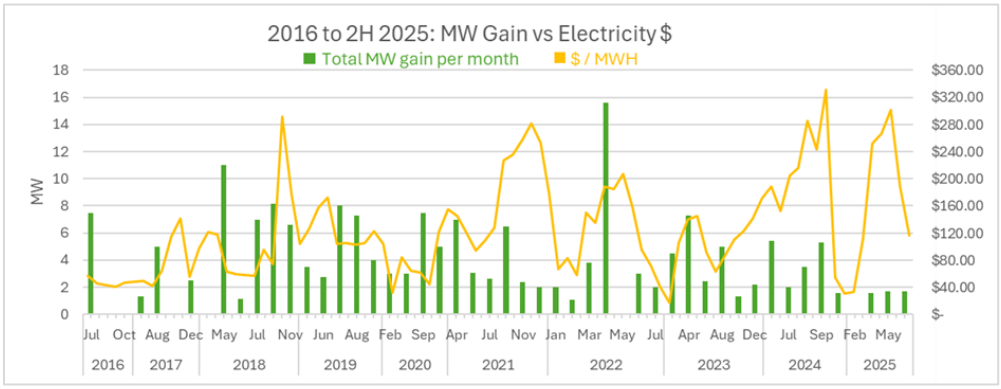


Figure 5: Total MWe gained and Electricity price (NZD) from 2016 to 2H 2025.

Of the 71 well cleanouts, notable wells are the following:

- Well A is a production well in the Wairakei geothermal field. Since 2019, it has undergone 6 live well cleanouts (Cleanout No. 24, 36, 48, 53, 62 and 71). All of these cleanouts had a 100% recovery. Live well cleanout in Well A is being used as a routine intervention activity.

- Well B is a dry steam production well in the Wairakei geothermal field. In 2023, this well had zero flow. Live well cleanout was done on this well in 2024 (Cleanout No. 65) together with a low emission, compact muffle (LECM) as a temporary silencer, resulting in a 233% recovery and a 3.5 MWe gain.

- Well C is a production well in the Ohaaki geothermal field. This well had a rig cleanout in 2011. In 2014, a mechanical clean out was done utilising the MacDrill which resulted in a 100% recovery. In 2016, a coiled tubing hammer (Cleanout No. 5) was attempted but caused severe internal erosion. A motor had to be brought in for a quenched cleanout on coil (Wilson & Anderson, 2021). The well was offline for 2 weeks to allow it to heat up after the quenching and there was 0% production recovery. In 2019, a coil tubing hammer (Cleanout No. 23) was completed that cleaned out 264 m of scale and provided 100% production recovery. In 2022, another live well cleanout was done (Cleanout No. 45). Pre-works included broaching and an XY Caliper survey; this survey indicated a cumulative scale build-up of 6.46 m^3 throughout the entire wellbore, with approximately 4.5 m^3 in the liner section between 1150m and 2150 m. This cleanout was a success with 900 m of scale removed and a 100% production recovery.

Table 2: Field Results of the 71 Live Well Cleanouts on Contact Energy Wells from 2016 to 2H 2025.

Cleanout	Month & Year	Well Usage	Job Type	Meters of scale	Liner size, inches	Scale Type	%Recovery in total mass flow
1	Jul 2016	Production	Milling	50	7"	Calcite	55%
2	Jul 2016	Production	Hammer	78	7"	Calcite	100%
3	Jul 2016	Reinjection	Hammer	70	7-5/8"	Silica	0%
4	Aug 2016	Production	Hammer	N A	7"	Calcite	0
5	Oct 2016	Production	Hammer	N A	7"	Calcite	0%
6	Oct 2016	Production	Milling	0	10-3/4"	unknown	0%
7	Oct 2016	Production	Milling	0	10 3/4"	Calcite	0%
8	Jul 2017	Reinjection	Hammer	257	6-5/8"	Silica	100%
9	Aug 2017	Production	Hammer	50	6 5/8"	Calcite	50%
10	Aug 2017	Production	Hammer	120	6 5/8"	Calcite	100%
11	Nov 2017	Production	Milling	55	7"	Calcite	69%
12	Dec 2017	Production	Hammer	N A	7"	Calcite	0
13	Dec 2017	Production	Milling	10	7"	Calcite	85%
14	Feb 2018	Production	Hammer	N A	10 3/4"	Calcite	0%
15	May 2018	Production	Hammer	49	10 3/4"	Calcite	100%
16	Jun 2018	Reinjection	Hammer	825	6-5/8"	Silica	40%
17	Jul 2018	Production	Hammer	50	6 5/8"	Calcite	100%
18	Jul 2018	Production	Hammer	21	6 5/8"	Calcite	75%
20	Aug 2018	Production	Hammer	88	6 5/8"	Calcite	100%
19	Aug 2018	Production	Hammer	99	7"	Calcite	100%
21	Nov 2018	Production	Hammer	33	7"	Calcite	100%
22	May 2019	Production	Hammer	222	10 3/4"	Calcite	100%
23	Jun 2019	Production	Hammer	264	7"	Calcite	100%
24	Jul 2019	Production	Hammer	112	7"	Calcite	100%
25	Jul 2019	Production	Hammer	152	9-5/8"	Calcite	100%
26	Aug 2019	Production	Hammer	588	7"	Calcite	100%
27	Aug 2019	Production	Hammer	629	10-3/4"	Calcite	100%
28	Dec 2019	Production	Hammer	110	10-3/4"	unknown	100%
29	Feb 2020	Production	Hammer	277	7-5/8"	Calcite	100%
30	Aug 2020	Production	Hammer	182	6 5/8"	Calcite	120%
31	Sep 2020	Production	Hammer	133	6 5/8"	Calcite	63%
32	Sep 2020	Production	Hammer	565	7"	Calcite	100%
33	Sep 2020	Production	Hammer	68	7"	Calcite	40%
34	Sep 2020	Production	Hammer	277	7-5/8"	Calcite	60%
35	Nov 2020	Production	Hammer	458	10-3/4"	Calcite	110%
36	May 2021	Production	Hammer	125	7"	Calcite	100%
37	Apr 2021	Production	Hammer	70	6 5/8"	Calcite	100%
38	Apr 2021	Production	Hammer	81	7-5/8"	Calcite	100%
39	Jul 2021	Production	Hammer	63	6 5/8"	Calcite	55%
40	Jul 2021	Production	Hammer	37	10-3/4"	Calcite	85%
41	Sep 2021	Production	Hammer	255	10-3/4"	Calcite	100%
42	Nov 2021	Production	Hammer	200	7"	Calcite	119%
43	Dec 2021	Production	Hammer	345	7"	Calcite	100%
44	Jan 2022	Production	Hammer	120	7"	Calcite	100%
45	Feb 2022	Production	Hammer	900	7"	Calcite	100%
46	Mar 2022	Production	Hammer	160	10-3/4"	Calcite	100%
47	Apr 2022	Production	Hammer	145	7"	Calcite	100%
48	Apr 2022	Production	Hammer	210	7"	Calcite	100%
49	Apr 2022	Production	Hammer	185	6 5/8"	Calcite	100%
50	May 2022	Production	Hammer	29	6 5/8"	Calcite	0
51	Jun 2022	Production	Milling + Hammer	62	6 5/8"	Calcite	100%
52	Jul 2022	Production	Milling + Hammer	258	6 5/8"	Calcite	100%
53	Mar 2023	Production	Hammer	415	7"	Calcite	100%
54	Mar 2023	Production	Milling + Hammer	164	7-5/8"	Calcite	100%
55	Apr 2023	Production	Hammer	82	10-3/4"	Calcite	126%
56	Jul 2023	Production	Hammer	106	9-5/8"	Calcite	100%
57	Aug 2023	Production	Hammer	97	6 5/8"	Calcite	100%
58	Oct 2023	Production	Hammer	120	7"	Calcite	79%
59	Dec 2023	Production	Hammer	25	6 5/8"	Calcite	100%
60	Mar 2024	Production	Hammer	70	7-5/8"	Calcite	100%
61	Mar 2024	Production	Hammer	260	7"	Calcite	100%
62	Mar 2024	Production	Hammer	123	7"	Calcite	100%
63	Mar 2024	Production	Hammer	60	7"	Calcite	100%
64	Jul 2024	Production	Hammer	234	7-5/8"	Calcite	100%
65	Aug 2024	Production	Hammer	108	9-5/8"	Calcite	233%
66	Sep 2024	Production	Hammer	9	9-5/8"	Calcite	77%
67	Sep 2024	Production	Hammer	56	6 5/8"	Calcite	63%
68	Mar 2024	Production	Hammer	96	10-3/4"	Calcite	100%
69	Mar 2025	Production	Hammer	211	7"	Calcite	100%
70	May 2025	Production	Hammer	177	7"	Calcite	100%
71	Jun 2025	Production	Hammer	50	10-3/4"	Calcite	100%

7 DISCUSSION

The progression from experimental trials to routine implementation of CT live well cleanouts by CEL and WES represented a decade-long evolution of innovation and continuous improvement in geothermal well maintenance.

The LWC technique has been applied to production wells about 95% of the time - 68 out the 71 cleanouts - as presented in Table 3. The success in using LWC mostly on production wells is due to the available upward wellbore flow that enables effective scale cuttings transport to surface. On the reinjection live well cleanouts, nitrogen was used to assist with transient well lifting and cuttings transport.

Additionally, CTH has been used in 66 operations, as shown in Table 4. Out of these 66 jobs, the CTH was used solely on 63 occurrences and was used in tandem with the CTM in only 3 occurrences.

Table 3: Total Number of LWCs based on Well Type.

Well Usage	Total Number of Cleanouts
Production Well	68
Reinjection Well	3

Table 4: Total Number of LWCs based on Job Type.

Job Type	Total Number of Cleanouts
Hammer using CTH	63
Milling using CTM	5
Combined (Hammer + Milling)	3

Table 5 summarizes the progressive improvement in well cleanout performance over the three phases. From the early trials in 2016 - 2017 with 43% average recovery, the technology advanced through validation and optimisation (2018 - 2019) achieving 88% success, and finally reached 95% average recovery as it became integrated to CEL maintenance practice from 2020 onward.

Table 5: Average %Recovery and Total Number of Cleanouts per Phase.

Phase	Years Covered	Average %Recovery in Total Mass Flow	Total Number of Cleanouts
Early trials	2016 - 2017	43%	13
Validation & Optimisation	2018 - 2019	88%	15
Integration to Maintenance Practice	2020 - Present	95%	43
Total		84%	71

The implication of the transition of CT LWC from experimental phase to routine maintenance practice reflects a broader cultural shift. From a reactive approach to forward-thinking and data-driven geothermal well maintenance.

WES has expanded the delivery of coiled tubing, live well cleanouts to geothermal clients in the United States (2019) using third-party CTU, Guatemala (2022), and in the Philippines (2024 - present) using client-owned CTUs.

These completed operations outside of New Zealand demonstrate the scalability in the application of the LWC technology to wells around the globe.

8 CONCLUSION

Western Energy's success in the refinement of the live well cleanout technology and application of the coiled tubing hammer (CTH) tool mark a significant milestone in geothermal well intervention technology. Through a decade of continuous innovation with Contact Energy, coiled tubing live well cleanouts have transformed from an experimental concept into a proven, routine maintenance practice.

The development journey from early trials with modest recovery of 43% to reliable 95% success rates demonstrate technological advancement and operational maturity. As of June 2025, Contact Energy and Western Energy have successfully implemented CT live well cleanout technology in 71 operations across geothermal wells in Wairakei and Ohaaki. For the recent decade, the technology recovered a total production capacity of 191 MWe. These operations were able to provide 84% recovery in total generation as overall average, 100% recovery in total generation at 68% of the time, and have proven to clean out scale column lengths of up to 900m.

The integration of CT interventions into regular maintenance routine helped Contact Energy proactively address wellbore mineral scaling before it leads to severe well impairment and higher generation losses. This approach transformed CT operations from being a reactive practice to a strategic maintenance solution while minimizing downtime, extending well useful life, and maintaining reliable steam supply.

Western Energy's successful and safe application of CTU in geothermal has supported its value as a cost efficient and technically robust solution for well maintenance. Its ability to operate under live well conditions, avoid quenching, and remove old hardened scales has consistently resulted in significant MWe recovery. CT interventions now represent a field-validated method of modern geothermal maintenance strategy. Beyond New Zealand, Western Energy has expanded the application of CT live well cleanouts to geothermal fields in the United States, Guatemala, and more recently in the Philippines, demonstrating its scalability and global relevance.

Western Energy is currently working on future tool enhancements, applications on barefoot completions, and additional CT operational data capture.

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