

SPE-224109-MS

Case History of Coiled Tubing Wellbore Scale Removal and Acidizing in High Temperature Geothermal Steam Producer Well with Fast Temperature Build Up Using Modified Acid Pumping Technique

H. Arstianti, R. Wijaya, A. Cahyono, D. Rochman, A. Terry, and K. Rahimov, Baker Hughes

Copyright 2025, Society of Petroleum Engineers DOI [10.2118/224109-MS](https://doi.org/10.2118/224109-MS)

This paper was prepared for presentation at the SPE/ICoTA Well Intervention Conference and Exhibition held in The Woodlands, Texas, USA, 25 - 26 March 2025.

This paper was selected for presentation by an SPE program committee following review of information contained in an abstract submitted by the author(s). Contents of the paper have not been reviewed by the Society of Petroleum Engineers and are subject to correction by the author(s). The material does not necessarily reflect any position of the Society of Petroleum Engineers, its officers, or members. Electronic reproduction, distribution, or storage of any part of this paper without the written consent of the Society of Petroleum Engineers is prohibited. Permission to reproduce in print is restricted to an abstract of not more than 300 words; illustrations may not be copied. The abstract must contain conspicuous acknowledgment of SPE copyright.

Abstract

WELL X, a prolific steam producer operated by a geothermal company in Sumatra, Indonesia, is completed with a 13.375-in casing and a 10.75-in perforated liner across the feed zone. Over time, scale buildup inside the wellbore and behind the perforated liner led to a decline in steam production. In January 2022, a workover operation successfully removed the scale, restoring the well to its previous production levels. However, by 2023—only a year later—scale buildup reoccurred, necessitating another cleanup. Due to challenges in securing a workover rig, a rigless scale removal operation using coiled tubing (CT) was chosen. The operator was cautious about using acid through the CT, given prior experiences of parted CT during similar operations.

WELL X exhibited a rapid temperature buildup, as observed during the PT survey conducted in September 2023, with a Bottomhole Static Temperature (BHST) of 566°F across the feed zone. No commercially available acid corrosion inhibitor could provide adequate corrosion protection for the acid required to remove the scale at such high temperatures. As a result, well quenching—cooling the wellbore by pumping cold fluid down the CT annulus—was necessary to safely pump the acid. The acid design factored in the reduced temperature from quenching and maintained sufficient acid strength to ensure effective scale removal. To maximize dissolution efficiency, quenching was halted during acid pumping on the CT backside, allowing the acid to react at its full strength within the feed zone.

The conventional approach to scale removal in geothermal wells using coiled tubing involves pumping acid down the coiled tubing while simultaneously quenching the well through the CT-casing annulus. This method helps maintain corrosion levels within acceptable limits for high-temperature wells during CT acid stimulation. However, the quenching process dilutes the acid, reducing its strength and effectiveness for scale dissolution.

The method described in this paper is innovative and specifically designed to eliminate acid dilution while improving acid strength for maximum effectiveness in the feed zone. The approach involved a coiled tubing wellbore cleanup operation utilizing a 2.875-in rotating jetting nozzle conveyed by a 2.375-in CT. This was followed by acid stimulation to effectively remove scale buildup behind the 10.75-in perforated liner.

Following the scale cleanup in the wellbore and acid stimulation to remove scale behind the perforated liner, the well was flow tested. The results showed a significant increase in steam production, with output reaching 2.5 times the level observed prior to the scale removal treatment. The coiled tubing operation was conducted safely, with no incidents were reported, addressing the operator's primary concern of potential coiled tubing failure based on past experiences.

The acid operation was performed as per plan. The corrosion inhibitor package performed as designed and more importantly the production from the feed zone was observed to be significantly increased post acid treatment.

The purpose of presenting this case history is to share insights and methodologies that can be applied to other geothermal wells. It highlights strategies to mitigate operational constraints, such as limited workover rig availability, by performing rigless scale cleanup operations to restore well production to its original levels.

Introduction

Geothermal energy plays a crucial role in the global energy sector, particularly in electricity generation, and is strategically important for renewable energy development and carbon footprint reduction. It has diverse applications, including industrial, agricultural, and district heating.

Geothermal energy is harnessed by drilling wells into hot reservoirs and extracting hot fluids (water in single or multiple phases) to capture the heat. High-temperature geothermal wells drive turbines that power electricity generators, while lower-temperature applications use heat exchangers to transfer energy to working fluids with a lower boiling point than water, typically in an Organic Rankine Cycle system. All condensed fluids from geothermal reservoirs are re-injected, creating a closed-loop system. Over time, this process leads to the accumulation of minerals such as silica, which are dissolved from the formation (D.W. McClatchie, 2020, p.1).

Scale formation in the wellbore reduces the cross-sectional fluid flow area (see Figure 1 for an example), resulting in a decrease in steam production. Therefore, applying the correct scale-removal solution is crucial.



Figure 1—Example of scaling in geothermal wellbore (source: <https://geo40.com/geothermal-innovation/>)

The two common types of scale found in geothermal wells are calcite and silicate, both of which can be removed using various acid treatments, including acetic acid, hydrochloric acid (HCl), and a combination of HCl and hydrofluoric acid (HF). The appropriate acid type and concentration are determined through scale solubility tests conducted in the laboratory. In cases of thick scale, mechanical reaming is typically required before acid treatment for effective scale removal. Several methods have been used over the years for scale removal in geothermal wells, including chemical scale inhibitors, chemical dissolution, and mechanical techniques like broaching, milling, and rotating high-impact jetting nozzles.

Geothermal wells often operate at high bottomhole temperatures (BHT), typically exceeding 450°F, particularly in feed zones. The conventional method of scale removal using coiled tubing (CT) involves pumping water (well quenching) at high flow rates of 5–25-barrel per minute (bpm) through the CT-

casing annulus while running the CT. This cools the well down to within the temperature limits of pressure control equipment, downhole tools, and the acceptable corrosion limits during acid pumping. However, this quenching operation reduces the acid concentration by 50-80%, significantly weakening the acid's ability to effectively dissolve scale.

Well Intervention History

The well was drilled and brought into production in 2017 but experienced a significant decline in production by early 2019. Several interventions were performed to restore production levels. An initial wellbore cleanout using 1.75-in coiled tubing (CT) was conducted, but it did not result in a notable improvement in steam production. In early 2021, a flowing Pressure-Temperature Survey (PTS) revealed that 4 out of the 5 original active feed zones (FZs) were no longer productive, with only the shallowest feed zone which located at depth 6742 feet measurement depth (MD) still contributing. Geochemical analysis also indicated calcite oversaturation.

In early 2022, a wellbore cleanout and acidizing operation were performed using rig. A total of 505 barrels of 10% acetic acid were injected through bullhead method to address calcite scaling in the deepest major feed zones. This scale removal intervention operation resulted in an increase of +/- 2 times of steam production compared to pre-stimulation steam production, with improved permeability in the major feed zones compared to the original conditions. However, high production decline reappeared about a year after the acidizing treatment, suggesting that scaling had started to accumulate once again.

Challenge

High Temperature across feed zone area

During the shut-in period, the bottomhole temperature (BHT) across the feed zone can rise significantly, reaching up to approximately 566°F (see Fig. 2 for visual reference). A detailed analysis from a Pressure-Temperature Survey (PTS) conducted in 2021 revealed that at a quenching rate of 5-bpm, the wellbore temperature cooled from 566°F to 456°F at total depth (TD). The temperature profile of the well is shown in Fig. 3. When the quenching rate increased to 13-bpm, a more significant reduction in wellbore temperature was observed within the depths of 4500 to 6760 feet MD, where the temperature dropped to around 330°F. This demonstrates the relationship between quenching rate and wellbore temperature: higher quenching rates lead to a more substantial reduction in wellbore temperature, especially in the feed zone interval.

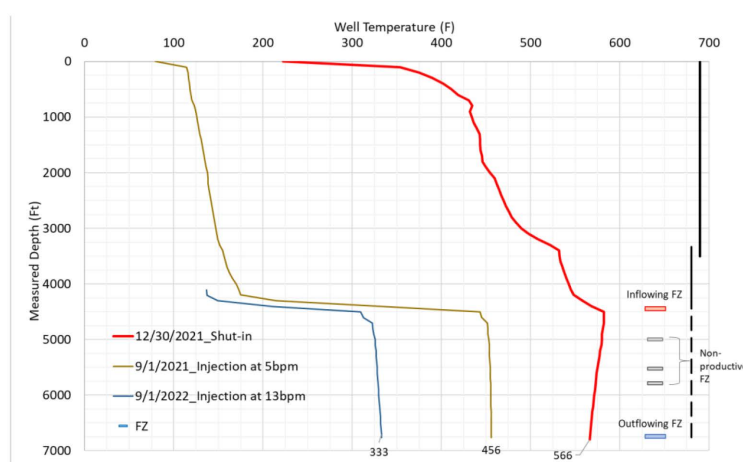


Figure 2—Well temperature profile 2021

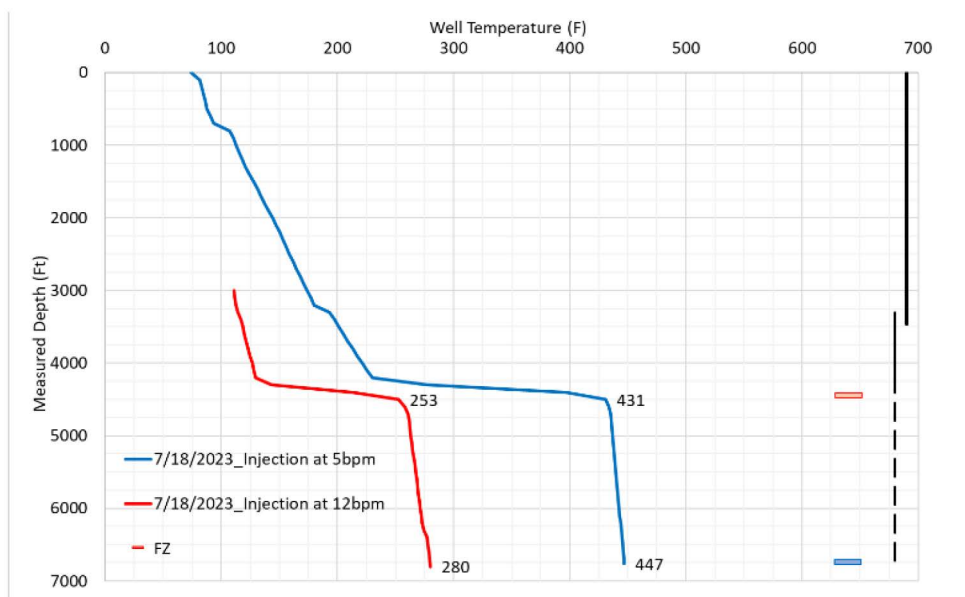


Figure 3—Well temperature profile 2023

In preparation for the coiled tubing (CT) acid job, a follow-up PTS run was conducted in September 2023 to confirm the current well profile (Fig. 3). At a quenching rate of 5-bpm, the wellbore temperature was reduced to 431–447°F in the depth range of approximately 4200 to 4500 feet MD. When the quenching rate increased to 12-bpm, the wellbore temperature (within the depth range of 4500 to 6760 feet MD) dropped further to around 280°F.

Fast Temperature Build Up

The well temperature build-up profile was recorded and analyzed (Fig. 4), showing clear temperature trends when the injection/quenching rate was reduced from 13-bpm to zero. Immediately after stopping the injection, the wellbore temperature increased steadily from 333°F to 350°F over the next 30 minutes. This gradual rise was followed by a more rapid escalation in temperature, which reached 475°F within 1.5 hours. This significant temperature increase is likely attributed to the shallowest feed zone, which appears to have responded quickly after the injection ceased.

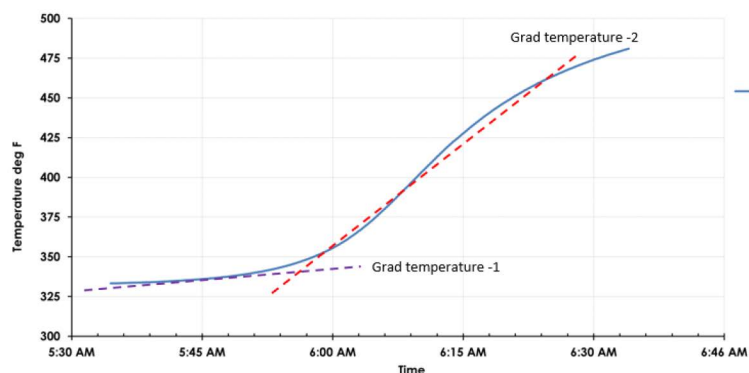


Figure 4—Well temperature build up profile

Large wellbore ID

This well features a large-bore completion, as shown in Fig. 5. It consists of a 13.375-in internal diameter (ID) casing extending from the surface to a depth of 3,500 feet measured depth (MD). Below this, a 10.75-in ID liner runs from 3,332 feet to 6,886 feet MD. One of the significant challenges in removing scale

from such a large completion is the considerable radial distance between the jetting port nozzle and the scale buildup on the 10.75-in casing, as well as behind the perforated liner. This radial distance reduces the effectiveness of the jetting action, potentially leading to inefficient scale cleanup. Additionally, when the coiled tubing (CT) downhole tool is deployed, it moves from the wider 13.375-in casing into the narrower 10.75-in casing, creating the risk of tagging the top of the liner (TOL), which could lead to complications during the operation.

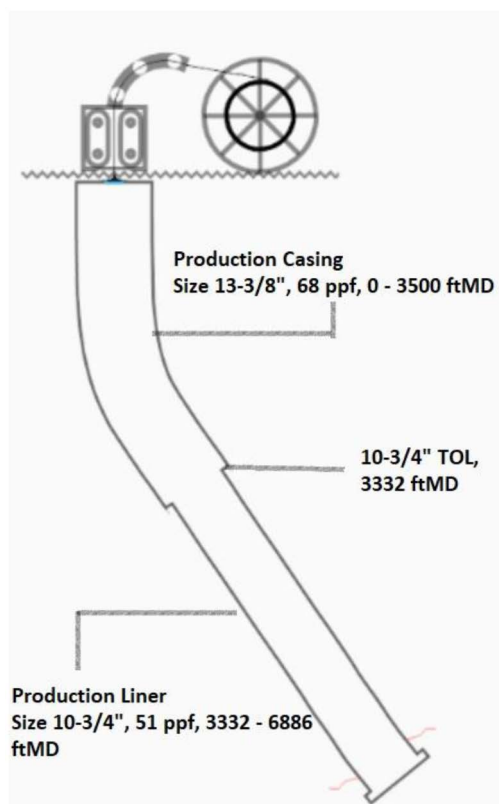


Figure 5—Completion profile

Method

CT Design

A large coiled tubing (CT) unit with a 2.375-in outer diameter (OD) and a length of 10,000 feet has been selected for this project to facilitate high-rate pumping. The choice of this relatively larger OD CT is essential because it allows for the higher pumping rates required to ensure the proper functioning of the rotary jetting tool and the effective removal of scale. The required pump rate for the rotating jetting nozzle is 3–3.5-bpm, while a static (non-rotating) nozzle requires a pump rate of 5-bpm.

In addition to supporting higher pump rates, the use of larger OD coiled tubing significantly reduces the risk of buckling when operating within large-diameter casings, compared to smaller CT options. It is important to note that substantial set-down weight can stall the tool's rotation. To address this issue, a simulation of the forces on the coiled tubing has been performed. This simulation predicts the run-in and pull-out weights that the equipment operator will encounter during the operation (see Fig. 6).

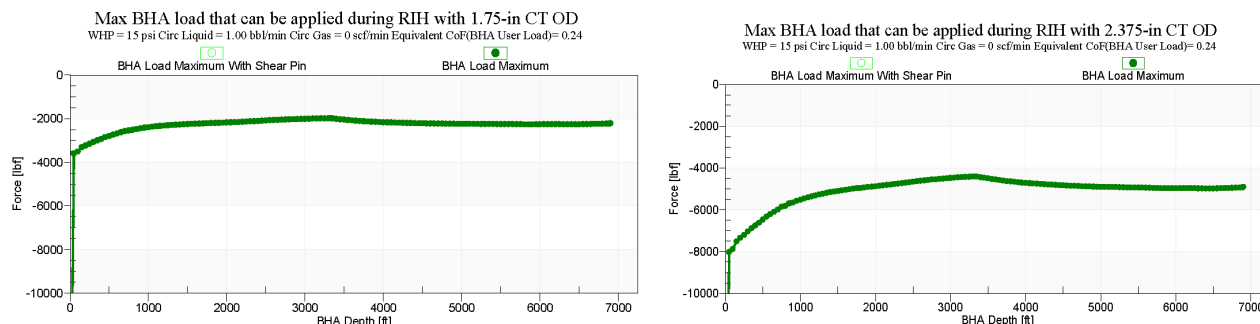


Figure 6—Comparison available WOB CT 1.75-in. OD VS CT OD 2.375-in. OD

BHA design

BHA Rotating Jetting Nozzle to remove scale inside the wellbore/completion.. The rotating jetting tool (Fig. 7) applies targeted, destructive stress cycling to downhole deposits. With each pass of the jet stream, surface cracks in the scale are briefly pressurized, inducing local tensile stress. This stress cycling occurs multiple times per second, causing the brittle scale to fracture into small particles that can be easily transported to the surface.

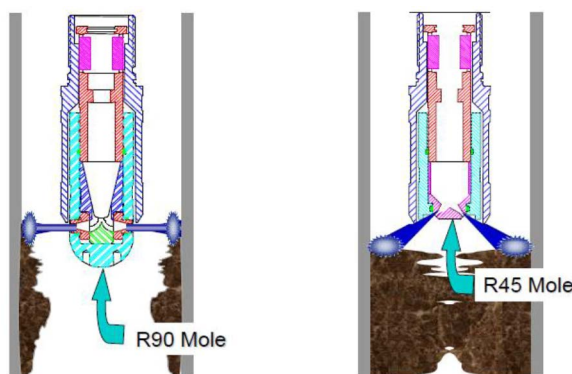


Figure 7—Jetting tool simulation illustration

In cases of thick scale buildup, the rotating jetting tool can be used following an initial run with a coiled tubing (CT) downhole motor and milling bit. The aggressive jetting action ensures full inside-diameter cleaning, including the completion jewelry profiles of varying geometries, without causing damage to the completion. The tool provides 360° coverage and achieves an optimal rotation speed.

Two different nozzle sizes are available for the rotating jetting tool: one is directed at a 45-degree angle (R45) to the tool axis, and the other is at 90 degrees (R90), perpendicular to the tool axis. The 90-degree side-jet nozzle offers the least standoff distance, generating the most jetting energy. However, side-jetting is less effective at cleaning directly in front of the tool. If cleaning in front of the tool is required, the 45-degree down-jet nozzle should be used. The 45-degree jetting tool, when run first, provides access to the wellbore, while the 90-degree tool cleans the remaining scale inside the completion that could not be broken by the 45-degree jetting tool.

Effective job design for the Rotating Jetting Nozzle tool in a geothermal well requires a thorough understanding of several factors, including the scale composition and hardness, the minimum deposit drift diameter, and the bottom-hole pressure (BHP) and temperature (BHT). Additionally, the type of well and environment (e.g., H₂S, CO₂ presence), the type of fluids to be pumped, and any debris or "junk" in the hole must be considered. Knowledge of the completion design, including depths, minimum restrictions,

wellbore internal diameter, and well surveys, is also critical. Coiled tubing injection pressure, along with the minimum and maximum flow rates and jetting impact pressure, must be accounted for as well.

The Bottom Hole Assembly (BHA) consists of a 2.875-in coiled tubing (CT) connector, 2.875-in motorhead assembly, 2.875-in downhole filter, and a 4.125-in rotating nozzle OD (Fig. 8). The rotating nozzle size is designed to pass through the top of the liner (TOL). The nozzle size is crucial when running coiled tubing in a geothermal well, as it determines whether the tool can pass the TOL. If the nozzle size is too small, there is an increased risk of the downhole tool tagging the TOL. Conversely, if the nozzle size is too large, it could lead to the risk of getting stuck.

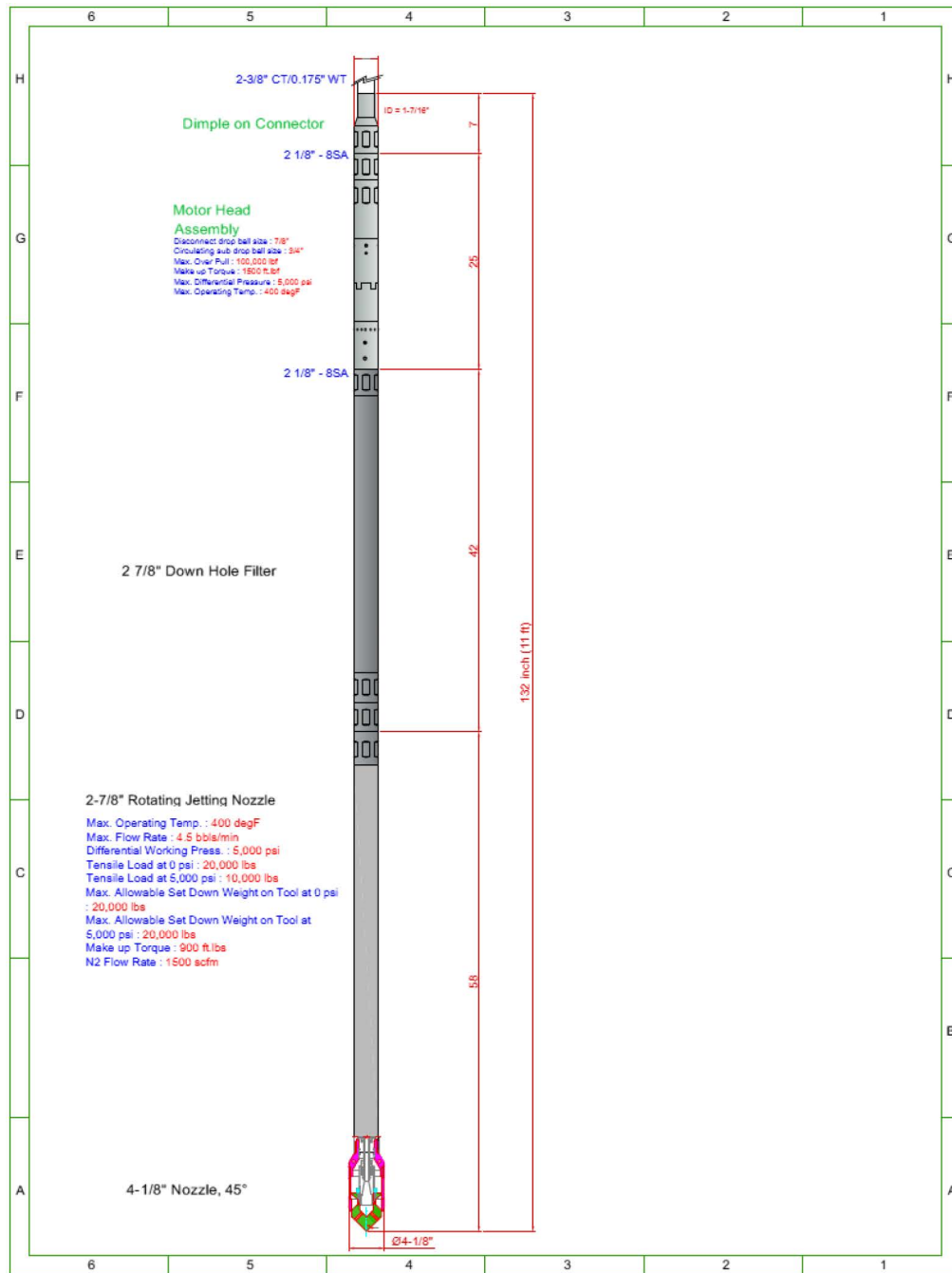


Figure 8—Rotating Jetting Tool Schematic

BHA Static (Non Rotating) Nozzle assembly to pumping acid at The Feed Zone interval. The static Bottom Hole Assembly (BHA) nozzle was selected for pumping acid to maximize the pumping rate, due to its lower pressure drop compared to the rotating jetting nozzle. The complete BHA assembly consists of several components: a 2.875-in coiled tubing (CT) connector, a 2.875-in motorhead assembly, a 2.875-in straight bar, and a 4-in OD static nozzle (Fig. 9). This 4-in static nozzle is specifically designed to navigate efficiently through the top of the liner (TOL), ensuring precise delivery of acid to the target feed zone.

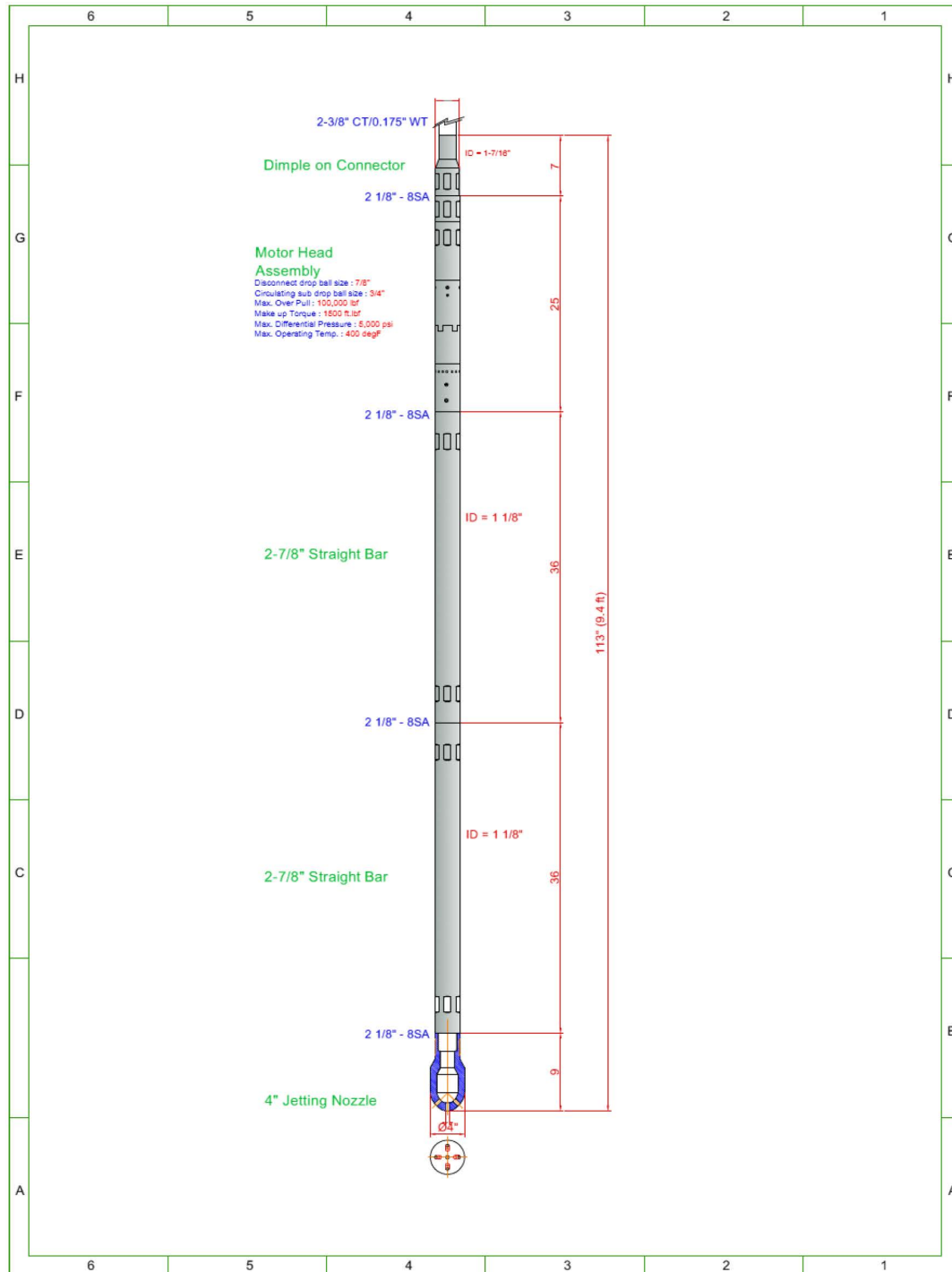


Figure 9—Static (Non Rotating) Nozzle BHA Schematic

Acid design

A 10% acetic acid system was selected for the acid treatment in this well to dissolve the scale behind the perforated liner and in the feed zone, which were believed to be obstructing steam flow and reducing production. While acetic acid is a weaker acid compared to hydrochloric acid (HCl), it remains effective in reacting with carbonate-based scales. This makes acetic acid a less aggressive option than HCl, potentially minimizing the risk of damage to the formation and completion. To further reduce the corrosion rate on both the coiled tubing and the completion, a corrosion inhibitor was mixed with the acid. However, it is important to note that the corrosion inhibitor is effective only at temperatures up to 350°F.

Running and Pumping Technique Plan

Rotating jetting nozzle to remove scale inside the completion/wellbore. The operation began with the deployment of a rotating nozzle designed to effectively eliminate scale buildup within the wellbore and completion. Initially, a 45-degree rotating jetting nozzle was introduced to the well to gain access and start the cleaning process. Following this, a 90-degree rotating jetting nozzle was used on the second run to address any residual scale remaining inside the wellbore. During operation, the jetting pump rate was gradually increased to 3-bpm, while maintaining a quenching rate of 12-bpm to optimize cleaning efficiency. To further enhance the cleaning process, the rotating jetting nozzle was reciprocated three times at critical points: the obstruction depth, the top of the liner, and the feed zone interval. This technique ensured thorough cleaning, with the nozzle moving at a steady speed of 10 feet per minute (fpm), allowing for effective removal of scale in all obstruction areas.

Pumping acid through CT to remove scale at feed zone interval. Following the scale cleaning process inside the completion using the rotating jetting nozzle, the operation moved to the next phase, which involved pumping acid through the coiled tubing. It was essential to ensure the acid was directed to the specific productive feed zone interval, located between 6700 and 6800 feet measured depth (MD) at the bottom section of the well. This precise targeting aimed to enhance permeability and stimulate steam flow, thereby improving the well's overall steam productivity.

During the acid pumping process at the feed zone interval, quenching was stopped to minimize acid dissolution. The pump rate and coiled tubing movement were adjusted to ensure that the total acid pumping duration did not exceed 45 minutes (as shown in Fig. 16). This 45-minute window was included in the design to prevent the feed zone temperature from rising above 350°F, which is the maximum temperature limit for the acid corrosion inhibitor.

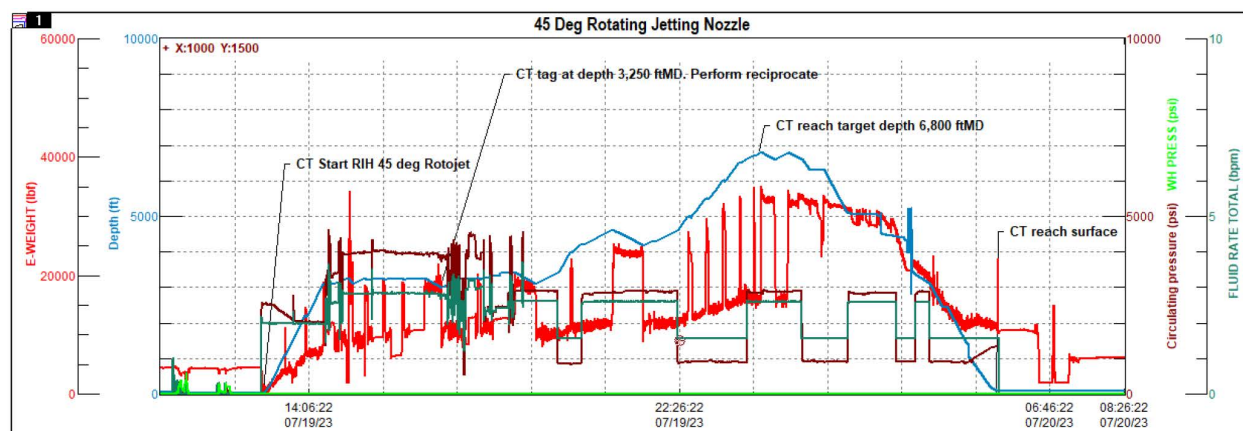


Figure 10—Running 45 deg Rotating Jetting Tool

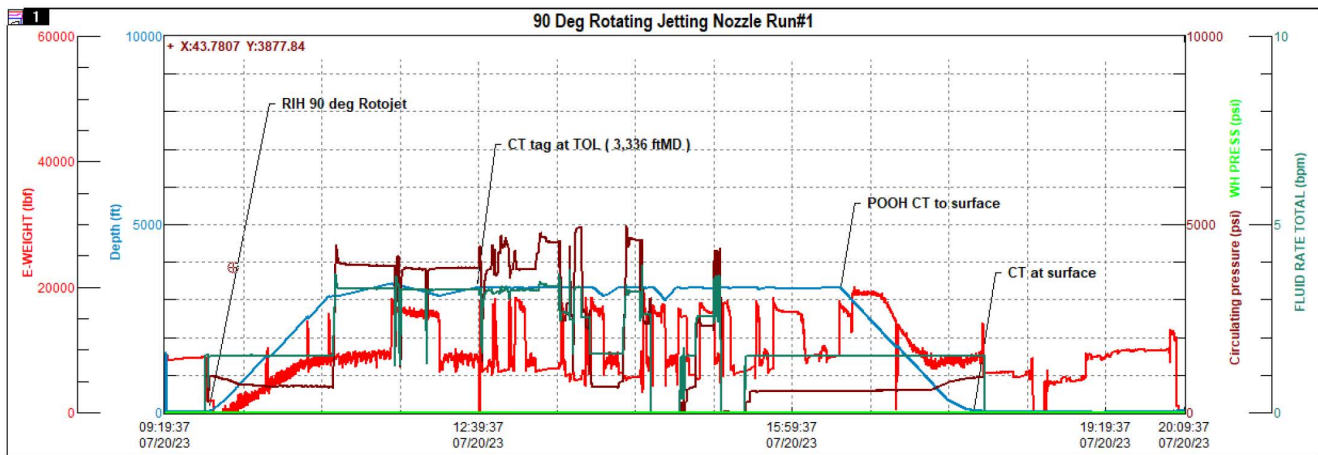


Figure 11—Running 90 deg Rotating Jetting Tool Run 1

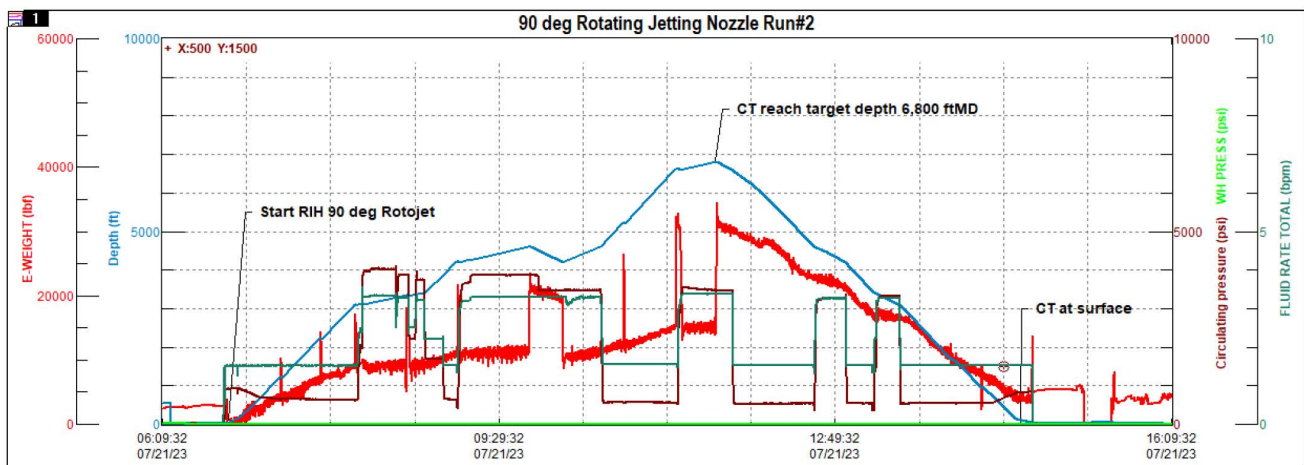


Figure 12—Running 90 deg Rotating Jetting Tool Run 2

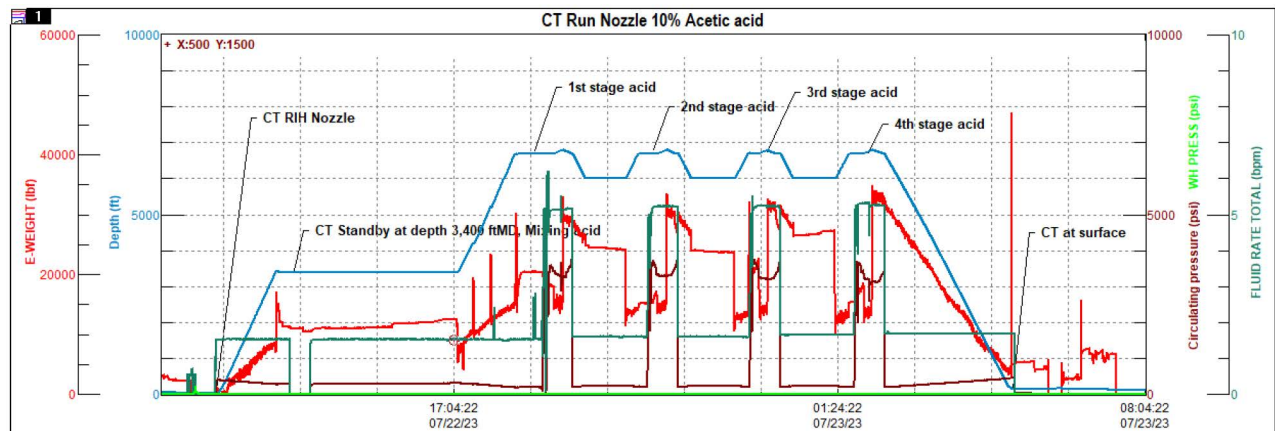


Figure 13—Running Static Nozzle to pump acid

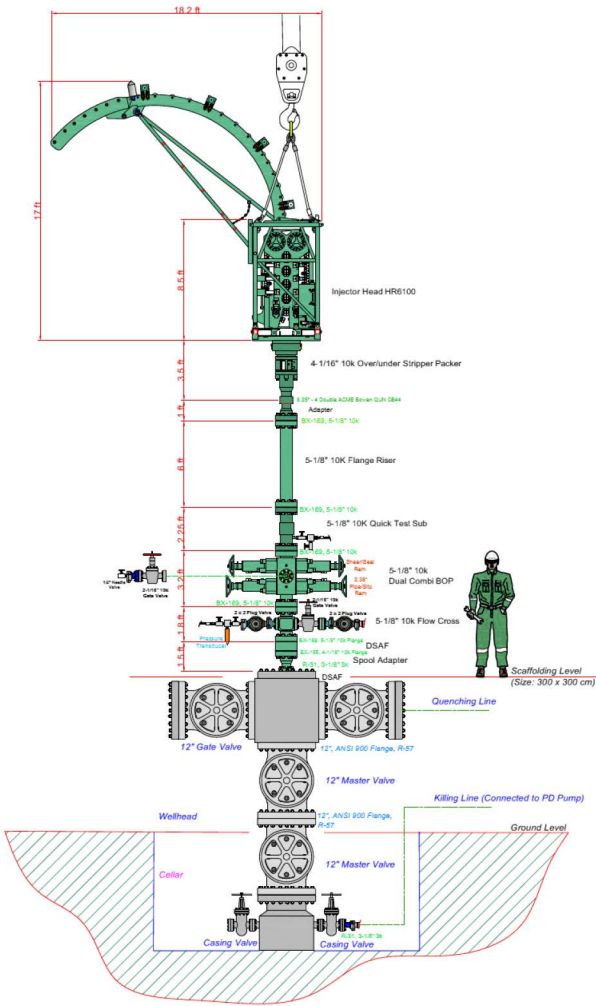


Figure 14—Well Control Stack up Rotating

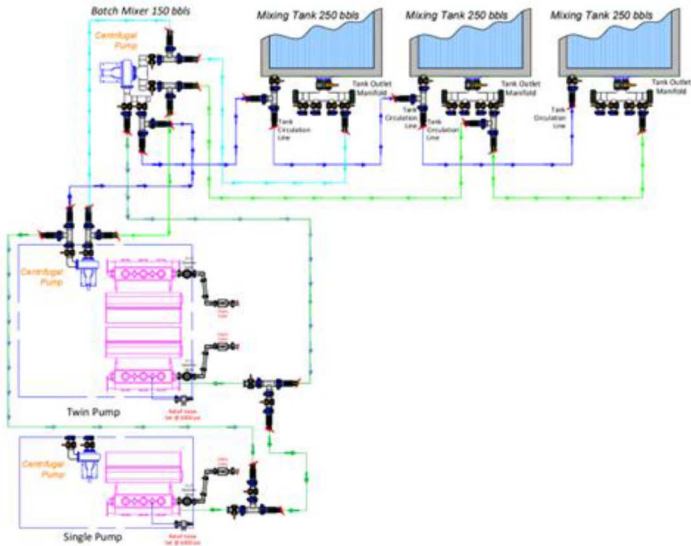


Figure 15—Pumping Line Schematic

No.	Description	Fluid	Pump Volume					CT Speed (fpm)	Time (mins)	Accumulated Time (mins)	Start Depth (ft)	End Depth (ft)	Remarks
			CT Liquid Rate (bpm)	Backside / Quenching Rate (bpm)	CT Liquid volume	CT Accumulative Liquid Volume (bbl)	Backside Liquid volume						
Acidizing with jetting nozzle													
1	RH CT to top of target FZ	Water pond	2	25	335	335	4187.5	4187.5	40	167.5	167.50	0	6700/RH
2	Preflush water at FZ Stage#1	Condensate	4	0	10	345	0.0	4187.5	0	2.5	170.00	6700	6800/Move CT
3	2 bbls CI Slughead	Main Acid	5	0	2	347	0.0	4187.5	0	0.4	170.40	6800	6700/Move CT
4	110 bbls Acetic acid	Main Acid	5	0	110	457	0.0	4187.5	0	22.0	192.40	6700	6800/Move CT
5	Overflush + Displace 1 Volume CT	Condensate	4	0	41	498	0.0	4187.5	0	10.3	202.65	6800	6700/Move CT
6	POOH CT to 6000 RMD	Water pond	2	25	35	533	437.5	4625.0	40	17.5	220.15	6700	6000/POOH
7	RH CT to top of target FZ	Water pond	2	25	35	568	437.5	5062.5	40	17.5	237.65	6000	6700/RH
8	Preflush water at FZ Stage#2	Condensate	4	0	10	568	0.0	5062.5	0	2.5	300.15	6700	6800/Move CT
9	2 bbls CI Slughead	Main Acid	5	0	2	570	0.0	5062.5	0	0.4	300.55	6800	6700/Move CT
10	110 bbls Acetic acid	Main Acid	5	0	110	680	0.0	5062.5	0	22.0	322.55	6700	6800/Move CT
11	Overflush + Displace 1 Volume CT	Condensate	4	0	41	851	0.0	5062.5	0	10.3	332.85	6800	6700/Move CT
12	POOH CT to 6000 RMD	Water pond	2	25	35	886	437.5	7000.0	40	17.5	350.30	6700	6000/POOH
13	RH CT to top of target FZ	Water pond	2	25	35	921	437.5	7437.5	40	17.5	367.80	6000	6700/RH
14	Preflush water at FZ Stage#3	Condensate	4	0	10	1041	0.0	7437.5	0	2.5	430.30	6700	6800/Move CT
15	2 bbls CI Slughead	Main Acid	5	0	2	1053	0.0	7437.5	0	0.4	430.70	6800	6700/Move CT
16	110 bbls Acetic acid	Main Acid	5	0	110	1163	0.0	7437.5	0	22.0	452.70	6700	6800/Move CT
17	Overflush + Displace 1 Volume CT	Condensate	4	0	41	1204	0.0	7437.5	0	10.3	462.95	6800	6700/Move CT
18	POOH CT to 6000 RMD	Water pond	2	25	35	1239	437.5	7875.0	40	17.5	480.45	6700	6000/POOH
19	RH CT to top of target FZ	Water pond	2	25	35	1274	437.5	8312.5	40	17.5	500.00	6000	6700/RH
20	Preflush water at FZ Stage#4	Condensate	4	0	10	1404	0.0	8312.5	0	2.5	520.00	6700	6800/Move CT
21	2 bbls CI Slughead	Main Acid	5	0	2	1406	0.0	8312.5	0	0.4	520.40	6800	6700/Move CT
22	110 bbls Acetic acid	Main Acid	5	0	110	1516	0.0	8312.5	0	22.0	542.40	6700	6800/Move CT
23	Overflush + Displace 1 Volume CT	Condensate	4	0	41	1557	0.0	8312.5	0	10.3	552.70	6800	6700/Move CT
24	POOH CT to 6000 RMD	Water pond	2	25	35	1592	437.5	8750.0	40	17.5	570.15	6700	6000/POOH
25	RH CT to top of target FZ	Water pond	2	25	35	1627	437.5	9187.5	40	17.5	587.65	6000	6700/RH
26	Preflush water at FZ Stage#5	Condensate	4	0	10	1637	0.0	9187.5	0	2.5	600.15	6700	6800/Move CT
27	2 bbls CI Slughead	Main Acid	5	0	2	1759	0.0	9187.5	0	0.4	600.55	6800	6700/Move CT
28	95 bbls Acetic acid	Main Acid	5	0	95	1854	0.0	9187.5	0	19.0	710.00	6700	6800/Move CT
29	Overflush + Displace 1 Volume CT	Condensate	4	0	41	1895	0.0	9187.5	0	10.3	720.25	6800	6700/Move CT
30	POOH CT to surface	Water pond	2	25	35	1930	437.5	9625.0	40	17.5	737.75	6700	0/POOH
Total			Accumulative liquid volume (bbls)					2230.0	17875.0	Accumulative time(hrs)	14.80		

Figure 16—Acid Running & Pumping Schedule

The acid pumping operation was divided into four stages, pumping a total of 540 barrels (bbls) of 10% acetic acid at a pump rate of 5-bpm. Each stage (Stages 1 to 4) followed this sequence:

- 10 bbls of preflush water
- 2 bbls of corrosion inhibitor slug
- 110 bbls of 10% acetic acid
- 41 bbls for overflush and displacement

Stage 5 consisted of:

- 10 bbls of preflush water
- 2 bbls of corrosion inhibitor slug
- 100 bbls of 10% acetic acid
- 41 bbls for overflush and displacement

After each stage, the coiled tubing was held at a depth of 6000 feet MD while quenching was performed at a rate of 25-bpm for 1 hour to cool the wellbore temperature. The volume of 10% acetic acid for each stage was optimized based on the maximum pump rate during execution.

Operational Sequence

Execution was conducted in following sequence

Running 45 deg rotation jetting nozzle. The operation began with the deployment of a rotating jetting nozzle specifically designed to effectively eliminate scale buildup within the wellbore. To initiate the process, a 45-degree rotating jetting nozzle was carefully lowered into the well. During this phase, the jetting pump maintained a steady flow rate of 2.6 to 3.2-bpm through the coiled tubing, while the quenching rate was set at 12-bpm to cool the wellbore.

The rotating jetting nozzle was reciprocated for three separate passes, moving at a controlled speed of 10-fpm. These passes were deliberately executed at critical points: the obstruction depth, the top of the liner, and the feed zone interval. This approach ensured thorough cleaning and optimal removal of debris.

At the conclusion of the operation, as the rotating jetting nozzle was being pulled out of the hole, it made one final pass to ensure complete removal of the scale inside the wellbore.

Running 90 deg rotation jetting nozzle. While running the 90-degree rotating nozzle tool, it was observed that the tool became stuck at the top of the 10.75-in liner. Despite multiple attempts to navigate past this difficult point by increasing the pump rate and employing reciprocation techniques, these efforts to pass the top of the liner were unsuccessful. Faced with this obstruction, the decision was made to pull the tool out of the hole and manually adjust the orientation of the coiled tubing. After making the necessary adjustment, the 90-degree rotating nozzle tool was successfully run again, passing the top of the liner and reaching the target depth of 6,800 feet MD.

Throughout the operation, a consistent pump rate was maintained, ranging from 3.2 to 3.4-bpm, while a quenching rate of 12-bpm was applied. To ensure thorough cleaning, the rotating jetting nozzle was reciprocated three times at critical intervals—specifically at the obstruction depth, the top of the liner, and within the feed zone. The tool was moved at an efficient speed of 10-fpm. Additionally, a final pass was performed during the pulling-out process, further enhancing the cleaning and optimizing the overall performance.

Running static (non rotating) nozzle to pump acid. Following the successful removal of scale from within the completion, the next step involves the application of a 10% acetic acid solution using a static nozzle.

1st pumping acid stage. For the first acid stage, the coiled tubing (CT) was run to the top of the treated feed zone at 6,700 feet measured depth (MD), with quenching applied at a rate of 25-bpm. Quenching was then stopped during the acid pumping process. The CT pump operated at a rate of 4-6-bpm, beginning with a preflush of 10 barrels of water, followed by 2 barrels of CI Spearhead corrosion inhibitor (CI), and 130 barrels of 10% acetic acid. After these injections, 41 barrels of water were pumped to displace the acid. Once the acid stage was completed, the CT was pulled out of the hole (POOH) to a depth of 6,000 feet MD.

During this pull-out phase, the CT pump rate was reduced to 1.5-bpm, while the quenching rate was increased to 25-bpm. The total duration of the quenching stop during this stage was 28.55 minutes. Once the CT reached 6,000 feet MD, it remained stationary while maintaining a pump rate of 1.5-bpm and a quenching rate of 25-bpm to ensure the wellbore was adequately cooled.

2nd pumping acid stage. After allowing the well to cool for 52 minutes, the coiled tubing (CT) was run back into the hole, reaching the top of the treated feed zone at 6,700 feet MD. During this run-in-hole process, the CT pump rate was maintained at 1.5-bpm, with a quenching rate of 25-bpm.

Upon reaching the top of the feed zone at 6,700 feet MD, Acid Stage #2 commenced. In this stage, the CT pump rate was increased to 4 to 5.2-bpm, and the quenching pump rate was stopped. The CT was reciprocated within the treated feed zone interval (6,700 to 6,800 feet MD).

The acid pumping sequence included:

- A 10-barrel preflush of water.
- 2 barrels of CI Spearhead corrosion inhibitor (CI).
- 140 barrels of 10% acetic acid.
- Followed by 41 barrels of water to displace the acid.

After completing this sequence, the CT was pulled out of the hole (POOH) to a depth of 6,000 feet MD. During the pull-out, the CT pump rate was reduced to 1.5-bpm, while the quenching rate was increased to 25-bpm.

Once the CT reached 6,000 feet MD, it was placed on standby, maintaining a pump rate of 1.5-bpm and a quenching rate of 25-bpm to cool the well. During this stage, the quenching pump was temporarily stopped for a total of 38 minutes.

3rd pumping acid stage. After a 56-minute cooling period, coiled tubing (CT) operations resumed, and the CT was run into the hole to the target depth of 6,700 feet MD. During this run-in process, the CT pump rate was maintained at 1.5-bpm, with a quenching rate of 25-bpm.

Upon reaching the target depth of 6,700 feet MD, the quenching pump was stopped, and acid treatment for Stage #3 commenced. The CT pump rate was increased to between 4 and 5.3-bpm, while the quenching pump rate remained at 0-bpm.

The acid pumping sequence included:

- A 10-barrel preflush of water.
- 2 barrels of CI Spearhead corrosion inhibitor (CI).
- 140 barrels of 10% acetic acid.
- Followed by 41 barrels of water to displace the acid.

After completing the acid treatment, the CT was pulled out of the hole (POOH) to a depth of 6,000 feet MD. During the pull-out, the CT pump rate was reduced back to 1.5-bpm, and the quenching rate was increased to 25-bpm.

The total time for stopping quenching during this stage was 34 minutes. Once the CT reached a depth of 6,000 feet MD, it was placed in standby at that depth, with the CT pump rate maintained at 1.5-bpm and the quenching rate kept at 25-bpm to ensure effective cooling of the well.

4th pumping acid stage. After a 60-minute cooling period, coiled tubing (CT) operations resumed by running in hole (RIH) to a target depth of 6,700 feet measured depth (MD). During this operation, the CT pump rate was maintained at 1.5-bpm, with the quenching rate set at 25-bpm.

Upon reaching 6,700 feet MD, the acid pumping for Stage 4 was initiated with the following parameters:

- The CT pump rate was increased to between 4 and 5.3-bpm.
- The quenching pump rate was set to 0-bpm.

The acid pumping sequence included:

- A 10-barrel preflush of water.
- 2 barrels of CI Spearhead corrosion inhibitor.
- 130 barrels of 10% acetic acid.
- Followed by 41 barrels of water to displace the acid.

Once the acid pumping was complete, the CT was pulled out of hole (POOH) to a depth of 6,000 feet MD. During the pull-out, the CT pump rate was reduced back to 1.5-bpm, and the quenching rate was increased to 25-bpm. The quenching pump was stopped for 32 minutes during this phase.

Post-Stimulation and Cooling

After successfully completing the acid stimulation stage, coiled tubing was pulled out to surface while maintaining a pump rate of 1.6-bpm. The quenching rate was kept at 25-bpm to ensure optimal cooling

during this operation. Once the CT reached a measured depth of 3,300 feet, the pump rate was maintained at 1.6-bpm, but the quenching rate was reduced to 12-bpm. The CT was then pulled out to surface.

Process Improvement

Throughout the operation, the total number of acid stages was successfully reduced from five to four. This improvement was achieved by increasing the pump rate to 5.3-bpm, allowing for more efficient acid injection and ultimately reducing the number of stages required compared to the original plan, which called for 5-bpm.

Conclusion

The project was successfully completed as per plan. The well intervention reached the target depth and completed the operations with a total of 4 runs with total operation time to perform the operation was 3.7 days. **The coiled tubing (CT)** operation was carried out with a strong emphasis on safety; there were no incidents, no **corrosion** was found on the coiled tubing which was a major concern for the client based on their history with a previous failure. The acid treatment was carried out as per plan, in compliance to all established safety and operational protocols. Following a comprehensive cleanup of scale in the wellbore and the effective removal of scale behind the perforated liner using acid, the well is now demonstrating a remarkable increase in steam production. Specifically, the steam output has increased to **2.5 times** the rate observed prior to the scale removal treatment, highlighting the effectiveness of this intervention. Most significantly, **production from the feed zone** has shown a notable increase post-treatment, indicating that the intervention not only addressed the scale issues but also positively enhanced the well's overall performance.

Acknowledgement

The authors would like to thank to our customer for the collaboration in completing this project. We would also like to acknowledge Riski Kurniawan, Baker Hughes CT supervisor, for his technical input during preplanning and execution stage.

Reference

1. Emilya Mammadova, Haleyna Arstianti, Agus Cahyono, Tan Aik Seong, Sabardi Sabardi, Vincentius Valentino, Baker Hughes Company. Removing scale in geothermal wells - An economic alternative to workover rigs. Paper presented at the 11th ITB International Geothermal Workshop 2022
2. Portman L. (1997). Use of stress cycling to remove downhole scale from geothermal wells using coiled tubing. *Geothermal Resources Council Transactions*, 21.
3. Putra R.B., Souvanir T., Panggabean P., Purba E., Arstianti H., Cahyono A. (2018). First time in Indonesia, CTU Clean Out Totally Plugged Scale: Risks, Mitigations, and Lessons Learned. *GRC Transactions*, 42.
4. Campbell A., Brunskill D. (2000). Advances in Coiled Tubing Jetting Technology. SPE 60721.
5. Boudreaux C.D.M. Falk, K. (2005). A unified approach for the removal of barium sulfate scale using coiled tubing. SPE 94323
6. McClatchie D.W., Verity R. (2000). The removal of hard scales from geothermal wells: California Case Histories. SPE 60723.
7. Allahvirdizadeh P. (2020). A review on geothermal wells: Well integrity issues. *Journal of Cleaner Production*, 275. Retrieved from <https://www.sciencedirect.com/science/article/pii/S0959652620340543>.