Geothermal Operators are Embracing Geothermal Multifinger Caliper Technology for Derisking Well Interventions and Workovers

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ABSTRACT

Since the commercialisation of a digital geothermal multi-finger caliper in early 2020, operators have been transforming the decision making behind highly critical well intervention and workover operations. Previously, operators were either forced to quench their high temperature well in order to acquire data that informs the condition of the casing or resorted to deploying a limited analogue-based caliper measuring tool. The quenching operation incurs cost and subjects the casing to potentially damaging thermal cycling. Technological limitations and the burden of quenching often deterred operators from conducting any data acquisition as part of the decision-making process behind well interventions and workovers. Since the technological breakthrough of the geothermal casing inspection caliper, operators have been embracing data to plan activities with confidence, de-risking operations in the process. Pre-workover evaluation and well integrity diagnostics are the two key areas benefiting from digitally enabled data acquisition that eliminates quenching as a pre-requisite. In pre-workover evaluation, wellhead maintenance is being made safer through the appropriate selection of plugs as a well control barrier based on accurate and reliable data that informs where the plug should be set and areas to avoid. Wells with compromised casing can be treated with re-lining remedies which can save a well from abandonment. The geothermal MFC enables pre-rig mobilisation assessments, flagging internal diameter restrictions, scale build-up, or deformations. In wellbore integrity diagnostics, the geothermal MFC is becoming a key tool in diagnosing issues that cause wellbore integrity failure, resulting in improved best practices that help prevent recurrence. This digitally-fueled, data-driven transformation of geothermal well operations are helping operators extend the lifespan of wells, reducing inefficiencies that can add risk and cost to the management of their assets.

1. INTRODUCTION

Multi-finger calipers (MFC) are downhole logging tools used for radial measurements to recognize anomalies in the casing. MFCs are utilized in casing and tubing inspection by recording the diameter of the internal surface of the pipe logged. Damaged pipe may be accounted for by extreme downhole environments (Kotlar, 2020).

In the geothermal industry, complex high temperature wells that can exceed 300 degC are drilled to exploit prolific reservoirs (Xie & Droessler, 2020). Historically, geothermal wells with elevated temperatures force operators to quench their wells to gather casing inspection data (Ingason & Árnason, 2022) or must resort to deploying a limited analogue-based caliper measuring tool (Bixley & Wilson, 1985). The quenching procedure subjects the casing and cement to thermal cycling, resulting in plastic deformation (Eidsvik, 2019). Until the arrival of electronic geothermal MFCs, the analogue caliper was the established well logging instrument for assessing the condition of casing in geothermal wells owing to its capability of operating in elevated temperatures. Today, digitally recording MFC technology is available to the geothermal industry, providing oilfield standard measurements in geothermal wells (Khastoo, 2025).

Table 1. Caliper Maximum Operating Temperatures

Mlulti-Finger Caliper	Max. Operating Temperature (ºC)
Analogue-based MFC	343ºC
Geothermal MFC	343ºC

In response to the need for digital monitoring of the condition of casing in geothermal wells without resorting to quenching, in 2020, an appropriate MFC technology (see Figure 1) was commercialised (Sledz et al., 2020), fully digitalising the data acquisition and delivery process, in turn. Since the introduction of the geothermal MFC, the applications it is deployed for have expanded making it an opportune time to highlight how geothermal operations are changing in response.

Casing damage and anomalies including corrosion, holes, splits, scale build-up, ovalisation and collapse are accurately assessed using MFC data (Maxted et al., 1995). The high-resolution data of the MFC can generate conventional 2D caliper log, pipe cross sections and 3D tubular geometry visualisation. These modes of MFC data presentation are used in drilling, workover, injection and production (Ajgou et al., 2019).

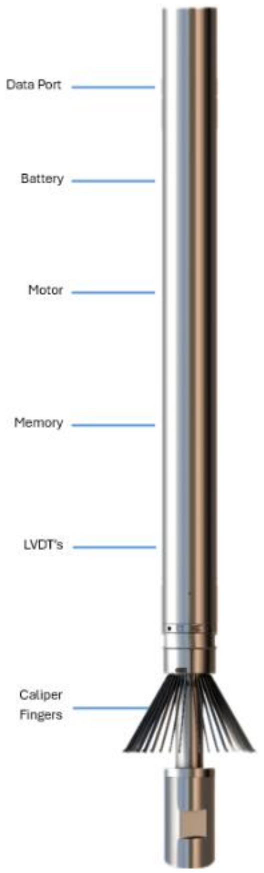

Figure 1. SDI Vulcan MFT40 Caliper (SDI, 2025)

2. PRE-WORKOVER EVALUATION

In their work-over experiences at the Kawerau Geothermal Field, New Zealand, Clements and Quinao (2019), explain that well workover programs and well asset management are carried out through collective and solutions-based methods. Technical expertise from multiple service providers and practical inputs from other experienced geothermal operators play an important role in carrying out programs addressing unique issues encountered in geothermal wells. Downhole logging tools and wellhead equipment repair tools were utilized in relining the well and for wellhead replacement workovers, paving the way for ensuring the long-term integrity of two wells. High-temperature casing condition and pressure-temperature-spinner tools were the downhole logging tools deployed to evaluate the casing wall condition and locate casing damage and leaks.

Prior to workover operations, the condition of the casing and appropriate tools are identified to execute activities safely, efficiently and economically. Workovers such as wellhead replacement and well relining require the setting of plugs and packers to safely isolate a section of the well to perform such operations. Reliable logging tools are a key source of downhole data for informed decision making.

2.1 Plug Size and Setting Depth Determination Case Studies

In the Philippines in 2024, a geothermal operator elected to deploy an electronically-set plug as a well control barrier during wellhead replacement operations (SDI, 2024). To help ensure the plug would form an effective seal, the geothermal MFC was utilised to determine the casing internal diameter (ID) and to highlight any areas of poor casing condition. Pipe ovality is indicated by misshapen casing, deviating from its circular cross section. It is a vital statistic for plug and packer setting, and its severity dictates the plug and packer's sealing capability. Plug setting depth is determined by establishing the maximum allowable ovality of the pipe (Kotlar, 2020), as presented in Figure 2. Without the data provided by the geothermal MFC, the operation could be subject to higher risks such as a mismatch between the plug OD and casing ID or an ineffective seal owing to the plug being set in an area of poor casing condition.

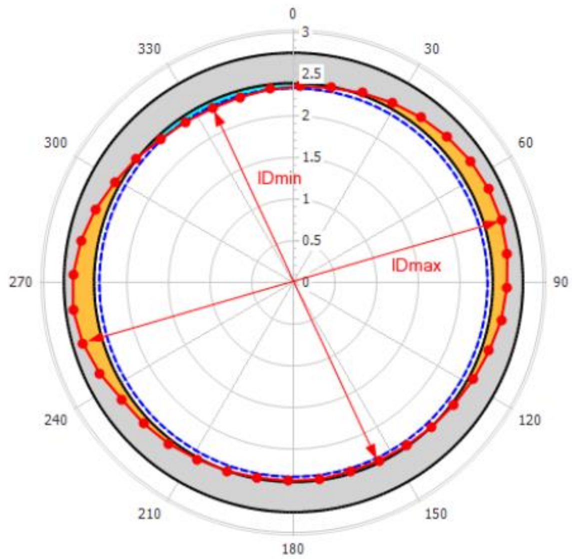

Figure 2. Ovalization (Kotlar, 2020)

2.2 Packer Placement and Well Relining

Well 1: Common challenges encountered in low pH, high temperature geothermal wells are corrosion risks and damage in the production casing, which leads to reduced well performance and integrity. A geothermal operator in the Philippines deployed a modified metal expandable packer technology with cementing system to seal off the well for relining operations in the 13 3/8" production casing. Upon identification of the packer setting depth, the packer, together with a cementing tool, was run in hole to the target depth and a pressure test was conducted to verify that the packer succeeded in holding the hydrostatic pressure. After the successful expansion of the packer, a cementing job followed providing a bond for the relined casing in place (Welltec, 2024). The well diagnostics was aided by the geothermal MFC data (see Figure 3) which showed low ovality, acceptable metal loss, low wall penetration and minimal restriction values. These caliper results data assisted in overcoming the challenges associated with running the packer: identifying the casing condition, packer expansion integrity and suitable depth determination.

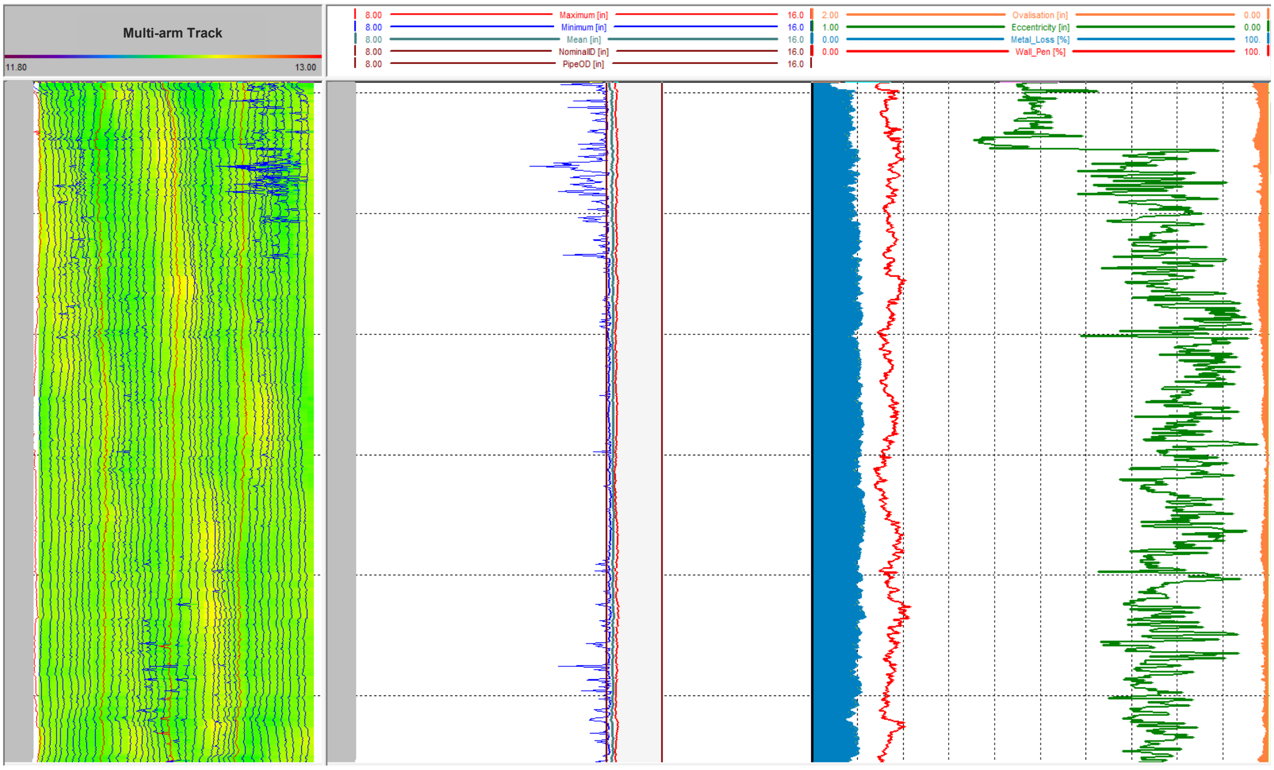

Figure 3. Packer Setting Depth Joint for Metal Expandable Packer

Well 2: A production well was found to have parted casing at a shallow depth as confirmed by a downhole video camera in 2019. As part of further investigations, in 2024, the geothermal operator decided to deploy three diagnostic tools including a downhole video camera, electro-magnetic pulse and MFC to assess the casing situation above the parting. The caliper results revealed buckling, and deep wall penetrations were detected immediately above the casing collars across almost 85% of the casing joints logged (see Figure 4).

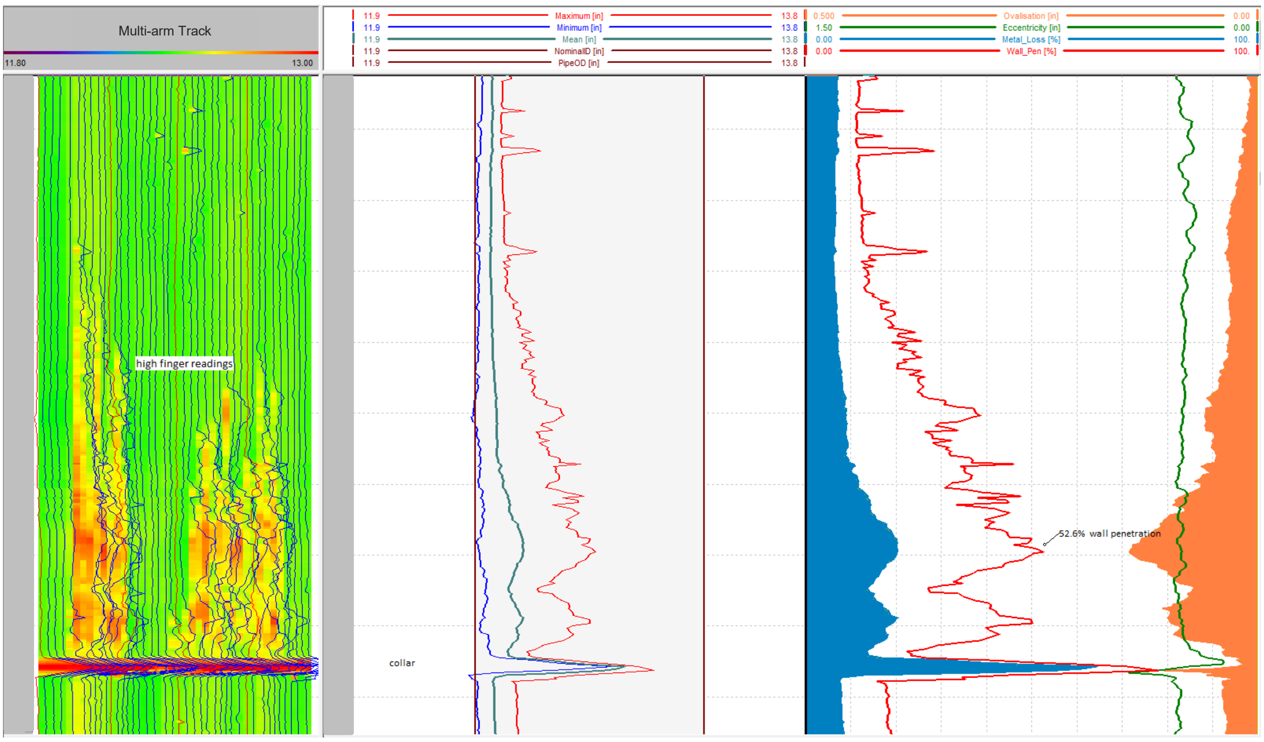

Figure 4. Example of casing damage immediately above a collar

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The following year a workover was planned to address the issues identified by re-lining the well. Prior to this, another set of pre well workover diagnostics were conducted including a downhole video and geothermal MFC. The MFC bottom log depth was set at 10 meters below the casing break and, upon calculating the depth of the parting using the casing tally, it was determined to be 2.4 meters above a casing collar. The parting was indicative of the damage observed across the joints logged with the caliper (see Figure 4), where, in most cases, the damage is most severe in the vicinity above the collars. The goal of the workover operations was to safely replace the master valve and reline the well with 9 5/8" casing inside 13 3/8" production casing, requiring installation of a retrievable plug and metal expandable packer. The operator indicated a pre-selected depth interval to set the packer; however, upon consulting the MFC log, ovality was discovered and therefore avoided (see Figure 5).

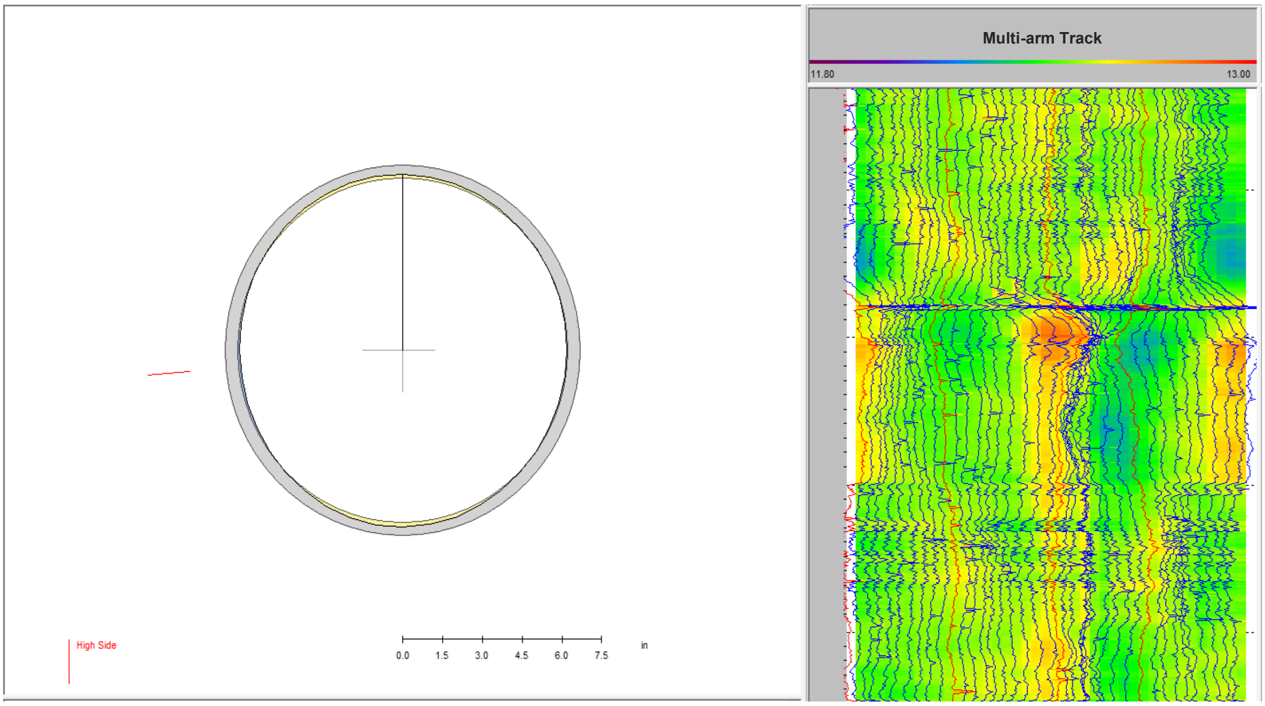

Figure 5. Pipe ovality discovered at operator's pre-selected depth interval for plug and packer setting depth

Pipe ovality issues across other areas were also discovered. A new setting depth interval was selected; the plug was set in place, and pressure tested providing the required isolation for the operator to replace a corroded master valve. The metal expandable packer was installed where leakage was not detected after the packer setting. As a result, the operator was able to replace the master valve and set the packer in place to retain the cement during the relining operation.

3. WELLBORE INTEGRITY DIAGNOSTICS

The necessity for well workovers and interventions are commonly verified by well condition monitoring programs. The implementation of these programs may be on an annual frequency or higher. These allow evaluation of the casing condition in terms of pipe wall thickness and potential metal loss, and prompt detection of casing problems. Monitoring is enforced using various diagnostic tools, such as caliper and pressure-temperature-spinner tools for better understanding of the well issue. Wells with significant casing damage are monitored and upon confirmation of severe casing damage, the well will be a candidate for well intervention (Clements & Quinao, 2019). A well integrity monitoring system relies heavily on casing degradation assessments. Integrated to torque and drag simulations and well trajectory parameters, this assessment contributes to qualifying the well casing barrier from the combination of two log data (Ahmed et al., 2021).

Well Integrity Failure Analysis

Data from the geothermal MFC was key to the analysis of wellbore integrity failure in Indonesia in 2024. Zaifulla et al. (2025) discuss the well integrity failure analysis of deformed casing in a geothermal well using data from the geothermal MFC in the analysis. The well was undergoing production testing when a steam leak was suspected owing to parity in the annulus pressure and wellhead pressure. To investigate the compromised casing integrity, the geothermal MFC was deployed to a depth of 669m, and logging was conducted to surface inside 13-3/8" casing. A maximum temperature of 289 degC was recorded by the geothermal MFC. Data processing revealed deformation of the casing between depths of approximately 23m and 26m. The casing collapse – the top of which was near a casing connection – resulted in a restriction in the well of 10.513" compared to a nominal internal diameter of 12.415" (see Figure 6 for visualisation of collapse). In the failure analysis, it was observed that the annulus was water-filled ahead of the commencement of production testing. The top 23.5m of the annulus was not cemented, and it was likely that thermal expansion of the water was the root cause of the collapsed casing. With thermal expansion, annulus pressure increased beyond the collapse pressure of the 13-3/8" casing. Because of the close proximity of the casing connection to the area of collapse, a compromised seal at the connection was the likely leak path of the steam. The ultimate findings of this study recommend preventing water from entering any uncemented sections of the annulus or removing the water prior to exposure to elevated temperatures.

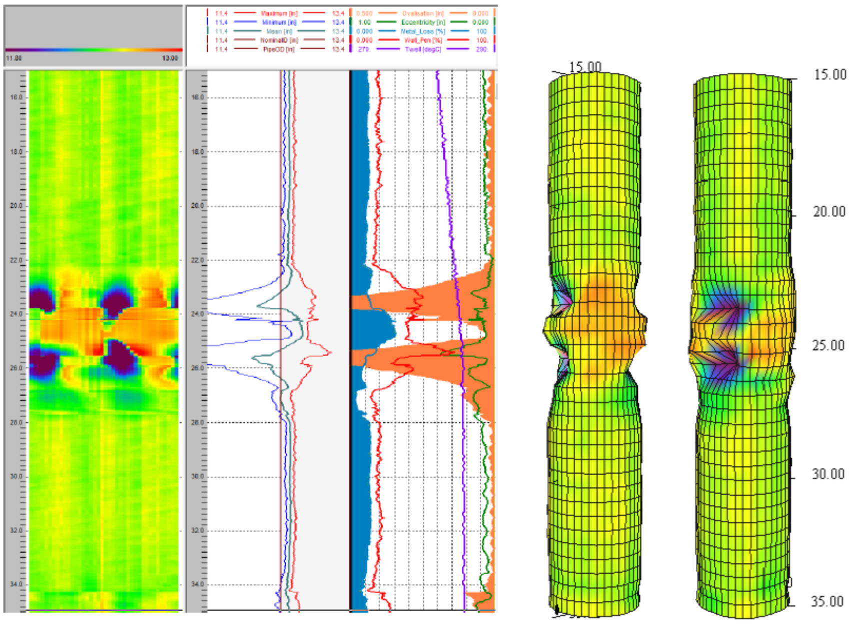

Figure 6. Adapted from Zaifulla et al. (2025): Casing deformation analysis using caliper data and 3D visualization

4. CONCLUSION

In recent years the geothermal MFC has been aiding geothermal operators diagnose problems with the precision afforded to the oil & gas industry for decades. A major ancillary benefit of the technology is the reduction of quenching and the associated risks to wellbore integrity. Compared to the incumbent analogue caliper technology relied upon by geothermal operators for many years, the fully digital geothermal MFC provides the opportunity to accelerate the decision-making process. This factor was crucial to aiding the diagnosis of the well integrity failure in the case study in Indonesia where a newly completed well exhibited a serious issue during production testing.

It is arguable that the geothermal MFC now provides other technology developers the incentive to innovate new geothermal well integrity solutions for issues that are diagnosed by the caliper. The digitalisation implications of the geothermal MFC enable the data that technologists need to inspire and justify engineering programs, for example.

Although the requirement for well quenching has been reduced with the commercialisation of the geothermal MFC, other technologies for assessing the casing condition – such as electro-magnetic thickness tools and downhole video cameras – in high temperature wells, remain dependent on quenching for their deployment. Such limitations, however, may not persist for much longer with large public bodies such as the United States Department of Energy offering funding for the development of casing evaluation technologies for elevated temperatures.

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