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Casing Failure in Shallow Formation Based on Geochemical Properties and Casing Integrity Data in Patuha Geothermal Field

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ABSTRACT

Casing integrity is one of the important values for old geothermal wells. Most of the casings have bad properties after the well begins producing. The source of issue is because of the expansion and shrinkage temperature values in the well. Sudden changes on temperature could make the casing crack, deform, or hole for the worst condition. PPL-Z was drilled in 1997 and is one of the production wells in Patuha field in West Java, Indonesia. The Patuha field itself is a vapor dominated geothermal system with 55 MW Power Plant capacity and had been operating since 2014. After 4 years of production from PPL-Z, there is a sudden change on geochemical properties. The well became wetter. Decreasing value of enthalpy and increasing magnesium in water has proved the well had a non-reservoir water breakthrough. Concurrent with the result of geochemical properties change, a well investigation is conducted to find the source of problem. Magnetic Thickness Detector (MTD), pressure temperature spinner (PTS), and Downhole Video become the best choices of tools, given the current well condition. The intervention objective of the evaluation was to check the 13 3/8” and 20” casing for the purpose of well integrity. Therefore, the data was acquired at an interval from surface to 854 meters depth, in the well. The 9 5/8” casing liner have maximum metal loss up to 5.6% and the casing 13 3/8” casing wall have maximum metal loss up to 47.2%. PTS survey have defined a reverse temperature at 176 meters and a change of spinner speed at the same depth. The result of downhole video provides the most reliable indication that there is a hole in the casing with depth near the surface ground level. A series of recommended actions were taken to make sure there was no further environmental impact on the field, while keeping the well safely producing.

1. INTRODUCTION

The Patuha geothermal field is located about 50 kilometers southwest from Bandung, West Java Province (Figure 1). Patuha geothermal field is a steam dominated field with reservoir temperature about 210 to 230 °C in West Java which is located near other steam dominated fields such as Wayang Windu, Darajat, and Kamojang. This Concession Area is owned by PT Geo Dipa Energi (Persero), an Indonesian geothermal Stated Owned Company (SOE). Drilling was started by Patuha Power Limited (PPL) with a 17 well slim hole campaign in 1996. The field development continued by drilling 14 wells with big hole configuration until 1998. In 2014, Patuha geothermal field entered the commissioning phase and started operating with 1 x 55 MWe single flash turbine.

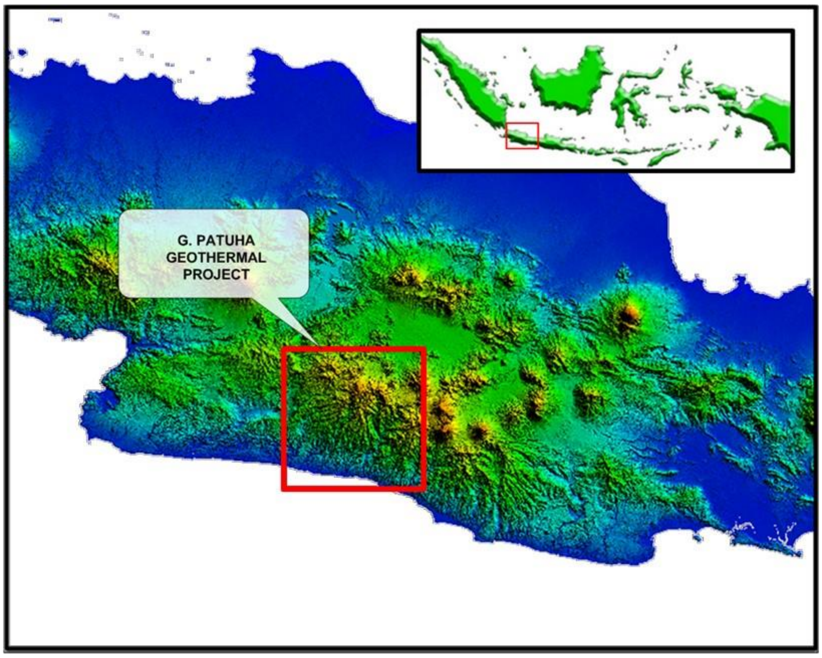

Figure 1. Location of Patuha geothermal field

Geothermal wells consist of several casings that are mainly exposed to high temperature reservoir fluid. In some of the wells, temperatures could reach more than 300 °C, with mineral deposition from the fluid itself. Highly temperature gradients in the well and across the casing itself will make the steel (casing) expand during the production period, and also shrink during the injection period.

Corresponding with the vast temperature range the casing material is exposed to, the method of setting the casing is critical to ensure the life of the well itself. Good temperature and pressure tolerance of the material are needed to ensure the casing can be exposed to vast temperature ranges and a good cement and cementing processes are needed to ensure there is no APB (Annular Pressure Build-Up) during the heating up and production period.

During heating up and production periods such pockets of water-based fluids will expand when temperatures rise in the well and the annulus. However, if the fluid cannot expand, the pressure will rise and may exceed the collapse strength of the inner string before the outer string bursts. Potential problem locations are at the liner-surface casing interface, between the surface pipe and conductor between tiebacks and surface pipe, or in sections where the collapse rating of the casing is below the pore pressure (in the case of permeable formations) or the frac-gradient (in the case of impermeable formations) (Lentsch et al., 2015)

A series of studies have been conducted on Patuha Geothermal Well in West Java, Indonesia. The studies were conducted because there was a chemical property change on the well during the production period. The geochemical data shows that the well is getting wetter than its initial condition.

Geochemical and Well Integrity Survey approaches have been conducted to confirm the anomaly at the Patuha Geothermal Well in West Java, Indonesia. This paper describes the casing failure analysis based on geochemical properties and casing integrity data affecting the action plan, taken to cure the well.

2. WELL HISTORY

The Patuha PPL-Z well was spudded on Jan. 20, 1997 and reached TD on Mar. 6, 1997. Three flow tests were performed during drilling the well to identify a possible feed zone encountered in this well. All of the tests were performed using an orifice plate method to calculate the single-phase dry steam mass rate. A conversion factor of 7.26 T/h/MW (gross) was used to calculate the power generated for each well test.

The first rig test was performed after the well reached 1398 mMD (meter measured depth) and resulted in 24.5 T/h steam rate at 160 psig stabilized wellhead pressure with 10% valve setting. The steam rate is associated with 3.4 MWe. Geological and drilling data showed that the well encountered drilling breaks between 928 mMD and 1385 mMD.

A second rig test was performed after drilling reached 1678 m. Several drilling breaks were encountered between interval 1404 m to 1658 m, but the intervals were getting thinner. The test itself demonstrated a 40.4 T/h steam rate and 152 psig at the end of the test with a 30% throttle valve setting, which is associated with 5.6 MW.

The third rig test was performed after drilling reached the depth of 2014 mMD. One minor drilling break was encountered between interval 1980 - 1990 m MD. The test resulted steam rate of 65.8 T/h at stabilized wellhead pressure of 151 psig with 25% throttle valve setting. The above-mentioned rate is associated with 9.2 MWe power generated.

Rig Test	TD (mMD)	Shut-in WHP (psig)	Stabilized Flow rate (T/h)	Stabilized WHP (psig)	Valve opening
1	1398	275	24.5	160	10%
2	1678	253	65.8	152	30%
3	2014	230	40.4	151	25%

Table 1. Summary of PPL-Z Flow Test

The well reach TD at 2089 mMD using a 12-1/4” Bit and a 9-5/8” liner was set as the production liner on the well. More detailed set depth shown on Table 2.

Hole Size	Top (mMD)	Bottom (mMD)
30"	0	17
26"	17	273
17 1/2"	273	857
12 1/4"	857	2089

Csg Size	Top (mMD)	Shoe (mMD)
30"	0	17
20"	0	273
13 3/8"	298	855
9 5/8"	775	2082

Table 2. PPL-Z Hole size & Casing depth

3. GEOCHEMICAL PROPERTIES

During the production period, fluid samples were taken periodically from all production wells consisting of non-condensable gas, brine, and steam condensate. The samples collected were used to determine reservoir characteristics such as fluid composition, reservoir processes, and possible fluid changes.

The initial well of PPL-Z has a high enthalpy with most discharge consisting of steam. Starting with the commissioning in 2014, PPL-Z produced steam at about 33.72 t/h and minor condensate with pH 3.8. The geochemistry monitoring results from PPL-Z suggest that fluid has changed during the production period from 2014 to 2015 (Table 3). Increasing amounts of water with low chloride concentration (0.3 to 1 ppm) indicate the reservoir fluid has changed. Based on the TFT data, the enthalpy decreases from 2760 to 1749 kJ/kg. The fluid composition also changes by the increasing of magnesium value. Magnesium levels in high temperature geothermal fluid are usually very low (< 0.1 ppm). High concentrations of magnesium can indicate near surface reactions leaching Mg from the local rock or dilution from groundwater (Nicholson, 1993). The water type has a sulphate-bicarbonate composition with SO_4 concentrations of about 37.3 ppm and HCO_3 concentrations of about 16.7 ppm. These concentrations indicate interaction between steam condensate and surface water. The bicarbonate water is thought to be formed by condensation of CO_2 rich steam into groundwater (Giggenbach, 1997).

Year	Steam rate (T/h)	Brine rate (T/h)	Entalphy (kj/kg)	WHP (psig)	Magnesium (ppm)	NCG (wt.%)	pH
2011	44.29	n/a	n/a	150	0.6	4.4	n/a
2014	33.72	0.43	2760	167	1.9	2.23	3.8
2015	56.67	30.01	2065	116	2.2	1.34	6.07
2018	23.62	24.91	1749	117	3.37	1.09	6.24

Table 3. The PPL-Z properties from 2011 to 2018.

4. WELL INTEGRITY SURVEY

To find the root cause of the properties change, on August 2018, Pressure Temperature Spinner (PTS) and Magnetic Thickness Detector (MTD) tools were run. PTS tools were run to record the pressure temperature gradient of the well, while the spinner tools were run during injection to record the flow tendencies of the well. The result of PTS tools show there was an incremental spinner speed around 176 mMD, consistent with pressure and temperature changes on the same depth of measurement. The fluid started to decrease in temperature around the depth of 176 mMD (Figure 2).

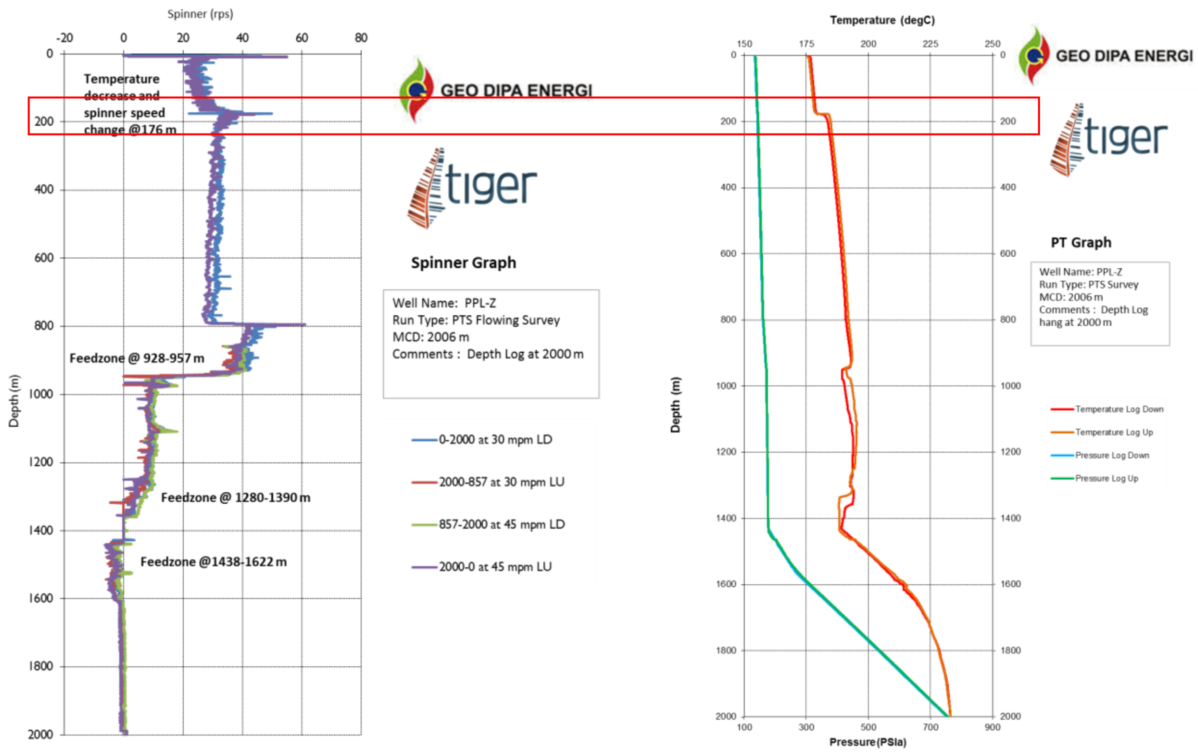

Figure 2. PTS Data Patuha Well PPL-Z

An additional MTD tool was run to confirm the casing thickness data. By inputting the casing properties and well schematic data, the tools calculated some major wall losses (casing thickness) from the thresholds that have been given (Table 4)

Grade	Max_ML	Corrosion Level	Diagnosis & Recommendations
A	0-5%	Negligible	Within tool accuracy calculation. Generally not a matter of significant concern.
B	5%-10%	Light	This is on the threshold of accurate detection and may indicate onset of localized corrosion activity.
C	10%-20%	Moderate	This grade may be associated with higher level of corrosion activity and/or with possibility of critical damage across a localized area. Further evaluation and if required, remedial action may be considered if means and access to this tubular is available.
D	>=20%	Intensive	Generally, this is associated with integrity issues in that part of the tubular. Peak corrosion activity in one depth has a higher probability of penetration damage of the tubular. Remedial action after further evaluation is recommended.
E	<0%	Special Joint	Associated with joints that have a higher weight or electro-magnetic permeability.

Table 4. Metal Losses Classification (PPL-Z MTD Internal Report, 2018)

The MTD result shows that there was high corrosion at a depth of 163.9 mMD on the 20” casing and 161.5 mMD on the 13-3/8” Casing (Figure 3). All of the metal losses were more than 20% and already classified as intensive corrosion. The depth of losses between the 13-3/8” casing and 20” casing were nearly identical, which mean one source is the root cause of the problem.

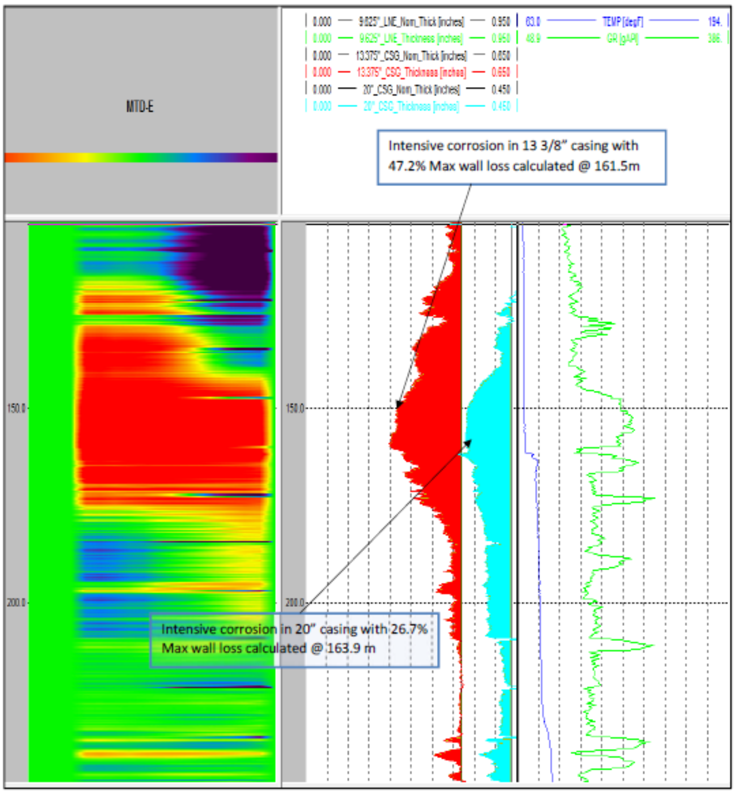

Figure 3. MTD Data Patuha Well (PPL-Z MTD report, 2018)

5. CONFORMANCE OF CASING FAILURE

Another factor that influences the casing failure is load distribution of the production casing. Since the casing design of deep geothermal wells commonly reach more than 1 km long, the forces that have been applied during each processes’ period is critical. This paper classifies the production casing load in four stage. During installation (A), stimulation of the well (B), discharge of the well (C) and production of the well (D) (Figure 4).

During the installation period, gravitational force is the main factor that influences production casing load. The first load on the casing is tensional force due to gravity (shown on Figure 4, A). The tension increases with increased depth, putting the highest strain on the last installed casing component that supports the whole casing before the cement sets (Kaldal et al., 2011).

During the stimulation period it is common that cold fluid will flow through the casing, this will result in a vast temperature range since the reservoir is hotter than the fluid. The production casing should be able to withstand the force from the reservoir to prevent thermal shock that could result in thermal cracking on casing (shown on Figure 4, B).

The period of discharging the well would have a different force applied. The main cause is because during the discharge period the well will have the maximum temperature build up. Corresponding with this, the casing would be expanding from its initial condition while the fluid forcibly interacts with the casing (Figure 4, C). If it is not controlled correctly it could cause a rapid depressurization and a temperature increase which could result in casing deformation.

The last period is the production period, after conducting all of the processes the well will begin production, which means a more stable temperature and pressure will be hold. These activities will make the casing tend to shrink while the fluid rises (shown on Figure 4, D). If it's not controlled correctly the end result is the casing could decompress and another deformation inside could occur.

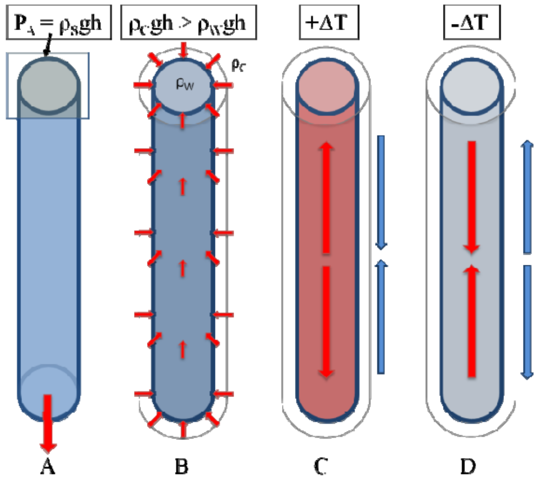

Figure 4. Production Casing Load (Kaldal et al., 2011)

Additional tools that could determine the source of problem is by using Downhole Video / Video Record. Casing collapse in geothermal wells is normally due to the thermal expansion of trapped fluid in the casing to casing annulus. With the use of downhole video cameras, this type of failure is readily identified by the deformation being segmented to one side of the casing circumference (Shouton, 2005).

As an additional confirmation DHV tools were run. The result shows a leakage at a depth of 163.5 mMD. The image shown there was a fluid influx into the production casing. The fluid was flowing heavily thorough the wellbore. The casing seems to have collapsed and cracked when the processes occurred (Figure 5).

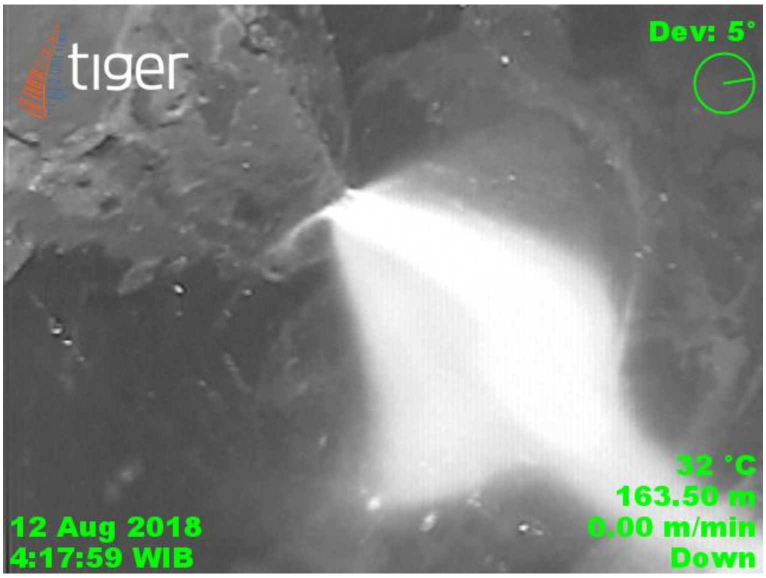

Figure 5. DHV Image of PPL-Z

The root cause of this problem might come from implosion or thermal cracking during the production period of the well. There might be some kind of fluid trapped near a depth of 163.5 mMD which could come from the leakages of the 20" casing. As the fluids are trapped in the annular surround of the 13-3/8" and 20" casings, the higher temperature steam flows out from reservoir. These events cause the trapped fluid to expand, since there is no atmospheric discharge the expanded fluid forces the casing to deform. The event here resulted in casing collapse and breakage, so the surrounding fluid entered the wellbore.

Same research had been conducted by Kaldal et al, (2011) to determine the casing buckling effect from water trapped using the finite element model (Figure 6). The result is similar to the shape of the casing buckling in the Patuha Wells. This result confirmed that the collapse of the Patuha Well production casing was of a similar nature.

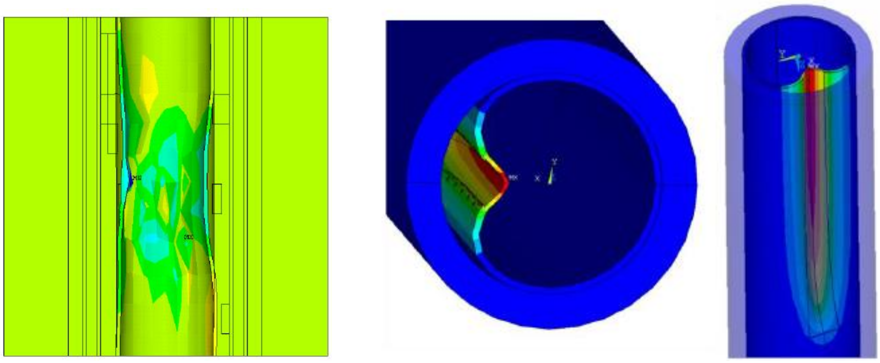

Figure 6. Left-Finite Element Model Result of Casing Buckling (Kaldal et al., 2011), Right-Collapsed Casing with external defect depth of 40% thickness (Kaldal et al., 2013)

6. ACTION PLAN

To make sure the same event could not happen again, an analysis of the future action plan took place. The main reason for the implosion needed to be clarified. The source of fluid is not from the annulus of casing-to-casing interface at the 13-3/8" and 20" steel, so the workover needed to be able to repair the 20" casing leakage from the formation. One of the methods to repair this leakage is to squeeze cement to penetrate the formation behind the 20" casing (Figure 7).

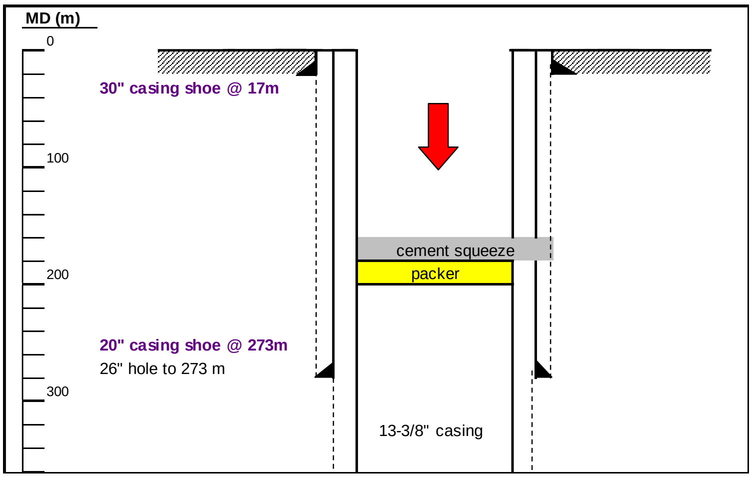

Figure 7. Squeeze Cementing method to cover leakage from formation behind 20" casing (internal workover program Geo Dipa Energi for PPL-Z Well, 2019)

Another plan was necessary to make sure the squeezed cement did not get contaminated during discharge and production. As mentioned by Southon (2005), the connection between the tieback and the liner will invariably leak down the lap during the productive life of the well (Table 5).

	Confirmed failure incidents (%)		
Production casing string profile	Total Trapped fluid	Parted Casing	Lap Leaks
Single string casing ()			
Big holes	7.1%	2.4%	N/A
Standard holes	1.0%	2.6%	N/A
Tieback and Liner			
Big holes	11.1%	5.6%	5.6%
Standard holes	0	9.1%	0

Table 5. Quantity of casing failure incidents between single string and tieback liner (Southon, 2005)

A better method to case the cement is by using a single string casing or often what is commonly called a long-string. The idea is by setting down another 9-5/8” casing of the same grade on top of an existing 9-5/8” liner. The long-string is then cemented using the stab in stinger method to reduce the probability of trapped fluid on the annulus of casing to casing (Figure 8).

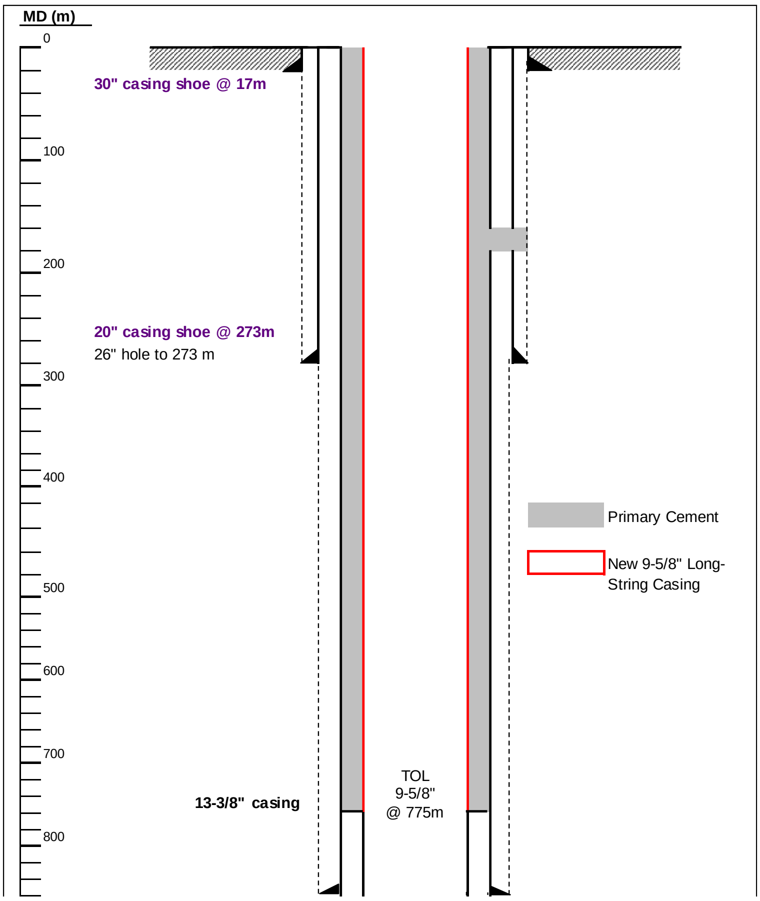

Figure 8. Long String method to cover casing failure inside the wellbore (internal workover program Geo Dipa Energi for PPL-Z Well, 2019)

With this method hopefully the probability of another casing failure event will be reduced and the well can continuously produce with a better steam purity.

7. CONCLUSION

An early indication of this anomaly on geothermal production wells could be detected with geochemical survey data. As shown in this paper, differences in geochemical data year-over-year might indicate fluid and enthalpy changes on PPL-Z. Additional reconfirmation of data by using the common wellbore survey tools (such as PTS) could lead to a better interpretation of wellbore/reservoir conditions.

For old geothermal wells, information about casing integrity is needed to draw a conclusion. Magnetic Thickness Detector (MTD) tools are proven to increase confidence levels when identifying the source of a casing problem. The MTD shows the percentage of wall loss on a casing, based on inputted casing grade and magnetic decaying rate values. The result in this case shows that a 47.2 % wall loss occurred on the 13-3/8” casing at a depth of 161.5 mMD along with a 26.7% wall loss at 163.9 mMD in depth for the 20” casing. These results confirm bad casing was found in PPL-Z and could be the source of the problem.

After all the data was gathered, downhole video tools provided direct evidence of the anomaly. The image shows that there was a fluid influx entering the wellbore with a relatively high flowrate. This phenomenon is in conformance with property changes demonstrated by geochemical data.

A proper action plan is needed to make sure the problem is not repeated. Research found that long-string casing is the appropriate method, in geothermal wells, to decrease the possibility of implosion. Therefore, a program to do workover realignment (install long-string casing) in the wellbore was prepared.

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