

## Comprehensive Production Casing Stress Evaluation in Geothermal Well

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### ABSTRACT

Casing stress is increasing while the well is cemented and exposed to a higher temperature formation. Normally, temperature is increasing as the well depth is getting deeper corresponding to in-situ ground temperature. Heat from cement slurry hydration that occurred when the cement is set and locked up onto the casing, could increase casing temperature which varied at the points along the casing. Most of casing problems found in the initial well productive period are mechanical problem and will occur in the upper section of the production casing. Those problems are casing implosion, compression failure, sulfide stress cracking, corrosion, and quenching. It is important to analyze each of the problems to analyze casing failure mechanism. This study will focus on evaluating casing stress based on temperature effect and failure mechanism which is casing implosion, compression failure, sulfide stress cracking, corrosion, and quenching. The comprehensive recommendation is developed to prevent such casing failure based on lesson learned from case study in Indonesia geothermal field.

### 1. INTRODUCTION

Typically casing is cemented in tension state that equal to normal buoyant weight of casing plus partially drag that might occurs when casing lifted and slip is placed. In directional well, total vertical buoyant weight of casing minus the fact that half of the weight is beared by formation along the deviated section. But, because of this, drag is increasing and stress on the rig floor will shows quite high drag component if casings were set at upstroke when reciprocating operation.

Secondary stress caused by directional well is bending that is caused by bent casing on dog legs. High dog legs will not present at vertical hole. But, severe dog legs could be experienced at or below the kick off point or at the position where correction run is done. This bending causing compression and tension at the casing. Tension stress usually considered in casing design, while compression stress is frequently neglected. However, compressive stress must be considered in the thermal stress analysis because compressive stress has critical role on casing failure.

### 2. CASING STRESS MECHANISM

#### 2.1. Purpose of Casing Cementing

The purpose of casing cementing in geothermal well is to set all casing assembly firmly to anticipate thermal change during production life of well. Two phase of production high temperature in the field causing consequence, that concept and methodology of casing setting depth relatively more sensitive. Also, cement must provide barrier to fluids transmission or gas in the annulus, either towards the surface or going into reservoir. Proper cement has a function as a barrier to anticipate corrosion attack on casing by formation fluids. Stress inflicted by casing to cement during thermal change typically greater than compressive strength of cement. It will be tough for cement to become a homogenous impermeable barrier if exposed to stress like this. Microfracture will be formed and bond between cement and casing will be damaged after a while.

#### 2.2. Casing Installation

Minimum depth to install casing 20" must be based on formation pressure that might encountered while drilling to maximum vertical depth for 17 1/2" hole. According previous wells, this pressure is identical to reservoir pressure. Maximum pressure that is read on the wellhead of the wells recorded has a magnitude of 1400 psig (100oC). Therefore, minimum vertical depth for 20" casing must be 500 m (with assumption that average SG overburden pressure is 2.0). This depth is also important to resist every leaks on the liner lap.

The main reason why casing setting in geothermal well is so important is, because, very high compression stress due to high temperature difference when cement harden (and lock in the hanging state, or tensile stress) and the temperature on that section passed through by hot geothermal fluid.

#### 2.3. Cementing Temperature

From several temperature profile checked, formation temperature in Field X decreasing constantly from reservoir temperature (300+oC) above point 1600 m. Circulation temperature before cementing typically predicted from flowline temperature. If better data to casing depth (e.g. MWD) is available, therefore the data should be used.

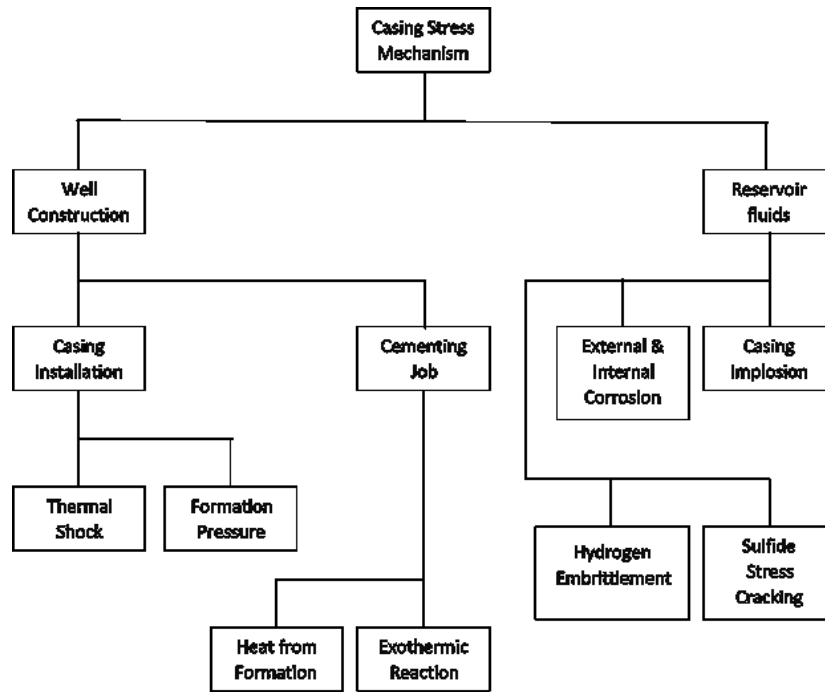


Figure 1. Casing Stress Mechanism Diagram.

#### 2.4. Other Mechanism

Casing Implosion.

Casing implosion could give virtual effects on well productivity immediately after first discharge. Casing collapse in geothermal well mostly caused by thermal expansion from the fluid trapped in the casing annulus.

Compression Failure.

This failure type occur in error while determining tension failure casing on coupling when well with high temperature starts to cool down. The failure generally occurs in:

- a. Fields with high temperatures.
- b. Production at high temperatures (wellhead temperature reached 260oC).
- c. A good cement operation on production casing.

High temperatures in wellhead could occur when the well at pressure hot bleed (example at maximum discharge pressure).

Hydrogen Embrittlement and Sulfide Stress Cracking.

Sulfide stress cracking is not a normal thing in geothermal well. It could occur if we use production casing and well head anchoring string grade K55 and L80, or if operator keep the well at high temperature even when the well does not connected to gathering system.

Corrosion (Internal & External).

CO<sub>2</sub> rich environment at the shallow reservoir fluid is caused external casing attack. In the early 1990s, CR22 casing (steel with 22% of chromium) is used by operator in geothermal field to overcome external corrosive attack from the formation.

Quenching.

Quenching process is recommended to be done by increasing the temperature slowly thus the casing can "relax" and prevent the minimum stress on the iron. As the new casing has a perfect thickness, the maximum stress generally unaffected by quenching. However, when the casing has been eroded as a result of damage or corrosion, the casing can be deformed.

3. CASE STUDY

Well X has up to 300°C isotherm profile till the depth of 230 m. Above that level, the temperature profile isotherm at 80°C and shows the occurrence of small steam escaping.

Table 1. Well X data.

<b>Depth of Kick off Point</b>	700 mRKB
<b>CASING DETAILS</b>	<b>MEASURED DEPTH (mRKB)</b>
20" K55 133 ppf, BTC, R3	447
13-3/8" K55 68 ppf, BTC, R3, ECP/DVC at 679.5 m	1555.
9-5/8" N80, 47 ppf BTC, R3 (blank top 5 jts).	2554 (TOL 1496)
Blind uncemented liner 7" C75, 29 ppf, BTC, R2	1215 to 1599.6
Slotted uncemented liner 7" C95, 29 ppf, BTC, R2	1599.6 to 2030
<b>Discharge History</b>	Kicked for hours. Gas bleed 1180 psig to steam (750 psig) Tested for 5.5 days Feb. 12-17 1997. NC 0.7% wt (H2S 1100 ppmw).
<b>Post-discharge down hole runs</b>	Problem with steam exiting at 300 m - sharp temperature drop. Check well history shut in conditions and well construction.

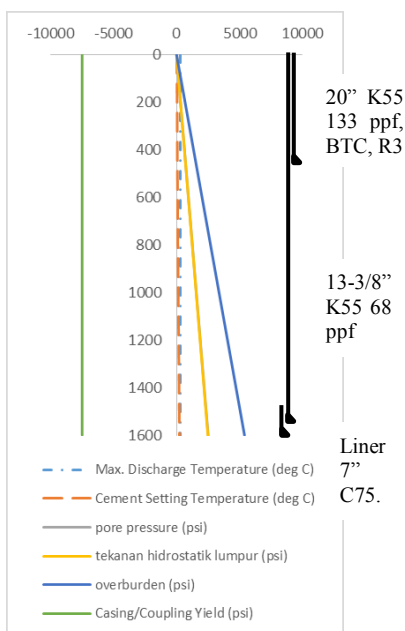


Figure 2. Casing/coupling yield, maximum discharge temperature, and cement setting temperature of the well.

Figure 2 shows casing/coupling yield in psi, maximum discharge temperature in celcius degree, and cement setting temperatur in celcius degree of the well.

4. RESULT AND DISCUSSION

Strained casing joint indicated that the casing is deformed while experiencing compression (and also permanent shortening) when the well is heating up. This mostly caused by lack of initial tensile stress at the casing when cement is installed and due to high temperature different. Figure 1 shows the possibility of actual stress at casing when cement is pumped (full weight and partially slacked off), and

experiencing heating up and stuck. Even though at full weight, compression stress while heated up is in the range that exceeds yield line. The fact that not all couplings are fail is the sign that variability on cement shear resistance exist between two casing.

If L80 casing is used, this casing may not failed although that is also depend on tension remained in the casing during cementing. Drilling log shows casing is slacked off after waiting on cement at the first stage. This was done to insert expansion spool centralizer. There is concern of failure at external casing packer (ECP) if full original pick up load is applied. There are no notes available to this review although geograph may could help to explain this problem. Leakage from 20" casing is very possible. It is likely occurs at the coupling. High temperature leak test of buttress thread coupling that was done by Japanese steel manufacturer company shows that leak resistance is way lower than resulted from cold test. This occurred on 7" casing and it should be noted that the larger the diameter of coupling, as in 20", the smaller API resistance to resist pressure than coupling at the pipe that has smaller diameter. Leakage in Well X will be relatively smaller, otherwise, there will be signs at the surface from this leakage or indication at another well in this pad.

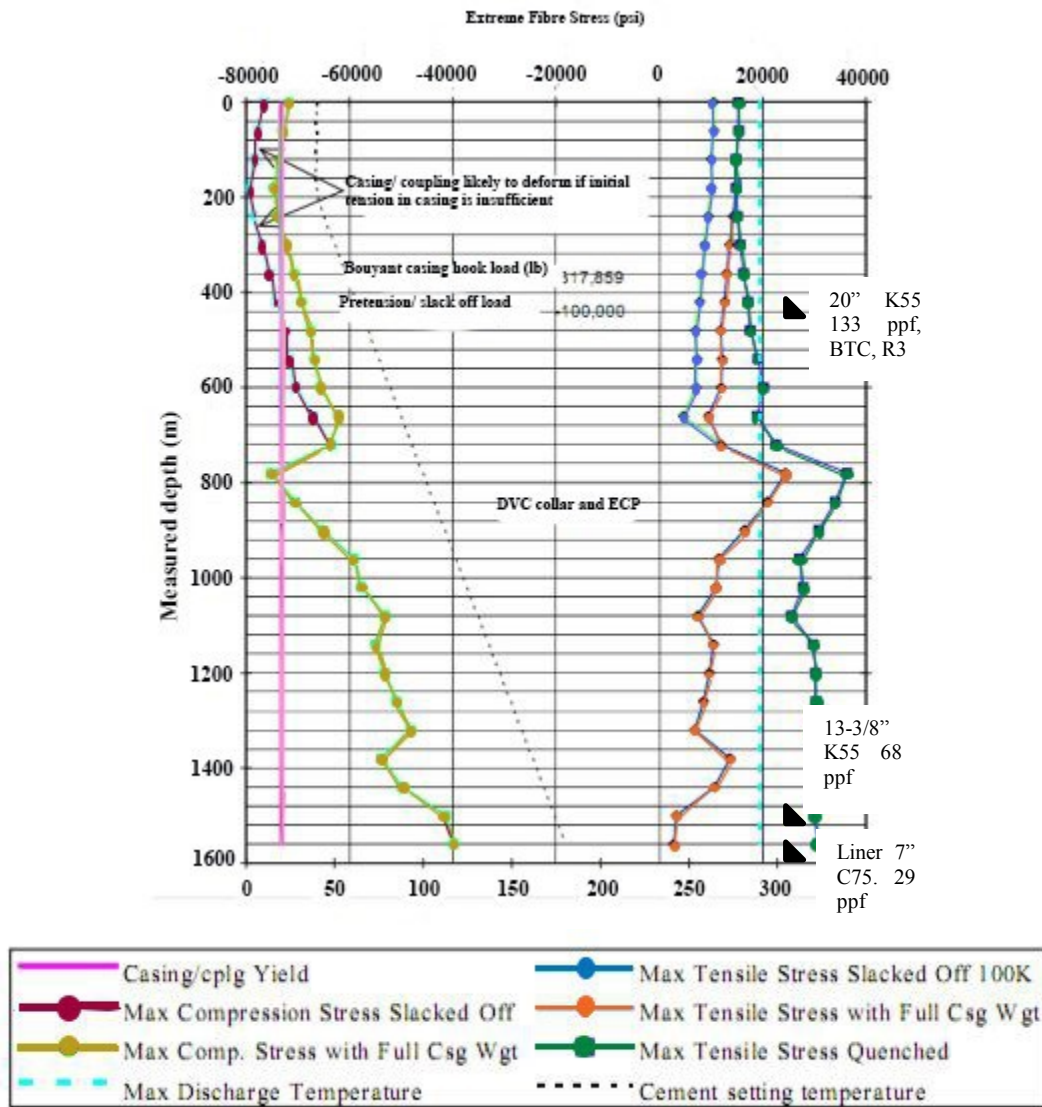


Figure 3. Stress and Temperature Diagram for Well X.

5. CONCLUSION

- i. Practical design in this field cannot prevent casing failure caused by pressure and heat from trapped fluids in casing to casing annulus. Therefore, it is recommended to focus on minimizing the risk of fluid entrapment in the casing annulus by:
  - a. Choose retarder that insensitive to small concentration fluctuation.
  - b. Make sure system quality to keep uniformity while pre-mixing the chemicals and mixing of the slurry during cementing operation.
  - c. Test the slurry design immediately before cementing using water on the rig site (mix water chemistry may vary, especially on rainy season).
  - d. Provide disposal channel if slurry does not suitable with the specifications needed.

- ii. When acid mineral identified in cased 17-½” hole, it is recommended to consider corrosion resistant casing material at the section of the hole.
- iii. When scab liner used with small annulus space (e.g. 10 ¾” in 13 3/8”), it is recommended to limit the length to about 700 m to prevent slurry hydration when slurry passing through annulus or by changing slurry design to reduce hydration risk.
  - a. It is recommended to use casing protector, now available in the market that could be utilized for a limited period in open hole. The cost using casing protector might be higher, but this also have to be considered with workover cost that may have to be done in the future and reduction in production revenue.
- iv. It is recommended to slowly heat the well before first discharge.
- v. It is recommended to keep the well at hot condition, considering these reasons:
  - a. To prevent casing corrosion on gas-liquid interface.
  - b. To reduce oxygen solubility outside the casing
  - c. To reduce sulfide stress cracking risk around wellhead and top section of the casing.
  - d. To prevent gas accumulation in great quantity near the housing area and needs to implement special safety measures when the gases released before doing well testing.

## 6. NOMENCLATURE

mRKB = Meters from Rotary Kelly Bushing

OD = Outer Diameter

ECP = External Casing Packer

BTC = Buttress Threaded Coupling

ASME = American Society of Mechanical Engineers

NACE = National Association of Corrosion Engineers

API = American Petroleum Institute

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