Reducing Casing Heatup Rates in Geothermal Production Wells by using Coiled Tubing Gas Lift

Matthew J Sophy[1], Paul F Bixley[1], Katherine Newman[1], Daniel Wilson[1] and Toby Ryan[2]

[1]Contact Energy Limited, Wairākei Power Station, Te Aro Road, Wairākei, Taupō 3377+

[2] Western Energy Services

Matthew.sophy@contactenergy.co.nz

Keywords: *Vertical Discharge, Casing, Coiled Tubing.*

ABSTRACT

After drilling completion, geothermal production wells are allowed to heat up for some time, then discharge tested to remove drilling debris and determine well output characteristics. Vertical discharge is a practical and inexpensive method of conducting the initial flow test. However, in some cases this method can result in rapid, uncontrolled heating of the casing with increased potential for casing damage or failure.

While it is preferable to heat the casing slowly, this is not always possible and wells may be opened from zero to 100% flow in a few minutes with associated casing temperature changes in the order of 200°C. Some wells have static temperature conditions with up to 800 meters of <150°C above hot 300°C reservoir. The cold column of water can be difficult to heat to saturation temperature required for boiling and initiation of self discharge. To reduce the heating rate and have better control of the flow it is now common practice to initiate well discharge using coiled tubing with air or nitrogen gas lift.

Recently Contact Energy have used Western Energy's coiled tubing unit to initiate flow in several otherwise difficult-to-start wells. During two of these jobs a temperature-pressure gauge was attached to the bottom of the coiled tubing string to record actual downhole conditions while initiating flow.

This paper compares heatup rate between "traditional" uncontrolled well discharge and that measured during a coiled tubing airlift.

1. INTRODUCTION

Tauhara is a high temperature geothermal field near Taupō, Aotearoa New Zealand. It is the eastern upflow associated with the Wairākei-Tauhara geothermal system. Tauhara feedzone temperatures are commonly 280-300°C. Most of the deep-cased production wells have <150°C temperature down to at least 800m and may not develop a positive wellhead pressure when fully heated, although some wells can develop a high shut-in gas pressure up to 70 bar-g. In the latter case, discharge can be easily initiated by rapidly bleeding off the gas pressure until deep boiling starts and natural two-phase flow begins. Other wells require some kind of stimulation to initiate two-phase discharge.

Until recently, the initial flow test has usually been done by "vertical discharge" where the well is opened from shut-in or bleeding condition and flowed directly to atmosphere (Figure 1). This method is inexpensive and often a 1-2 hour test can give a good estimate of the well potential. However, the combination of high feedzone temperatures, deeper cemented casing strings and the rapid heatup associated with vertical discharge increases the potential for casing failure. Recently Contact has used coiled tubing with gas lift to initiate flow in order to reduce the casing heatup rate during the initial discharge period. During two of the coiled tubing well stimulation jobs, a memory PT tool was attached to the bottom of the coiled tubing string in order to measure the actual casing heating rates while initiating discharge. This paper compares the heatup rate during vertical discharge and the rate during coiled tubing gas-lift.

Note that while vertical discharge has been the preferred method to use for the initial flow test, an atmospheric separator/silencer can equally be used. However careful monitoring and flow management is required to cope with large flow changes, sometimes accompanied by large quantities of solids, which can damage pipelines and block the silencer brine discharge lines.

Figure 1: Typical vertical discharge after 10 minutes flow

Proceedings 45th New Zealand Geothermal Workshop
15-17 November, 2023
Auckland, New Zealand
ISSN 2703-4275

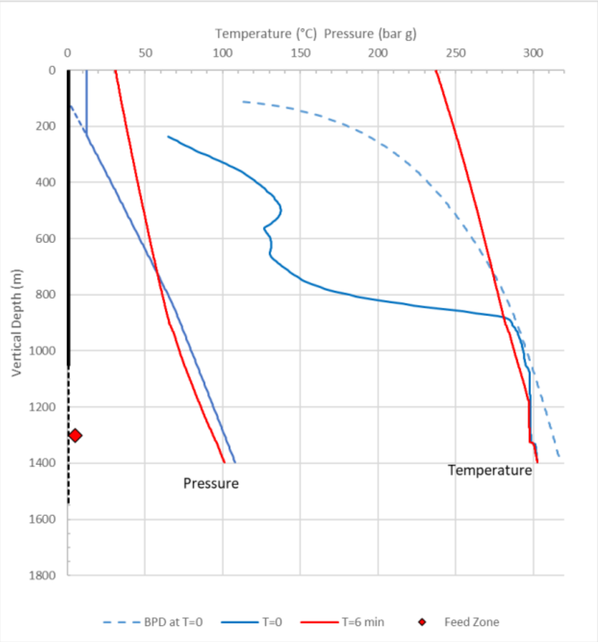

Figure 2 Well A: Typical pressure-temperature profiles for Tauhara production wells. Black line represents production casing, dashed black line is production liner. The fully heated shut-in pressure-temperature with the associated boiling-point-for-depth temperature(dashed) is shown in blue (T=0 min after discharge). The pressure-temperature profile measured while the well is flowing at T=6 minutes after discharge are shown in red.

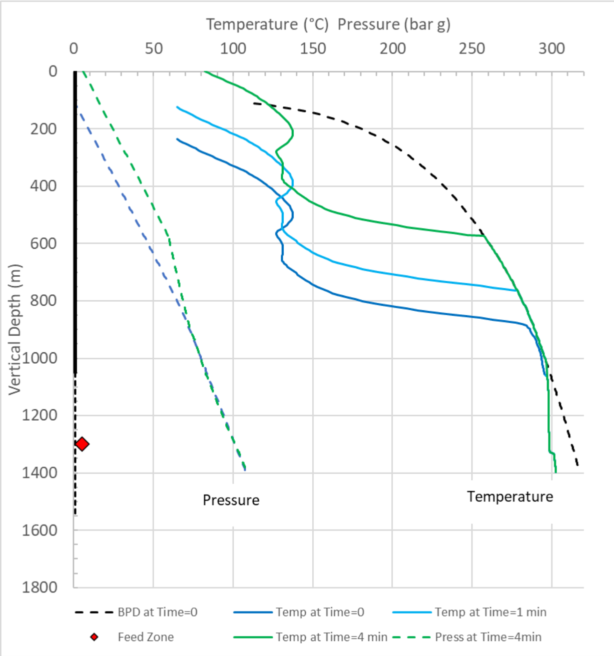

Figure 4 Well A: Expected temperature changes for the first four minutes of discharge, based on displacing the shut-in temperature profile up the wellbore while limiting temperatures to boiling point for depth. Temperature after 6 minutes are expected to be close to the flowing PT survey plotted on Figure 2

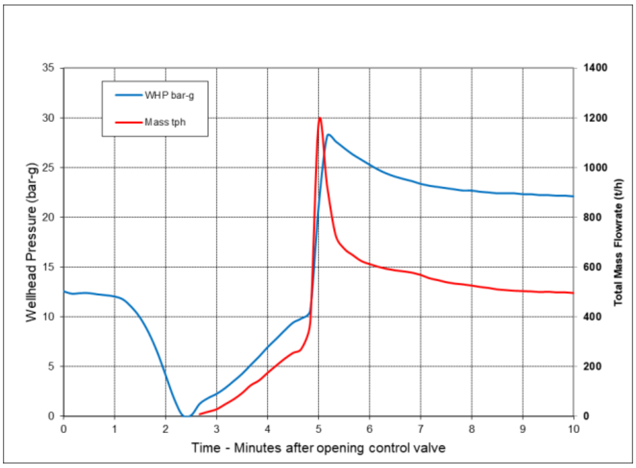

Figure 3 Well A: Wellhead pressure and flowrates observed during the first 10 minutes of vertical discharge to atmosphere from shut-in condition. (This is for a well cased 9-5/8" and feedzone temperature close to 300°C and very high productivity, in the order of 100 tph/bar).

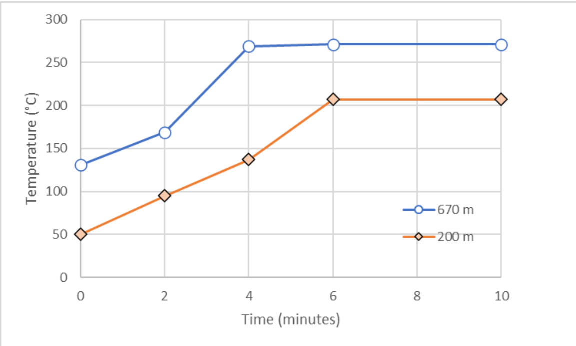

Figure 5: Expected casing temperature change at 200 and 670m, based on profiles plotted on Figure 4. The maximum rate is 50°C/min at 670m.

ISSN 2703-4275

2. VERTICAL DISCHARGE

2.1 Downhole conditions

A typical fully-heated, shut-in and flowing pressure temperature survey is plotted on Figure 2. Under shut-in conditions temperatures typically approach boiling-point-for-depth (BPD) at about 1000m depth. However, due to the cool section from surface down to 800m these wells may not flow without stimulation by compression or gas-lift. In this case the well stands shut-in with no wellhead pressure and a "water level" at about 120m depth. Figure 2 shows the well temperature between 900-1050m is already close to or at boiling point. Due to near water-steam saturation conditions at feed zone, only a small aircap pressure needs to be applied to initiate deep boiling and discharge. Figure 2 shows the pressure profile where aircap at 13 bg WHP has been applied, depressing the water level from 110m down to 240m.

2.2 Vertical Discharge Flow Evolution

A typical record of WHP and flowrate for the first 10 minutes of discharge is plotted on Figure 3. Note that for this data the flow control valve is electric-powered and the valve opening time from shut to full open is in the order of 1-2 minutes.

2.3 Evolution of downhole pressure-temperature conditions during vertical discharge

The discharge can be divided into four main stages (See Figure 3):

- 0-2 minutes: Gas discharge with no liquid: The well is opened, releasing the gas pressure and the gas-liquid interface quickly rises up the wellbore from 240m to 110m. This results in the complete fluid column (down to the feedzone) rising up the wellbore with the expansion of the deep two-phase zone

- 2-4 Minutes: The deep two-phase zone continues to expand and in combination with the inertia of the ascending liquid, cool non-boiling liquid is discharged at the wellhead

- At about 4.5 minutes the boiling two-phase column reaches the wellhead and the flowrate and wellhead pressure rapidly increase

- After 6 minutes a stable two-phase column has been established.

2.3 Casing Heatup Rate

The expected changes of casing temperature at 200 and 670m associated with the vertical discharge are shown on Figure 5. The maximum rate is 50°C per minute at 670m. Cemented casing across cold temperature inversions can be problematic due to encountering differential pressure regimes while drilling. These casing intervals have a higher potential for damage during heating. While vertical discharge quickly initiates flow and well characterization, it has higher thermal stress on the casing.

Figure 6 Vertical discharge sequence. See Figure 3 for timing – 6A T=2 minutes, gas-only discharge; 6B T=3 minutes, non-boiling liquid discharge; 6C T=5 minutes, Maximum two-phase flow

3. GAS LIFT

Over the last 10 years, gas lift has become Contact's preferred method for initiating flow from otherwise hard to start geothermal wells (Hanik, 2014). Well B, the example well used here is drilled from the same pad and has very similar characteristics (casing depth, high productivity and feedzone temperature) to Well A, the vertical discharge well discussed above.

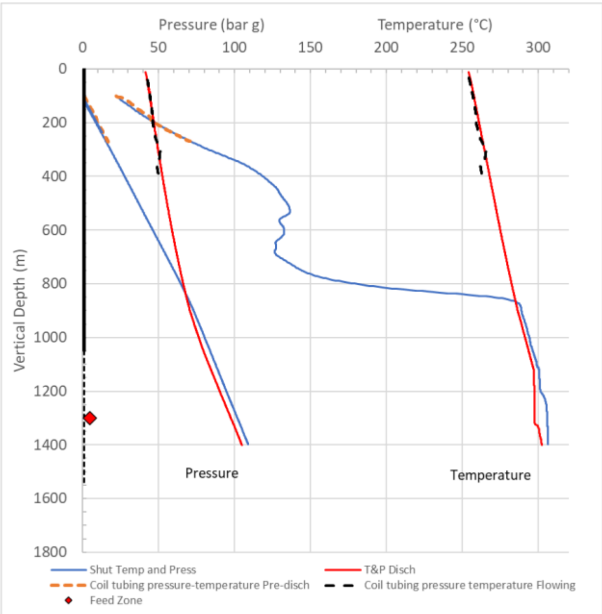

Figure 7: Well B - Shut-in and flowing pressure-temperature surveys

The shut-in PT profile prior to gas-lift is plotted on Figure 7. This shows the cool section, less than 150°C down to 800m, near-boiling conditions from 900-1150m and water level 120m below the wellhead. As expected, the measured pressure-temperature data from the coiled tubing conveyed tool prior to starting the gas lift are the same as those from the normal wireline PT survey data.

The full sequence of events associated with the gas lift are Well B are plotted on Figure 9. The fluid produced at the wellhead was diverted to an LECM (Low Emission Compact Muffler, Kyuden Group) where flowrate and enthalpy are derived from the standard James lip pressure method. The standard LECM setup employs a "Magflo" electromagnetic flowmeter which provides very accurate brine flow measurement (although care must be taken when reviewing flow data during flow change periods as there is a delay of up to 10 minutes in the brine flowrate due to the large volume holdup in the LECM). For the initial flow period when cool brine is being produced the total flowrate can be calculated from the brine flow and enthalpy based on the measured temperature (Figure 8)

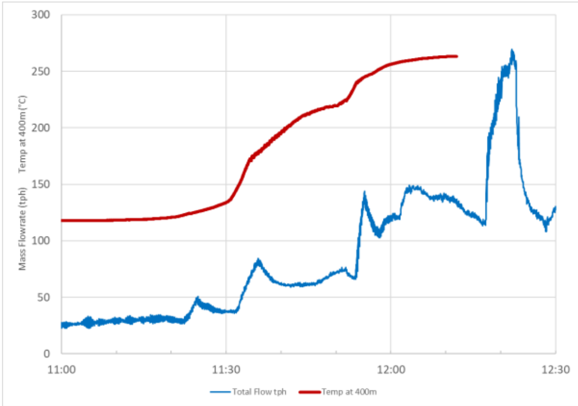

Figure 8: Well B Measured temperature at 400 metre depth and mass flowrate at wellhead during gas lift.

3.1 Casing Heatup Rate

The temperature measured at 400m during gas lift operation is plotted on Figure 8. The temperature starts to increase at 11:30 when approximately 30 m3 of brine has been produced. This is close to the volume of cool brine (<200°C) from water level to 800m (Figure 7).

From 11:30 to 12:30 the temperature at 400m increases steadily at ~ 4°C per minute until the temperature approaches the stable flowing value just above 260°C.

After the well becomes self flowing the coiled tubing was tripped out from 400m to surface. The pressure-temperature profile measured during the trip out is almost exactly the same as that expected from a normal flowing PT survey (Figure 7)

4. CONCLUSION

The temperature data measured while initiating flow in Well B shows a controlled casing heatup rate of 4°C per minute can be achieved using a coiled tubing stimulation. This compares with a heating rate of 40-50 °C per minute expected during a gas cap compression start.

Thermal stresses developed when initiating two-phase flow in high temperature geothermal wells have the potential to damage or collapse the cemented casing string. In order to reduce these stresses, the preferred method used to initiate discharge should attempt to minimise the rate of heating. The primary factor to consider is the total temperature change over the cemented casing interval. Other well construction attributes such as casing and coupling grade, potential defects in casing cement (if known from cement bond logs or other information) and the well age and casing degradation due to corrosion also should be taken into account.

These well criteria should be considered when selecting a well discharge method as a discussion between drilling and reservoir engineers.

ACKNOWLEDGEMENTS

The authors wish to thank Contact Energy for permission to publish this paper.

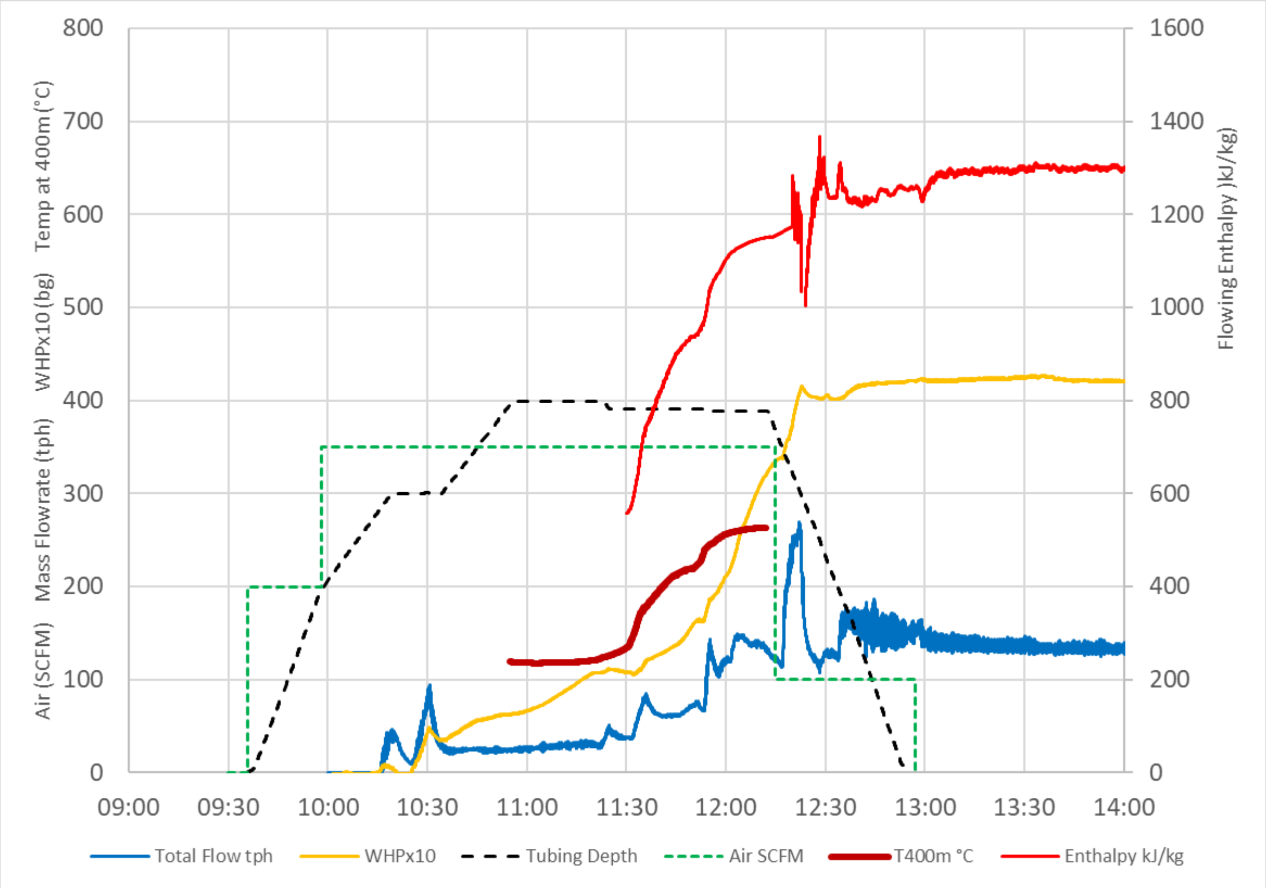

Figure 9 Well B: Well flow initiation using coiled tubing with gas lift. Mass flowrate and enthalpy are determined from a combination of the measured flowing temperature and lip pressure-brine flowrate

REFERENCES

Hanik, F., (2014). Initiating Well Discharge with Coiled Tubing. Proceedings 36th New Zealand Geothermal Workshop 24 - 26 November 2014 Auckland, New Zealand

Kyuden Group. Specifications for Well Testing Facilities and Instrumentation for High Accuracy Well Testing Operations. Thermochem 40x40 LECM. thermochem.com

ISSN 2703-4275