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COMPLEX FEED ZONE OBSERVED AT WAIRAKEI

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ABSTRACT

A recent Wairakei well showed anomalous behaviour compared to other adjacent wells. The major feedzone(s) was marked by a deep, narrow temperature inversion with upflowing steam and downflowing liquid at different temperatures. The same phenomenon had been observed in a Philippine well. A similar mechanism may be responsible for this behaviour by two feed zones located in different types of reservoir.

INTRODUCTION

After 30 years of exploration and production at Wairakei, an infill well can still produce completely unexpected results. Recent wells have been drilled to tap the steam zone to the west of the main production sector. One of these wells appeared to have failed to encounter permeability within the steam zone and was completed as a two-phase producer. The absence of a permeable feed in the vapour zone was tested by a halt to drilling. With water shut off no significant wellhead pressure was obtained, although earlier tests had indicated pressures consistant with a steam zone.

We were somewhat astonished by the results ,of the completion tests and heating surveys. The pressure surveys indicated a highly permeable or steam zone above the expected steam/water interface, which was verified by water loss temperature surveys. These are shown in Fig. 1. The well came under pressure rapidly, also indicating the presence of mobile steam.

The biggest surprise however was the pronounced, deep and narrow temperature inversion recorded on the temperature survey run after 3 days heating (Fig. 1). This feature , with a high temperatue upflow above and a downflow at an intermediate temperature appeared to be similar to a phenomenon observed in another anomalous well in the Philippines. This well in the Nasuji-Sogongon sector of the Southern Negros geothermal field was observed to have an anomalously hot two-phase zone in a liquid-dominated area of the reservoir. It likewise had a high temperature upflow and a cooler downflow within 50 m of each other. This profile was also was marked by a very narrow, deep temperature inversion during the early heat-up period.

The subsequent behaviour of inversion zone of the Wairakei well however was different. This feature was only observed briefly in the Sogongan well, during bleed after quenching (Fig. 2). A clue to the cause of the very localised cooling was given by the icing of the bleedline. It was believed that the expansion of COz on entry into the wellbore was responsible for this cooling, by the Joule-Thomson effect. Because of the simultaneous downflow from just below there was no mixing with hotter fluid to conceal this feature. The well continued to produce a very strong gas bleed but he pressure control point was apparently 400 m deeper in the well and the output testing showed only a low excess enthalpy. The major production . zone may have been near the bottom of the well although frustatingly near the same temperature, 275 C. The downflow at 230 C plus temperatures continued after discharge testing.

At Wairakei the inversion persisted throughout the 2 1/2 month heating period (Fig. 1). The temperature rose steadily towards the final upflow temperature, which was also attained by the downflow. One day after a vertical discharge the downflow temperature was slightly higher than the upflow. The discharge enthalpy was not measured directly but inferred by gas sampling and from the quartz temperature. It appears that that well was essentially a single-phase liquid producer. The CO_2 level in the steam phase was low. The chemistry was however still affected by drilling fluid.

Mechanism

The two wells may have similar mechanisms responsible for the presence of a two-phase upflow and liquid downflow emanating from within 50 m of each other. In Sogongon there must be a vertical structure feeding high temperature fluid up through the liquid-dominated reservoir. Some condensation of steam would occur leading to high gas concentration. It is not clear if the cooler liquid water downflowing into the wellbore is from the same fracture zone with phase separation taking place in the fracture or is a discrete feed.

Two hypotheses are put forward for the Wairakei well. The steam zone induced by pressure drawdown from large scale production overlies the liquid reservoir.

The first hypothesis is that there are discrete vapour and liquid feeds separated by a small interval of impermeable rock. This would be consistant with the layered nature of the Waiora Formation. The inversion would then be due to the slow thermal recovery of the impermeable layer between the zones. Against this hypothesis is the fact that the pressure surveys show that the steam/water interface lies at or very close to the centre of the inversion. This is at a depth lower that the depth at which this interface has been consistantly identified in surrounding wells. The alternative hypothesis is that there is a vertical or near-vertical fracture connecting the steam and liquid feeds. In this case the steam appears to be drawn down through the liquid-dominated reservoir. Condensation would enrich the steam in CO_2 . If this is correct there must be a permeable zone higher in the well which accepted the upflow, as condensation in the upper casing seems inadequate to account for the flow. The inversion would then be due to the Joule-Thomson effect.

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REFERENCE - Not published

CATACUTAN, A.V. (1981): Sogongan-2 Completion Tests Report PNOC-EDC Internal Report.

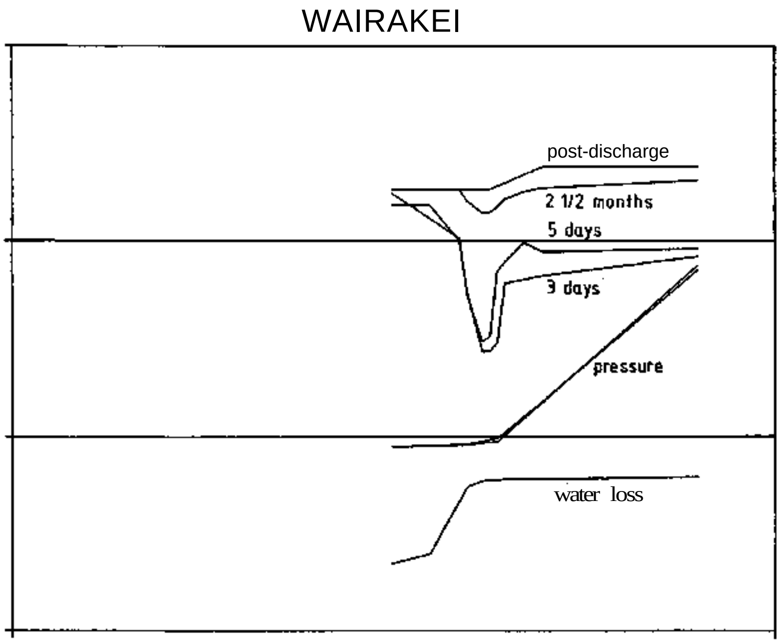

Figure 1

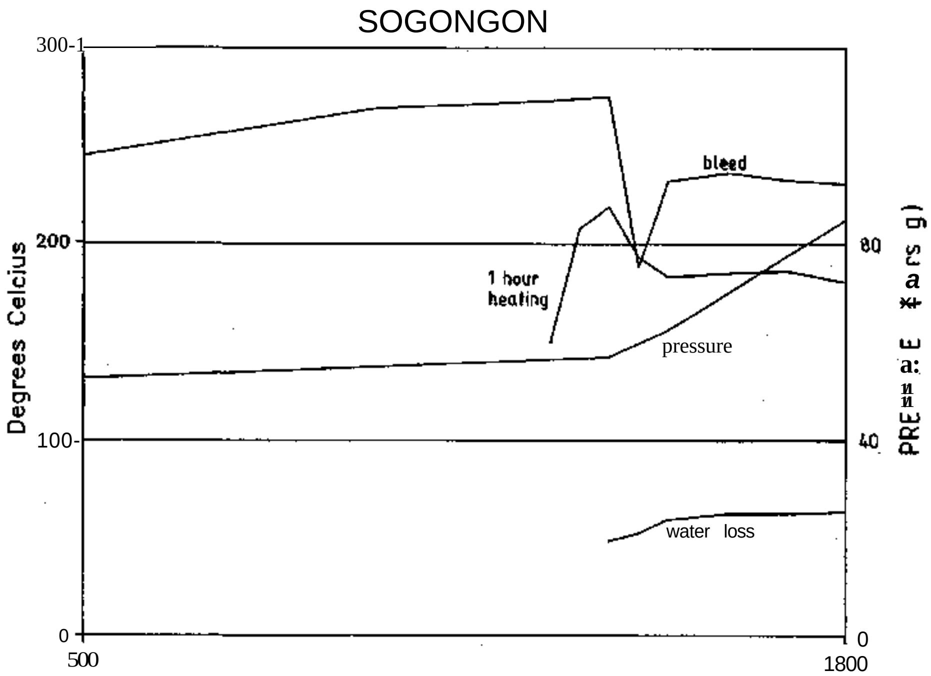

Figure 2.