

INTERPRETATION OF INTERFERENCE EFFECTS IN THREE PRODUCTION WELLS IN THE KAWERAU GEOTHERMAL FIELD, NEW ZEALAND

Lynell Stevens and Kevin J Koorey

Works Geothermal Ltd
PO Box 341, Taupo
New Zealand

ABSTRACT

Downhole temperature and pressure, mass flow, and enthalpy measurements on three production wells at Kawerau geothermal field are interpreted to illustrate interference effects between these wells. Feed zone locations within the wells, together with geology and chemistry are discussed. Downhole measurements are made in one well while production flow changes are made on another well to monitor pressure transient effects. The interference effects have implications for planning future production drilling.

INTRODUCTION

The Kawerau geothermal field covers an area of 20 to 35 km² and is located on the northeastern boundary of the Taupo Volcanic Zone. Fluid temperatures exceed 310°C. The deep fluid has a chloride concentration of around 925 mg/kg and a gas content of 2.8 wt % most of which is CO₂. Natural heat flows to the surface, pre development, were 100 to 150 MW (thermal).

The Kawerau geothermal field has been utilised since 1958 to supply steam to the Tasman Pulp and Paper Ltd mill for process and power generation. The geothermal production facilities are owned by the New Zealand Government and operated by Works Geothermal Ltd.

Five two phase production wells are connected to four separation plants. These supply up to 320 tonnes/hour of steam at 7 and 9 bar g to the Tasman mill and timber drying kilns. The steam demand varies with the mill's operational requirements.

Separated water is supplied to two Ormat binary power plants. Two reinjection wells and two cooling ponds are utilised for waste water disposal. A number of investigation and former production wells are used for resource monitoring.

There has been little measurable pressure decline in the deep reservoir due to production, and reservoir pressures still exceed a hot hydrostatic pressure gradient to the surface. Although there are cool downflows around 500 to 1000m, there has been little temperature change below 1000m depth.

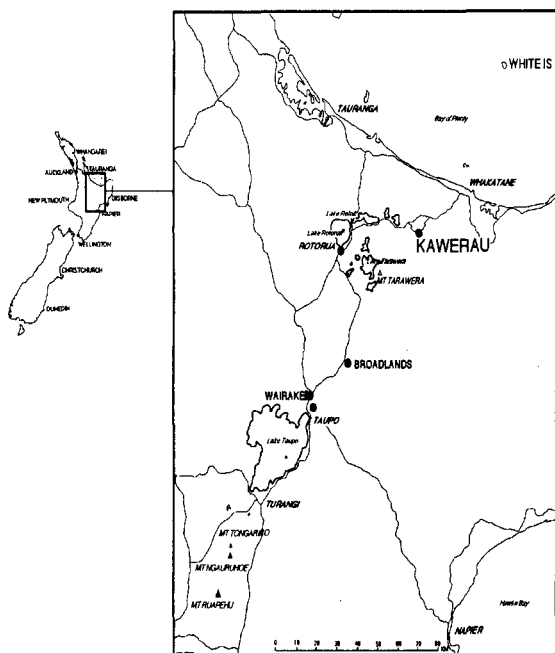


Fig 1 Location of the Kawerau geothermal field

This paper is a progress report on the interference effects between three of the production wells, and a recommendation for future work.

STEAM PRODUCTION

Wells KA21 and KA27 produce 150 tonnes/hour steam and have been reliable production wells for about 15 years. In 1990 when additional steam production was required a new well, KA36, was drilled in the same area. This was considered to be the lowest risk option for production drilling with the highest probability of increasing the steam supply.

KA36 was drilled 300m from KA21 and 450m from KA27 wellheads and was deviated 70m horizontally to target the same fault zone intersected by KA21 and KA27. KA21 and KA27 are not deviated. Fig 2 shows the relative location of KA21, KA27 and KA36 to each other and to the fault structures.

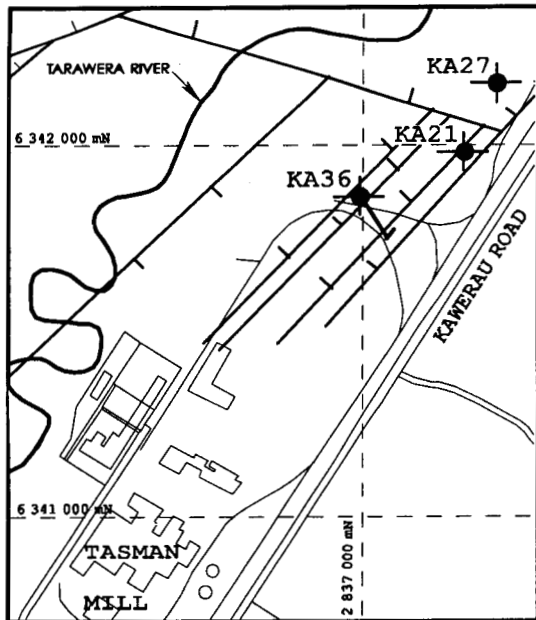


Fig 2 Location of KA21, KA27 and KA36

	KA21	KA27	KA36
Production Casing Diameter	9 5/8"	8 5/8"	9 5/8"
Production Casing Depth	532m	655m	1088m
Slotted Liner Diameter	7 5/8"	6 5/8"	7 5/8"
Bottom Hole	1223m	1521m	1354m

Table 1 Well data for KA21, KA27 and KA36

KA36 PRODUCTION WELL OUTPUT

After drilling in December 1990 KA36 was connected to the KA21 and KA27 combined two phase line. KA36 was output tested over two days in April 1991. The output was measured via Separation Plant SP21 when KA21 and KA27 were shut for maintenance.

The output curve is shown in Fig 3. The well stabilised quickly and had an enthalpy of 1260 kJ/kg and a feed water temperature of 287°C. KA36 produced 80 tonnes/hour steam (315 t/h mass) at 13.3 bars g WHP and 7.0 bars g separator outlet pressure.

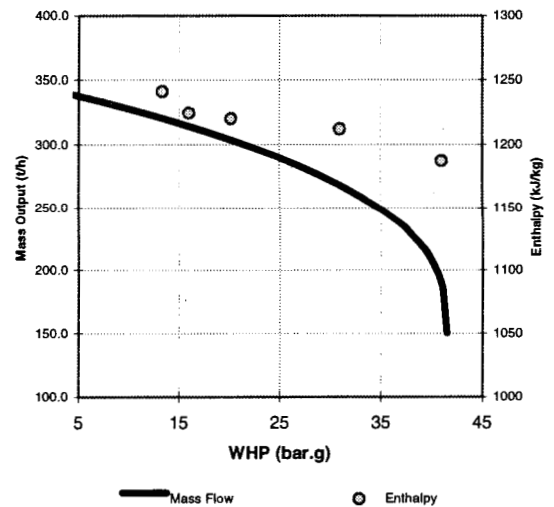


Fig 3 KA36 Output Curve with KA21 & KA27 Shut

Before the above test, and with KA21 and KA27 on production, KA36 WHP of 13.7 bars g and 7.0 bars g separator outlet pressure the incremental increase in steam supply from the addition of KA36 to SP21 was 40 tonnes/hour. Because all three wells were connected to the same separation plant only the total output from all three wells could be measured. Increased flow in the two phase pipeline caused a back pressure increase which affected the total steam production.

In December 1992 KA36 was connected to a new separation plant, SP36, which resulted in a lower KA36 wellhead pressure which improved the production from KA36 to 50 tonnes/hour steam. The new separator also allows the output of KA36 to be measured separately from KA21 and KA27. A cross connection is often used between the two two-phase

lines to share flow between the two separation plants. Only when the cross connection is closed can the output of KA36 be measured. KA36 output has not been measured again with KA21 and KA27 shut. The arrangement of the production pipework is illustrated in Fig 4.

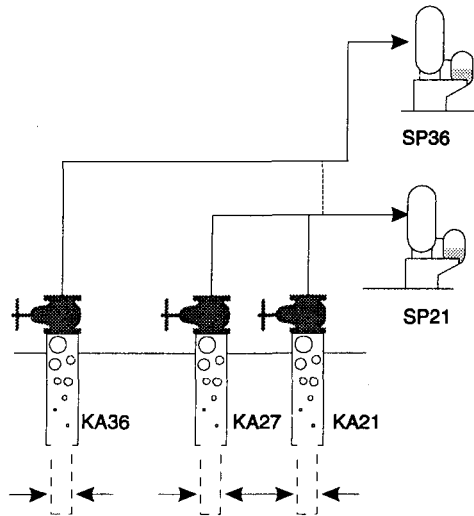


Fig 4 Two Phase Line and Separation Plant Arrangement

ENTHALPY AND MASS

Enthalpy and mass measurements were made in December 1995 with the crossover shut isolating KA36 from KA21 and KA27, and data was averaged over 12 hours. When KA21 and KA36 were on production, KA27 was opened for production and the enthalpy and mass flow decreased from KA36. It is probable that when KA27 was on production the reservoir pressure was lowered at the connecting shallower feed zone, causing increased production from the deeper lower enthalpy zone in KA36.

There could have been a change in KA21 enthalpy but with the combined two phase flow from KA21 and KA27 it is not possible to measure KA21 or KA27 enthalpy when both wells are on production.

The enthalpy decrease at KA36 was from 1187 kJ/kg before KA27 was on production to 1133 kJ/kg after KA27 was put on production. The mass flow at KA36, corrected to 10.5 bars g WHP, decreased from 185 tonnes/hour to 176 tonnes/hour. This is a 5% mass decrease caused by an interference effect in the shallower feed zones from a production well 450m

away. The nett mass gain from adding KA36 production to the system was 9%.

KA21 would be expected to have a more pronounced effect on KA36 as the wells are 300m apart, whereas KA36 and KA27 are 450m apart.

	KA36 Enthalpy kJ/kg	KA36 Mass t/h	KA21+ KA27 Mass t/h	KA36+KA21 +KA27 Mass t/h
KA27 shut	1187	185.4	512.4	697.9
KA27 open	1133	175.9	583.8	759.7
Difference	54	9.6	71.4	61.8
% change	-4.6	-5.2	+13.9	+8.9

Table 2 Enthalpy and mass change when KA27 is opened

CHEMISTRY

The production wells KA21 and KA27 are cleaned out approximately annually to remove calcite deposition. During production the liquid flashes in the well bore and calcite is deposited on the production casing and liner. As the well becomes blocked with calcite the deeper feeds become choked. Production oscillates between the deep and shallow feeds depending on the state of deposition in the well.

The deeper feed zones are dilute relative to those shallower in the well, and the chloride concentration in the production fluid changes as the contribution of different feed zones within the well changes. Following a cleanout the chemistry of the deeper feed zones will dominate. Fig 5 shows the lower chloride concentration with depth.

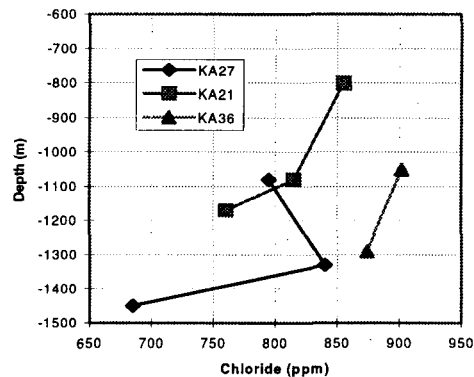


Fig 5 Downhole Chloride for KA21, KA27 & KA36

When KA36 was initially connected to the steam supply system and put on production the well affected the production chemistry of the fluid from KA21 and KA27. Lower chloride values from KA21 and KA27 showed an increase in proportion of production from the deeper feed zones, indicating less fluid production from the shallower feed zones due to interference from KA36.

The interference effect could be most pronounced when KA21 and KA27 are in a pre cleanout state and the deeper feed zones are choked with calcite. ie when production from depth is decreased and the production from the shallow feeds is more dominant.

DOWNHOLE TEMPERATURE AND PRESSURE

At production depths temperatures are in the range 250°C to 280°C. Small temperature inversions are present at shallow depths indicating cool crossflows. In the northern part of the field in the KA21, KA27, KA36 area the wells have a temperature inversion below 1000m depth illustrating the outflow nature of this part of the geothermal field. The subsurface pressure drawdown due to production has been within the measurement error of downhole logging surveys ± 1 bar (± 100 kPa). Below 500m the reservoir pressure still significantly exceeds hot hydrostatic pressure.

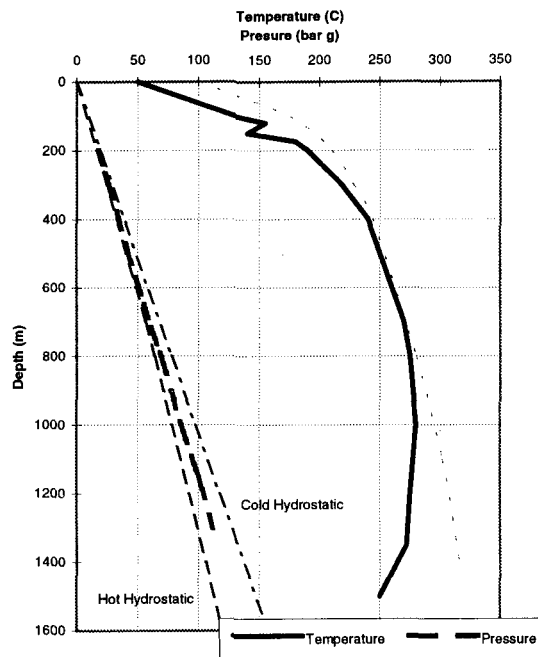


Fig 6 Reservoir Temperature and Pressure in the KA21, KA27, KA36 area

When KA36 was drilled a completion test was carried out with cold water injection at three flow rates. The water loss surveys located a minor loss zone at 1050m and indicated two main loss zones at 1150m and 1300m. KA36 had a maximum temperature of 279°C at 1150m and 260°C at 1300m.

GEOLOGY

Stratigraphy from drillholes shows that the basement greywacke surface is step faulted down to the northwest on northeast trending normal faults. These faults are production drilling targets. A sequence of volcanic units and sediments overlies the basement. The ignimbrite, rhyolite, andesite and greywacke are impermeable except where intersecting fractures. There is a sequence of sediments and ash at about 500m depth which form an aquiclude.

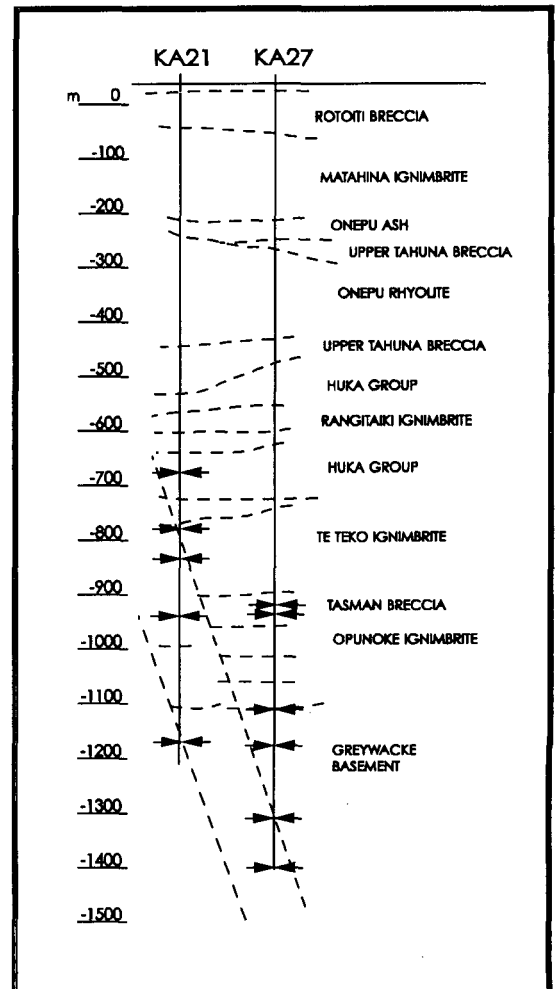


Fig 7 KA21, KA27 Geology, Faults and Loss Zones

KA36 was deviated 70m horizontally and intersected the same fault system feeding KA21 and KA27. The northeasterly trending fault fracture that feeds KA21 at approximately 1175m is thought to extend below KA36 at approximately 1550m depth.

The proposed hydrological connections between feed zones in the three production wells are shown in Table 3.

Feed Zone Depths (m CHF)		
KA27	KA21	KA36
685		
970		
1030		
1130		
1180	710	1050
1330	800	1150
1450	935	1300
	1080	
	1175	

Table 3 Feed zones in wells KA21, KA27 & KA36

INTERFERENCE

KA21 to KA27

When KA27 was cleaned out in 1988 a completion test identified a reservoir pressure increase in the 1330m and 1460m feed zones. A comparison with previous tests indicated no temperature change at the feed zones. The pressure increase from 109.7 to 110.4 bars g at 1330m depth is attributed to KA21, which was off production during the 1988 completion test at KA27. KA21 was discharging during the previous tests.

KA21 to KA36

When KA36 was drilled in 1991 interference effects were measured between KA36 and KA21. KA21 was opened for production following a cleanout while the pressure at 1290m was measured in KA36 to monitor any downhole pressure change. Downhole pressure measurements were repeated over the next 10 days, monitoring a pressure change of 0.45 bar g. This is analogous to decrease of 4.5m of cold static water level at a distance of 300m from the production well. The data from the interference test between KA21 and KA36 is plotted in Fig 8.

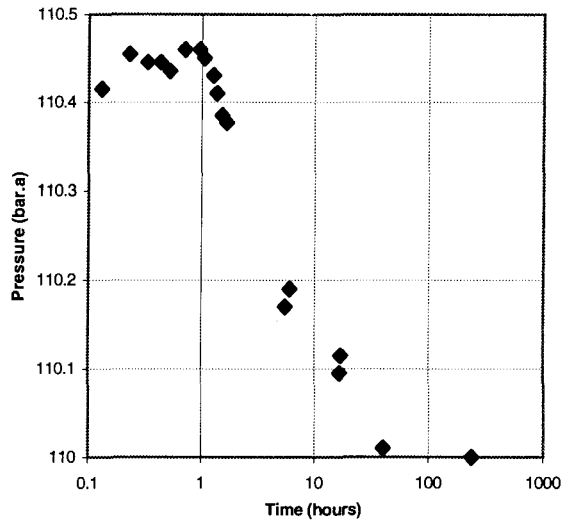


Fig 8 KA21 to KA36 Interference Test. Pressure in KA36 @ 1290m when KA21 was opened

KA27 to KA36

Interference was measured in 1995 between KA36 and KA27. KA36 was shut for 6 hours for maintenance then opened for production, while the pressure at 1330m was measured in KA27. The downhole pressure in KA27 increased from 111.50 to 111.85 bars g.

However, the downhole pressure in KA27 was still increasing when KA36 was required for production so the complete pressure transient could not be measured.

Transmissivity (kh) values are tabulated indicating that the area has good transmissivity. The 1986 data is from a field wide interference test, while the more recent data is from downhole measurements using the Works Geothermal STP tool.

Well	Date	Δ P (bars g)	kh (darcy-m)
KA36-KA27	1995	0.35+	
KA21- KA36	1991	0.45	160
KA21-KA27	1988	0.70	
KA21-KA31	1986		95
KA21-KA17	1986		48

Table 4 Downhole pressure change and transmissivity

FUTURE WORK

Changes have been measured in enthalpy, mass flow, chemistry, and downhole pressure as evidence of interference between production well feed zones. We plan to define the effect further by measuring mass and enthalpy changes between KA21 and KA36 as the distance between these wells is 300m and KA21 produces three times more mass than KA27. This will help to determine the distance to locate a new production well where the interference effect on production can be evaluated against the risk of drilling a new well further away from the known production area.

To obtain improved interference measurements from downhole pressure changes, access to shut in production wells is required. This is difficult to obtain in an operational steam field which has little spare steam capacity. There would be less interruption to steam production if measurements are obtained in flowing wells.

Downhole pressure, temperature and flow profiles for each of the three production wells under discharge conditions are planned to be measured. These measurements when used with a wellbore simulator can obtain calculated output curves for measured changes in downhole pressure. Interference effects can be predicted for a new average additional well drilled into the same fault structure, at a known distance from the current production wells.

The implication for future production drilling is the estimated nett gain in steam production expected from a new well tapping the same fault structure, the target feed zone depths, the optimal well diameter and well spacing. The method could also be applied to reduce the risk of production drilling in similar situations elsewhere in the Kawerau geothermal field.

ACKNOWLEDGEMENTS

We acknowledge the permission of Geothermal Trading to publish this paper, also the contribution from IGNS for the chemistry and geology and IRL for the interference tests.

REFERENCES

- Allis, R.G., Christenson, B. W., Nairn, I. A., Risk, G. F., Sheppard, D. S. and White, S. P. (1995), "Kawerau geothermal field: it's natural state and response to development," IGNS unpublished document.
- Stevens, L. and Wilson, D. M. (1991), "Kawerau Geothermal Field: KA36 Completion Test, Heating, Vertical Discharge, Output Test and Interference Effects," Works Geothermal unpublished document.
- White, B. R., (1988), "Kawerau Geothermal Field KA21 Completion Test Measurements and a Review of Previous Measurements," Works Geothermal unpublished document.