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THE DUAL COMPLETION OF A GEOTHERMAL WELL

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ABSTRACT

Multiple completion of a well to allow separate production from selected horizons within the well, while not uncommon in the petroleum industry, is rare in the geothermal industry. The dual completion of well NG9 is believed to be a first in a geothermal well. The high flow rates, elevated temperatures and completion philosophy associated with a geothermal well required the development of new techniques to successfully install a dual completion. As an exploratory technique it enabled separate measurement of the properties of fluids produced at two different zones within a reservoir without the need to drill separate wells to each zone. However the dual completion resulted in a significant reduction in total well output.

The design and installation of the dual completion are described and possible future uses for the technique are discussed.

INTRODUCTION

Well NG9 was cased 8 5/8" to 588 m and drilled 7 5/8" to 1000 m into the Ngawha Springs geothermal field (New Zealand) and was completed in 1979. Permeable zones in the open hole were identified at 673, 935 and 962 m. Some five days after completion, a downflow from 673 m was measured at 2.5 litres/second. The downflow prevented the obtaining of undisturbed static reservoir pressures or temperatures and would require extensive flow testing to ensure that fluid produced from the deeper zones was no longer affected by fluid from the upper zone. At the time, extensive testing was precluded by environmental constraints.

Had the well been intended for production it would have been used as completed. However the well was one of a number of exploration wells and it was important to ascertain whether the deeper fluids differed substantially from the shallower fluids. One alternative was to drill a new well which cased off the shallow production and produced from the deep zone only. As the well appeared to have two clearly defined and well separated permeable zones (673 m and the deeper 935-962 m zones) and the open hole section was in competent argillites providing an in-gauge hole, it was considered a prime candidate for a dual completion.

Design Concepts

Broadly the concept was to produce the lower zone through 5 1/2" casing and the shallower zone through the annulus outside the 5 1/2" casing. The 5 1/2" casing would be run from surface to some point between the two zones and the zones isolated from each other by sealing the annulus between the casing and formation for a short distance. The seal was to be obtained by use of a combined external casing packer/stage cementer to place cement over a 100-150 m interval of annulus.

Casing selection considered the following:

1. Provision of similar cross sectional areas for flow in the annular space outside the 5 1/2" casing and for flow inside the casing.
2. Casing sizes available on site.
3. The long term use of the well. While the future use would not be clear until the individual characteristics of the deep and shallow fluids were better known, it was envisaged that one of the following options may be required for the final completion:
   a. Cementing off the shallower zone and producing only the deep zone. This would be achieved by cementing the shallow zone through the annulus, and cutting and retrieving the 5 1/2" from some point above the 8 5/8" shoe.
   b. Cementing off the deep zone and producing only the shallow zone. This could be achieved by cementing through the 5 1/2" casing and then cutting and pulling the 5 1/2" casing above the cement used to seal the annulus.
   c. Producing from both zones. Because the presence of the 5 1/2" casing was expected to reduce the total potential well output, this would require cutting and pulling the 5 1/2" casing from above the annular cement and then endeavouring to washover the cemented section using 6 5/8" washpipe.

Consequently the casing string was to be comprised of a stage cementer/external casing packer around 860 m, 5 1/2" extreme line casing to above the
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8 5/8" shoe (to provide adequate joint strength should the upper zone require cementing off) and 5¼" round thread casing to the surface. The casing would be free standing from the top of the annular cement to the wellhead (Figure 1).

At the wellhead provision for separate production of fluids from inside and outside the 5¼" casing was made for the casing to be tensioned to its vertical movement in the associated pipework. While pretensioning the casing to overcome all thermal movement in the annulus required modification of a standard expansion spool to incorporate an 8" side outlet flanged for a control valve. Separation of the fluids would be achieved by passing the 5¼" casing through a packoff gland which would allow the free vertical movement of the casing under all thermal operating conditions. The gland packing nut and stuffing box were to be fabricated from stainless steel to avoid corrosion and would use Kevlar gland packing sealing against a length of hard chromed 5¼" casing. To prevent thread galling a proprietary anti scuffing compound and a temperature resistant anti scuffing grease would be used on both the male and female threads. A Teflon sleeve inside the gland follower would prevent the follower damaging the hard chromed surface on the 5¼" casing. Rather than fix control valves and piping directly to the top of the 5¼" casing, the casing was enclosed in an expansion cover - this eliminated the need to provide for extensive vertical movement in the associated pipework. While it was desirable to keep the overall height of the wellhead as low as possible, experience some decades earlier with casing expansion pushing a wellhead off suggested that a generous provision for expansion should be made. The alternative of pretensioning the casing to overcome all thermal expansion was not adopted because of uncertainties in the amount of stress relieving which could occur during extended shut in periods. However allowance was made for the casing to be tensioned to its self weight at the wellhead. In assessing the amount of expansion to be allowed for, the following conditions were considered:

. Minimum casing length would occur when cold water was pumped down both inside and outside the casing.

. Maximum casing length would occur when both zones were discharging.

. Some contraction through helical buckling of the free standing casing would occur.

. Reduction of expansion by friction between the casing and open hole would be ignored.

INSTALLATION

A small workover rig was placed over the well in March 1981, a retrievable bridge plug set in the 8 5/8" casing and the standard expansion spool was replaced with a modified spool fitted with an 8" side valve. The workover rig was removed and a larger rig set up over the well.

In programming for the dual completion two reservoir characteristics required special consideration. The deep reservoir (below around 500 m) was overpressured with respect to normal hydrostatic pressure by some 8 bars gauge. This required killing the well with weighted mud prior to opening and tripping into the well. However, experience with earlier exploratory wells in the area had shown the reservoir to be particularly susceptible to irreparable mud damage so any mud slugs could not be allowed outside the 8 5/8" shoe. Hence, each trip required placement of a mud slug and later inducing the well to "kick" so that the mud could be removed from the well.

After erecting a BOP stack on the master valve the well was sounded to bottom with a 7 5/8" bit. The 5 1/2" casing was run to locate the cementer/packer at 868 m, a travelling plug was pumped to seat below the packer and the packer was expanded against the open hole. An "opening bomb" was dropped and the ports in the cementing collar were opened. Sufficient cement to fill 150m of annulus was mixed and pumped, followed by a top travelling/closing plug. This plug was seated in the collar and pressure applied to close the ports. Throughout this operation a steady flow of water was maintained down the annulus presumably all going into the shallow zone after the packer was set.

After allowing time for the cement to set, a stretch test indicated the casing was cemented up to around 760 m.

The upper joint of 5 1/2" casing and BOP stack were removed and replaced by the gland assembly and a hard chromed length of 5 1/2" casing. The 5 1/2" casing was fitted with a small valve and BOP. Drilling out of the travelling plugs, cement and non-return valves in the 5 1/2" casing was followed by a trip to hole bottom. The integrity of the annular seal was then checked as far as possible by pumping to one zone and measuring pressures from the other and then reversing the process. No measurable interconnection was found between the two zones. The valve and BOP were then removed from the 5 1/2" casing and the expansion cover installed.

COSTS

At the time a 1000 m well at Nagwah Springs typically cost NZ$1.0M. The dual completion cost an additional NZ$0.4M. It is anticipated that a future workover to remove the dual completion would cost NZ$0.45M, but would recover re-usable materials worth NZ$0.08M. Hence the net cost of the dual completion experiment would be around NZ$0.35M - substantially less than the cost of a new well, (1981 costs).

SUBSEQUENT TESTING

After erection of two silencers the well underwent a series of output tests. Prior to the dual completion, the well output was 525 tonnes/hour at 15 bars wellhead pressure.
Following the dual completion the outputs at similar wellhead pressures were 90 tonnes/hour from the deep zones and 110 tonnes/hour from the shallow zone - a 60% reduction in total flow. Separate and mixed enthalpies showed little variation.

Radioactive tracer was injected into the annulus while the deep zone was discharged and monitored. A small but rapid return indicated a minor leak past the gland and the longer term returns indicated an interconnection between the two horizons at quite some distance from the well.

In 1982 the well was worked over to clear a blockage from inside the 5 1/2" liner. An inspection of the gland showed the chromed surface to be in excellent condition as was the gland packing. The fact that the casing expanded and contracted according to temperature fluctuations indicated that the cement was still intact.

Following the workover the pressure integrity of the system was tested by pumping air into the 5 1/2" casing to a pressure of 80 bars. While some 2.5 cubic meters of free air leaked from the casing into the annulus over 5 days, this was considered to be an acceptably minor leak past the gland. The gland can be considered water-tight but not gas-tight.

CONCLUSIONS

A dual completion of a geothermal well can enable separate measurement of reservoir characteristics from two separate horizons providing the reservoir conditions are suitable and the operation is competently designed and supervised. However, the reduction in gross well output can be severe particularly with wells with the potential for high outputs. Scaling in the annular space would be expensive to remove and would be expected to reduce the well output even further. Consequently dual completions have limited value as an exploratory technique in circumstances where drilling an additional well can be avoided.

Nevertheless such completions can be useful for obtaining fluid samples from selected horizons and for measurement of static reservoir pressures and temperatures in those wells which would otherwise be affected by internal downflows. Because it is not practical to run normal logging instruments into the annulus, such measurements would only be useful if the annulus stands full of water and the deeper zone does not control temperature conditions inside the casing at the depth of the shallow permeability.

Another possible use of a dual completion would be in reservoirs with highly corrosive fluids at shallow depth. A dual completion, albeit with a much smaller annular space, would allow injection of inhibitor into the annulus to provide protection to the production casing.

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FIGURE 1: CASING DETAILS

FIGURE 2: WELLHEAD DETAILS