. Proc. 5th NZ Geothermal Workshop 1983

LOCUS OF WELLHEAD PRESSURE WITH TIME UNDER PRODUCTION DISCHARGE

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ABSTRACT

For a fixed initial setting of surface control valves, wellhead pressures and flow will irrevocably decline with time under conditions of long-term production: This is because infinite system do not exist and hence pressure-temperature of the subterranean reservoir will fall with fluid removal, leading to the decreases mentioned. For less attractive geothermal fields other factors can intrude to aggravate the effect such as mineral deposition within the well casing but these will be ignored in this study. Taking a given well, a family of curves which plot flow versus wellhead pressure under declining potential indicates that the locus of pressure-flow at a fixed valve setting is a straight line passing through the origin. This means that it is preferable to throttle the wellhead pressure to a high initial figure which can be progressively reduced to sustain production by manipulating control valves, or by changing chokes. Hence a track record can be obtained over many years without; requiring tedious attempts (by a continuous drilling programme or other methods) to avoid fall in electric energy generated.

INTRODUCTION

Under production, geothermal boreholes settle down to a steady decline in pressure and discharge. Examples of this are shown in Figures 1 and 2 from the Wairakei and Larderello fields with characteristic output curves given for the years 1958 and 1964. It is seen that similar declines occur althaugh the Wairakei flashing water well of diameter 0.203 m originates in an all-liquid phase at about 250°C while *dry* steam is discharged from the Larderello well whose diameter is 0.321 m.

Rate of decline of wells is perhaps the most important single parameter in considering the economic life of a geothermal project and no successful method has been developed which can unambiguously predict flow and pressure conditions for more than a few years ahead. But perhaps that is because no attempt has been made in understanding, the production performance of a single well when considered in isolation and under fixed wellhead conditions. To examine this case, we imagine a well throttled by manipulating the surface valve to an initial flw and wellhead pressure and then leaving it discharging through this unaltered setting. The question posed is how would the flow and pressure vary with time. For example, point X is considered on Figure 2 for a set initial position in 1958 and we wish to locate its position six years later on the 1964 curve. Of course, selecting Figure 2 virtually guarantees that enthalpy will not change significantly as the Larderello wells produce from a reservoir of dry saturated steam whereas it is possible toenvisage rather large enthalpy changes of mixtures discharged from flashing water wells. However, a phenomenon worth noting is that the overall flow enthalpy of the Wairakei field has not significantly changed over 25 years of operation and in the case of Well 30 shown on Figure 1 has fallen from the 1958 value of 1100 kJ/kg to only 1050 kJ/kg in 1964. (Near well closure, this latter value reduced to about 980 kJ/kg at a wellhead pressure of 17.9 bar).

To determine the locus of a point such as X of Figure 2 or a similar one on Figure 1, it is necessary to examine output curves.

Characteristic of Output Curves

Such curves are often erroneously drawn so that they intercept the vertical and horizontal *axes.* This is certainly not true for steam-water wells and only half true for *dry* steam ones. This is because when discharged to the atmosphere wide open, there is a positive lip pressure at the extreme end of the pipe giving a significant value of wellhead pressure depending on the length of pipe between these two locations. For wide-open vertical discharge, this distance is usually only about 3 to 4 m and the wellhead pressure is about twice the lip pressure; this is located as point "A" for both types of well on Figures 1 and 2. When the discharge is switched from the vertical to the horizontal (the so-called open bye-pass condition), flaw and hence lip pressure decrease while wellhead pressure increases to give point C on both figures (the 1958 curves are taken as an example).

Closing the well progressively and raising the wellhead pressure can lead to interception of the horizontal (pressure] axis in the case of *dry* steam wells as inidicated by point "G" on Figure 2 but in the case of steam-water discharges, minimum stable flow occurs at point "E" of

Figure 1 (the so-called MDP or maximum discharging-pressure) and attempting to increase the wellhead pressure further leads to collapse of the discharge. Hence the maximum range of steam-water wells is shown on Figure 1 by that part of the curve along AE and the more usual range is over CE when a horizontal pipe to a silencer is installed. For dry steam wells as in Figure 2, the range is AG or CG with the curve closer to interception of the vertical axis. Further discussion on output curves is given by James (1980) while data on the changing flow of Larderello well 145 is taken from Rumi (1972) and shown in Figure 2.

Locus of "X"

The locus of the closed-in wellhead pressure for the dry steam well of Figure 2 is along the line GHO while calculated values for wide-open vertical flow and open bye-pass shows a similar radial movement along ABO and CDO during diminishing of the output curve from 1958 to 1964. Hence it is to be expected that point "X" will also follow a radial path with time. This is confirmed by tests on Larderello wells which take many days to stabilise as initial points 'float' along radial lines to their final position on the stable curve, as plotted from some data of Rumi (1972); this phenomenon has also been noted in the testing of steam-water wells of long stable times (from I.W.D. data).

Theoretical calculations based on critical flay nozzles substituted for throttled wellhead valves show flow directly proportional to wellhead pressure for a given nozzle throat diameter and hence a radial locus of the pressure-flow coordinate.

Similar arguments apply to steam-water wells and points "C" and "D" are plotted from H.W.D. data for the open bye-pass condition of Wairakei well 30 when tested in 1958 and 1964. There is, however, not enough data on the flow measured at MDP (maximum discharging-pressure) and hence it is uncertain whether EFO is a straight line. However, as the condition is relatively unstable with flow teetering on the brink of collapse, it is not at all likely that a well would be throttled to close to that position initially, with long term production in mind. Away from this location a radial locus should occur as for dry steam well unless a substantial change in enthalpy of discharge takes place; even here it is possible that particularly in the mid-range of the output curve, a radial locus obtains. The case has not been studied where mineral deposits diminish the output curve but tentative data from Kawerau well 8 suggest a radial locus with time, so future work will concentrate on obtaining reliable field results.

Actual Locus of Production Wellhead Pressure

As the highest turbine entry pressure was designed at 13.4 bar for Wairakei with 2 to 3 km of pipe connecting the wells with the power house, the condition was not at all for 'discharge to atmosphere'. Hence from 1958 to about 1965 the wellhead pressure remained constant at 14.75 bar (200 PSIG) for the so-called high pressure weals of which Wairakei well 30 of Figure 1 is an example; the path followed is shown as locus KI. From 1965 on, in an effort to sustain output, wellhead pressure was permitted to float down under constant discharge along the line IJ. One can expect with time that IJ will extent until it intercepts the radial KO at about 6 bar and from then on it may not be possible to hold constant conditions as both flaw and wellhead pressure would decline towards the origin.

A plot of KIJ With time is particularly useful and is given on Figure 3 where it is seen that over the last 18 years from 1965 to 1983, the wellhead pressure has declined in a straight line as if the subterranean reservoir was a tank being emptied with constant flow. Assuming it continues along the same line, it should fall to 6 bar by about 1988 and may start to diverge from then on with the rate of fall declining to further extend the field life but at reducing electric energy generated. A reasonably cheerful prognosis if well 30 is symptomatic of the general field behaviour.

CONCLUSIONS

There are advantages in operating production wells under constant flaw so that they follow a path such as IJ of Figure 1 as when wellhead pressure is plotted to a time base as in Figure 3, a straight line is likely permitting prediction and advanced planning of requirements. Extra wells would be initially required which are throttled to lower flows at higher wellhead pressure which would be reduced with time to sustain flow during the economic life of the field.

Before power development, it should be possible to discharge wells at constant discharge to the atmosphere by throttling at a fixed value of lip pressure (directly proportional to flow at constant enthalpy). If accomplished for a few years the initiation of a plot such as that of Figure 3 should indicate the slope of the decline and the economic size of development.

REFERENCES

James, R. 1980: Deductions of the Character of Steam-Water Wells from the Shape of the Output Curve. Proc. N.Z. Geo. Workshop, University of Auckland.

Rumi, O. 1972: Some Considerations on the Flow-rate/Pressure curve of the Steam Wells of Larderello. Geothermics, Vol. 1, No. 1, p 13.

Figure 1

Decline in output of Wairakei Well 30 under production.

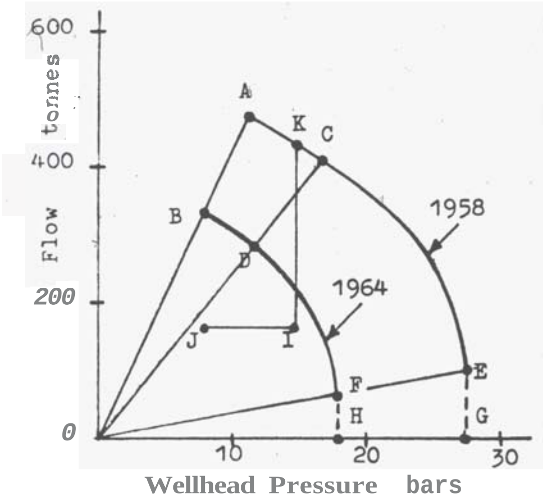

Figure 2

Decline in output of Larderello Well 145 under production.

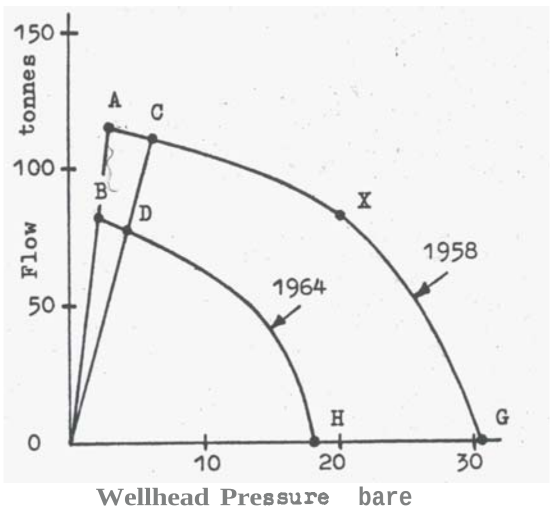

Figure 3

Wellhead Pressure of Wairakei Well 30 during 25 yeare of production