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BLEEDING CHARACTERISTICS OF GEOTHERMAL WELLS

Russell James and Tom Gould

D.S.I.R., Wairakei, New Zealand

ABSTRACT

Discharging small flows (order of 1 t/h) from wells is known as bleeding and is to relieve the build-up of gas pressure at the wellhead and to arrest corrosion in the bore.

First tests over a range of bleeding flows indicate it as a fruitful subject for study in that temperature and pressure measurements at the wellhead can indicate the well enthalpy and the non-condensible gas content of the production system.

Because of environmental restrictions on testing with large discharges in the future, bleeding may soon be the only valid alternative for proving a well's potential.

INTRODUCTION

The production output curve of geothermal wells is familiar to test engineers and its typical shape is shown on Figure 1 as that part AB of the whole curve ABC. The underlying significance which can be drawn from the various shapes that AB can take has been studied, James (1980a), and the mathematics of the curve examined, James (1984). No work has been attempted, however, into studying that part of the generalised curve shown as BC on Figure 1 for deep power-production wells. A recent work, Siitonen (1986), concerns this aspect, however, in testing shallow wells (down to 150 m) at Rotorua, which are used for heating buildings; a simulator has also been employed to establish full output curves, Freeston and Hadgu (1986) in Tibet and Rotorua. These have been studied principally because the Rotorua wells function over the BC region of the curve (which is the reverse of how powerful wells operate) in that more bleeding increases both flow and wellhead pressure. Hence for the powerful wells there has been little or no incentive to study the BC region except to be aware that it exists: this is because no useful result could be seen to accrue from any work undertaken. Although, of course, bleeding of wells is a common and recommended procedure as a steady state condition of wells which have not yet been coupled to a power project, and which if left completely closed would develop corrosion within the casing. This corrosion can be caused by trickle-down condensate in the presence of carbon dioxide and hydrogen sulphide gas, within the top vapour-filled reaches of the well. A steady bleeding reduces this hazard and also eliminates the possibility of dangerous gas build-up at the wellhead which can lead to explosive rupture of the main stop valve as has happened at well BR25 Broadlands, New Zealand and also at Dieng No. 2, Indonesia.

The direct correlation of wellhead pressure and flowrate of a bleeding discharge is no doubt due to the increased heat loss per unit mass flowing when this is of the order of 1 t/h. This heat is lost to the water table, or lower-temperature fluids surrounding the well nearer the ground surface, and increases when flow is reduced, resulting in a lower wellhead pressure. This effect is negligible when wells are operating along AB as here flows generally exceed 100 t/h even at point B, the so-called location of MDP (Maximum Discharging-Pressure) whose importance has been emphasized in a previous work, James (1980b).

REASON FOR THE WORK

Merely the incentive due to our ignorance of how that part of the output curve functions. It seemed easy to test, and if nothing of interest emerged, this minor project could be quietly abandoned.

TEST FACILITY

Broadlands well BR1 was available with a good bleeding range suitable for the present work. As a production well it was poor and had therefore been rejected for incorporation into the forthcoming power project; it was, however, performing useful service for a series of metallurgical experiments. During an interlude between these latter tests, the well was available for the present study.

TEST PROCEDURE

A 10.7 mm diameter lip pressure pipe was attached to the throttle valve (as shown in Figure 2) which was adjusted to give a steady bleeding discharge. This took 24 hours to stablise after which, lip pressure P_c, wellhead pressure P_w and wellhead temperature t_w were noted. Also the discharge was by-passed into the simple drum calorimeter into order to determine flowrate and enthalpy. Results are shown on Table 1. The range of wellhead pressures obtained by this means was from 14.2 bar with the throttle valve wide-open to 5.6 bar when nearly closed; presumably the range could have been extended by employing a lip pressure pipe of larger diameter and hence raising the wellhead pressure further, but sufficient data was collected during this early investigation to keep us fully occupied in interpretation. Besides, greater flows would have required a larger calorimeter which was not currently available.

Table 1: Test results, gas concentration, enthalpy and flow.

P_w Bar	t_w °C	Gas/Gasteam	P_c Bar	h_o kJ/kg	W kg/s
5.6	63	0.983	-	-	-
6.0	87	0.956	-	-	-
6.3	94	0.943	-	-	-
7.2	122	0.854	-	-	-
7.6	132	0.8	1.15	554.9	0.20
7.7	130	0.818	1.2	546.3	0.213
7.8	132	0.807	1.25	554.9	0.218
8.0	136	0.781	1.35	572	0.226
8.8	145	0.728	1.8	610.6	0.28
9.2	148	0.715	2.9	623.6	0.429
9.5	151	0.69	3.1	636.5	0.448
9.8	155	0.657	3.5	653.8	0.489
11.2	167	0.551	5.25	706	0.662
12.5	174	0.5	7.25	736.8	0.862
14.2	186	0.353	9.18	789.8	1.00

CALCULATIONS

From test values of P_w and t_w the gas/steam mass ratio m can be determined from the following equation:

$$m = \frac{(P_w - P)\, V_g}{R(273.15 + t_w)} \quad (1)$$

where P and V_g are the saturated vapour pressure and specific volume of saturated steam at temperature t_w. The gas constant R is evaluated from (a) the Universal Gas Constant 1.9858 cal/mol K, (b) Joule's Equivalent 4.1868 J/cal, (c) Gravitational Constant 9.8066 m/s^2, (d) The molecular weight of 44 for carbon dioxide which is the principal geothermal gas.

$$R = \frac{1.9858\ (4.1868)\ 9.8066}{44} = 1.853 \quad (2)$$

The gas concentration in the gasteam mixture (water not included) is calculated from m as:

$$\text{gas/gasteam} = \frac{m}{m + 1} \quad (3)$$

and results on Table 1 are plotted against wellhead pressure on Figure 3 where a straight line is obtained. The extrapolation of this line to zero gas gives a maximum wellhead pressure of about 19 bar, while for a gas/gasteam ratio of 0.1, a wellhead pressure of 17.5 bar is obtained. Downhole measurements on this well give a water phase below the casing at 227.3°C which from James (1980b) would be consistent with a maximum wellhead pressure under discharge, of 18.36 bar which would be in agreement with about 4% gas in the gasteam mixture of Figure 3. If this well is typical of bleeding conditions, it appears that an estimate can be made of the likely MDP (Maximum Discharging-Pressure) and hence of the well enthalpy merely by taking some values over a range of bleeding pressures (most production wells at Broadlands are in the range 2 to 6% gas). It would be useful, however, especially for new geothermal fields, to be able to estimate the gas concentration in the gasteam mixture at MDP from simple test results on bleeding as undertaken in this work. It should be noted that a knowledge of gas/steam or gas/gasteam ratio gives no information on the proportion of water present, which may be large or small.

The wellhead temperature t_w can be used to determine the enthalpy of single-phase liquid water h_f from Steam Tables of Keenan et al. (1969), and is shown plotted as a straight line on Figure 4 together with actual test results derived when the lip pressure pipe is discharged into the calorimeter. For wellhead temperatures exceeding 100°C, the enthalpy agrees well with that of the straight line, indicating that there is a negligible quantity of gasteam present and that enthalpy can be estimated as that of liquid water at the wellhead temperature. Hence, in Table 1, flowrate can be calculated from values of P_c and h_o according to the formula below from James (1987):

$$W = 1.6234\ \frac{d_c^2\ P_c^{0.96}}{h_o^{1.102}} \quad (4)$$

For the lip pressure discharge pipe diameter of 10.7 mm, this simplifies to

$$W = 185.86\ \frac{P_c^{0.96}}{h_o^{1.102}} \quad (5)$$

Therefore the lip pressure can be used to determine enthalpy without the requirement of a calorimeter, although whether this applies to all bleeding (high power) wells can only be confirmed by similar experiments on other boreholes.

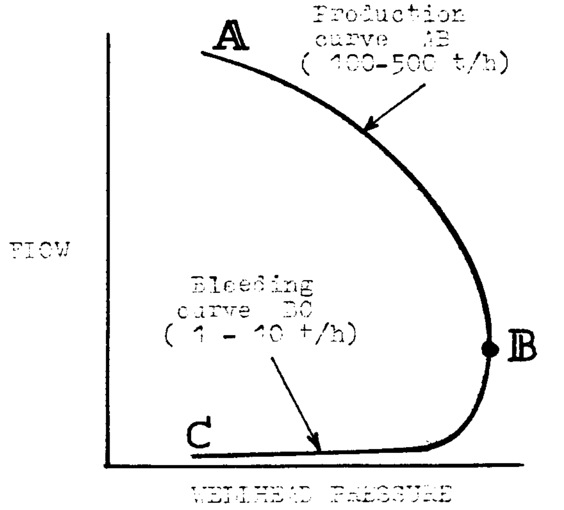

Figure 1 Output curve of Steam-Water geothermal well. (diagrammatic only)

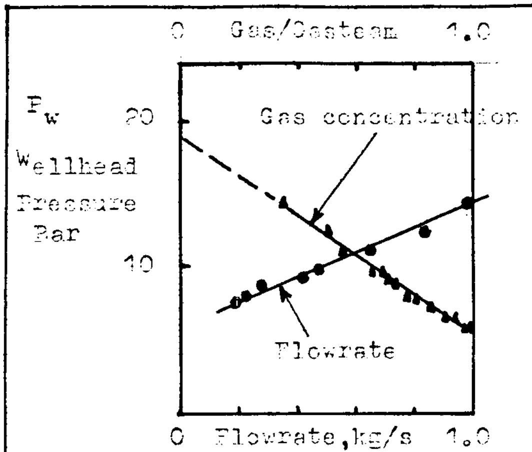

Figure 3 Gas concentration and Flowrate at various wellhead Pressures.

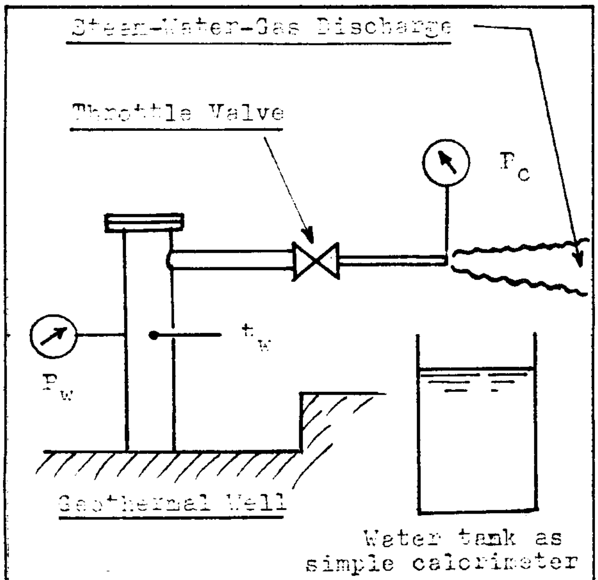

Figure 2 Test lay-out and principal variables.

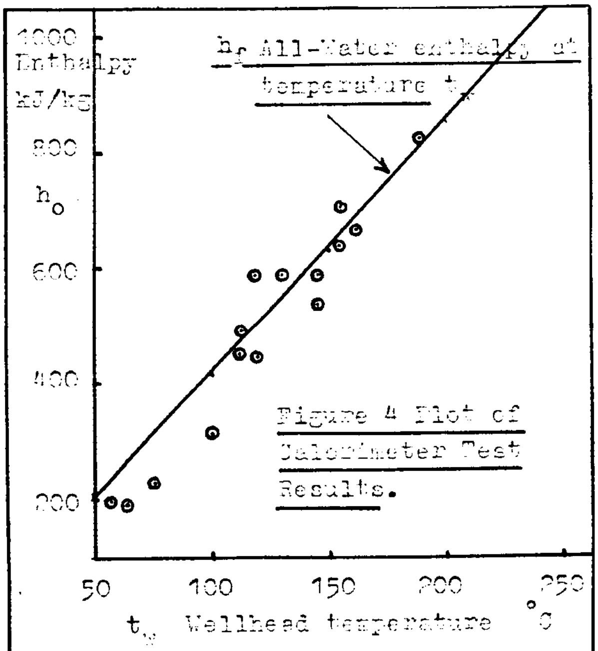

Figure 4 Plot of Calorimeter Test Results.

As lip pressures exceed atmospheric pressure only above wellhead pressures of about 7.5 bar, relevant values of P_c, h_o and W are not shown for lower pressures on Table 1.

GAS BUBBLE VELOCITY

The terminal vertical velocity of rising air bubbles in stagnant water is about 0.3 m/s, Wallis (1969), but this is for water at 20°C. As terminal velocity is inversely proportional to water viscosity which is 0.15 centipoise at 186°C compared with 1.0 centipoise at 20°C, we expect air bubbles (and similarly carbon dioxide bubbles) to rise at about 0.3/0.15 = 2.0 m/s in well water at 186°C.

From Table 1, at 186°C, the flowrate was 1.0 kg/s, hence the vertical velocity in 0.2 m diameter well casing for water of specific volume 1.1357 l/kg is:

Vertical water velocity =

$$\frac{(1.0)\ 1.1357}{(1000)\ \frac{\pi}{4}\ (0.2)^2} = 0.036 \text{ m/s}$$

Therefore at the low upward velocity of well water when bleeding at rates of the order of 1 kg/s (3.6 t/h), the bubble rise velocity is more than 50 times that of the water.

It appears likely, therefore, that over the range of discharges usual when bleeding a well, the non-condensible gas flow is relatively constant. This is confirmed by the common geothermal field experience of a steady gas build-up at wellheads even when total flow is halted by closure of the main stop valve (or comparable throttle valve).

If this is assumed, and employing mass distribution coefficients of carbon dioxide in steam and water, Ellis and Mahon (1977), together with equation (1), the percentage mass concentration of carbon dioxide in total flow, at bleeding wellhead pressures of 8.0 and 14.2 bar (from Table 1), is estimated to be 0.7% and 0.16% respectively.

CONCLUSIONS

This is only the first study (as far as we know) on bleeding of wells drilled for electric power development, which are relatively deep and of a temperature exceeding 200°C. Whether the results are symptomatic of the genre or untypical is impossible to determine without undertaking similar tests on a variety of wells.

REFERENCES

Ellis, A.J. and Mahon, W.A.J. (1977): Chemistry of Geothermal Systems. Academic Press, New York, U.S.A.

Freeston, D.H. and Hadgu, T. (1986): Calculation of Output Characteristics of Shallow Wells. Proc. 8th New Zealand Geothermal Workshop, Univ. of Auckland, Auckland, New Zealand.

James, R. (1980a): Deductions of the Character of Steam-Water wells from the Shape of the Output Curve. Proc. New Zealand Geothermal Workshop, Univ. of Auckland, Auckland, New Zealand.

James, R. (1980b): Significance of the Maximum Discharging-Pressure of Geothermal Wells. Proc. 6th Workshop Geothermal Reservoir Engineering, Stanford Univ., Stanford, Calif., U.S.A.

James, R. (1984): Successful Prediction of Mokai 5 Discharge. Geothermal Energy, 12, 2, p. 7.

Keenan, A.H., et al (1969): Steam Tables, Wiley, New York, U.S.A.

Siitonen, H.J. (1986): Output Tests of Shallow Rotorua Wells. Proc. N.Z. Geothermal Workshop, Univ. of Auckland, Auckland, New Zealand.