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9 in Reykjanes geothermal field, Iceland

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August 14, 1995

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Greinargerðasafn

Report
JÖB-SÞ-95/02
jöb

A NOTE ON THE PROPERTIES OF STEAM FROM WELL 9 IN REYKJANES GEOTHERMAL FIELD, ICELAND

The inflow to well 9, which is currently the only operational well in the Reykjanes field, is a steam-saturated brine at 295°C, with an enthalpy of 1317 kJ/kg and a salinity roughly equal to that of seawater. As this fluid moves up through the wellbore, it boils adiabatically as the pressure drops. At the surface, the fluid is flashed at some appropriate pressure, comparable to or lower than the wellhead pressure, and the steam is separated from the liquid phase.

The wellhead pressure depends on the rate of discharge. During the period 1985 to 1992, this pressure was generally kept somewhat higher than 40 bar, corresponding to a steam saturation temperature of a little above 250°C. The well output at this pressure ranged from 44 to 70 kg/s, but has since declined to 34 kg/s because of scaling and a break in the liner. The output of a new well of the same design is expected to be around 50 kg/s, yielding 6.5 kg/s of steam at 40 bar-gauge and 10.5 kg/s at 20 bar-gauge.

Since the flashing of the fluid is an isoenthalpic process, the steam fraction grows with decreasing separation pressure. The dissolved gases partition overwhelmingly into the steam phase upon boiling, so the concentration of gas in the steam drops with decreasing separation pressure, as the nearly constant amount of gas is diluted by the increasing steam fraction.

Table 1. Gas concentrations in steam.

Pressure (bar-gauge)	10	15	20	25	30	35	40
Saturation temperature (°C)	184.1	201.4	214.9	226.1	235.7	244.2	251.8
CO_2 (mg/kg)	5200	5900	6600	7300	8200	9100	10300
H_2S (mg/kg)	170	190	210	230	250	270	300
H_2 (mg/kg)	0.52	0.59	0.66	0.74	0.83	0.94	1.07
CH_4 (mg/kg)	0.23	0.26	0.30	0.33	0.37	0.42	0.48
N_2 (mg/kg)	6.8	7.7	8.6	9.6	10.8	12.2	13.8
Total gas (weight-%)	0.54	0.61	0.68	0.75	0.85	0.94	1.06

Table 1 displays the concentrations of gases in steam from Reykjanes well 9, calculated as a function of separation pressure. The figures are based on averages of measured concentrations for the years 1992 through 1994.

If the steam at 40 bar is condensed at, say, 25°C and atmospheric pressure, the steam condensate will dissolve approximately 1500 mg/kg of CO_2 and around 100 mg/kg H_2S, leaving about 4.7 liters of gas for every kg of condensate. The pH of this condensate is approximately 4.2.

Table 2 shows the molar composition of the gas, exclusive of steam. Note that the concentrations change slightly with separation pressure. This is because the solubilities of the gases in the liquid phase vary differently with temperature.

Table 2. Composition of dry gas.

Pressure (bar-gauge)	Temperature (°C)	CO_2 (mole-%)	H_2S (mole-%)	H_2 (mole-%)	CH_4 (mole-%)	N_2 (mole-%)
10	184.1	95.54	4.04	0.21	0.01	0.20
40	251.8	95.95	3.62	0.22	0.01	0.20

The mineral content of the condensate of 10 bar-gauge steam is approximately 3 mg/kg, of which chloride represents about 1 mg/kg and silica 0.6 mg/kg. At this pressure, the total content of dissolved solids (TDS) in the brine phase is about 45000 mg/kg. The presence of these non-volatile components in the steam is presumably due to droplet or mist carry-over in the steam separator. This carry-over corresponds to a steam wetness of about 0.007%, or a separator efficiency of around 99.993%.

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