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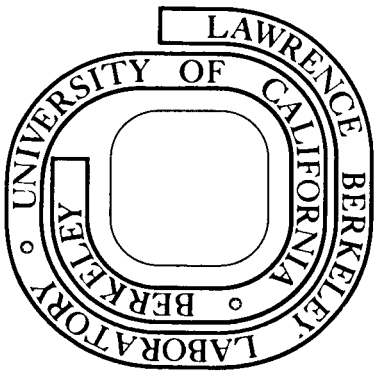

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ROUGH ESTIMATES OF FLUID PRESSURES FOR THE DESIGN OF THE LBL DOWNHOLE GEOPRESSURE SAMPLER

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These rough, "back of the envelope" estimates originated in a request by R. Schroeder, then Principal Investigator of the LBL-GRI agreement, in the early stages of that joint venture.

At that time the question was whether we needed to design for 20000 psi internal pressure when the sampler was brought to the lubricator and cooled to ≃70-80°F before removing the sampler. The downhole constraints where $P_D \simeq 20000$ psi, $T_D \simeq 400^{\circ}F$.

For the purpose of these quick estimates, I ignored the complications posed by dissolved solids and lesser noncondensible gases and considered an idealized system composed only of water and methane. Using Haas's (1978) correlation I found a methane solubility of 14390 ppm at 400°F and 20000 psi. I further assumed, following the general consensus, that the downhole fluid is a liquid (no gas phase present), saturated solution.

Neglecting leaks and thermal expansion effects, the composition and molar volume of the fluid in the sampler are constant.

The liquid molar volume is

$$v^L = x_1 v_1^L + x_2 v_2^L \qquad (1)$$

I approximate

$$v^L \simeq v_1^L (P, T) \qquad (2)$$

since

$$x_2 << x_1, \qquad (3)$$

and v_2^L is of the same order of magnitude of v_1^L at conditions far from those corresponding to the critical point of water.

The gas molar volume is

$$v^G = y_1 v_1^G + y_2 v_2^G \tag{4}$$

At the low temperatures considered (≃20°C)

$$y_1 << y_2 \tag{5}$$

Therefore I estimate

$$v^G \simeq v_2^G \tag{6}$$

Due to its high molecular symmetry, methane can be expected to behave as a fairly ideal gas, even at considerably high pressures. Thus I approximate

$$v_2^G \simeq RT/P \tag{7}$$

At the final sampler temperatures considered, the isochoric, closed water-methane system consists of two (liquid and gas) coexisting phases. From the isochoric condition, (2) and (3), the gas volume is approximately

$$v^G \simeq n_1^G\left[v_D - v_1^L\ (P,\ T)\right] \tag{8}$$

The molar volume of the gas is, from (5) and (6)

$$v_2^G \simeq v^G/(n_1^G + n_2^G) \tag{9}$$

Conservation of mass then implies

$$v_2^G \simeq \lambda_D\left[v_D - v_1^L(P,\ T)\right] \tag{10}$$

Given λ_D, v_D and T, (7) and (10) can be simultaneously solved for P. I have done this iteratively by hand for two "final" sampler temperatures: 20 and 93°C (68 and 200°F). The compressed water molar volume $v_1^L(P, T)$ was computed from the Keenan and Keyes Steam Tables. The number of iterations required for convergence was less than 6 in both cases. The results where P(20°C) ≃ 300 bars = 4350 psi, and P(93°C) ≃ 560 bars = 8120 psi.

These results are estimates of the maximum differential pressures to which the sampler would be subject if the lubricator pressure were released at 68°F and 200°F/ respectively. Assuming approximate thermal equilibrium of the sampler with the wellbore and lubricator fluids, the differential pressures on the fluid-surrounded sampler will be smaller.

The main conclusions drawn from the present estimates are:

(a) It is unnecessary to design the sampler to withstand 20000 psi; substantially lower pressures should be considered.

(b) Cooling the sampler to approximately ambient temperature before recovering and fluid transfer will significantly minimize personal and material risks.

AKNOWLEDGEMENTS

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NOMENCLATURE

variables:

n: mole number

P: pressure

R: ideal gas constant

T: temperature

V: volume

v: molar volume

x: mole fraction in the liquid phase

y: mole fraction in the gas phase

λ: mole fraction of methane in the system

SUPER- AND SUB-INDEXES

D: downhole conditions

G: gas phase

L: liquid phase

1: water

2: methane

REFERENCES

Haas, J. L., 1978, U.S.G.S. Open File Report No. 78-1004, "An Empirical Equation with Tables of Smoothed Solubilities of Methane in Water and Aqueous Sodium Chloride Solutions up to 25 Weight Percent, 360°C and 138MPa".

Keenan, J. H., Keyes, F. G., Hill, P. G., and Moore, J. G., 1969, Steam Tables (International Edition - Metric Units), J. Wiley and Sons, New York.

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