GEOTHERMAL RESERVOIR PRESSURE REQUIREMENTS FOR PRODUCTION

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Rogers is an engineering company, and as such our interest in reservoir engineering is concerned with the production aspect. Reservoir testing and production management techniques practiced today are largely rule-of-thumb. We are hoping to learn from you such parameters as proper well spacing and wellbore sizing for a given reservoir which will provide optimum production and life of the reservoir. We cannot contribute much in this area other than perhaps to ask the questions which may stimulate research and to relate some of our observations as to what we find is required to satisfy our needs. For example, in making reservoir modeling studies we feel it is very important that the chemistry of the system be considered, particularly where it is indicated that production will be affected by flashing in the reservoir.

There have been instances where well production has been limited by reservoir permeability rather than by wellbore diameter. When such wells are produced to their maximum capacity, the pressure drawdown in the reservoir exceeds the gas evolution pressure, and Flashing occurs in the reservoir. If the reservoirs are in shale or limestone (carbonate) formations, calcite precipitations can occur at the point of flashing. Well flow may cease entirely due to loss in permeability. This siituation has occurred in some of the wells drilled in Casa Diablo. Flashing in the formation could have been prevented by operating the wells at a higher back pressure, but this would have reduced the well flow to uneconomic production rates.

The wells in Kizildere, Turkey, have high fracture permeability, so they can be produced at high rates without flashing in the reservoir. Flashing occurs in the wellbore, and calcite precipitation and plugging occur there and in the surface equipment.

By installing a pump in the well, the point of flashing can be moved downstream of the wellbore and even the surface equipment, e.g., the heat exchangers of a binary cycle plant, but I do not think it possible to prevent flashing entirely because of the noncondensable gases dissolved in the geothermal water. The amount of noncondensable gases dissolved in geothermal brines varies from well to well, but most brines contain enough gases such that they will flash off even if the brines are cooled to below the atmospheric saturation pressure. Taking the KD-14 well for example, the discharge pressure of the pump would have to be high enough to hold 520 psig through the heat exchangers in order to hold the noncondensable gases in solution, while it would only take 230 psig *to* prevent steam flashing.

The pressure downstream of the 520 psig back pressure valve would be determined by the reinjection well pressure in a totally enclosed system. Reinjection well pressure requirements have been shown to be quite nominal in those situations in which it has been tried, so there would be a significant pressure drop across the back pressure valve. The noncondensable gases would evolve, and if they were not vented, the reinjection well would become "gas-bound." Therefore, I believe it will be an exceptional case if a binary cycle plant can be operated totally enclosed. The environmental pollution advantages claimed for the closed binary cycle plant therefore will not be realized.

The concept of using downhole pumps to prevent flashing by maintaining total required pressure on the system is an expensive one, not only in terms of the complex mechanical pump which must operate in a hot corrosive environment, but also from the higher pressures for which the power plant exchangers would have to designed.

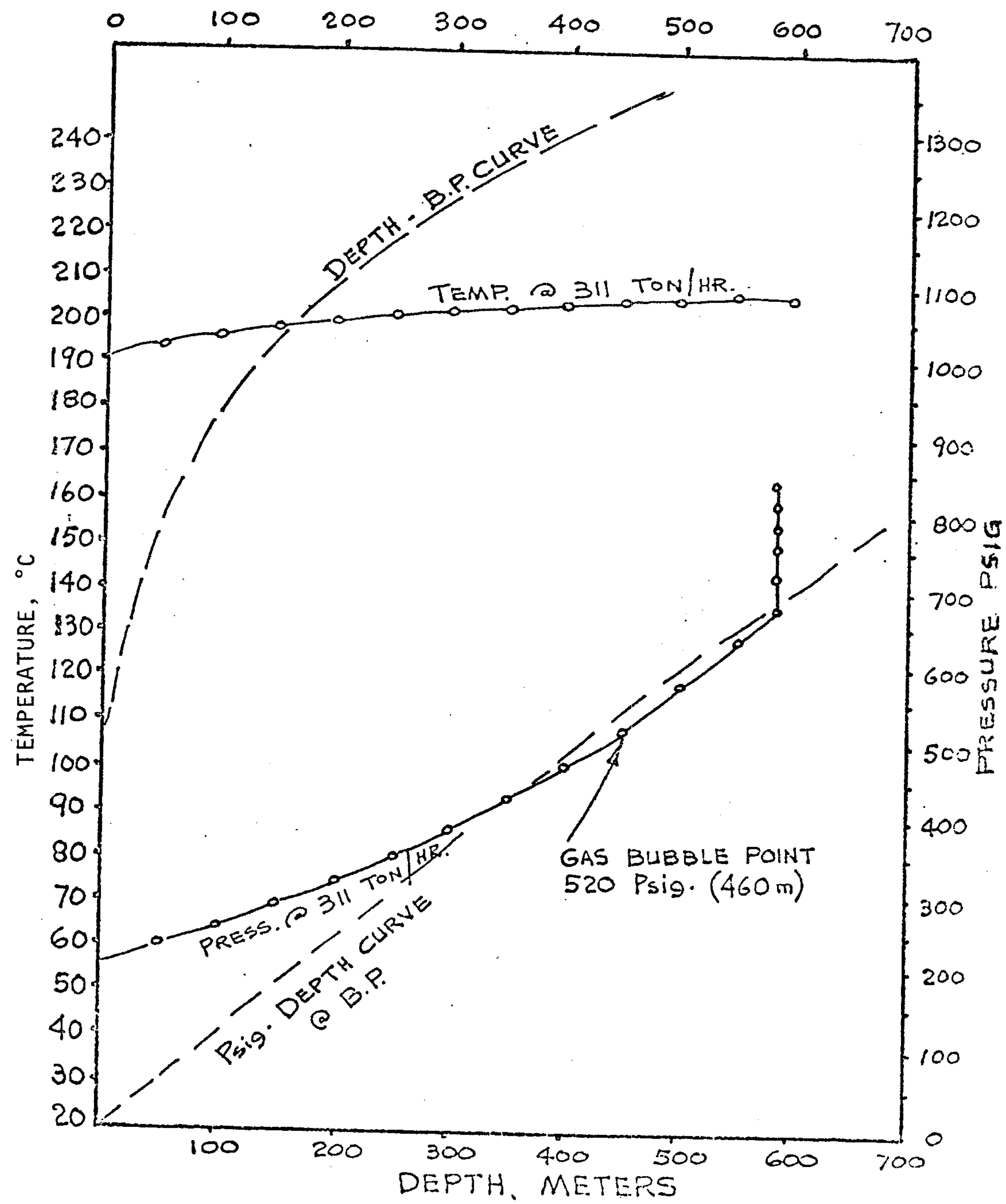
We have taken another approach to the problem which we believe will be more reliable and less expensive to operate. Our system permits the well to produce fluids by steam flashing in the wellbore, but we prevent calcite precipitation by recycling carbon dioxide gas down the wellbore in sufficient quantity to maintain the carbon dioxide partial pressure in the system and maintain the carbonates in the soluble bicarbonate form.

$$2\,HCO_3^- \rightleftarrows CO_3^{=} + H_2O + CO_2\uparrow$$

$$CO_3^{=} + Ca^{++} \rightarrow CaCO_3\downarrow$$

The adaptation of the recycle C02 system to the binary cycle is shown in Sketch No. 3. The capital and operating costs for this system are less than those for a pumping system utilizing long shaft well pumps. Maintenance costs should also be less because there are no moving, mechanical parts in the hot, corrosive environment of the wellbore.

Whether by pump or by the CO_2 recycle system, the control of calcite precipitation, we believe, will also control the silica laydown problem. We have run limited field tests which suggest that precipitated silica is cemented together by the precipitation of calcium carbonate.



DEPTH - B.P. CURVE
TEMP. @ 311 TON/HR.
PRESS. @ 311 TON/HR.
Psig. DEPTH CURVE @ B.P.
GAS BUBBLE POINT
520 Psig. (460 m)
TEMPERATURE, °C
PRESSURE PSIG
DEPTH, METERS

FIGURE 1.

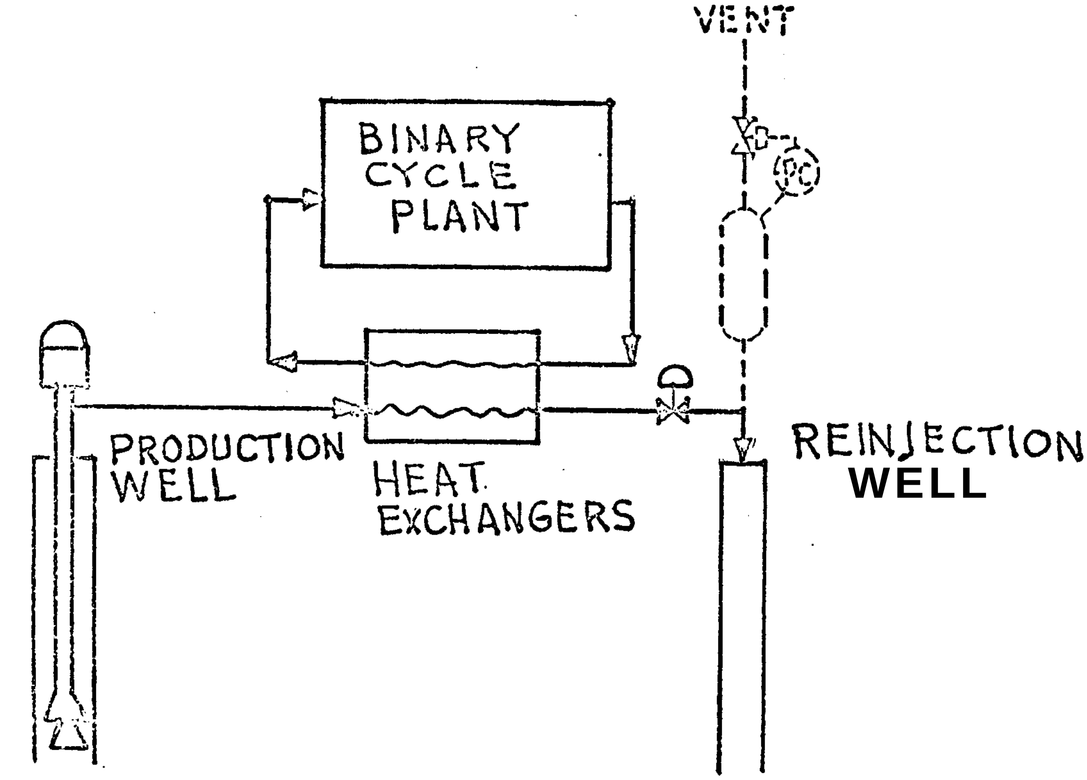


FIGURE 2.

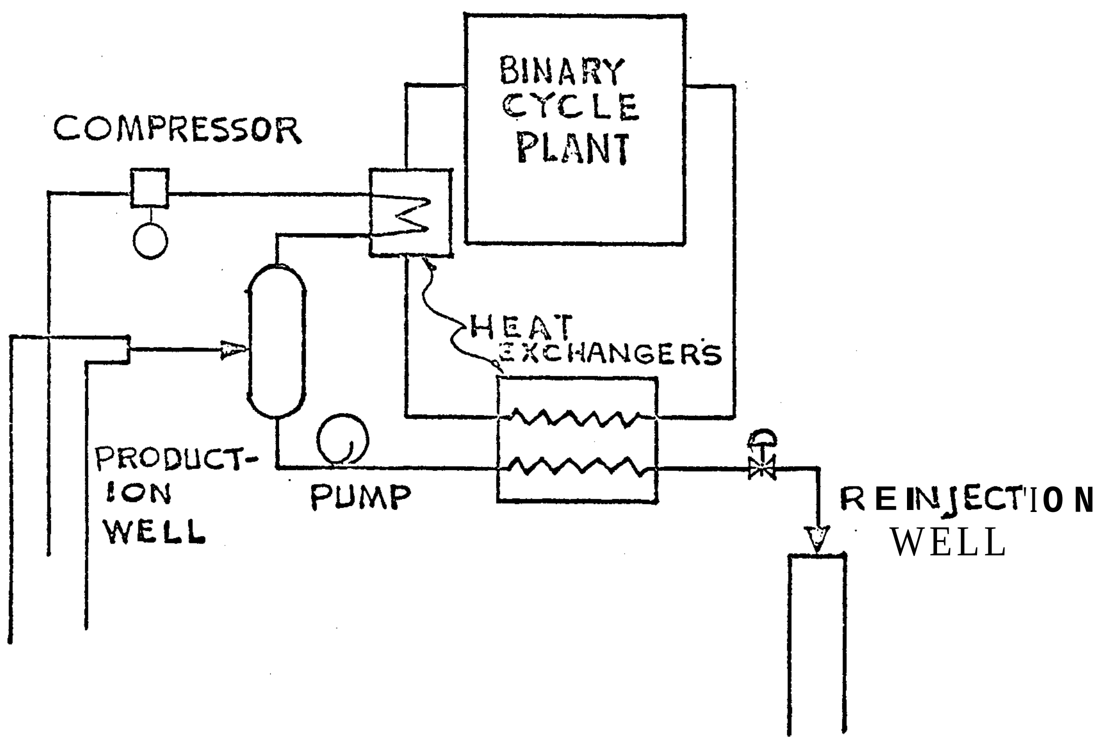


FIGURE 3.