FLUID FLOW IN GEOTHERMAL RESERVOIRS

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A discussion is presented of the material contained in Reference 1. This reference presents the results of an investigation of the fluid flow associated with pressure depletion in those geothermal reservoirs which are similar to oil and gas reservoirs. Geothermal reservoirs are often classified as either steam or hot water according to state of reservoir brine. These classifications imply the presence of only one phase; however, it is recognized that both liquid and vapor phases may be present initially or may develop as the pressure declines. This condition may involve the simultaneous flow of steam and hot water.

For two phase flow of steam and hot water the assumptions of small temperature and pressure gradients within the reservoir allow the simplification of the equations of heat and fluid flow.] This leads to a relation between the fluid pressure and the liquid saturation. Similar assumptions for single phase flow lead to an approximately constant reservoir temperature with fluid pressure decline.

The initial temperature and pressure in a geothermal reservoir determine its type.[2] The boiling point curve for pure water is presented by the dashed line in Figure 1. Dissolved salts in geothermal brines cause modification to this curve.3 Hot water reservoirs are represented by points to the right and below the curve as illustrated by initial point on curve A. Steam or single phase vapor reservoirs are represented by points to the left of the curve and points above the critical temperature, as illustrated by the initial points on curves B and C.

The solid lines in Figure 1 illustrate the behavior of closed geothermal reservoirs produced by pressure depletion with no water injection. The behavior of a hot water reservoir is illustrated by line A. Initially the hot water production causes rapid pressure decline since only liquid expansion and rock pore volume compressibility supply the driving energy. This essentially isothermal behavior continues until the boiling curve is reached. At this point the internal steam drive begins and a steam phase starts to build up within the reservoir. The temperature and pressure decrease along the boiling curve. When the steam saturation reaches the equil briurn saturation, steam begins to flow within the reservoir and hot water and steam are produced simultaneously. The steam saturation continues to bu ld up as production continues with an ever-increasing steam-hot water ratio of the produced fluid. This process continues until the water saturation s reduced to the point where the hot water becomes immobile and hot water production stops. The boiling process continues with only saturation steam production until all the water is boiled away. At this point the temperature departs from the boiling curve and remains essentially constant as the pressure continues to decline, as illustrated by curve A in Figure 1. The produced steam becomes increasingly more superheated as the pressure declines. The relatively high temperature at the end of pressure depletion indicates that considerable heat remains in the reservoir.

Curve B represents a steam reservoir which remains essentially isothermal with pressure decline. Only a small amount of heat initially in this type of reservoir is produced. Curve C represents a steam reservoir which is initially above the critical temperature and pressure. The temperature decline with pressure is slightly greater than reservoir B, but the overall temperature drop is small and most of the initial heat remains in the reservoir at pressure depletion.

The simplified equations of Ref. 1 do not strictly apply to conditions of gravity segregation of the steam and hot water. However, the insight obtained from the calculated results, coupled with the experience gained from oil and gas segregation in petroleum reservoirs, suggests the following behavior. Gravity segregation of the steam and hot water begins as soon as the steam phase begins to flow. Steam accumulation at the top of the reservoir increases the amount of steam produced from wells completed high in the reservoir. Correspondingly, wells completed low in the reservoir produce more hot water and less steam. Since the produced steam contains more heat than an equal mass of hot water completing wells high in the reservoir tends to increase the total heat produced under pressure depletion.

REFERENCES

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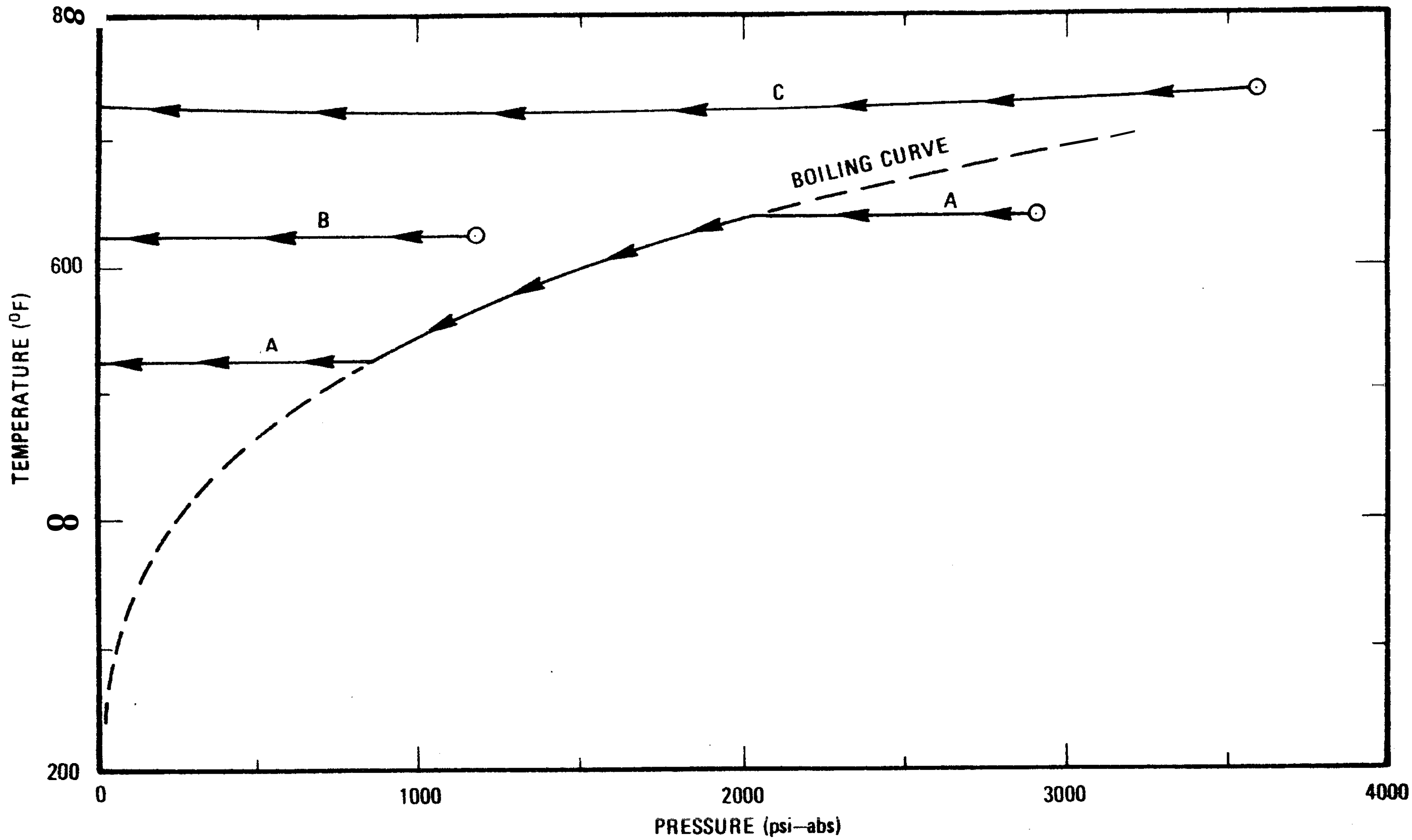

FIGURE 1

AN ILLUSTRATION OF THE TEMPERATURE VS. PRESSURE PERFORMANCE FOR A HOT WATER RESERVOIR, CURVE A, AND TWO STEAM RESERVOIRS, CURVES B AND C.