1) Overall thermal efficiency of Teapot Dome binary plant:

\[
\text{Efficiency } (\eta) = \frac{P_e + P_h}{P_{in}} \Rightarrow \eta = \frac{P_e}{P_{in}}
\]

\[P_e = 250 \text{ kW (given)}\]

\[P_{in} = \dot{m} c \Delta T, \quad \dot{m} = 40 \text{ kg/s} \quad c = 4.180 \frac{\text{kJ}}{\text{kg} \cdot \text{K}} \quad \Delta T = 70^\circ \text{C} - 70 \text{ K} (90 - 20 \text{ C})\]

\[\Rightarrow P_{in} = (40 \text{ kg/s}) (4.180 \frac{\text{kJ}}{\text{kg} \cdot \text{K}})(70 \text{ K})
\]

\[= 11704 \text{ kW}\]

\[\Rightarrow \eta = \frac{250 \text{ kW}}{11704 \text{ kW}} \approx 2\%
\]

2) \(P, T @ 100 \text{ m}\) for a boiling spring:

Assume \(\bar{p}\) for \(z = 0\) to \(z = 100 \text{ m}\) is 900 kg/m³

\[\Rightarrow P(\bar{p})\bigg|_{z=100} = \bar{p} g \bar{z} = (900 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(100 \text{ m}) = 8.82 \times 10^5 \text{ Pa} = 8.82 \text{ bar from } H_2O\]

But, need to add 1 bar for atmosphere \(\Rightarrow P = 9.82 \text{ bar}\)

\(P = 9.82 \text{ bar}\), find \(T\) for boilings:

from steam table, \(T\bigg|_{P=9.82} = 180^\circ \text{C}\)

For \(P, T @ 100 \text{ m}\), specific volume \((1/\rho)\) is 1.126 \(\text{m}^3/\text{kg}\) \(\Rightarrow 1.126 \text{ m}^3/\text{kg}\)

\[\Rightarrow \rho\bigg|_{z=100} = 0.888 \text{ kg/m}^3\]

\(\therefore \bar{p} = 900 \text{ kg/m}^3\) is acceptable.
3) Some info about a producing geothermal well:

Liquid feed zone @ 240°C => boiling @ 33.44 bar
Separator operates @ 7 bar gauge = 8 bar absolute

⇒ boiling @ 170°C ⇒ liquid from separator @ 170°C

Mass fraction of liquid & vapor from separator:

Conservation of energy requires:

\[ H_i = f H_{os} + (1-f) H_{ol} \]

for \( H_i \) = enthalpy of input fluid
\( H_{os} \) = enthalpy of output steam
\( H_{ol} \) = enthalpy of output liquid
\( f \) = steam fraction

\[ f = \frac{H_i - H_{ol}}{H_{os} - H_{ol}} = \frac{(1038 - 719)}{(2802 - 719)} = 0.16 \]

⇒ 16% steam (16 kg/s), 84% liquid (84 kg/s)

4) Efficiency of condensing turbine:

\[ \epsilon = \frac{P_e}{P_{th}} \]

\[ P_{th} = n \cdot H_{vap} \] for \( H_{vap} \mid p = 8 \text{ bar} = 2769 \text{ kJ/kg} \]

\[ m = 2 \text{ kg/s} \Rightarrow P_{th} = (2 \text{ kg/s})(2769 \text{ kJ/kg}) = 5538 \text{ kW} = 5.538 \text{ MW} \]

\( P_e = 1 \text{ MW} \) (given) ⇒ \( \epsilon = \frac{1}{5.538} = 0.18 \%

5) For the well in Q3, how much power can turbine in Q4 produce?

\[ P_e = n \cdot \epsilon \] for \( \epsilon = \frac{1}{2} \frac{\text{MW}}{\text{kg}} \) (2 kg/s per MW)

⇒ \( P_e = (16 \text{ kg/s})(\frac{1}{2} \frac{\text{MW}}{\text{kg}}) = 8 \text{ MW} \)
6) Overall efficiency of well (Q3) vs. turbine (Q5):

\[ \eta = \frac{P_e}{P_m}, \quad P_e = 8000 \text{ kW}(Q5) \]

\[ P_m = \dot{m} H_2 \quad \text{for} \quad H_2 = 10.38 \text{ kJ/kg}, \quad \dot{m} = 100 \text{ kg/s}(Q3) \]

\[ \Rightarrow P_m = (100 \text{ kg/s})(10.38 \text{ kJ/kg}) = 1038 \text{ kW} \]

\[ \Rightarrow \eta = \frac{8000 \text{ kW}}{1038 \text{ kW}} = 8 \% \]

7) Concentrations in separator output waters:

Chloride & silica remain in solution, so output water has concentrations based on liquid fraction from separator (0.84 from Q3):

\[ C_{Cl} = \frac{1000}{0.84} \text{ ppm} = 1190 \text{ ppm} \]

\[ C_{Si} = \frac{400}{0.84} \text{ ppm} = 476 \text{ ppm} \]

But, silica is saturated @ 400 ppm \( \Rightarrow \) output water is super-saturated & silica will precipitate in outflow pipes.