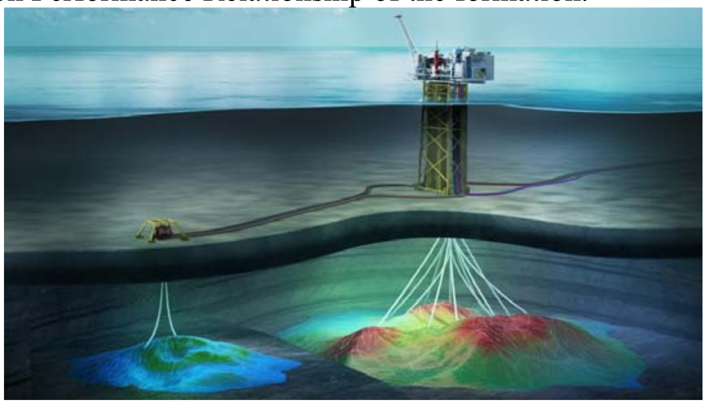
<u>Problem 1:</u> Vertical water injection well in a circular geometry

You are part of the planning team in Lundin that is in charge of designing a vertical water injector for the Hanz reservoir in Edvard Grieg. Your main task is to determine the injectivity index and the Injection Performance Relationship of the formation.



To calculate the injectivity index, adapt the equation that was provided for the productivity index of a undersaturated vertical oil well with radial geometry. Consider the following information

- External formation radius, r_e = 500 m
- Wellbore radius, r_w = 0.15 m
- Formation horizontal permeability, k = 10 md
- Layer thickness= 20 m
- Reservoir pressure = 300 bara.
- Reservoir temperature = 80 °C

Consider that the flowing bottom-hole pressure of the injector will range between 300-500 bara. Neglect skin.

Task 2. A service company has suggested to frack the formation to increase the injectivity of the well. How would you include this effect in your calculations above?

Additional information:

- To compute the behavior of formation volume fraction and viscosity of injection water versus pressure and temperature, use equations 9.18 and 9.22 of the attached pdf "Brine_properties.pdf". Assume that the formation and the injected water have a salinity of 150 000 ppm (seawater is around 35 000 ppm). Neglect the effect of gas dissolved in water.

<u>Problem 2:</u> Flow equilibrium calculations in a undersaturated oil well

You are part of the design team that are working on a vertical oil well that will produce undersaturated oil. The properties of the well are given in the Excel sheet provided. The well will be produced at a constant wellhead pressure of 2 bara.

The polynomial coefficients of a tubing performance relationship curve are provided. The tubing performance relationship curve depicts required pressure at the bottom-hole calculated counter current from wellhead, considering pressure drop in the tubing and a constant wellhead pressure.

Task 1:

Perform flow equilibrium calculations at bottom-hole to determine the oil flow rate of the system (assume a reservoir pressure of 300 bara).

Task 2:

If a pump (electric submersible pump) is placed bottom-hole, calculate the pressure boost required from the pump to deliver an oil rate of 350 Sm3/d.

Task 3:

The bubble point pressure of the oil at reservoir temperature is around 80 bara. The manufacturer of the ESP has specified that there should be no free gas at the suction of the pump to ensure high efficiency and avoid excessive vibration and heating. What is the maximum oil rate that is possible to achieve with the pump while guaranteeing that there is no free gas at the suction?

Calculate the required pump power. The required pump power, when pumping liquid, can be calculated using the following expression:

$$P = \frac{\Delta p \cdot q_o}{\eta_H}$$

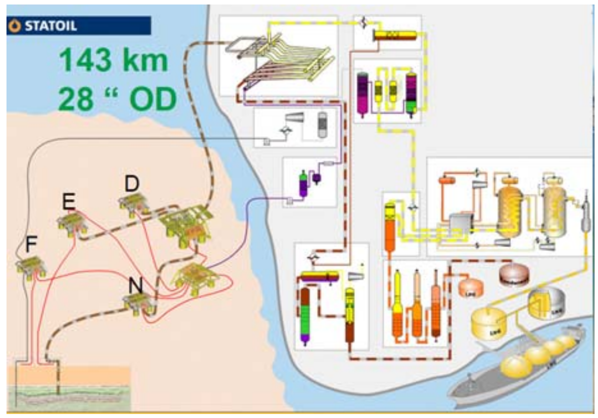
Where:

- Δp, pressure boost provided by the pump
- q_o, oil volumetric rate at inlet conditions. Assume an oil formation volume factor at the inlet of the pump of 1.15
- η_H , Hydraulic efficiency of the pump. Assume a value of 0.7.

You must use the proper units for Δp and q_o to obtain power in W. After you obtain the required power in W, convert to horsepower (hp)

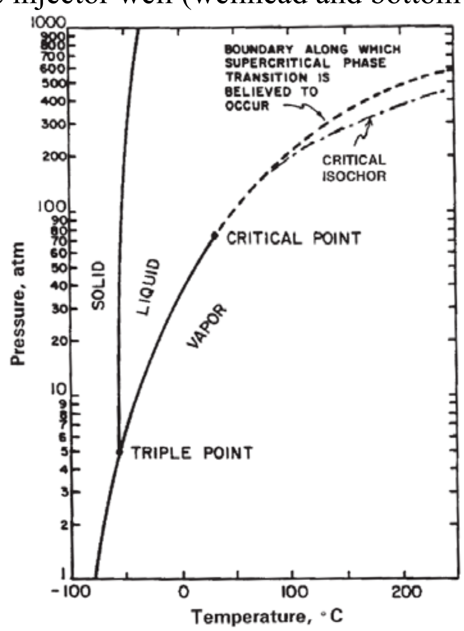
<u>Problem 3:</u> m function for a vertical CO_2 injection well

The Snøhvit field is a subsea dry gas field, located in the Barents Sea. The field produces to a LNG facility on the island of Melkøya through a pipeline that is 140 km long. In the LNG plan, CO2 is captured, it is then pumped and transported for 140 km back to the field and injected in a deep formation (Tubåen). The CO2 is injected in an aquifer, but in this problem, we will assume that the layer has pure CO2.



The discharge of the CO2 in Melkøya is usually at around 270 bara. During the transport in the CO2 pipeline, the temperature can be around 4 C (seabed temperature) or less, due to cooling because of the Joule-Thompson effect. The maximum injection bottom-hole pressure is 390 bara. The initial temperature of the formation is 95 C.

Task 1. Consider the phase diagram of CO2 shown below. Discuss/speculate in what phase is the CO2 in when it reaches the injector well (wellhead and bottom hole).



Task 2. To compute the Injection Performance relationship of this well, the m function is required, that is a function of pressure and depends on fluid properties. Calculate the m function at reservoir temperature for pressures up to 390 bara.

$$m(p^*) = 2\int_{0 \to p_{sc}}^{p^*} \frac{p}{\mu_g z}\, dp$$

Additional information:

- Some properties of CO_2 are available in the attached pdf "CO2_properties.pdf". You can steal the points from the charts using https://automeris.io/WebPlotDigitizer/ . After this, you can interpolate on the data points using the VBA function provided in earlier exercises.

<u>Problem 4:</u> Determining IPR of dry gas well using production data

Your team has made a multi-rate test on a dry gas well. The measurements of flowing bottom-hole pressure versus gas rate at standard conditions are given in the Excel file provided.

1. What are the units of C and n in the backpressure equation?
2. Using the backpressure equation, obtain a C and n that match the measured values.

Tips:

- The backpressure equation is programmed in VBA, available with function name IPRqg()
- Assume initial values of C = 200 and n = 0.5
- Calculate the difference squared between the rate provided by the equation and the measured value. Sum all differences for all points.
- Use the Excel Solver to minimize the sum by changing C and n.
- To help the solver finding a solution, add the constraint that n>=0.5 and n<=1