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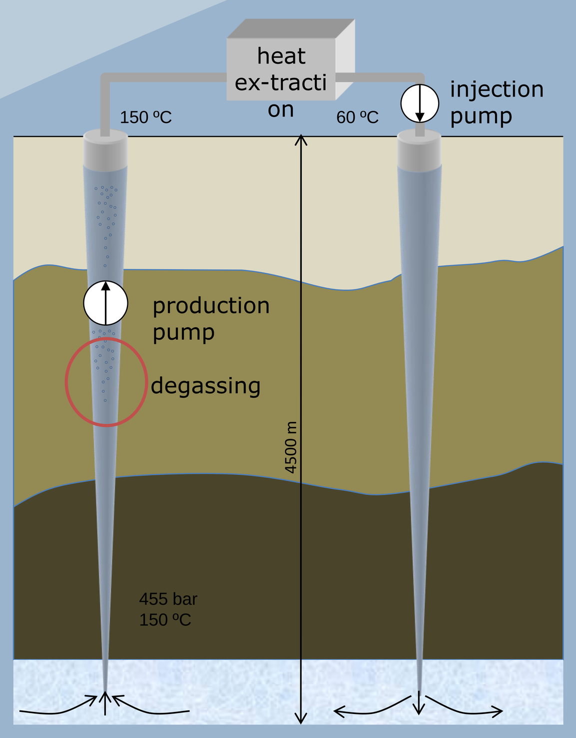
Two-Phase Flow in the Brine Circuit of a Geothermal Power Plant

Henning Francke, Ali Saadat (advisor)

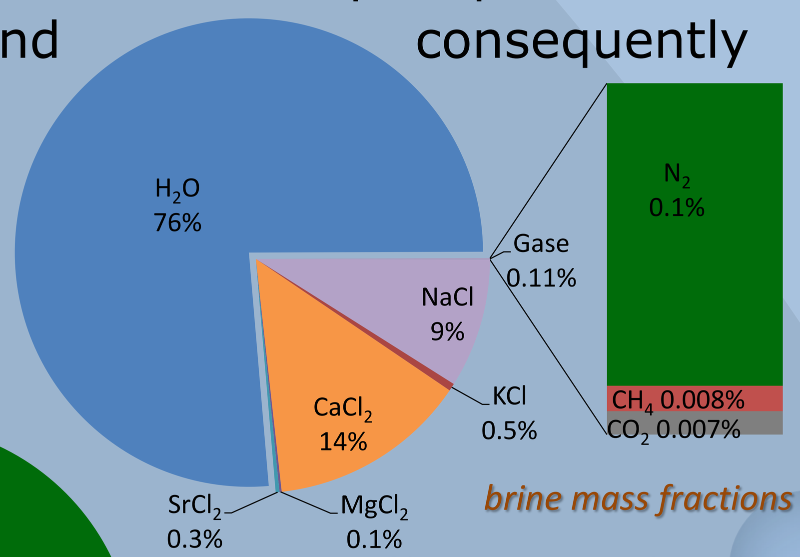
Section 4.1 – Reservoir Technologies

1.Introduction



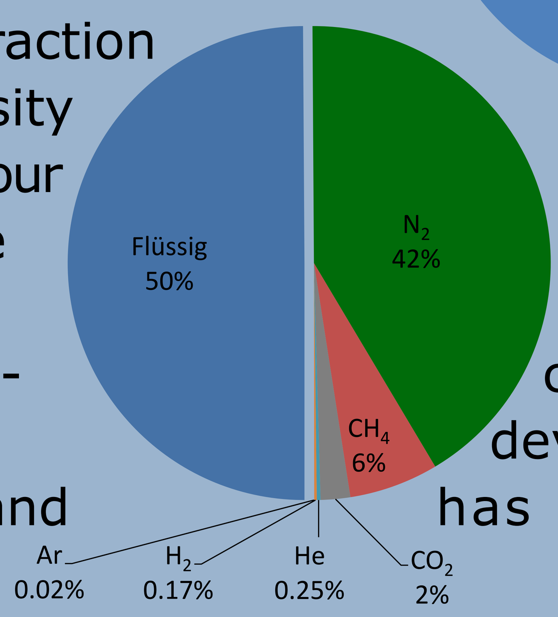
examplary brine circuit of a geothermal doublet

Brine extracted from deep aquifers for thermal exploitation usually contains dissolved salts (e.g. NaCl, CaCl) and gases (N_2, CH_4, CO_2). Due to pressure difference (hydrostatic + friction) between aquifer and the above ground facility, degassing can occur. If CO_2 degasses, pH rises which can lead to precipitation of solids and consequently scaling.



composition of brine in Gross Schoenebeck[1]

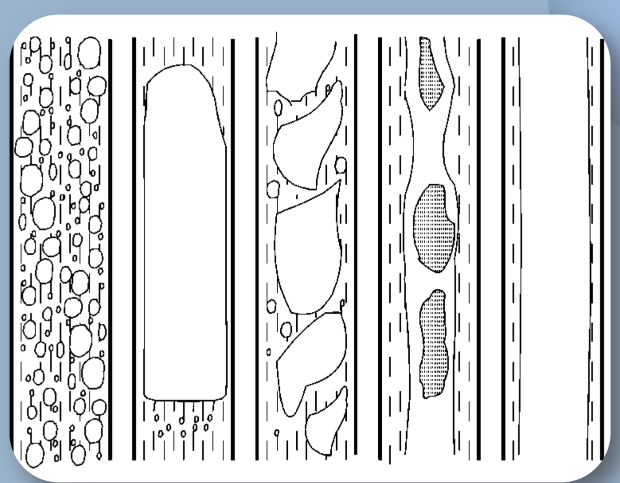
To avoid this, the pressure Must be kept above a certain level in the whole brine circuit. Also, the gas fraction influences density and flow behaviour (friction) of the resulting two-phase medium. Thus, the gas fraction can significantly de-crease the performance of the affected devices (pump, heat ex-changer etc.) and has to be known for the dimensioning of the facility.

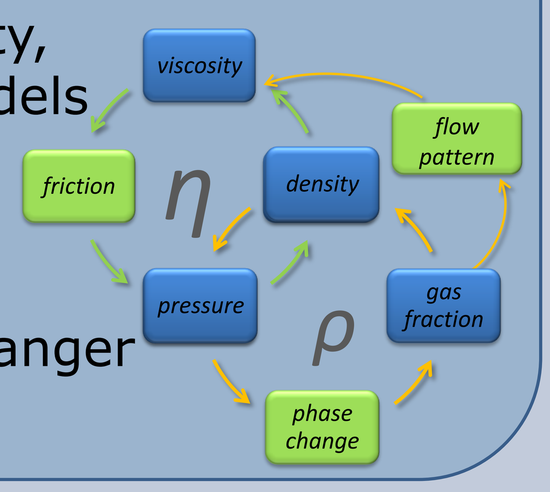


brine volume fractions at 0°C, 1 bar

2.Challenges

- There is no property function for brine
- The flow in the brine circuit
  - is turbulent
  - is a mixture of several components
  - has a liquid and a gaseous phase
  - is subject to phase change by gas solution and evaporation
- phase equilibrium is determined by the solution
- In order to reduce computational complexity, these phenomena require approximate models instead of microscale modelling (bubble formation, turbulence)
- The domain in consideration is multiscale (borehole depth ≈4000 m, plate heat exchanger gap width ≈2.5 mm)


possible flow patterns in vertical flow



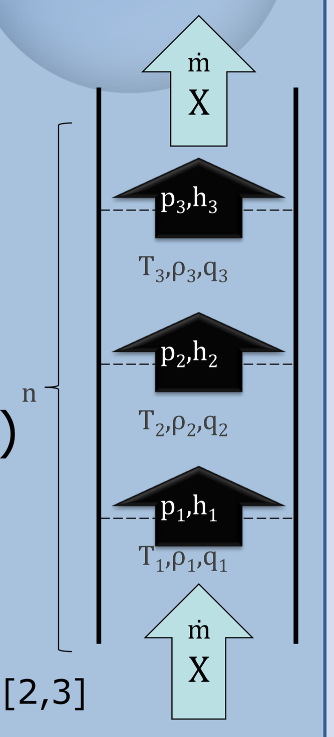
3. Objective

- Predict field of absolute pressure
- Identify potential locations of degassing
- Develop, apply and evaluate numerical model for the two-phase brine flow with degassing
- Implement as Modelica.Media component, compatible to standard libraries, ready to use in geothermal power plant model

4.Approach

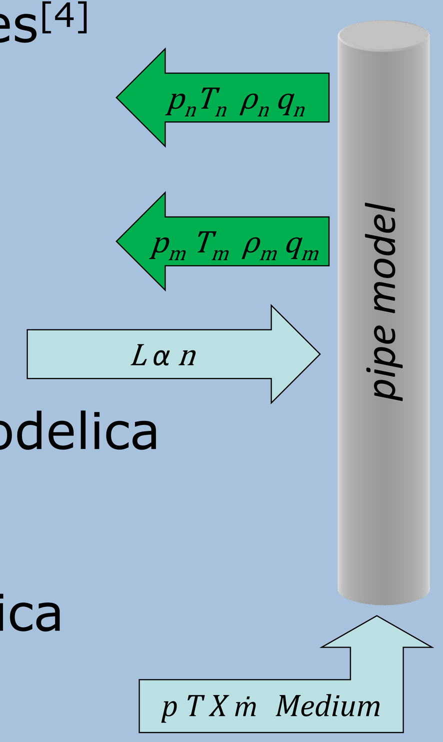
Physical

- split up domain in simple geometries (e.g. tube) with single scale problems
- reduce spatial dimensions (1D-flow)
- discretize flow domain (n pipe segments)
- apply simplifications
  - consider only 2 gases (later 3 gases)
  - adiabatic flow (later heat flow through pipe wall)
  - quasistatic phase equilibrium
- homogenous two phase fluid model (no slip between the continuous phases)
- calculate phase equilibrium using solubility function[2,3] →gas mass fraction q
- calculate phase properties separately
  - liquid phase: aqueous solution of chlorides[4]
  - gas phase: ideal mixture of ideal gases
- calculate balances of mass, momentum & energy in each segment



Computational

- Create template for two-phase mixture in Modelica
- Create models of circuit components (pipe, pump, heat exchanger, reservoir, etc.)
- Assemble model of the brine circuit in Modelica

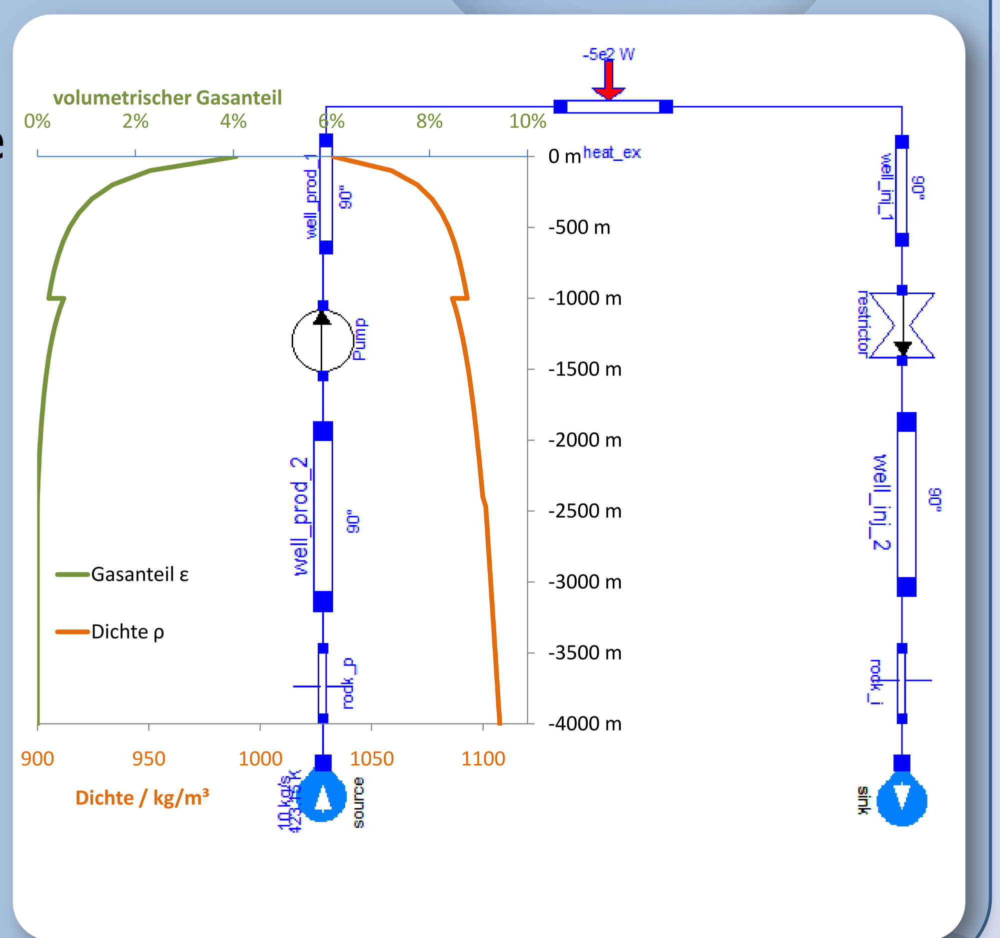


Practical

- Validate model with measurements from Gross Schoenebeck

5.Results

- Modelica Fluid property model of two-phase brine including degassing and evaporation
- Simplified Model of brine circuit for Modelica
- Degassing in pipe can be simulated



References

[1] Huenges, E. & Winter, H. (2004), Experimente zur Produktivitätssteigerung in der Geothermie-Forschungsbohrung Groß Schönebeck 3/90 , Scientific Technical Report 04/16

[2] Mao, S. & Duan, Z. (2006), 'A thermodynamic model for calculating nitrogen solubility, gas phase composition and density of the N2-H2O-NaCl system', Fluid Phase Equilibria 248 (2) , 103-114

[3] Duan; Sun.; Zhu. & Chou, I.-M. (2006), 'An improved model for the calculation of CO2 solubility in aqueous solutions containing Na+, K+, Ca2+, Mg2+, Cl-, and SO42-', Marine Chemistry 98 (2-4) , 131 - 139.

[4] Mao, Duan, 2008, 'Properties of binary aqueous chloride solutions up to T=573 K and 100 MPa', Chemical Thermodynamics

Tools

- Modelica [language] in Dymola [solver] (multiphysical systems simulation)
- REFPROP – material property database

Contact

francke@gfz-potsdam.de

www.geoen.de
www.gfz-potsdam.de/geothermie

The GeoEn project is funded by the German Federal Ministry of Education and Research

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