Geothermal Reservoir Research in Iceland

What works? What doesn't?

Orkugarður, Grensásvegi 9, 9:00-15:00, March 4th 2010

Relative permeabilities for two phase flow in geothermal reservoirs

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General Information on Project

Ph.D. Project that started in 2009

Participants:

- Reykjavík University
- University of Iceland
- Keilir Energy Lab
- ÍSOR

Financed by:

- Georg
- Orkurannsóknarsjóður Landsvirkjunar
- Tækjasjóður Rannís

Theoretical Background

Traditional relation for velocity of a fluid in groundwater reservoirs:

Darcy equation:

$$v = \frac{k}{\mu} \cdot \left(-\frac{dp}{dz} - \rho \cdot g\right)$$

v	Velocity, m/s
k	Intrinsic permeability, m^2
μ	Dynamic viscosity, kg/(m·s)
dp/dz	Pressure gradient, Pa/m
ρ	Fluid density, kg/m^3
g	Earth´s gravity m/s^2

Intrinsic permeability accounts for the ability of the geothermal reservoir rock to transmit fluid

Two Phase Flow

Darcy Equation for two phase flow

$$v_w = \frac{k \cdot k_w(S_w)}{\mu_w}\left(-\frac{dp}{dz} - \rho_w \cdot g\right)$$

$$v_s = \frac{k \cdot k_s(S_w)}{\mu_s}\left(-\frac{dp}{dz} - \rho_s \cdot g\right)$$

k_w Relative permeability for water
k_s Relative permeability for steam

Both depend on the volumetric water saturation, s_w and can only be found by measurements

Relative permeability of a phase is the effective proportion of the intrinsic permeability for that phase

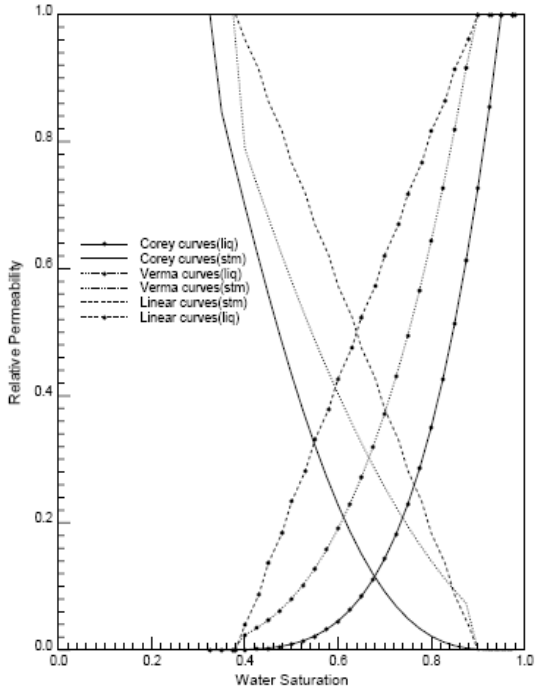
For two phase flow of water and steam:
$0 < k_w < 1$
$0 < k_s < 1$

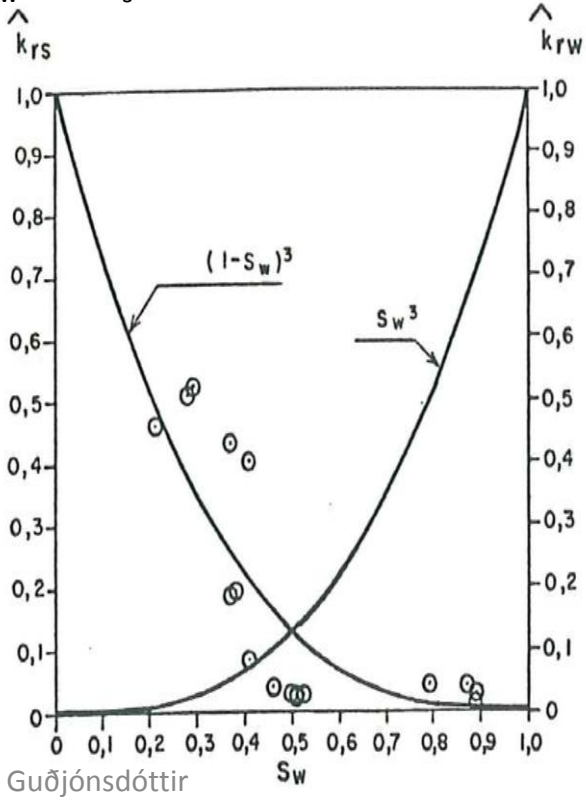
Results from Flow Tests

The flow relation (Darcy equation) does not account for phase interaction between the two phases.

If no interaction: $k_w=s_w$ and $k_s=1-s_w$. That is not the case according to results of measurements of the relative permeability.

There are several known relations for k_w and k_s from experiments





Problems Regarding Current Relation

- Contradiction between the theory and measurements
- Indicates that the traditional relation lacks factors accounting for phase interaction
- Current relation does not work for all theroetical cases
- Simulation tools used for flow in geothermal reservoir base on the current flow relation

Measurement Device

- To achieve improved relation for the two phase flow, empirical relation must be developed from experimental data

- The experiments made until now show the disadvantage of current flow models, but are not detailed enough to base new empirical relation on them

- To mimic reservoir condition, measurement device will be installed:
  - Vertical steel pipe
  - 15 cm diameter
  - 10-12m high
  - Filled with gravel of known (absolute) permeability
  - Inlet pressure of water up to 100 bar
  - Two phase flow up the steel pipe
  - Variable steam quality
  - Temperature and pressure measured along the pipe
  - Pressure drop and gravity forces measured

Expected Outcome of the Project

- Relative permeabilites for two phase flow will be measured
- Data from the measurements will be used to achieve empirical relation for the two phase flow
- Current relation for two phase flow can be improved
- Improvements in simulation tools used for flow in geothermal reservoir
- Comparison with actual data from geothermal reservoir
- Better understanding of flow in geothermal reservoir