The impact of equations of state and impurities on simulation of decompression of CO_2 pipelines

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Motivation

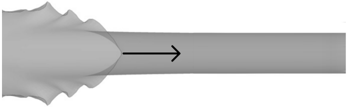
Decompression/depressurization can occur due to

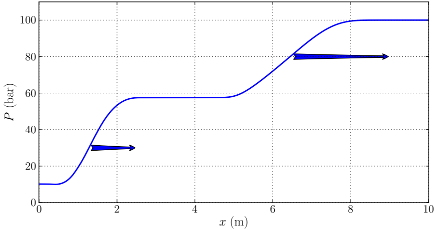
- Planned maintenance or shutdown
- Accidental rupture

Necessary to predict

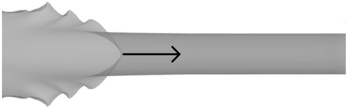
- Low temperatures
- Saturation/bubble pressure

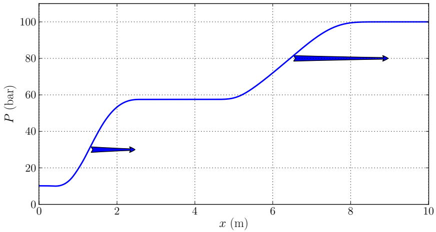
Running ductile fracture





Running ductile fracture





Crucial factor: the saturation pressure

Two-phase flow model

Conservation equations:

$$\text{Mass: } \frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} = 0,$$

$$\text{Momentum: } \frac{\partial(\rho u)}{\partial t} + \frac{\partial(\rho u^2 + p)}{\partial x} = -\text{friction},$$

$$\text{Energy: } \frac{\partial E}{\partial t} + \frac{\partial(u[E + p])}{\partial x} = \text{heat from pipe}.$$

$$p, T = \mathrm{Thermodynamics}(\rho, E, \text{equation of state})$$

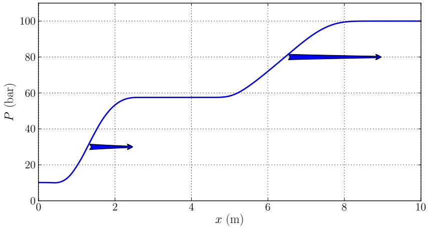
Isentropic decompression

Assume

- No friction
- No heat from pipe
- Infinitely long pipe

Gives *isentropic decompression*, given simply by

$$\frac{\mathrm{d}|u|}{\mathrm{d}p} = -\frac{1}{\rho c}.$$



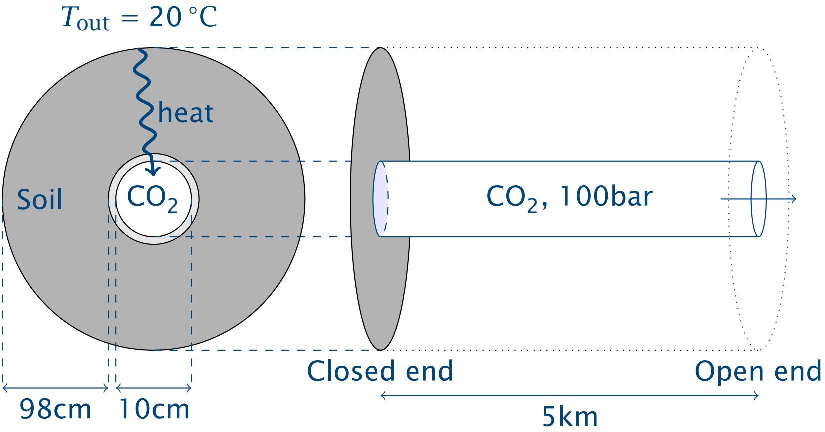
Equations of state

Equation of state (EOS) relates temperature, pressure, density, etc.

We compare two EOSs:

- Peng–Robinson (simple cubic EOS)
- EOSCG-GERG: combination of
  - EOS-CG, developed at RUB (for CO_2, N_2, O_2, Ar)
  - GERG-2008 (for H_2, CH_4, C_2H_6)

Decompression case



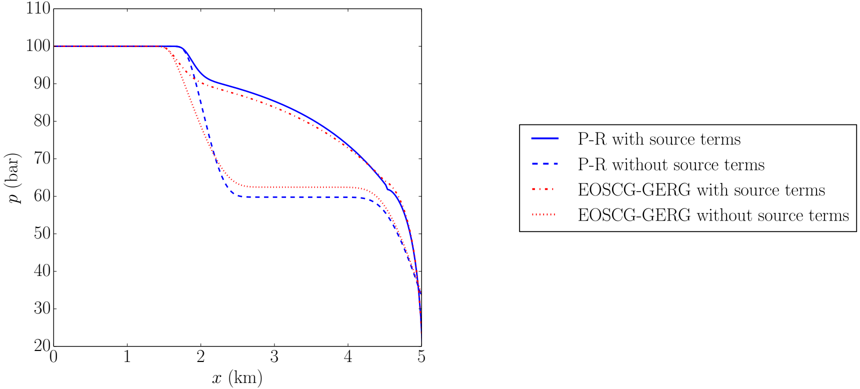
Compositions

- Binary mixtures: N_2, O_2, H_2, Ar, CH_4, C_2H_6
- CCS relevant mixtures:

Description	CO_2	N_2	O_2	Ar	H_2	CH_4	C_2H_6
Coal, amine	99.77%	2000	200	100			
Coal, selexol	98.25%	6000		500	1%	1000	
NG, amine	95%	5000				4%	5000

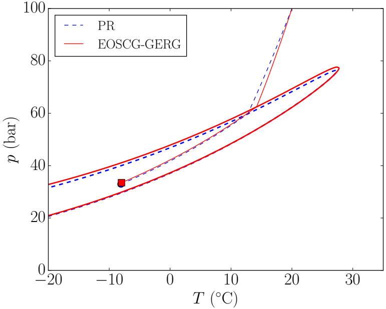
(ppm or %)

Impact of equation of state

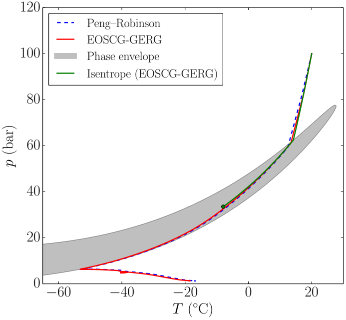


Decompression of CO_2 mixture from natural gas processing with amine capture

Impact of equation of state



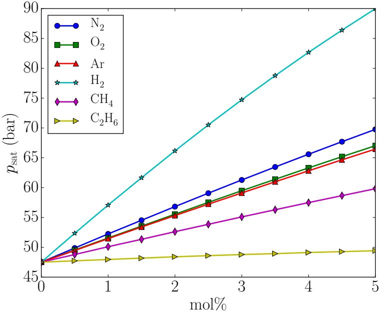
(a) Isentropic



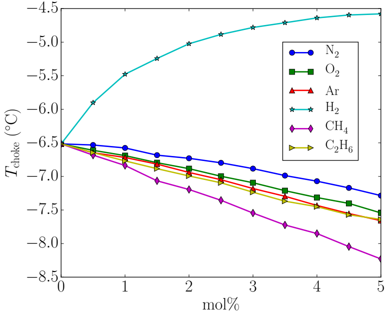
(b) Flow simulation with friction and heat

Decompression of CO_2 mixture from natural gas processing with amine capture

Impact of impurities



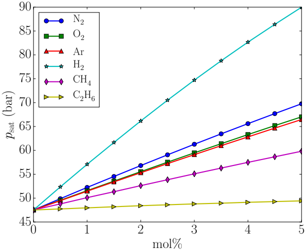
Saturation pressure



Choke temperature

Summary

- EOS has little impact on depressurisation simulations
- Impurities have a large impact on saturation pressure
- Impurities have little impact on lowest temperature
- Less than ≈1000 ppm is insignificant



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