Safe CO_2 transport –
Rapid depressurization of CO_2-rich mixtures

SINTEF NTNU Norwegian University of Science and Technology NCCS ECCSEL

Background

The energy system of the future will be based on renewable energy sources, but for several decades to come, we will be dependent on fossil fuels, which leads to emissions of CO_2, contributing to global warming. In addition, several industrial processes have significant amounts of CO_2 as a by-product. Therefore, we need to establish a system for capture, transport and storage of CO_2 (CCS). This project is one contribution to that end.

CO_2 captured from combustion or industrial processes can be safely stored in the underground. In Norway, the most relevant storage locations are on the continental shelf. The CO_2 must be transported wholly or partly in high-pressure pipes. Should a fault occur in a CO_2 pipeline occur, we want to avoid the formation of a running-ductile fracture. Whether the fracture stops or not is a function of the pressure-propagation speed in the fluid inside the pipe, and the crack-propagation speed in the steel. Current engineering tools work for natural gas, but not for CO_2. Thus, more physical insight is needed.

This project focuses on rapid depressurization of CO_2-rich mixtures in pipes. Upon depressurization, phase change will occur. Some experiments indicate that it may not be correct to assume that the process is in equilibrium. We will therefore investigate the effect of non-equilibrium in one or more of the quantities temperature, chemical potential, pressure and velocity. This will affect the mathematical formulation of the flow model.

SINTEF Energy Research has a numerical workbench for compressible multiphase flow of multicomponent CO_2-rich mixtures, which will be used in the project. As part of the European CCS Research Laboratory Infrastructure (ECCSEL), a depressurization facility is under construction at the NTNU-SINTEF Thermal Engineering Laboratories. Depending on the schedule, it may become possible to carry out experiments there as part of this project. Furthermore, the project will be carried out as part of the new NCCS Research Centre for Environment-Friendly Energy Research (FME), where a PhD grant has been allocated for this subject.

Tasks

A collection of the following tasks will be performed:

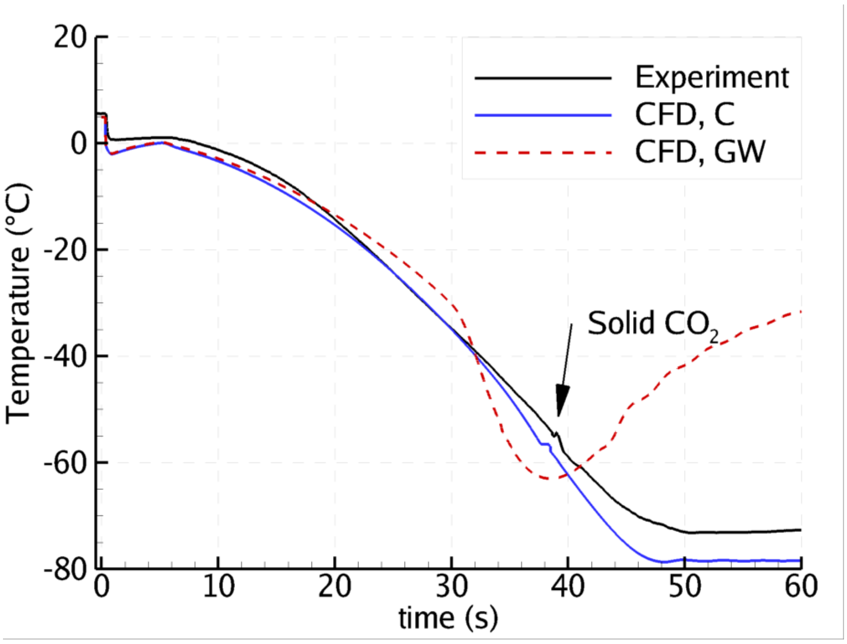
- Getting acquainted with the problem at hand
- Mathematical analysis of the coupled thermo-fluid model
- Numerical discretization
- Implementation of submodels
- Study of the effect non-equilibrium assumptions and thermodynamic models
- Comparison with experimental data

Prerequisites

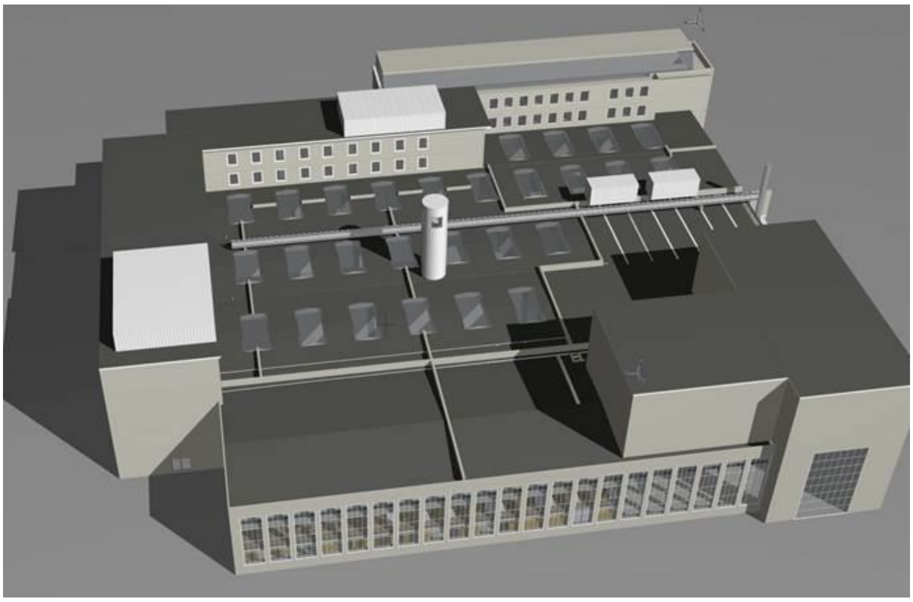
- Interest for thermo- and fluid dynamics
- Interest for numerical methods
- Interest for numerical mathematics and analysis of systems of hyperbolic partial differential equations
- Knowledge of (or ability to learn) Fortran 95/2003 and Linux

Contact Persons

- Chief Scientist Svend Tollak Munkejord, SINTEF Energy Research, svend.t.munkejord@sintef.no
- Research Scientist Morten Hammer, SINTEF Energy Research, morten.hammer@sintef.no
- NN, NTNU (to be decided)



Depressurization of a 200 m tube. Temperature is plotted against time for the position 195 m from the outlet. Experimental data compared to our CFD calculations with two different in-tube heat-transfer models. Notice that only one of the calculations predicts the formation of solid CO_2.



Sketch of the 60 m long depressurization tube on the roof of the Thermal Engineering Laboratories at Gløshaugen.