KEM Research Question (max. 4 pages + annex)

TITLE KEM-58 Fracture initiation and propagation after abandonment of salt caverns

Objective

Maximum 200 characters (short description of the objective of the research question, which knowledge gap is resolved)

The objective of this research is to investigate the development and growth of fractures during the abandonment of salt caverns.

State of the art, background

Maximum 400 characters (description of state of the art knowledge, practices and flaws, including link to references documents, data, models).

In KEM-17 it was concluded that enhanced knowledge is needed for assessing and managing the risks after abandonment of relatively large and deep caverns in Northern Netherlands. Both permeation as well as hydraulic fracturing can play a role during the abandonment of these large salt caverns.

In the recent reports of the CCC (2024,2025) abandoning of salt caverns was modelled including permeation and hydraulic fracturing. Even though the likelihood of the formation of fractures during abandonment of salt caverns is thought to be small, it cannot be ruled out. A runaway fracture leading to leakage of brine above the salt rock is a potential risk to the environment. As such a need arises to develop coupled codes to assess the formation of hydraulic fracturing, with or without a permeation/micro-fracturing/dilatancy processes, the potential growth of a hydraulic fracture and the cessation/healing of a hydraulic fracture.

In CCC (2025) the formation of hydraulic fracturs was studied in more detail concluding that after abandonment small-scale hydraulic fracturing could occur. However the propagation of hydraulic fractures beyond 15 meters remained highly unlikely. In the long term the likelihood of a hydraulic fracture diminishes further. While hydraulic fractures cannot be completely rules out, the possibility of a large subvertical fracture propagating beyond 15 meters from the cavern wall, according to this study, is extremely low.

For gas production hydraulic fractures are used to enhance gas production at certain stages. General fracture mechanics modelling for gas fields is therefore commonly used. In these analysis both the fracture initiation as well as the fracture propagation are modelled (e.g. Carter 2000). The medium modelled however is a gas field which has very different characteristics compared to salt.

In Spiers (2024,2025) the CCC work was reviewed concluding that additional fracture mechanics modelling capability in salt formations is desirable to test the presented conclusions. This project will be a first step to building fracture mechanics modelling capability in salt.

Research Question

Maximum 400 characters (what to be addressed and what not AND Link to KEM Research Agenda)

The project will comprise the following main activities:

A1. Combining numerical modelling of salt cavern abandonment with knowledge on fracture mechanics to get more insight into fracture mechanics in salt during salt cavern abandonment.
A2. A sensitivity analysis on the initiation and growth of hydraulic fractures in salt
A3. An analysis on the role of hydraulic fracturing and permeation in salt domes after salt cavern abandonment
A4. An analysis on the effect of healing in salt
A5. Reporting

Based on the above activities the following research questions will be addressed

On the initiation of the hydraulic fracture:

1. How can a hydraulic fracture initiate during salt cavern abandonment?
    a. What conditions initiate the fracture?

b. Does permeation/micro-fracturing/dilatancy play a role in the formation of a hydraulic fracture?
c. What other mechanics play a role in the initiation of a hydraulic fracture?
d. How does the hydro-mechanical stress state and material properties contribute?

On the propagation of the hydraulic fracture in salt:

2. Under what conditions can a hydraulic fracture in salt propagate?
    a. What mechanisms play a role in the propagation of the hydraulic fracture?
    b. What factors limit or accelerate growth?
    c. Is it easier to propagate the existing fracture or initiate a new fracture?
    d. How do propagating fractures interact with existing fractures/permeation/weak zones?

On healing of fractures:

3. Does a hydraulic fracture which has been closed form a permanent weak zone where other fractures may form?
    a. Does healing play a role?
    b. On what time scales does a hydraulic fracture in salt heal?

Deliverables expected

A final written report with a management summary preferably in Dutch.

Timeline

18 months for the project work and an additional 3 months for finalizing the project within the KEM.

Expected use

The results will give a better insight into the risk of runaway hydraulic fractures developing after abandonment of salt caverns, both the initiation as well as the propagation. The result of the project will be used to improve knowledge on the abandonment phase of salt caverns

Expertise and tools preferred for the team

Knowledge on:
- Geomechanics
- Fracture mechanics
- Salt behaviour on micro- and macro-scale, including modeling salt mechanics

Quality assurance, Organisational and communication requirements

A technical guidance group will be formed consisting of one or two representative(s) of the KEM panel ensuring continuity and reporting to the KEM panel, as well as a representant of the ministry of KGG. Progress meetings will be held at least once every 3 months. The report will be evaluated by the KEM panel. The KEM panel encourages scientific papers from the KEM projects.

The project will be presented at the bi-annual KEM meetings.

Additionally, the results of the project should be reviewed by independent researcher(s) with demonstratable knowledge on this subject, organized by the project team. The reviewer should be known at the start of the project.

Remarks and Suggestions

Maximum 200 characters (extra information concerning the Innovation/Research question)

References

No limit (reference list of papers, tools and reports)

- KEM-17 (www.KEMprogramma.nl)
- Carter, B. J., Desroches, J., Ingraffea, A. R., & Wawrzynek, P. A. (2000). Simulating fully 3D hydraulic fracturing. *Modeling in geomechanics*, *200*, 525-557.Cavern Closure Consortium –
- CCC (2024), Abandonment of solution mining cavern field Zuidwending, The Netherlands (https://cavernclosure.com/portfolio/)
- Cavern Closure Consortium – CCC (2025), Abandonment of solution mining cavern field Zuidwending, The Netherlands. Statement on hydraulic fracturing risk (https://cavernclosure.com/wp-content/uploads/2025/03/250218_CCC_Zuidwending_Statement.pdf)
- C. Spiers (2024). A brief review of the report on "Abandonment of solution mining cavern field Zuidwending, The Netherlands" by the Cavern Closure Consortium (https://cavernclosure.com/wp-content/uploads/2025/03/CCC_ZW5.1_Final_Report_ver.240411.pdf)
- C. Spiers (2025). A brief review of the reports entitled "Abandonment of solution mining cavern field Zuidwending, the Netherlands. Statement on hydraulic fracturing risk" by the Cavern Closure Consortium
-