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TNO report

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Public Summary: TKI “Downhole field lab – Wellbore sealing by rock salt

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Contents

Project information

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Upstream Gas – Decommission and Abandonment

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Project partners:
TNO (coordinator), EBN, ENGIE E&P Netherlands

Motivation and project scope

The total costs for P&A of hydrocarbon wells will be tens of billions globally and several billions for the Netherlands only and despite the long history of O&G operations, there is uncertainty about the long-term reliability of materials used for zonal isolation during conventional well plugging and abandonment. Traditionally used cement may react chemically under certain downhole conditions, especially on extended time spans. Especially in case of natural gas or CO_2 storage where the field pressure will be increased and might impact the cement plug over a longer period of time, ultimate sealing materials would decrease the overall costs by reducing costly workover and remediation activities. Consequently, the abandonment of thousands of wells in NL in the near future constructed for various subsurface applications, such as hydrocarbon production, geothermal energy or gas and energy storage, requires more cost-efficient and reliable technologies than those available today.

Naturally occurring materials, such as shales and evaporates, are proven hydrocarbon seals over geological time scales – and could therefore be regarded as ultimate long-term well sealing materials. Salt plugging of a well, subject of this project, involves the closure of an open section of the well (created by section milling) by the natural process of salt creep. If successful, this concept can altogether remove the need for setting cement plugs in wells penetrating sub-salt formations (in NL) and this by reduced costs. Previous studies indicate that a wellbore closure by the natural creep of salt can occur a within (operationally) feasible time scales

This study was based on previous studies and research of the partners. A first field test has already been performed (by ENGIE) in Germany, which needs verification so that the applicability for the NL can be confirmed.

The overall objective of this project was maintaining long-term well integrity after abandonment by ensuring that the well remains its zonal isolation over extended time spans after abandonment and simultaneously ensuring a cost-efficiency plugging operation. Focus was intended to be on exploring and testing the feasibility of the formation of a salt sealing interval by preparing and conducting a field experiment downhole. The project was planned to consist of two phases with a decision gate in between:

1. Preparation and design of the field experiment; go/no-go for phase 2
2. Conduct a field test in an ENGIE wellbore offshore, evaluate the creep behavior of salt under real conditions and calibrate numerical models for future predictions

This report provides a summary of phase 1 as phase 2 could not be initiated as explained below.

In the preparation phase 1 the following activities were executed to meet the objectives explained above. Each activity is reported in a (restricted) related deliverable report.

Baseline geomechanical modelling of the downhole lab conditions

Geomechanical models were based on the preferred set-up of downhole field lab. Simulations were conducted for a range of natural and operational boundary conditions. A brief literature review of earlier field experiments of borehole convergence in salt formations, executed in different industries, is presented. Experiences form the Altmark field test of borehole closure are described and reviewed. Estimated convergence rates and borehole closure times for the range of conditions considered in geomechanical simulations can be used to select a well for the field experiment, suitable depth-range of the reamed section and the preferred type of salt over the reamed section. Estimates of creep strain rates and closure times are useful for planning the experiment and developing a monitoring plan in the other activities.
Technical conclusions from this study are summarized below.

- Depth of the reamed section, ambient temperature, salt type and underbalance comprise the key factors that will determine the creep strain rates and borehole closure times.
- Larger depths are more favorable for the field test because the salt convergence rate increases with temperature.
- Larger depths are also more favorable because of larger achievable underbalance in deeper salt formations.
- Length of reamed sections should be sufficient to avoid slowing down of the rate of convergence due to stress redistribution around short reamed sections. A 10 m long reamed section would be sufficient in many cases. Shorter, a few meters long, reamed sections are not recommended.
- Estimated closure times in rock salt (halite) are in the range of 2 - 4.5 weeks for a depth of 3100 m, 2.5 - 6 months for a depth of 2500 m and 1 - 3 years for a depth of 2000 m.
- Convergence rates in carnallite (squeezing salt) are very fast and closure times are short, in the range of several hours to several days.

When a well candidate for the field test has been chosen, geomechanical modelling of borehole closure will be required with the well-specific input data.

Monitoring plan for the field lab

This report describes a monitoring plan with data and boundary conditions set in the first phase of the project. To execute a monitoring plan is an operation itself and thus a site-specific document. Within the boundaries and uncertainties given in phase 1, some good ideas have formed on what would be required, desired and possible.
The monitoring plan focusses on two aspects:

- Monitoring the creep process of the salt
- Assuring the quality of the salt plug

Three monitoring techniques have been identified as most favorable and promising to deliver relevant data on the creep process. The first and most simple one is a pressure gauge. Pressures measured by this device can be translated to fluid level rise in the well, which would be due to salt intrusion/creep into the open wellbore. A second technique could cover (at least) two measurements. One or more fiber optic cables can be mounted onto the outside of the micro annulus during installation. Through this fiber optic cable pressure caused by salt contacting the cable can be measured along the whole open section. The fiber optic cable can also be used as a conventional (distributed) pressure gauge forming a backup for the conventional pressure gauge. Third option is a fairly unconventional but promising one and will most likely supply unique information on the well diameter change over sections through time. This technique relies on electrical resistivity. Via this technique the potential differences over certain intervals along the micro annulus would be measured, which can be related to the maximum open hole diameter.

Although multiple standard techniques exist in the industry to test the quality of plugs, none would fit our demands. We came up with the idea to test the quality / integrity of the plug from below, by setting a (bridge) plug significantly below the reamed section and pressurizing the well in the section between the salt seal and the man-made plug. With respect to CO_2 storage, the testing pressure should go up to the virgin pressure of the reservoir which the salt plug should seal off.

Project plan for the field lab operation design, including technical and financial requirements

A high-level project plan for the second, operational phase of the project was established. It contains a list of activities along a time line and financial estimates for the single steps of the operation, onshore and offshore. It is based upon and refers to other technical reports of this project (deliverable reports), such as the developed monitoring plan and the design of the operation, which describe in detail in the technical and regulatory issues.

One of the most challenging tasks is the selection of a test well. For that reason, selection criteria have been established to guide the decision making towards a candidate well. Aspects with regard to the well design and history, geological and operational parameters have been defined which are explained in detail in the technical project reports. The generic criteria are:

- Thick and deep enough Zechstein salt cap with appropriate properties, e.g. 100 m of pure Halite at at least 3000 m,
- Sufficient data (well logs, etc) on the Zechstein salt cap, e.g. GR, Sonic, etc.,
- Complete history of the well with respect to complications and workovers,
- Exact data on the well configuration, such as deviation and number of casings/ casing size, etc.,
- Well in a cluster/on platform where well activities are planned,
- Appropriate time between test and other well related activities on the platform to finalize the test,
- Nice to have: Well/field earmarked or suited for CO_2 storage operations.

There are still uncertainties and questions regarding the field lab operation that can only be tackled accurately when a candidate well has been chosen. However, the ideas and techniques reported in this report present a good step forward and

should be re-evaluated and refined during the actual field test, when more certainty exist on the geological conditions and configuration of an actual candidate well.

Current regulatory framework for the application of rock salt well barriers in NL

This activity of project phase 1 looked into the regulatory framework for the implementation of the new sealing method into Dutch law. The work was two-fold: i) to investigate whether special permissions for the downhole measurements are required and ii) the overall conformity of the new technology with regulations in force (Dutch Mining Law), as preparation for a detailed study in phase 2 of the project.

i) As the planned pilot test will be embedded in a normal P&A operation using cement plugs where required, no regulatory issues are expected for the field test. The interval of the lab test is not used as a required P&A plug and the operational plan will consider that during casing milling the barrier envelop principle is followed. No materials or tools that are not allowed to remain downhole during usual P&A will be left in the well. However, SodM should be informed in due time about the testing plans.
ii) According to the Dutch Mining Law a (new) P&A barrier technology needs to fulfil the same sealing criteria as the currently used (cured) material: cement. For that reason, the new barrier material salt would need to be tested in a similar way as cement, which would require further definitions of procedures and maybe also adaptions or alternatives for the currently applied weight and pressure tests. Main challenge is the longer duration the salt plug would need to build up its final sealing properties and to settle before it is tested by the required weight testing as verification of the ductile salt plug.

Principally it could be beneficial to investigate the “scientific principles” behind proper well plugs as the current verification methods are simply based on good practice and experience. This could help to define proper verification criteria and testing procedures for old and new permanent barrier materials.

Finalization of phase 1

Phase 1 provided all information needed to select a candidate well for the salt creep sealing test and to conduct the field test in phase 2. Unfortunately, all identified potential candidate wells and fields of ENGIE were not scheduled for decommissioning in the coming months/years so that phase 2 could not be initiated although phase 1 met its objectives and provided the proposed findings, plans and suggestions for the field lab operation. Efforts of the project team to find another test well led to discussions with Taqa and a promising well was identified and offered for testing to the project team by Taqa. First geological investigations however showed that the required ductile salt rock formations along potential test intervals are absent, not thick enough and/or too heterogeneous to ensure a successful downhole test. Conclusively, the project team decided unanimously to stop the project and not to initiate phase 2.

Improved knowledge position and future prospects

The project developed a portfolio of procedures and methods to perform a downhole salt plugging test, including options for monitoring and verification.

The developed methodology and plans are readily available for operators in case they want to test the concept during their decommissioning activities. The gained

knowledge can be taken up by future downhole natural sealing tests and serves as basis to further develop a tailored, well and field specific testing plan. The challenge remains to find an ideal well candidate which intersects identified potential ductile formations at the right depths and well section.

Contribution of the project to sustainable energy production

Durable and more economic P&A solutions for annular sealing and well plugging would have a beneficial impact on the feasibility and economic competitiveness of promising sustainable geo-energy options, such as geothermal energy or energy storage. Recent research focusing on safe and durable P&A options identified natural downhole formations as a promising seal for wellbores in deep subsurface geo-energy applications. The potential application of natural formation in the context of well sealing and abandonment could increase the sustainability of energy production in the following ways:

- Lower CO_2 footprint of the used sealing materials considering the energy intensive cement production/industry,
- Lower environmental footprint of the P&A operation itself, e.g. due to no or less rig use,
- Lower risk of leakage of greenhouse gases or pollutants out of the sealed reservoir towards the surface by superior sealing efficiency, particularly on long-term.

Collaboration within the project

The cooperation between all project parties was fruitful and constructive. In six official project meetings and several additional discussion meetings the developed methodology was discussed and designed in close collaboration between all parties.

Dissemination and publications

The project results were communicated and presented at various events within TKI Upstream Gas such as yearly meetings and general assemblies of the Decommissioning program line. Furthermore, a presentation at an international conference on P&A in Norway was prepared to disseminate the results within the scientific community and to promote the concept to operators. A generic publication on natural formation sealing potential which is related to this study has been presented at the EAGE conference 2017 in Paris.

Additionally, the concept has been discussed in technical meetings with various operators in NL within and outside TKI Upstream Gas/New Gas.

Conference contributions and papers

Orlic, B., Heerens, G.J., Wollenweber, J., 2017. Salt as a barrier. Experimental P&A Research for the North Sea, SINTEF, 20-21 March 2017

Orlic B. and Geel, K., 2017. Integrity of seals in subsurface energy applications. 79th EAGE Conference & Exhibition 2017, Paris, France, 12-15 June 2017

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