CYCLIC TEST PROGRAM
PUBLIC SUMMARY

HYPSTER PROJECT

Deliverable 2.2

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V1	M. Schlichtenmayer (ESK)	00	
V2	M. Schlichtenmayer (ESK)	25.06.2021	Clarification on dynamic pressure range added, spelling corrections
V3	M. Schlichtenmayer (ESK)	22.07.2021	Adapted cycle duration
V4	M. Schlichtenmayer (ESK)	29.07.2021	Final comments and process parameter tables included

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1. INTRODUCTION

The cyclic test program provides a proposal for the cyclic tests to be conducted at the cavern Etrez EZ53 with hydrogen. It is aiming at finding a good compromise between the requirements resulting from the original request for proposal by the FCH2-JU, the scientific interest to validate the modeling of multiple effects and the operational constraints resulting from the unavoidable limitations of the technical equipment.
Further considerations regarding the conduction of the cyclic test will take place in the course of the project in WP1 and WP3 allowing a further preciziation of the actual test program.
Detailed modeling of the pressure and temperature evolution during the cyclic test will be performed in the coming months and will be presented in deliverable D2.4.

2. AIM OF THE CYCLIC TEST

The aim of the cyclic test is mainly defined by two aspects

- The original call of the FCH2-JU required more than 100 cycles to be realized over the project duration by e.g. daily cycles. Based on the previous findings in the project a cycle will be defined as the period between any two neigboring local maxima of the gas content of the cavern. Thus, the goal to reach more than 100 cycles can be reached by performing a corresponding number of day cycles, for instance, which may differ from each other in shape and amplitude and which may be superimposed by some other long-term withdrawal or injection events. It should also be possible to interrupt the cycling for some standby periods.
- The results of the cyclic test should allow us to validate the modelling of as many effects in the cavern as possible. This is expected to be mainly relevant for the thermodynamics of the cavern, but it may also allow some insights into the geomechanical cavern behavior.
  As a side effect, the cyclic testing with a small gas volume may also support conclusions on the long-term tightness of the cavern.

3. BOUNDARY CONDITIONS

A number of boundary conditions have to be regarded for defining the cyclic test program for cavern Etrez EZ53. Rigid conditions, that have to be obeyed strictly are :

- The total gas inventory must not exceed a limit of 3 tons of hydrogen. This includes gas in the cavern as well as gas in above ground installations (e.g. piping etc.).
- Following a rock mechanical assessement, the cavern must be operated between a certain maximum and minimum pressure. This is considered a hard limit.
- As the test at cavern EZ53 will be conducted by the brine compensation method the minimum cavern pressure is technically limited to the respective halmostatic pressure (i.e. the static pressure of the brine column in the central string).
- The pressure build-up rate will be limited by the design of the brine pump.
- According to the current project planning, the test will have a total duration of 3-4 months and will start in March 2023.

Generally, some other conditions may apply, but are not binding in the case of the cyclic test program at EZ53 :

- Rate of pressure change
- Standby duration at low caverns pressure
- Operation time above halmostatic pressure

- It is also common to limit the flow velocity of the gas in the tubing to limit the risk for erosion. Typical values are in the range from 15 m/s to 20 m/s. For hydrogen, there would be a potential to increase this limit due to the lower molecular mass. For the cyclic tests, however, this is not considered relevant, as there is practically no hydrogen flow in the annulus due to the use of brine for (de-)pressurization.

Additionally, the following aspects should be considered :

- The dynamic pressure range for the cyclic test is very limited, as the cavern is only operated between halmostatic and maximum pressure. Increasing this range would be beneficial for the validation of the cavern modeling.
    - Lower minimum pressures could be obtained during the final gas withdrawal, conditions at the brine wellhead and the gas-brine-interface level have to be observed.
    - In principle, a wider pressure range for the cyclic tests could also be obtained by replacing brine with a medium with lower density (e.g. freshwater or oil) to pressurize the hydrogen in the cavern. However, this procedure is considered technically too complex to be realized in the current project phase for the actual cycling. Instead, it is planned to inject freshwater from the top into the central string for the final phase of the test and to withdraw hydrogen gas for the final depressurization at the end of the test.
- It is assumed, that the test can be continued during the weekend and during public holidays. Depending on the organization of the test control, this can induce additional effort, if the availability of operating staff on-site needs to be assured.

4. PROPOSED TEST SCHEDULE

A cyclic test program has been defined that has the following characteristics:

- The full pressure range between halmostatic and maximum pressure is used by several large-scale cycles with different net ramping rates. These have periodicities between a few hours and up to six weeks.
- Between the large-scale pressure drops und build-ups there are standby periods with durations between a few hours and up to one week.
- The large-scale cycles are superimposed by several periods of short small-scale cycles. These have an average periodicity of 12 hours and an amplitude of 1/10th of the full test pressure range.
- The test should be finalized by replacing the brine in the central string by fresh water resulting in a reduced pressure difference between the central string wellhead and the cavern. This allows the withdrawal of hydrogen until hydrostatic pressure without risking to draw a vacuum at the central string wellhead. It may also be possible to extract hydrogen slightly below this limit.
- The proposed cycle program includes a total number of 125 cycles. It has a total duration of 2450 hours or 102 days including 1022 hour of standby.

Theoretical calculations of the thermodynamical and geomechanical cavern behaviour will be presented in the deliverable D2.4 “Numerical models representing the test cavern EZ53”.

The results of the cyclic test are expected to allow the validation or improvement of the calibration of the applied numerical models.

The defined cycle is conservative with respect to time requirements. If the test can be conducted without delays, the potential to extend the test can be evaluated in early 2023. An extended test program should then be developed based on the preliminary findings obtained from the first test results.

5. ANNEXES

ANNEX X – ELECTRONIC FILLING IDENTIFER

Document Name and version	<D2.2 CYCLIC TEST PROGRAM, Version 3>
Description	<This document outlines a proposal for the EZ53 cyclic test program that should allow the validation of the main cavern modelling effects.>
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FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

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