2012 Activity Report

ESV EURIDICE EIG

ACTIVITY REPORT 2012
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2012
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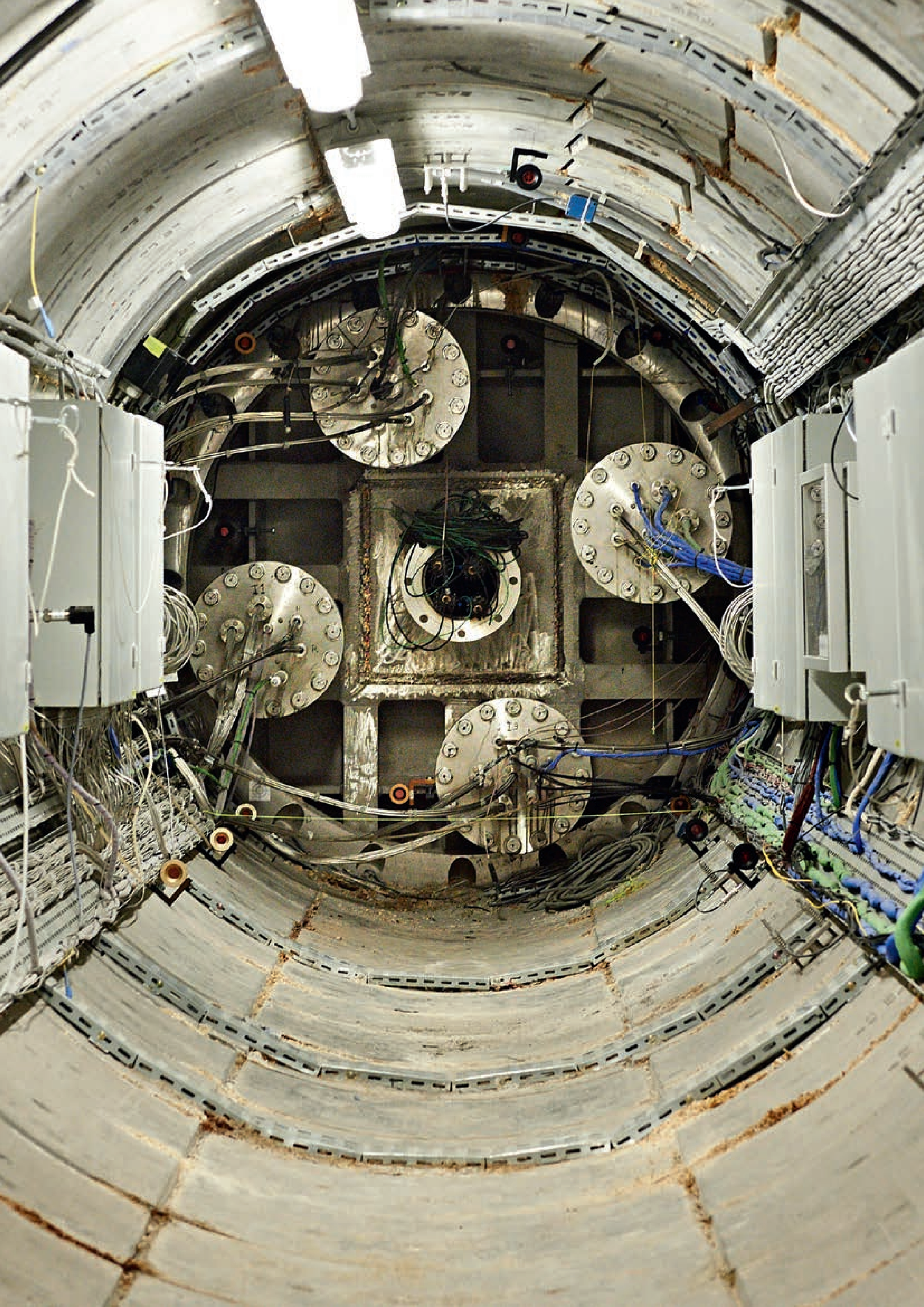


General foreword

Marc Demarche, Chairman of the Board of EIG EURIDICE

Dear reader,

This Activity Report 2012 gives an account of the main developments and achievements with respect to the statutory tasks and missions of EIG EURIDICE.

One of the main tasks is the development and realisation of the PRACLAY project. With the extension of the HADES underground research laboratory (HADES URL) during the period 1997-2007, important steps have already been taken in this project, such as the excavation of the Connecting gallery and the PRACLAY gallery, including the crossing of both galleries, using appropriate industrial techniques. All these achievements have contributed to demonstrating the feasibility of constructing an underground repository in a clay host rock in Belgium.

Since then EIG EURIDICE has largely focused its activities on preparing the large-scale Seal & Heater experiment. This experiment is a key element of the PRACLAY project, and aims to demonstrate, confirm and, where needed, improve our understanding of the combined excavation-induced and thermal disturbance of the clay host rock. The ultimate goal is to convincingly demonstrate that these repository-induced disturbances of the clay host rock do not jeopardise the containment and isolation capacity of the clay barrier.

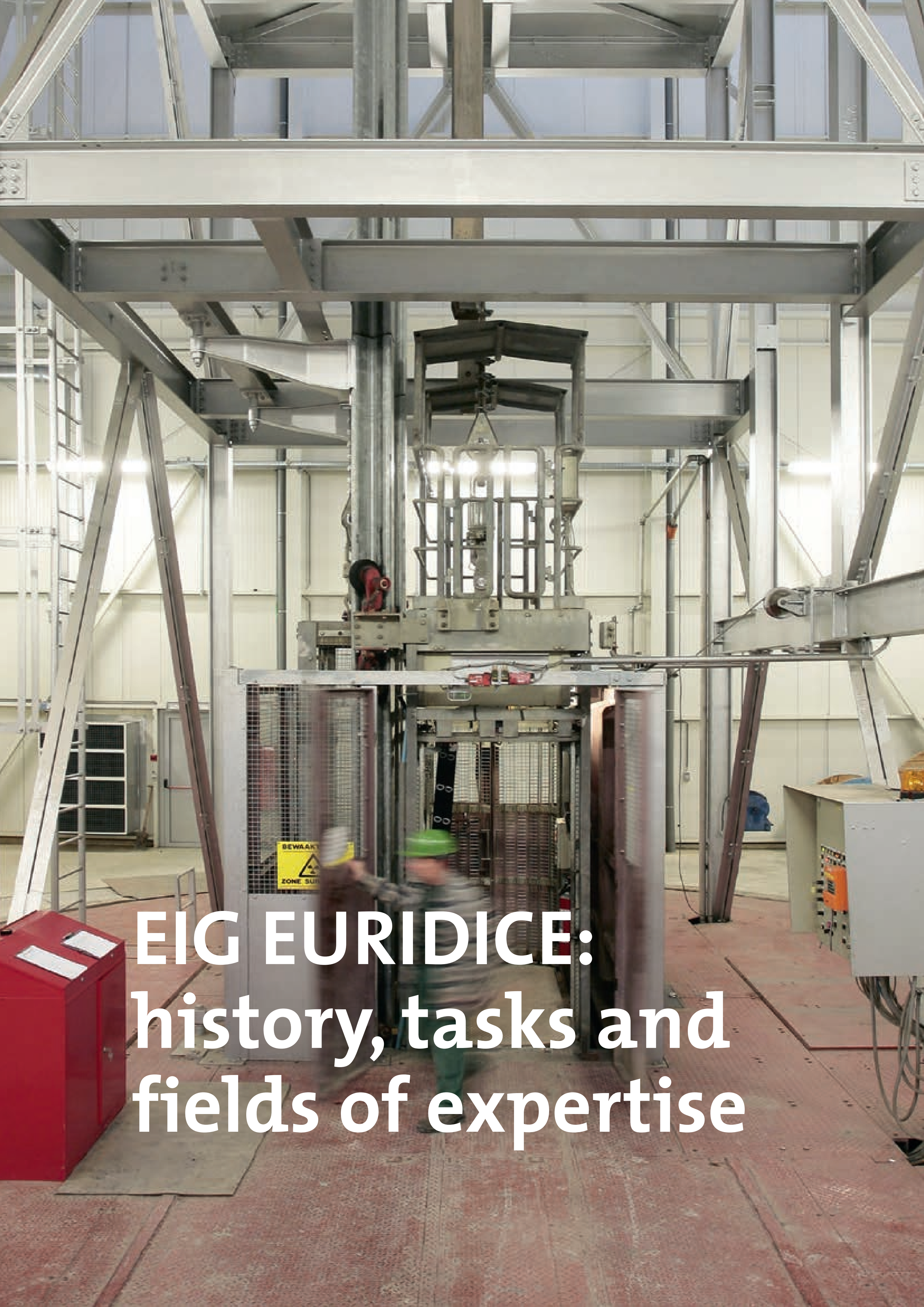
By the end of 2011 almost all components of the PRACLAY Seal & Heater experiment had been installed in the PRACLAY gallery: the instrumentation devices in the Boom Clay and in the PRACLAY gallery, the metallic seal structure with its ring of bentonite blocks, the primary heater system and the central tube for the secondary heater system. In addition, the gallery was backfilled with sand and the seal structure was completely closed by welding on the manhole plate. After closure of the gallery, work began on saturating the backfilled gallery with water, bringing the part of the PRACLAY gallery that will be heated to its final configuration before the start of the heating phase.

During 2012 EIG EURIDICE completed the final installation work: the secondary heater was inserted into the central tube inside the part of the PRACLAY gallery that will be heated.

The actual moment when the heater system can be switched on is determined by the swelling behaviour of the bentonite ring in the seal structure. Sufficient bentonite swelling is required to reach the experimental hydro-mechanical boundary conditions to be able to conduct the experiment in sufficiently conservative conditions. In order to assess the status of the seal with respect to evolution of its swelling pressure, EIG EURIDICE organised a workshop in November 2011, bringing together international experts to discuss and advise on the timing of switching on the heater system. The main conclusion then was that swelling behaviour was insufficient to allow a rapid switch-on and that a new assessment needed to be made around mid-2012. In the course of 2012 it became apparent that the organisation of a second workshop in 2012 would be premature, and EIG EURIDICE decided to define a new evaluation path for preparing for the switch-on decision in interaction with its Scientific Advisory Committee. The path defined in 2012 will lead to a second workshop by the end of 2013. In order to bring together all the information required for a switch-on decision, further assessment of seal performance and behaviour in terms of consequences and risks for the Heater test will have been performed by then.

EIG EURIDICE also contributes to the feasibility demonstration programme for the construction of a supercontainer for high-level waste. In 2012 it helped prepare for the second phase of the half-scale tests (2012-2013), e.g. by defining, preparing and implementing the complete instrumentation plan of the experiment. The actual test itself is planned in the first half of 2013.

Faced with the challenge of managing all the acquired knowledge and expertise for long periods extending over many decades, EIG EURIDICE is making continuous efforts to organise its expertise and know-how in its main fields of activity, both within the EURIDICE team itself and in collaborations with external partners. A structured approach for collaboration networking with universities and research and engineering centres is being defined together with our constituent members, SCK•CEN and ONDRAF/NIRAS.



EIG EURIDICE: history, tasks and fields of expertise

EIG EURIDICE (European Underground Research Infrastructure for Disposal of nuclear waste In Clay Environment) is an Economic Interest Grouping (EIG) involving the Belgian Nuclear Research Centre (SCK•CEN) and the Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS). It manages the HADES underground research laboratory and carries out R&D, including feasibility studies for the disposal of high-level and long-lived radioactive waste in a clay host rock. In this way, EIG EURIDICE contributes to the national disposal programme for high-level and long-lived waste managed by ONDRAF/NIRAS, organised in a stepwise manner with major milestones at key decision points.

In 1974 SCK•CEN started research into the geological disposal of high-level and long-lived radioactive waste in a clay host rock. The Boom Clay, a poorly indurated clay (or plastic clay), was and still is regarded as a potentially suitable host formation. This clay layer is found at a depth of 180 to 280 metres below the SCK•CEN research site in Mol. In 1980 SCK•CEN began construction of the HADES (High-Activity Disposal Experimental Site) underground research laboratory (HADES URL - Figure 1), situated at a depth of about 225 metres. This was the first purpose-built underground research facility in plastic clay in Europe and worldwide. The laboratory was gradually extended, with the excavation of a second shaft (1997-1999) and a Connecting gallery (2001-2002) linking the second shaft to the then existing underground laboratory. At each stage of excavation and construction, new techniques were used and new technological and engineering expertise was gained. The HADES URL has been fully managed by EIG EURIDICE since 2000.

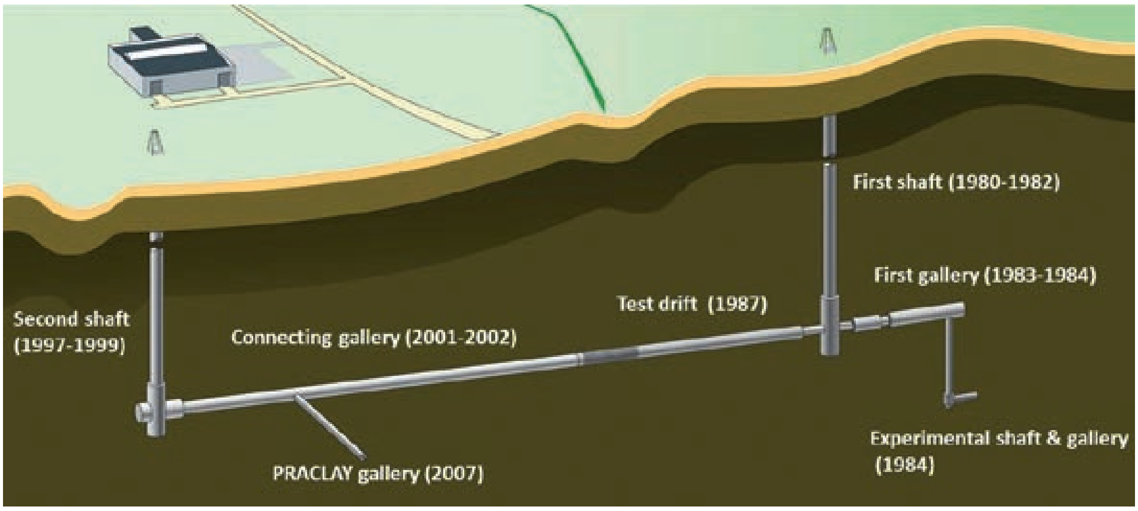


Figure 1 The underground research laboratory HADES
(High-Activity Disposal Experimental Site)

The main statutory tasks of EIG EURIDICE entail a range of activities relating to the development and operation of an underground research laboratory with a view to developing and facilitating the activities of EURIDICE's constituent members:

- The management and operation of HADES and all the installations situated on the land for which EIG EURIDICE has a building lease.
- The development of the PRACLAY project, which aims to contribute to demonstrating the feasibility of disposal of radioactive waste in a clay host rock.
- The possible development, implementation and valorisation of other research projects and experiments with regard to the disposal of radioactive waste.
- The possible realisation, exploitation and valorisation of other research projects concerning the long-term management of radioactive waste in order to support the scientific programmes of its members using their resources.

- Communication about its own activities, in dialogue with its members, including the organisation of visits to the HADES URL.

After 30 years of research in and around the HADES URL, a lot of expertise and know-how have been acquired in different scientific and technological fields, of key importance for developing an underground radioactive waste disposal facility in poorly indurated clay formations such as the Boom Clay. The scientific and technological expertise of EIG EURIDICE focuses on three areas:

1. Excavation and construction techniques for an underground repository in a clay host rock;
2. The thermo-hydro-mechanical (THM) behaviour of the clay host rock (i.e. the Boom Clay);
3. Instrumentation & monitoring.

EIG EURIDICE's first area of expertise has changed significantly over the past 30 years, with excavation and construction of the HADES URL evolving from semi-manual and slow to industrial, using tailor-made tunnelling machines. The tunnelling techniques used for excavating in poorly indurated clay at great depth, including the crossing between galleries, have greatly reduced excavation-induced disturbance of the clay layer and have demonstrated that it is feasible to construct a disposal infrastructure, at a reasonable speed and cost. Since the natural clay layer will be the main barrier for radionuclide migration in a geological disposal system, reducing the excavation-damaged zone (EDZ) is a key objective and relates directly to the safety of a disposal system.

The second field of expertise of EIG EURIDICE involves understanding the THM behaviour and characterisation of a clay host rock, including all disturbance processes induced by the construction of the galleries and by the emplacement of heat-emitting radioactive waste. In low-permeability clays such as the Boom Clay, THM processes are strongly coupled. EIG EURIDICE's knowledge base is mainly built on the research activities in and around the HADES URL in the Boom Clay. The intensive scientific instrumentation systems installed in the clay before, during and after the construction of galleries made it possible to create a valuable geotechnical knowledge base and database to characterise and understand the hydro-mechanical response of Boom Clay in the short and long term, including the generation and evolution of the EDZ. Proper understanding of the coupled THM processes in the Boom Clay around the repository is essential to determine to what extent these processes could affect the containment and isolation capacity of the clay. The most important project in this area is the large-scale PRACLAY experiment. Here, the combination of the hydro-mechanical disturbances due to excavation of galleries and the further coupled thermo-hydro-mechanical disturbance due to heat production, as in the case of the disposal of high-level vitrified waste or spent fuel, are studied on a large scale.

The R&D programme in and around the HADES URL relies heavily on the use of various instrumentation devices and techniques to measure and monitor the main THM characteristics of the clay; some of these have been developed in-house. This is the third main area of expertise of EIG EURIDICE. Experience has been gained in several aspects specific to this type of instrumentation and monitoring, such as the long-term management of sensors and their measurement data, reliability (e.g. how to implement field calibration and what the alternatives are when this is not possible) and robustness under adverse conditions, such as corrosion and mechanical strains. This extensive instrumentation experience will be an essential element in designing a monitoring programme for an underground repository for high-level and long-lived waste in a clay host rock.

With its R&D activities and fields of expertise, EIG EURIDICE contributes to the national programme for high-level and long-lived waste disposal managed by ONDRAF/NIRAS. In 2011 ONDRAF/NIRAS published its final waste plan for the long-term management of high-level and/or long-lived waste (NIROND 2011-02, September 2011), with a view to obtaining a policy decision on the long-term management of this waste.

The next milestones of this programme will largely depend on the timing and nature of the policy decision eventually made. For EIG EURIDICE, the execution of the PRACLAY project, including the start-up of the PRACLAY Heater experiment, will be key. This will enable EIG EURIDICE to obtain and interpret the results and findings of the first few years of heating, during which important observations can already be made, and provide this valuable input for the safety and feasibility assessments of ONDRAF/NIRAS in the context of its next programme milestone, i.e. Safety and Feasibility Case 1.

Objectives for 2012 - Evaluation

The main objectives for 2012 formulated in the Activity Report 2011 were as follows:

1. Installation of the PRACLAY Seal and Heater experiment

- Installation of the secondary heater system to complete the set-up of the PRACLAY in-situ experiments;
- Positioning of the steel structure at the crossing of the Connecting gallery with the PRACLAY gallery to avoid axial displacement of the PRACLAY gallery during the heating phase (security);
- Installation of a permanent observation system in order to monitor the movement of the whole structure of the seal;
- Finalisation of the design of the intervention device to be used in the event of a leakage in the feed-throughs during the heating phase (security);
- Publication of the report on the second phase of the PRACLAY in-situ experiment, entitled "Installation of the PRACLAY seal and heater experiments".

2. Technical and scientific follow-up of the PRACLAY Seal and Heater experiment

- Testing the whole seal performance (cold conditions) by slight pressurisation of the PRACLAY gallery;
- Follow-up of the hydration and swelling of the bentonite in order to be able to decide when the Heater test can be started. A second workshop on the heater switch-on is planned in the second half of 2012;
- Conducting baseline measurements before starting the Heater test;
- Follow-up of the measurements and observations after starting the Heater test.

3. Scientific tasks related to the THM behaviour of a disposal system in a clay host rock

- Follow-up, analysis, interpretation and numerical investigation of the fourth phase of the ATLAS test;
- Continue the laboratory creep tests at high temperature;
- Continue the laboratory investigation of anisotropic THM behaviour of Boom Clay;
- Numerical investigation of the excavation-damaged zone (EDZ) in Boom Clay;
- Continue the laboratory investigation of THMC behaviour of Ypresian clays.

4. Supercontainer feasibility demonstration test (on surface)

Start the second half-scale test, perform corrosion tests and continue the numerical investigation of the first half-scale test.

5. Specific support to ONDRAF/NIRAS on disposal technology and 6. Safety and Feasibility Case 1

- Continued participation and contribution of EIG EURIDICE in/to the SATELITE working group meetings of ONDRAF/NIRAS, contribution to the investigation on disturbances of the clay host rock and to the reporting within the context of Safety and Feasibility Case 1 (planned by ONDRAF/NIRAS for 2015 at the earliest).

- A state-of-the-art report on THM behaviour of the Boom Clay, specifically a topic report on its "constitutive laws", with the focus on identifying the reference model of the Boom Clay together with a range of associated reference parameters.

6. Operation and management of EIG EURIDICE and its facilities

Operation and management of EIG EURIDICE and its facilities according to the Statutory Rules of EIG and in line with ISO 9001-2008 standard (recertification audit February 2013).

Prepare the replacement of the hoisting system of shaft 1 (public tender procedure), in order to make the replacement in due time (2012-2013 timeframe).

7. European Commission FP7 projects

Participation in and contribution to the European Commission's FP7 MoDeRn project according to the agreed work programme, with implementation of specific measuring techniques for the PRACLAY Heater test and the large-scale supercontainer feasibility demonstration tests.

As coordinator of the European Commission's TIMODAZ project, EIG EURIDICE will organise an international post-TIMODAZ workshop in 2012, as defined and scheduled in the final dissemination plan of the project.

8. Communication

- Creation of a new website as part of the communication contract
- Communicate in different ways on the status of the PRACLAY experiment:
  - Scientific PRACLAY report: second phase
  - A publication for a wide target audience on the PRACLAY experiment
  - News item about PRACLAY on the new website
- Organisation of an event on the occasion of the heater switch-on
- Organisation of an Exchange Meeting
- Implementation of changes to guided visits as planned (for example, new module on clay properties in the demo hall)

9. Knowledge domains of EIG EURIDICE

- Review the functioning of the advisory bodies (SAC – Scientific Advisory Committee and POP – Programming committee for underground testing) in order to make the necessary changes to the Rules in 2012.
- Take further concerted action for collaboration with universities on Master's theses and PhDs.

10. Surface disposal project for category A waste

EIG EURIDICE will support ONDRAF/NIRAS in the preparation and subsequent presentation and defence of the Safety Case for the near-surface disposal site for category A waste. This support concerns the tasks entrusted to EIG EURIDICE and will be provided as per the agreed planning.

On 31 December 2012 the status of these objectives was as follows:

1. Installation of the PRACLAY Seal and Heater experiment

In 2012, the secondary heater system was installed in the PRACLAY gallery, bringing the experimental set-up to its final configuration awaiting the switch-on of the heater system. A permanent observation system was installed to monitor the movement of the whole structure of the seal. The design of the intervention device to be used in the event of a leakage in the feed-throughs of the seal during the heating phase was finalised. Moreover, the four beams (thick-walled tubes) were re-installed between the support structure at the crossing of the Connecting gallery and the PRACLAY gallery to counter any possible axial movement of the PRACLAY gallery lining due to heating (and related effects). Finally, the report on "The design and installation of the PRACLAY in-situ experiment" was finished and reviewed by the Scientific Advisory Committee and ONDRAF/NIRAS. Publication is scheduled for the first half of 2013.

2. Technical and scientific follow-up of the PRACLAY Seal and Heater experiment

The saturation of the bentonite ring in the seal structure and its subsequent swelling behaviour were continuously monitored and analysed. The seal performance was systematically tested by conducting water pressure tests, permeability tests and gas tests. The numerical model of the seal swelling behaviour was further fine-tuned. The consequences of different scenarios for the future Heater test, related to the swelling behaviour of the seal, were assessed by means of numerical scoping calculations to support the risk analysis, which is planned for 2013.

A thorough assessment of the evolution of the swelling behaviour was conducted during two SAC meetings in the course of 2012 and guidelines were provided to prepare for the second workshop with external experts with a view to assessing the timing of the switch-on of the heater system. The second workshop will be organised at the end of 2013.

3. Scientific tasks related to the thermo-hydro-mechanical behaviour of a disposal system in a clay host rock

- The fourth phase of the ATLAS heating test that was started at the end of 2011 was continuously monitored and analysed. A permeability test was performed during the heating phase, and another is planned during the cooling phase.
- Prior to the laboratory creep tests at high temperature, a series of short-term triaxial tests were carried out at different temperatures to obtain a reference data baseline. The creep tests at high temperature have just been started.
- Laboratory research on the anisotropic thermo-hydro-mechanical behaviour of the Boom Clay continued during 2012. Preliminary results have been obtained.
- Numerical investigation of the excavation-damaged zone (EDZ) has progressed as part of two PhD research programmes in collaboration with ULg and DUT.
- The initial laboratory programme on the thermo-hydro-mechanical-chemical behaviour of Ypresian clays has finished. A PhD thesis on the subject is due to be defended in March 2013. Additional triaxial tests with several loading and unloading cycles will start early in 2013 at the request of EURIDICE and ONDRAF/NIRAS.

4. Supercontainer feasibility demonstration test (on surface)

In 2012 preparatory work for the second half-scale test continued:

- the concrete composition used for the first half-scale test was further tested and optimised:
  - a viscosity-modifying agent was added to the concrete to avoid segregation;
  - the high sensitivity of the composition to water content was once again observed during these tests.
- the instrumentation plan was further developed:
  - digital image correlation (DIC) and acoustic emission sensors will be used to continue monitoring the onset and evolution of cracks in the concrete buffer (DIC and speckle pattern application were tested in the laboratory first);
  - several corrosion measuring techniques will be implemented during the test (prior pilot testing of new corrosion sensors, developed at VUB, has been completed).

The execution of the second half-scale test was initially planned for 2012, but the enhanced instrumentation plan delayed the planning schedule and the test was postponed until early 2013.

5. Specific support to ONDRAF/NIRAS on disposal technology and 6. Safety and Feasibility Case 1

EURIDICE continued to support ONDRAF/NIRAS in its R&D technical feasibility programme of geological disposal through its experimental programme on the supercontainer (research on the fabrication of the waste disposal packages). No specific activities relating to excavation technology took place in 2012.

EURIDICE continued to support the development of ONDRAF/NIRAS' first Safety and Feasibility Case (SFC-1) with its expertise in the thermo-hydro-mechanical (THM) behaviour of Boom Clay and Ypresian clays. This involved supervising several PhD projects on the THM behaviour of both clay formations and preparing a synthesis report on the evolution of the disturbed zone around a deep repository for high-level and/or long-lived radioactive waste in a clay layer. This synthesis report is part of the set of documents supporting ONDRAF/NIRAS' SFC-1. The state-of-the-art report on the THM behaviour of the Boom Clay was well advanced and was discussed with ONDRAF/NIRAS; the final version is due early in 2013.

7. Operation and management of EIG EURIDICE and its facilities

Management and operation of EIG EURIDICE and its facilities proceeded according to the Statutory Rules of the EIG and in line with ISO 9001-2008 standard (external audit on 16 February 2012).

In 2011 EURIDICE decided to start investigating the possibility of renewing the hoisting system of shaft 1. Before a public tender can be launched, some ambiguities concerning applicable regulations have to be resolved. It was therefore decided to embark on a study of the various hoisting system options and corresponding regulations. This study will be performed by DBE (Germany) and should help us to reach a decision on what kind of hoisting system will be needed in the future and provide an answer regarding which regulations must be complied with (checks, controls, regulations, etc.).

8. European Commission's FP7

MoDeRn project

EIG EURIDICE participated in and contributed to the European Commission's FP7 MoDeRn project according to the agreed work programme. Its main contributions are the development, fabrication, installation, follow-up and use of specific measuring equipment and techniques in the PRACLAY Heater test and the half-scale supercontainer feasibility demonstration test (see 3.1).

EURIDICE also contributed as technical expert to the socio-technical work performed as part of the project. This involved participation in workshops and a field trip with local stakeholders to explore the role of monitoring in confidence-building in the context of geological disposal of high-level radioactive waste.

TIMODAZ project

As coordinator of the project, EURIDICE – with help from NAGRA – successfully organised the international post-TIMODAZ workshop on 6 and 7 February 2012 in Mont Terri, as defined in the final dissemination plan of the project. The workshop attracted more than 60 participants and contributions from all over the world, including the United States, Canada, Japan and China. More than two-thirds of the participants were not involved in the TIMODAZ project.

9. Communication

Concerning communication about the status of the PRACLAY experiment, a publication for a wide target audience has been available since September 2012 in Dutch, French and English. The scientific report "The design and installation of the PRACLAY in-situ experiment" was finished during 2012 and will be published early in 2013. Due to the postponement of the switch-on of the heater system, no event was organised.

The new "draft" website of EURIDICE was presented during the meeting of the Board on 20 November. Based on feedback from ONDRAF/NIRAS and SCK•CEN management, some changes will be made before the website goes online in 2013.

The permanent exhibition in the demo hall was updated as planned during the month of December. New modules on "Clay" and "Time" were installed.

10. Knowledge domains of EIG EURIDICE

In 2012 two scientific staff members were recruited, one with expertise in the thermo-hydro-mechanical field and the other in the instrumentation & monitoring field.

The functioning of the advisory bodies (SAC – Scientific Advisory Committee and POP – Programming committee for underground testing) was reviewed and new rules were established and approved by the general assembly of EIG EURIDICE during the meeting held on 23 April 2012.

Concerted action with SCK•CEN and ONDRAF/NIRAS to structure and enhance collaboration with universities in the form of Master's theses and PhDs led to an agreement document that will form the basis for all future action in this area.

In line with the strategic knowledge domains of EURIDICE, an overview was made of all actions in the context of the development of EURIDICE as a centre of excellence. The priorities for these actions will be defined during 2013. To integrate the knowledge management of EURIDICE with that of SCK•CEN and ONDRAF/NIRAS, structured interaction will be established.

11. Surface disposal project for category A waste

As contractually stipulated, EIG EURIDICE supported ONDRAF/NIRAS in the preparation of the Safety Case for the near-surface disposal site for category A waste.

EURIDICE carried out the instrumentation work for the set-up of the demonstration test that was completed early in 2012.

EURIDICE also took part in discussions on the future experimental set-up for the test cover.

Objectives for 2013

1. Technical and scientific follow-up of the PRACLAY Seal and Heater experiment

- Follow up the hydration and swelling of the bentonite in order to be able to decide when the Heater test can be successfully started;
- Continue to test the seal performance (cold conditions) in different sections, at the Boom Clay/bentonite interface and inside the seal by means of gas tests, water tests, permeability measurements, etc.;
- Enhance the risk analysis and the analysis of what associated consequences various scenarios will have for the Heater test, list all possible related actions and start preparing for these actions;
- Organise the second workshop on the heater switch-on at the end of 2013;
- Conduct baseline measurements before starting the Heater test.

2. Scientific tasks related to the thermo-hydro-mechanical behaviour of a disposal system in a clay host rock

- Follow-up, analysis, interpretation and numerical investigation of the fourth phase of the ATLAS test and, at the end of the cooling phase, preparation of the "heating pulse" test;
- Continue the laboratory creep tests at high temperature, the laboratory investigation of the anisotropic thermo-hydro-mechanical behaviour of Boom Clay and the thermo-hydro-mechanical-chemical behaviour of Boom Clay and Ypresian clays;
- Numerical investigation of the excavation-damaged zone (EDZ) in Boom Clay;
- Start the laboratory investigation of gas transport in Boom Clay;
- Establish the plan for a detailed investigation and follow-up of the stability of the liner in HADES. This will involve a systematic inspection plan, long-term monitoring programme, additional laboratory tests and numerical investigation, and a PhD project;
- Continue the development of the short-term and long-term hydro-mechanically coupled constitutive models and validate with long-term in-situ measurements.

3. Supercontainer feasibility demonstration test (on surface)

- Execution of the second half-scale test with the following specific objectives:
  - Test and optimise the concrete composition of the buffer;
  - Monitor the onset and evolution of cracks in the concrete buffer;
  - Measure corrosion of carbon steel in the buffer using different methods.
- First analysis/interpretation of the test results.

4. Specific support to ONDRAF/NIRAS on disposal technology and 5. Safety and Feasibility Case 1

- Support ONDRAF/NIRAS in developing an approach to manage operational safety in the geological disposal concept using our expertise and experience in the operation of the HADES URL.
- Continue to contribute to the investigation of disturbances in the clay host rock and the thermo-hydro-mechanical behaviour of repository components, and to the reporting within the context of Safety and Feasibility Case 1.
- Consolidate the large body of knowledge (and data) available on the hydro-mechanical and thermo-hydro-mechanical behaviour of Boom Clay (and to a lesser extent Ypresian clays). This

will be done in particular through the finalisation of a geotechnical synthesis report for Boom Clay (update of the 2004 "state-of-the art" report, EURIDICE 04-251) of which the drafting was started in 2012.
- Progressively introduce key Boom Clay (and Ypresian clays when available) parameters and their values in the data clearance system implemented by ONDRAF/NIRAS to ensure consistency within the whole R&D program.
- Support ONDRAF/NIRAS (provide samples, data, technical and scientific expertise) for the follow-up of PhD's and post-docs on the (thermo-)hydro-mechanical(-chemical) behaviour of Boom Clay and Ypresian clays and on gas transport through Boom Clay.

6. Operation and management of EIG EURIDICE and its facilities

- Operation and management of EURIDICE and its facilities according to the Statutory Rules of the EIG and in line with ISO 9001-2008 standard (recertification audit February 2013);
- Prepare for the replacement of the hoisting system of shaft 1. Due to some ambiguities concerning the applicable regulatory framework, replacement of the hoisting system will take longer than initially estimated. A preliminary design study will first explore the different options for renewing the hoisting system. This will give a clearer view of the possibilities and the related regulations that have to be complied with;
- In association with SCK•CEN, EURIDICE will prepare all the documents needed to apply for an environmental licence. The goal is to submit the application in the first half of 2013;
- Concerning a possible separate visitors' entrance, all elements will be prepared to enable the constituent members to reach a decision.

7. European Commission projects

The MoDeRn project will end in 2013. Major activities therefore include final reporting on instrumentation performance in PRACLAY and in the Supercontainer test programme.

As coordinator of the European Commission's TIMODAZ project, EIG EURIDICE, together with ENPC (France), will edit a special issue in "Rock Mechanics and Rock Engineering" (Springer, WoS referenced) on the topic of "Thermo-Hydro-Mechanical effects in clay host rocks", which will be published in March 2013.

8. Communication

- Go online with the new website;
- Update the programme for guided visits and develop a coherent new manual for the visitor guides;
- Prepare to comment after a decision in principle on the long-term management of B&C waste;
- Publication of the scientific report "The design and installation of the PRACLAY in-situ experiment".

9. Knowledge domains of EIG EURIDICE

- Take further steps to develop an integrated knowledge management system:
  - Draw up a complete and structured inventory of all information produced by EURIDICE;
  - Efficiently integrate the information management of EURIDICE with the knowledge management systems used by SCK•CEN (Alexandria) and ONDRAF/NIRAS (Vignette);
  - Launch a knowledge management project on excavation technology.

- Take further concerted action for collaboration with universities on Master's theses and PhDs, on the basis of the agreement between SCK•CEN and ONDRAF/NIRAS.
- Input all experiments into the GSIS system.

10. Surface disposal project for category A waste

EURIDICE will support ONDRAF/NIRAS in the presentation and defence of the Safety Case for the near-surface disposal site for category A waste. This support concerns the tasks entrusted to EURIDICE and will be provided as stated in the agreed planning schedule.

EURIDICE will provide the final report on the instrumentation of the demonstration test. Depending on how far advanced the test cover set-up is, EURIDICE might also assist in the instrumentation work for this project.

Activities: PART I

High-level and long-lived waste disposal

1. PRACLAY “Demonstration & confirmation experiments”

1.1. Introduction: the PRACLAY project

One of the aims of EIG EURIDICE is the development of the PRACLAY project to demonstrate the feasibility of the disposal of high-level, heat-producing vitrified radioactive waste or spent fuel in deep clay layers such as Boom Clay.

The PRACLAY project consists of several sub-projects and experiments. Together, these are referred to as the PRACLAY “Demonstration & confirmation experiments”. The aims of these experiments are:

- To demonstrate the feasibility of underground construction in Boom Clay;
- To demonstrate the feasibility of the disposal concept for high-level waste in Boom Clay;
- To confirm and expand knowledge about the thermo-hydro-mechanical(-chemical) behaviour of Boom Clay and the gallery lining.

With the PRACLAY experiments, EIG EURIDICE is making an important contribution to Safety and Feasibility Case 1 (SFC-1) and 2 (SFC-2), which are part of the ONDRAF/NIRAS research programme for long-term management of category B&C radioactive waste.

In general, a distinction can be made between two groups of experiments: PRACLAY IN-SITU (meaning “in HADES”) and PRACLAY ON-SURFACE experiments:

PRACLAY IN-SITU

DEMONSTRATION EXPERIMENTS

Second shaft
Connecting gallery
Gallery & Crossing test
PRACLAY gallery
Supporting studies: European Commission’s CLIPEX project

CONFIRMATION TESTS

Heater test
Seal test
Supporting studies:
- EDZ test (European Commission’s SELFRAC & TIMODAZ projects)
- PhD theses (CIMNE, CERMES, ULg, IRSM, DUT)

PRACLAY ON-SURFACE

DEMONSTRATION EXPERIMENTS

OPHELIE (SAFIR 2 repository design)
SUPERCONTAINER feasibility tests
- Small-scale test
- Half-scale tests
- Annular backfill test in European Commission’s ESDRED project

PRACLAY IN-SITU experiments can be divided into demonstration experiments and confirmation tests. **Demonstration experiments** focused on excavation techniques and construction. The excavation of the Connecting gallery using a tunnelling machine, for example, demonstrated the feasibility of constructing galleries on an industrial scale. With the construction of the PRACLAY gallery in 2007, it was shown that it is possible to make perpendicular connections between a disposal gallery and a main gallery, making use of a reinforcement ring. Most of the demonstration experiments are now finished. **Confirmation tests** are focusing on confirming and improving existing knowledge about the thermo-hydro-mechanical(-chemical) behaviour of the Boom Clay surrounding a disposal infrastructure. The Heater test is the main experiment in this regard. The main objective of this test is to confirm, on a large scale, that the thermal load generated by the heat-emitting waste will not jeopardise the safety functions of the host rock. In particular, the Heater test aims to assess the consequences of the coupled thermo-hydro-mechanical impact on the Boom Clay and the evolution of the excavation-damaged zone (EDZ) during the thermal transient in the case of disposal of heat-emitting waste.

For this purpose, part of the PRACLAY gallery (30 m) is closed and will be heated for a period of 10 years at a temperature of 80°C at the interface between the gallery lining and the clay. After the construction of the PRACLAY gallery in 2007 and the design and installation of the seal (2007-2010), installation of the heater system started in 2010 (primary heater) and was completed in 2012 (secondary heater).

PRACLAY ON-SURFACE experiments are studying different components of a disposal system and comprise laboratory tests to characterise these different components and their interaction. Many of the aspects that are studied on the surface are based on a specific disposal system design.

The current Belgian reference design for heat-producing high-level radioactive waste is based on the supercontainer concept. Tests are performed on different scales to demonstrate the feasibility of constructing a supercontainer.

1.2. Achievements in 2012

1.2.1. PRACLAY IN-SITU

The different parts of the PRACLAY Seal & Heater experimental set-up are shown in Figure 2.

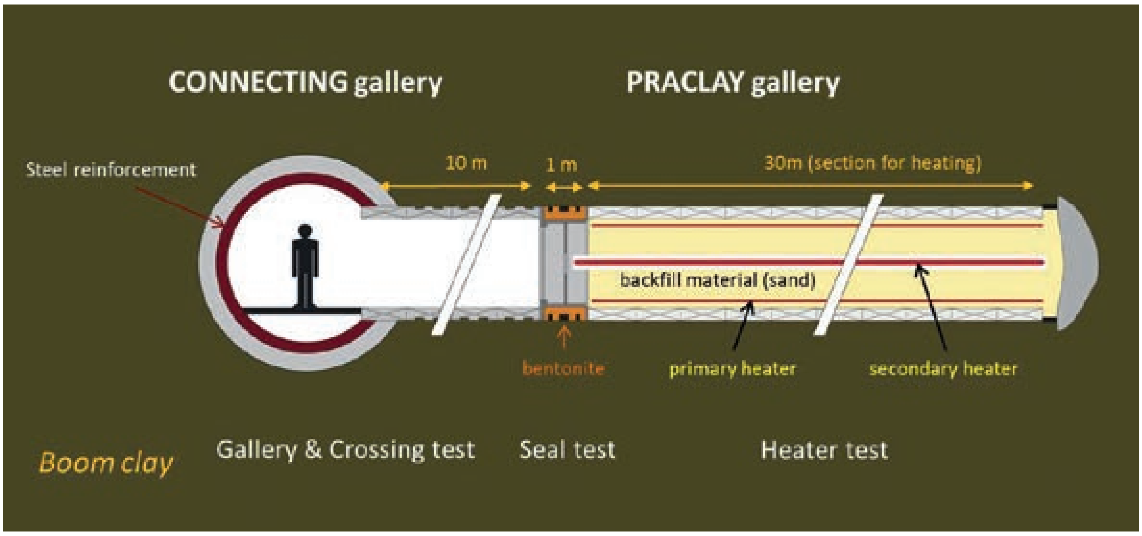


Figure 2 Design of the PRACLAY Seal & Heater experiment

After the excavation of the PRACLAY gallery in 2007, the hydraulic seal was designed and installed in 2010. The hydraulic seal consists of a stainless steel structure closing off the heated part of the gallery from the underground infrastructure and an annular ring of bentonite (MX80) placed against the clay. (Figure 3)

Figure 3 3D view on the seal with a central steel cylinder and an annular ring of bentonite (orange) against the clay

The hydraulic seal not only has to close the PRACLAY gallery; it also has to hydraulically cut off the excavation damaged zone (EDZ) around the gallery, which can provide a preferential pathway for water towards the main gallery. Bentonite has a very low hydraulic conductivity and swells when it is hydrated. The swelling pressure exerted by the hydrated bentonite on the clay will lower the hydraulic conductivity of the clay around the seal, thus creating the “undrained hydraulic boundary conditions” for the Heater test. The behaviour of the seal, and more specifically of the bentonite, is studied in the **Seal test**.

The placement of a heating system and water-saturated sand in the heated section of the PRACLAY gallery completed the experimental set-up. The water-saturated backfill sand has to ensure undrained hydraulic boundary conditions at the interface between the clay and the gallery lining.

The closed part of the PRACLAY gallery (30 m) will be heated for a period of 10 years at a temperature of 80°C at the interface between the gallery lining and the clay. A detailed report about the design, preparation and installation of the PRACLAY Seal & Heater experiment has been written and will be published in 2013, concluding the installation phase of the experiment.

In this section of the Activity Report, you will find the most important research and installation activities conducted in 2012.

INSTALLATION OF THE HEATING SYSTEM

The heating system consists of a primary heater, attached to the gallery lining, and a secondary heater, which is placed in a central tube that rests on a support structure. Both of these are electrical heaters. Since the primary heater is inaccessible during the Heater test, twice as many primary heater cables as necessary are installed (100% redundancy). The secondary heater is a back-up and will remain accessible and replaceable at all times during the test.

A control system regulating the heating power as a function of measured and target temperatures is also part of the heating system. During the start-up phase the temperature will be increased stepwise and very slowly to limit the thermal gradient over the gallery lining during this phase.

The **primary heater** was installed in the PRACLAY gallery in 2010. The gallery is divided into three sections (front, middle and end), each of which is subdivided into four zones (upper, lower, left, right). Each zone is equipped with two heater elements, ensuring the 100% redundancy of the system. Systematic monitoring of the performance of the primary heater cables was continued in 2012. Since 2011, one cable has been found to be damaged after backfilling the upstream part of the PRACLAY gallery with sand and closing the hydraulic seal. However, during a test of the heating system (see below), the cable functioned properly.

The **secondary heater** was installed in the PRACLAY gallery in February 2012. This consists of four heater elements, which were inserted into the central tube inside the part of the PRACLAY gallery that will be heated. This central tube contains five guide tubes (four for heater cables and one for other purposes; see Figure 4) and remains accessible at all times so that the heater elements can be replaced if necessary. The secondary heater is a back-up and will only be used in the event of failure of the primary heater. If this should happen, it is ready to be connected to the central heater control system so that heating can continue with only a brief interruption. Whereas the primary heater is regulated to provide a constant temperature (80°C at the interface between the gallery lining and the Boom Clay), the secondary heater will provide a constant power output, the value of which will be set at the time of the switch-over.

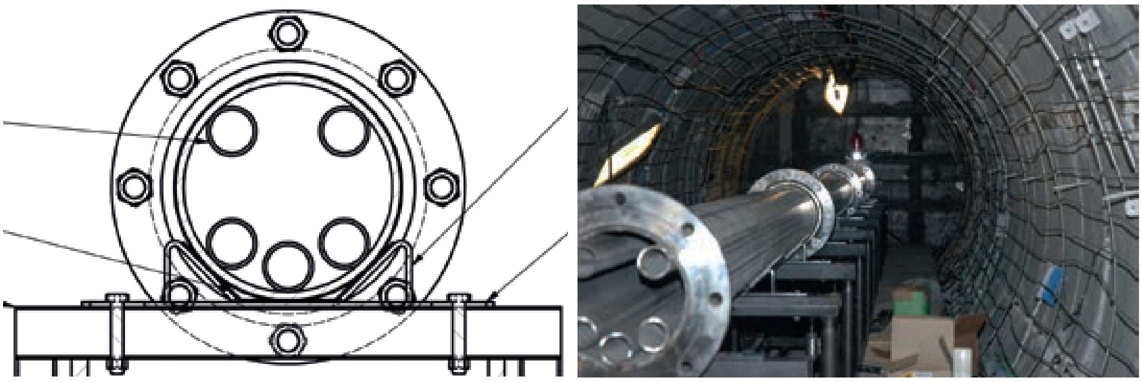


Figure 4 Cross-section of the central tube

TEST OF THE HEATING SYSTEM

The heating system was tested on 28 August 2012, primarily to check that the heater elements, the control system and the link with EURIDICE data acquisition were functioning properly. The tests consisted in a brief switch-on of the heater system; the effect on the test set-up was monitored.

The short heating period started at 10:00. The heaters were switched on. At the start of the test, the heater system worked at full power. After a while the control system started to lower the power output (consistent with programmed heating protocol) and subsequently increased it. The short heating test ended at 13:30; the total power input in the system was estimated to be equivalent to 3 hours at full power (~25 kW). The automatic switch between normal and redundant heaters - scheduled to occur every 24 hours during the future heating phase - was performed successfully. All heater elements delivered the requested output, including one element with a very low Megger value, which was believed to be defective.

During the test some points for improvement were identified. These were mainly data-acquisition aspects and were addressed in the months that followed. The on-site implementation of the improvements and a similar short heating test are scheduled for early 2013.

The maximum temperature increase of the heater cables was about 8°C, while the gallery lining temperature increase varied between 0°C and 1.4°C. A pore water pressure increase of 0.05 bar was measured inside the

PRACLAY gallery. Figure 5 shows the temperature increase in the lining of ring 50 of the PRACLAY gallery during the Heater test. Ring 50 is located in the middle of the heated section of the gallery. The temperature sensors are located in the middle of the 30 cm thick lining segments. Note: the temperature at this location increased by 0.6°C and it took several months to cool down to the initial temperature.

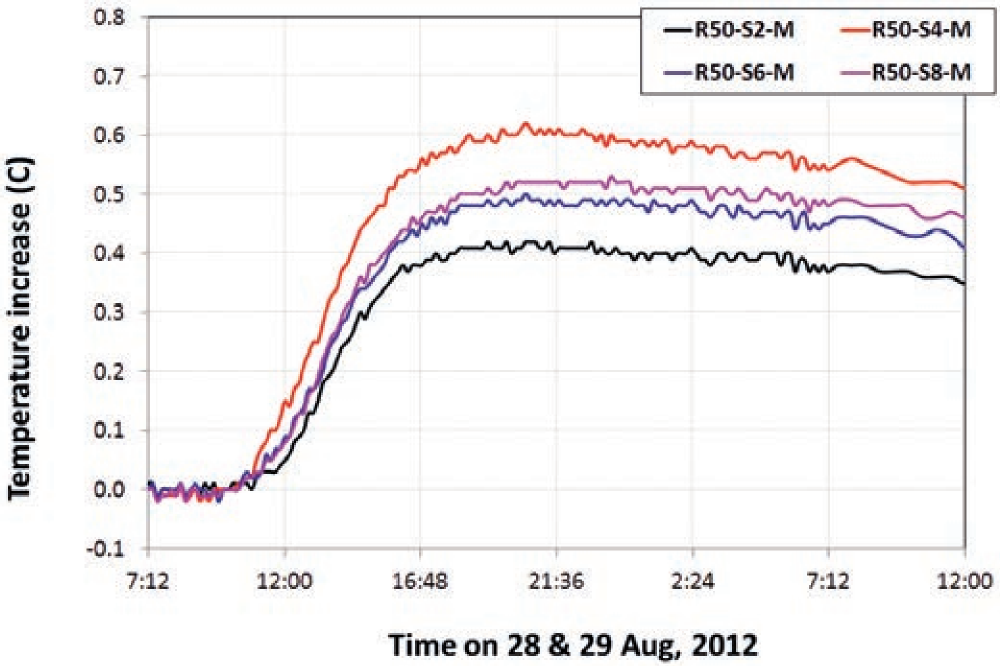


Figure 5 Temperature increase in the lining of ring 50 of the PRACLAY gallery during the Heater test. The temperature sensors are located in the middle of the 30 cm thick lining segments.

The saturation degree of the backfilled sand at the time of the test was estimated to be about 96% (derived from the relationship between the injected water volume and the injection pressure). Assuming the saturation degree of the backfilled sand to be 96%, numerical modelling was performed to reproduce the short heating test. A good agreement between measurements and modelling was obtained for the temperature increase and the pore water pressure in the gallery. This confirmed that the backfilled sand was not yet fully saturated, and its saturation degree was indeed about 96% at the time of the test.

SATURATION OF THE PRACLAY GALLERY

After the installation of the central tube for the secondary heating system (February - April 2011), the part of the PRACLAY gallery that will be heated was backfilled with Mol sand (M34). Backfilling was finished in September 2011. The dry density of the backfilled sand is about 1.61 g/cm3, which gives a saturated thermal conductivity of about 2.9 W/m.K and a saturated hydraulic conductivity of about 5.10-4 m/s, thus meeting the requirements for PRACLAY backfill material.

The saturation of the backfilled PRACLAY gallery started at the end of November 2011 by injecting tap water through six filters placed at the bottom of the gallery. In total about 38 m3 of water was injected until 9 January 2012. During this period, no leakage was observed from the outside of the seal and the seal did not show any clear response to the gallery saturation. To increase the saturation of the PRACLAY gallery, an additional 4.8 m3 of tap water was gradually injected into the gallery, between 9 January 2012 and 25 June 2012. Accordingly, the pressure in the gallery increased from 1.3 bar to 5 bar (pressurisation phase).

On 25 June 2012 the artificial injection was stopped. The pore water pressure (PWP) in the gallery has increased slowly since then and by the end of 2012 it had reached about 5.55 bar. This means that the gallery is being saturated smoothly by the Boom Clay.

The saturation degree of the PRACLAY gallery at the end of 2012 was estimated to be around 97-98%, based on the additional volume of water injected into the gallery during the pressurisation phase and subsequent evolution in pore water pressure.

INSTRUMENTATION

In 2012 two additional monitoring systems were installed for the PRACLAY in-situ experiments:

- Strain gauges to monitor the load in the PRACLAY support beams
- Permanent monitoring of the seal structure stability

MONITORING THE LOAD IN THE PRACLAY SUPPORT BEAMS

To counter any possible axial movement of the PRACLAY gallery lining into the Connecting gallery due to heating (and related effects), a support structure with four beams, which was used during the start of the PRACLAY gallery excavation in October 2007, has been re-installed between the reinforcement structure of the Connecting gallery (at the entrance of the PRACLAY gallery) and the first segmented lining ring of the PRACLAY gallery (see Figure 6 Support structure (white) at the entrance of the PRACLAY gallery).

Figure 6 Support structure (white) at the entrance of the PRACLAY gallery

To monitor any load that might develop in these beams due to a possible displacement of the PRACLAY gallery lining, strain gauges have been installed at four locations in the middle of each beam (evenly distributed along the circumference). At each location, both a dual strain gauge and two single strain gauges have been installed. The main monitoring directions are axial and circumferential. The circumferentially oriented gauges allow for a more accurate set-up (temperature compensation in the bridge configuration). Because of the well-known properties of the steel used, the load can be derived from the strain (compression) of the beams.

The gauges have been wired to a System 7000 acquisition unit from Vishay. A total of 24 channels measure in different configurations (Figure 7). To validate the monitoring set-up, including the data analysis, a mock-up tube was wired with an identical strain gauge set-up. This tube was put under mechanical stress to subject it to a known load (and hence the strain could be predicted). Comparison of the strain gauge readings with the applied load allowed us to validate the measurement system set-up.

So far, no strains have been observed. In fact, the beams are not yet loaded as they are not yet in contact with the first lining ring.

Figure 7 Strain gauge Vishay CEA-06-250UT

PERMANENT MONITORING OF THE SEAL STRUCTURE STABILITY

The hydraulic seal, installed in 2010, had a square manhole to keep the upstream part of the PRACLAY gallery accessible for the installation of the heating system and sand backfill material. After this work was completed, a plate was welded over the manhole in September 2011 to fully close the seal. This finalised the complete installation of the hydraulic seal.

In February 2012 optical targets were installed on the seal structure as well as on selected segments of the PRACLAY gallery (accessible part) to detect any movement (mainly axial movements are expected) due to the pressurisation and heating of the PRACLAY gallery. A total station (theodolite) was set up at the front of the PRACLAY gallery to check/measure these targets (Figure 8). The frequency of measurements can be adjusted according to the events in the PRACLAY gallery.

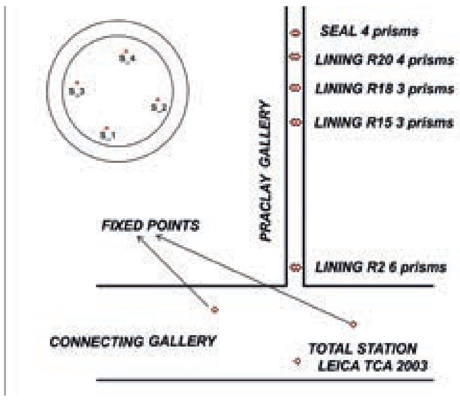


Figure 8 Monitoring system for analysing the movement of the seal structure

The measured displacements of four target points on the seal structure up to the end of 2012 are shown in Figure 9, in which the evolution of the pore water pressure inside the PRACLAY gallery has also been plotted, indicating that the maximum measured displacement is about 1.5 mm (measuring accuracy: 0.1 - 0.2 mm) and that the seal structure stays stable during pressurisation of the PRACLAY gallery: the four target points move in the same way and in the same direction (towards the Connecting gallery).

So far, no significant displacement has been observed on selected segments of the PRACLAY gallery (accessible part), taking into account the accuracy of the measurements.

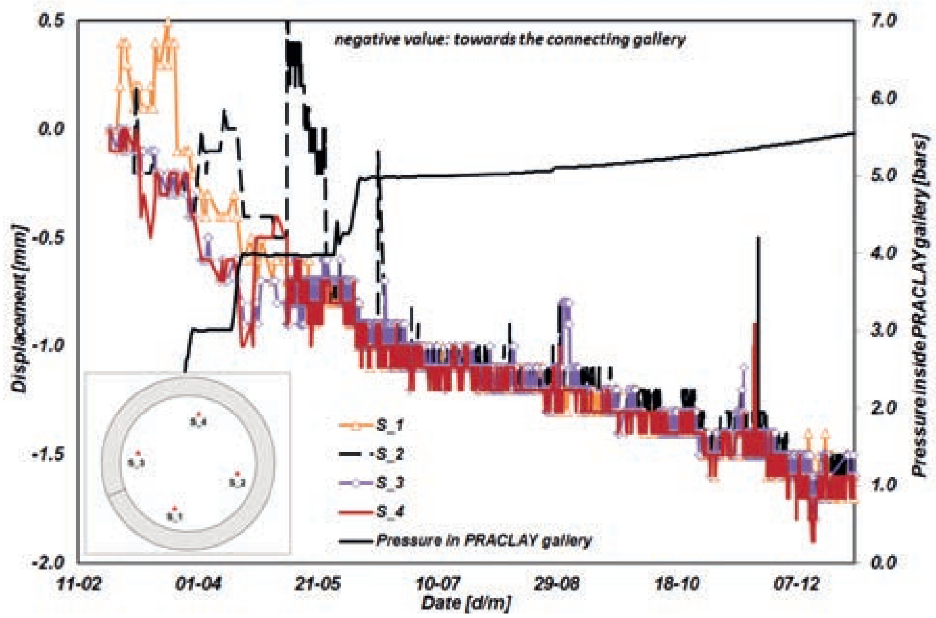


Figure 9 Displacement of four target points on the seal structure and correlation with the evolution of the pressure inside the PRACLAY gallery

THE SEAL TEST - EVOLUTION OF THE SEAL

The bentonite seal is being hydrated by pore water coming from the Boom Clay (since its installation in January 2010) and by water injected through filters placed on the extrados (outer surface) of the cylinder (since April 2010). (Figure 10)

Figure 10 Water injection filters on the outer surface of the steel cylinder (light grey areas)

Changes in the following **parameters** are monitored during the hydration of the bentonite:

- water injection rate
- relative humidity in the bentonite
- stress (swelling pressure) in the bentonite
- pore water pressure in the bentonite
- pore water pressure in the Boom Clay around the seal
- displacement of the interface between the bentonite and the Boom Clay

To measure these parameters, different kinds of instruments were incorporated in the bentonite rings during the installation. The instruments are grouped in three sections: A, B and C (Figure 11). The evolution of the different parameters is discussed below.

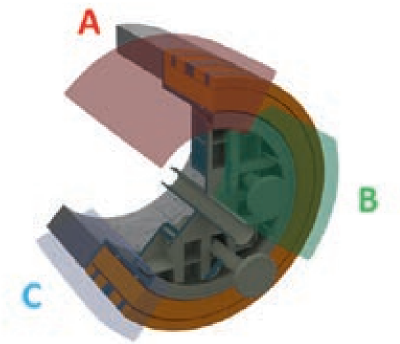


Figure 11 Various instruments inside the bentonite, grouped in sections A, B and C

At the end of 2012, a total of 42 kg of water was injected into the bentonite after the disappearance of a leakage that occurred at the beginning of the artificial injection phase (Figure 12). The injection pressure has no clear impact on the injection rate, suggesting the persistence of high suction inside the bentonite.

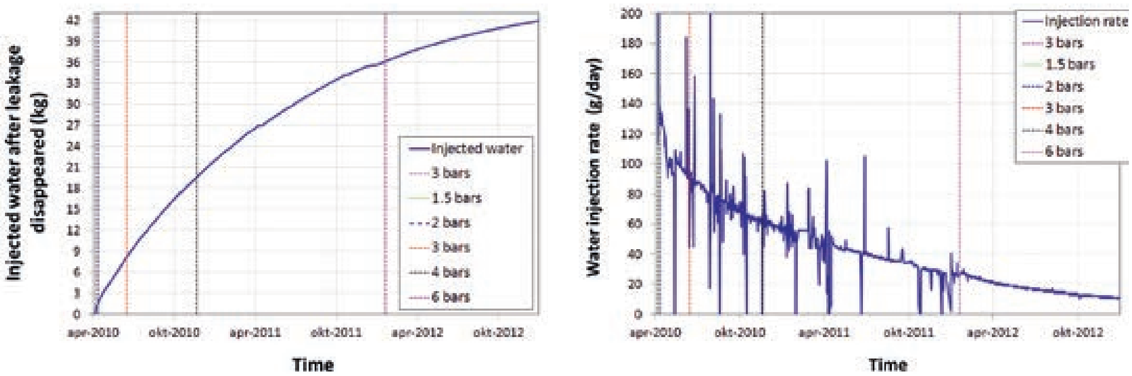


Figure 12 Artificial water injection of the seal:
total amount of water injected (left) and measured water injection rate (right)

Concerning **relative humidity**, all sensors failed once they came into contact with water, caused by artificial hydration of the seal. Consequently, no measurements were obtained during 2012. It is known that this kind of sensor is fragile once inundated with water.

The evolution of the **stresses** (all stress values are relative) in the bentonite ring and the stresses exerted by the bentonite on the Boom Clay and the steel structure of the hydraulic seal are shown in Figure 13, Figure 14, Figure 15 and Figure 16.

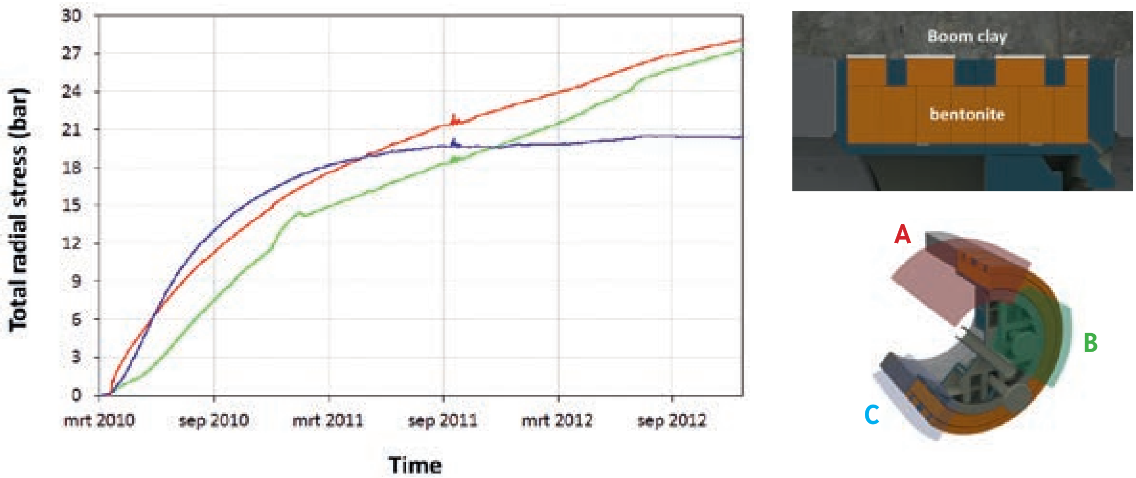


Figure 13 Radial stresses measured at the interface between the bentonite
and the Boom Clay sidewall (white line), for the sections A, B and C

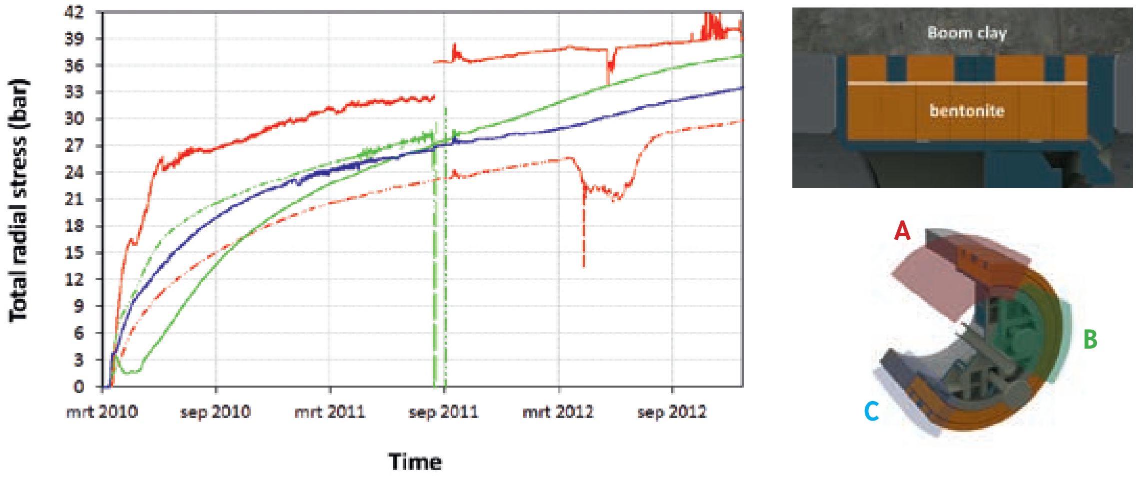


Figure 14 Radial stresses measured in the void between the inner and outer bentonite ring (white line), for the sections A, B and C

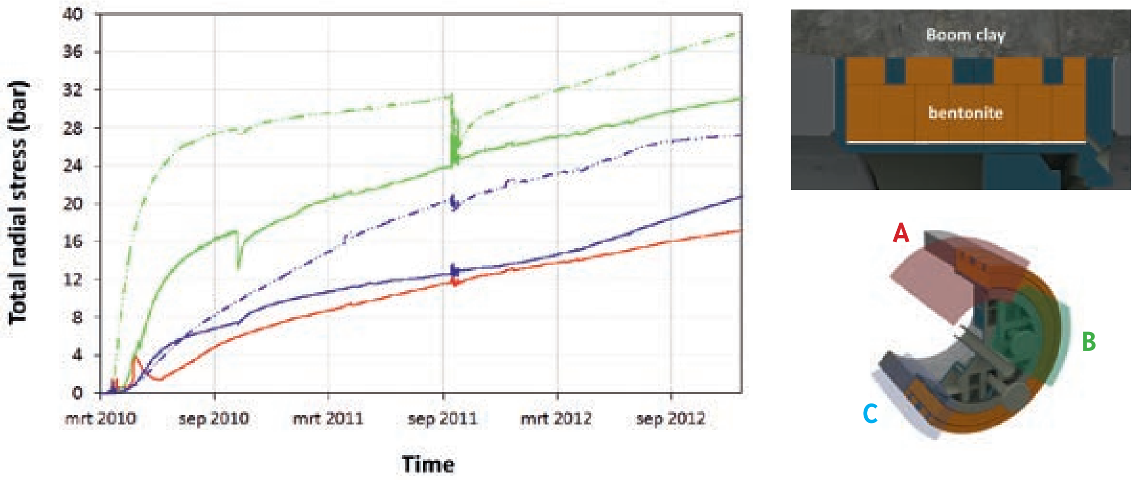


Figure 15 Radial stresses measured at the interface between the bentonite and the steel cylinder (white line), for the sections A, B and C

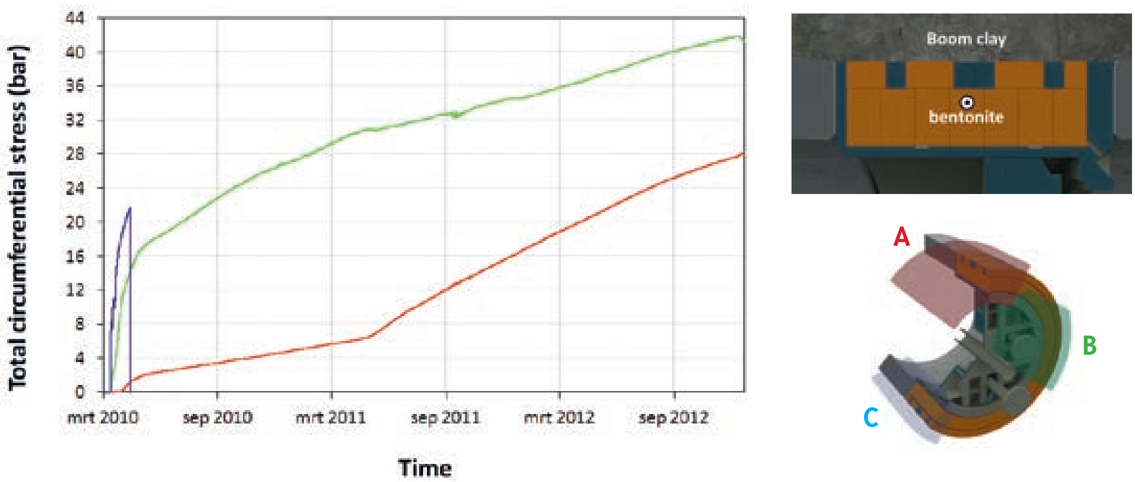


Figure 16 Circumferential stresses measured in the inner bentonite ring (white point), for the sections A, B and C

Although the rate of increase differs for the different sensors, most of the sensors show a clear increasing trend. These stress increases began a few days after the start of the artificial hydration, indicating that during the first few days of artificial hydration, closure of the voids took place. After all voids were closed, the stresses in the bentonite ring started to increase.

The radial stresses (swelling pressure) measured at the interface between the bentonite and the Boom Clay at three sections is shown in Figure 13. The swelling pressure at sections A and B shows a relatively homogeneous evolution and has already reached 27 bar (the target swelling pressure for heater switch-on is 25 bar based on the scoping calculations). However, the swelling pressure at section C seems to “level off” at about 20 bar. This is being further investigated by means of numerical modelling, seal performance tests and permeability tests.

The radial stresses measured in the void between the inner and outer rings of bentonite show a relatively homogeneous evolution, ranging from 30 bar to 39 bar (Figure 14). However, the swelling pressure measured at the interface between the bentonite and the steel cylinder is quite heterogeneous (Figure 15) due to the artificial injection filters that are installed in only two rings and do not cover the complete circumference.

The circumferential stresses measured at sections A and B range from 28 bar to 42 bar respectively, and are still increasing (Figure 16). This indicates that the contact between the blocks is improving.

The measured **pore water pressure** at the interface between the bentonite and the Boom Clay shows a positive pore water pressure of 3 - 4.5 bar, indicating full saturation of the bentonite in the contact zone (Figure 17). The temporary jumps in pore water pressure at different filters were due to the seal performance tests (filter manipulations to check the saturation state), permeability tests (hydraulic water conductivity measurements) and gas tests that were performed on these filters to check the gas breakthrough pressure. However, the filters at the interface between the inner and outer bentonite rings and in the inner bentonite ring have not yet significantly deviated from atmospheric pressure, indicating the unsaturated state of the bentonite in these locations. This is confirmed by the results of the manipulations performed on several filters to gain better insight into the bentonite status since October 2010.

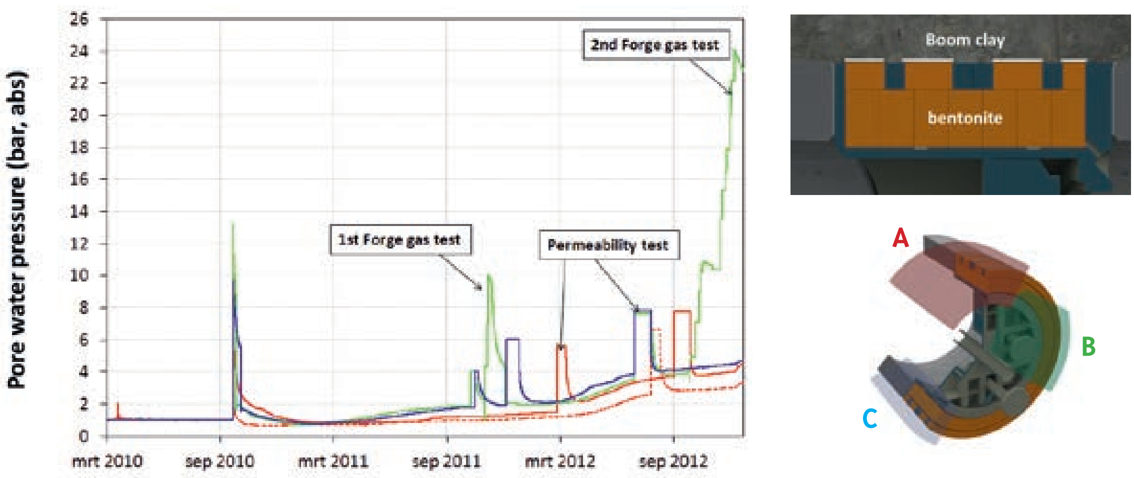


Figure 17 Pore water pressure at the interface between the bentonite and the Boom Clay (white line), for the sections A, B and C

Hydraulic conductivity was measured at the interface between the bentonite and the Boom Clay at different sections and in the Boom Clay in the vicinity of the seal in 2012. The values obtained on two filters in the Boom Clay at a distance of 55 cm and 75 cm from the seal are 4.0 x 10-12 m/s and 3.5 x 10-12 m/s respectively (measured in September 2012), which are very close to that of the undisturbed Boom Clay. Similar values (ranging from 3.2 to 5.0 x 10-12 m/s) were obtained at the interface between the bentonite and the Boom Clay (early 2012), indicating the seal's relatively good performance. Systematic measurement of the hydraulic conductivity in and around the seal will be continued.

The gas test consists in injecting Ar gas into the system through a filter on the bentonite/Boom Clay interface. The gas pressure is increased stepwise, whilst monitoring for the possible onset of gas flow out of the filter into the environment. The gas test at section B started on 8 October 2012. On 18 December 2012, the gas pressure was increased to 24 bar. Shortly after this increase, a steady but limited gas flow was detected. The test results will be interpreted after completion of the test, which is expected at the beginning of 2013.

The two extensometers to measure the displacement of the seal failed at the end of 2011 due to liquid water penetration when saturation of the gallery began. There have been no further measurements since then.

All measurements indicate that bentonite hydration is evolving in the right direction. The bentonite had swelled up to 13 mm towards the Boom Clay by the end of 2011, and most of the measured radial swelling pressures are greater than 27 bar, except at section C on the interface between the bentonite and the Boom Clay where the measured swelling pressure is "levelling off" at 20 bar. The stresses measured indicate that almost all the gaps in and around the seal were closed shortly after the start of the artificial injection. At the bentonite/Boom Clay interface, pore water pressures higher than atmospheric pressure are measured, which indicates a good saturation of this interface. Finally, the hydraulic conductivity measured at the bentonite/Boom Clay interface is close to that measured in the Boom Clay around the seal, which is similar (order of magnitude of 10-12 m/s) to the hydraulic conductivity measured for undisturbed Boom Clay.

SEISMIC MONITORING

The seismic installation in the around the PRACLAY gallery consists of 23 transmitters (T) and 19 receivers (R). The sensors used are micro-seismic piezoelectric sensors that can both transmit and receive signals. They are installed in boreholes as well as at the interface between the gallery lining and the Boom Clay (Figure 18).

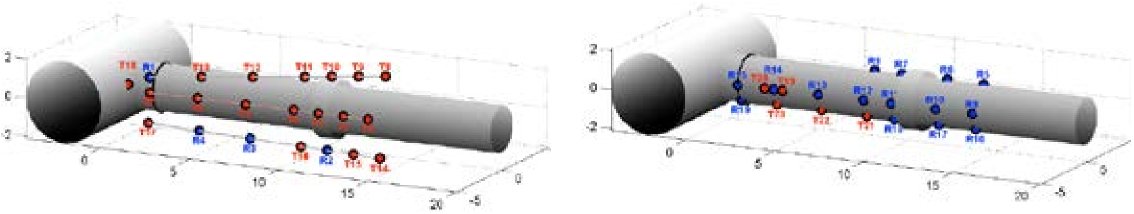


Figure 18 Transmitters (T) and receivers (R) installed in boreholes [left] and at the extrados (outer surface of the PRACLAY gallery) [right]

The main objectives of the seismic installation are to:

- Determine both near- and far-field background seismic characteristics of the Boom Clay;
- Monitor evolution of the excavation-damaged zone (EDZ) created around the PRACLAY gallery during and since its construction in 2007; and
- Provide seismic data on the Boom Clay during the future PRACLAY Heater experiment.

The seismic installation continues to be monitored. A new seismic hammer is being built and is due to be tested in 2013. The new hammer is partly funded by the MoDeRn project and, if successful, will enable S waves to be generated in any desired orientation. S waves propagate mostly in the low-frequency range and are better suited than the generally high-frequency P waves for detecting structural changes in clay. Once operational, the hammer will be tested in HADES and further evaluated to see if it can provide high-quality signals for seismic monitoring of the PRACLAY Heater test.

Finally, efforts are being made to improve the analysis of the seismic signals recorded in HADES. This consists partly in evaluating new methods of signal analysis that can be successfully applied to the seismic data from HADES.

NUMERICAL MODELLING OF THE PRACLAY SEAL AND HEATER TESTS

During 2012, continuous efforts were devoted to the numerical modelling of the PRACLAY Seal and Heater tests to improve our understanding of the observations from the tests, to further identify the important factors affecting the Seal and future Heater test, to support the risk analysis of the tests, and to predict the future test.

The sensitivity analysis carried out in 2011 enables us to determine the important factors affecting bentonite behaviour and to identify a series of questions and uncertainties. For example:

- What is the capability of the mechanical constitutive model used (BBM model) to simulate the behaviour of the compacted bentonite?
- How do the micro/macrostructures of the bentonite evolve and what is the evolution of bentonite permeability during the hydration/swelling phase?
- What can numerical simulations learn us about the interaction between the bentonite and the Boom Clay?

In order to answer these questions and investigate these uncertainties, the “Double structures Model”, a more advanced constitutive model developed by CIMNE (Alonso E. et al. 1999, Sanchez M. et al. 2005 *) was implemented in 2012 and verified in the finite element code “Code-Bright” (also developed by CIMNE). This model can take into account the interaction of micro/macrostructures and their evolution during the hydration phase, in that way providing information on the evolution of the bentonite permeability, which may help to understand the seal swelling process. Moreover, an extensive numerical study is being carried out to further investigate the important factors affecting seal behaviour:

- By considering the anisotropy (both stress anisotropy and material anisotropy) of the host Boom Clay;
- By taking the pore water pressure around the PRACLAY gallery and its evolution better into consideration; for this purpose, a set of hydro-mechanical parameters of Boom Clay has been obtained by numerical modelling, which reproduces the measured pore water pressure better. The modelling of the Seal test is improved based on the improved hydro-mechanical parameters of the Boom Clay and, as an example, the modelled radial swelling pressure at the Boom Clay/bentonite interface is presented in Figure 19;
- By considering the realistic experimental procedure: pressurisation and subsequent evolution of the saturation (and consequently the variation in the compressibility of the pore liquid) of the PRACLAY gallery.

* Alonso E., Vaunat J., Gens A. - *Modelling the mechanical behaviour of expansive clays* - In: Engineering Geology, 54(1999), pp. 173-183.
Sanchez M., Gens A., Guimaraes L., Olivella S. - A double structure generalized plasticity model for expansive materials – In: International Journal for Numerical and Analytical Methods in Geomechanics, 29(2005), pp. 751-787.

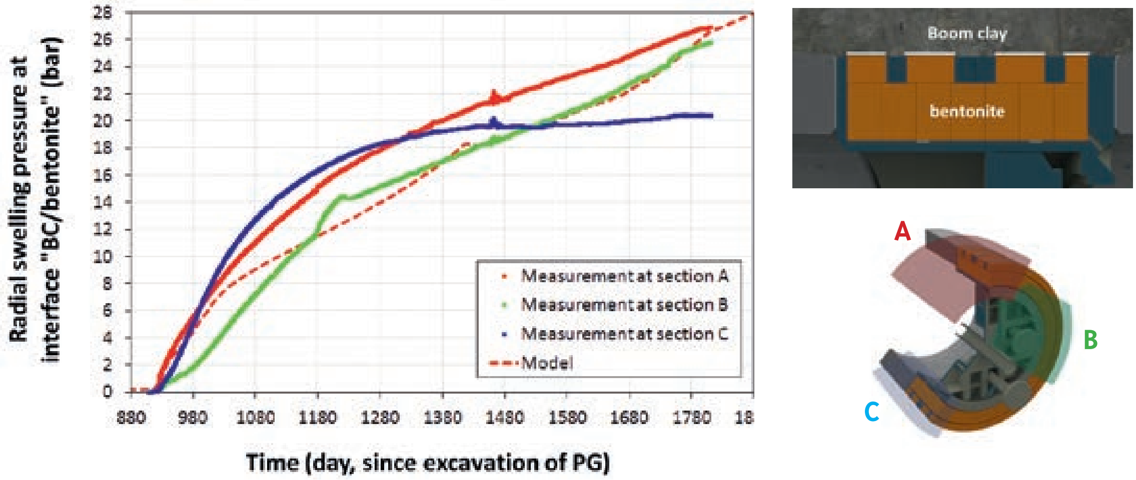


Figure 19 The measured and modelled radial swelling pressure at the interface between Boom Clay and bentonite (white line), for the sections A, B and C

Meanwhile, a series of numerical modelling experiments have been performed to assess different scenarios in terms of risks and consequences for the whole PRACLAY experiment, in order to support the decision-making for the experiment. These scenarios address questions such as:

- *What if water pressure in the gallery is lost for some time during the heating phase?*
  Different scenarios on feed-through leakage were analysed.
- *What if the heating is stopped for some time?*
  The influence of the respective failure of the twelve sections (3 zones x 4 sections/zone = 12 sections) of the primary heater on the thermo-hydro-mechanical responses in the host Boom Clay was studied. This study will be the basis for establishing the protocol for the secondary heater switch-on, to ensure the continuity of the experiment.
- *What if water pressure in the gallery is too high?*
  This could happen if the PRACLAY gallery is fully saturated with water before switch-on. The PRACLAY gallery is currently being saturated by Boom Clay pore water. As a result, the pore water pressure inside the PRACLAY gallery will increase. The effect of the pore pressure inside the PRACLAY gallery prior to heating (initial condition) on the future PRACLAY Heater test has been studied numerically by considering different timings for the heater switch-on. This study will contribute to deciding the "initial conditions" to be adopted for the future Heater test.
- *What if the PRACLAY gallery is not fully saturated before switch-on?*
  This scenario concerns mainly the effect of compressibility of pore fluid inside the PRACLAY gallery on the pore pressure generation in the host rock during the heating phase. This study enables us to decide whether further pressurisation of the PRACLAY gallery is necessary.
- *What if the swelling pressure of the seal is too low (as measured at section C on the bentonite/ Boom Clay interface) or too high at the time of the switch-on?*
  This analysis focuses on the risk of hydraulic fracturing at the seal during the heating phase. Different scenarios were studied by considering the heterogeneity of the swelling pressure at sections A, B and C on the interface of the bentonite and the Boom Clay.
- *What if the heating rate during the transient heating phase is too high/low?*
  This study aims to investigate whether a slower heating rate could increase the required functioning of the seal in terms of the effective stresses in the seal (a negative effective stress would increase the risk of hydraulic fracturing).

Moreover, efforts were also devoted to predicting the heater test by fine-tuning the thermo-hydro-mechanical (THM) parameters of Boom Clay based on recent knowledge of its THM behaviour (anisotropic

THM properties of Boom Clay, excavation-damaged zone, etc.).
The numerical scoping calculations are helpful and necessary due to the complex coupled THM processes in the whole experiment and also due to the complex interplay between the Heater test and the Seal test. However, it is important to bear in mind that the numerical simulations are based on a set of assumptions and simplifications. For the Seal test, due to the complex behaviour of the bentonite, the complex initial conditions and the complex boundary conditions in and around the seal, modelling the Seal test remains difficult, and more numerical modelling of the Seal test is still necessary to interpret the measured data.
All the results of the risk an consequence analysis will be interpreted in the course of 2013 and presented and discussed during the process of preparing the heater switch-on.

LABORATORY EXPERIMENTAL EVALUATION OF THE HYDRAULIC RESISTANCE OF THE COMPACTED BENTONITE/BOOM CLAY INTERFACE

Tests were performed in the CERMES laboratory in Paris to evaluate the risk of hydraulic fracturing at the interface between Boom Clay and bentonite, by considering:

- the deformability of Boom Clay.
- the effect of the gap between bentonite and clay.

The set-up of the tests is illustrated in Figure 20. The bentonite block was placed in a hollow cylinder of Boom Clay, initially with a gap between them to simulate the technological void in the PRACLAY Seal test. The height of the soil specimens is fixed by the piston. A force sensor was placed on top of the piston of the cell. A total pressure sensor was installed at the inner surface of the Boom Clay specimen to measure the horizontal pressure at the Boom Clay/bentonite interface. The whole system was hydrated by injecting water from the bottom base of the cell at a rate of 1 mm3/s by means of a pressure/volume controller (CPV). The subsequent swelling pressure and injection pressure were monitored. Their evolution can provide information about the hydraulic resistance of the interface.

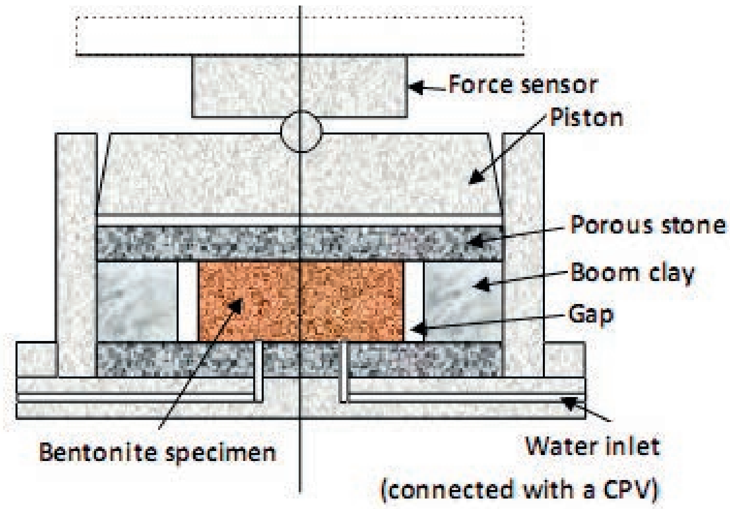


Figure 20 Laboratory experimental set-up to evaluate the risk of hydraulic fracturing at the Boom Clay/bentonite interface

The typical results are illustrated in Figure 21.

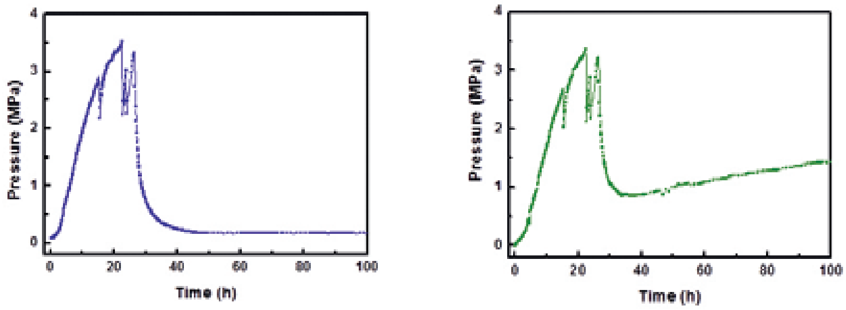


Figure 21 Injection pressure (left) and horizontal total pressure at Boom Clay/bentonite interface (right) versus time

When water was injected into the cell, it flowed freely through the gap, leading to a constant water pressure until the gap was sealed by the swelling of the bentonite. Swelling occurred through the formation of a gel that slows down the water flow, resulting in an increase in the water pressure required to keep the injection rate constant. When the water pressure reached the hydraulic resistance of the gel in the gap, fracturing took place, resulting in a drastic pressure decrease. After fracturing occurred, water was continuously injected into the cell and the bentonite continued to swell; the hydraulic resistance increased, resulting in hydraulic fracturing at higher pressure. Such characteristics are related to the swelling properties of bentonite. The highest hydraulic resistance recorded is between 3 and 4 MPa. The horizontal pressure measured during the tests performed at the bentonite/Boom Clay interface confirms this hydraulic fracturing mechanism.

The preliminary results suggest that the interface between Boom Clay and bentonite may have sufficient hydraulic resistance, but these results need to be further interpreted when comparing with and up-scaling to the in-situ conditions. It's worth mentioning that one test showed that the Boom Clay/bentonite interface (in this specific test) may possess a self-sealing capacity: after a forced hydraulic fracturing at 3 MPa pore water pressure, the water injection was stopped for 20 hours. After this stop, when water was re-injected continuously, no more hydraulic fracturing occurred even at an injected pressure as high as 3.5 MPa!

PROPOSED DESIGN OF PLUG TO STOP POTENTIAL LEAKAGE IN THE SEAL FEED-THROUGHS

The seal's steel structure contains four main conduits (Figure 22) through which are fed the numerous cables, water pressure tubing and wiring connecting the sensors inside the heater part of the experiment to their respective measurement and data acquisition systems located outside the experimental gallery. The various feed-through components use Conax™-type sealing glands. These can withstand pressures of up to 300 bar, depending on the applied torque. If one or more of these glands leak, immediate action is necessary to stop the leakage in order to limit possible disturbance of the experiment. The proposed design consists of a pre-fabricated plug that can be placed over either an individual or a set of leaking glands to completely stop leakages (Figure 23).

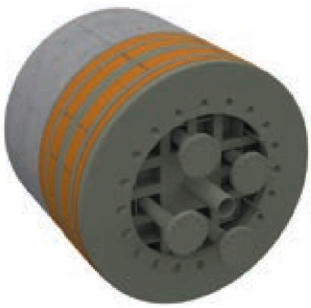


Figure 22 Overview of seal showing the four main feed-through conduits

Figure 23 Proposed design for plug to stop potential leakage in seal feed-throughs

TIMING FOR SWITCH-ON OF THE PRACLAY HEATER

The timing of the switch-on depends in part on the progress of the bentonite hydration as a sufficiently high swelling of the bentonite is needed for the seal to perform its function. The pore water pressure in the clay is expected to increase up to a value of at most 3 MPa around the PRACLAY gallery if no drainage takes place at all. To ensure that the seal function can be maintained during the Heater test, the bentonite pressure has to reach a comparable pressure at that time. Scoping calculations suggest that this will be the case provided that the swelling pressure before switch-on of the heater has reached a value of 2.5 MPa (target switch-on pressure). The decision to switch on the heater test will be taken based on the evolution of this swelling pressure, a comparison with updated modelling results (also taking into account the uncertainties associated with these results) and the general readiness of the EURIDICE team to conduct the experiment once it is started (drafting of a risk analysis document, determination “a priori” of the temperature, pressure and stress “trajectories” expected after switch-on and establishment “a priori” of clear procedures to be followed in case of significant deviations).

A heater switch-on workshop with external experts was organised in November 2011. Based on this, the experts considered that, at that moment in time, there was not yet sufficient confidence that the seal would fulfil its role for switch-on and suggested enhancing the risk analysis and further fine-tuning the models (hypotheses, constitutive law, etc.) to obtain more indicators for a new assessment of the switch-on in the course of 2012.

Two assessments were conducted with EURIDICE’s Scientific Advisory Committee in 2012, in May and November. In view of the evolution of the seal, especially the heterogeneities in swelling pressure, the SAC experts suggested giving further consideration to the importance and consequences of these heterogeneities in swelling pressures in the bentonite seal (cf. Figure 0 19) and further enhancing the risk analysis. They took the view that we are not yet ready to switch on and must continue observations and improve modelling by taking better account of the aforementioned heterogeneities. Finally, it was decided to carry out a new assessment with SAC experts in mid-2013 and organise a second heater switch-on workshop at the end of 2013 to discuss the switch-on decision.

1.2.2. PRACLAY ON-SURFACE

HALF-SCALE TESTS: SUPERCONTAINER CONSTRUCTION FEASIBILITY TEST NO. 2

The half-scale tests are part of the ON-SURFACE experimental programme aimed at demonstrating the feasibility of constructing the different components of the supercontainer conceptual design proposed by ONDRAF/NIRAS for the packaging of high-level radioactive waste, including spent fuel assemblies. The primary goal is to demonstrate the feasibility of constructing the supercontainer using currently available techniques (Figure 24). In addition, the tests contribute to the validation of finite element calculations performed to simulate the thermo-hydro-mechanical (THM) behaviour of the concrete materials and provide valuable practical experience for optimising the design, safety and construction procedures for the supercontainer.

Figure 24 Half-scale test set-up

During 2012, EURIDICE prepared the design and instrumentation plans for the second half-scale test, which will be performed in 2013. The second half-scale test addresses a number of issues revealed during the first test carried out in 2009. These include the potential development of cracking in the buffer, the quality of the self-compacting concrete (SCC) mixture and the corrosion performance of the carbon steel overpack.

The test also provides an opportunity to install new state-of-the-art monitoring technologies, including the use of different types of fibre optics to measure semi-distributed temperature and strain in axial, radial and circumferential directions, three types of corrosion sensors to measure active corrosion of the carbon steel overpack, acoustic emission (AE) to help identify and locate the onset of cracking in the concrete buffer, and digital image correlation (DIC) capable of detecting and measuring the evolution of potential microcracks on the surface of the concrete buffer.

DIC is a full-field image analysis method, based on grey value digital images, which can determine the contour and displacements of an object under load in three dimensions. Three-dimensional digital image correlation (DIC) uses two digital cameras to view a test subject and determine its location and shape in space. The technology is a combination of single camera image correlation and two camera photogrammetry. Photogrammetry is a measurement technique in which the three-dimensional coordinates of points on an object are determined by measurements made in two or more photographic images taken from different positions. In practice, a random high-contrast digital pattern is fixed on the surface of the test object to supply a grid of unique points to correlate. This pattern then deforms or moves along with the object. The deformation under different load conditions is recorded by the digital cameras and then evaluated by specially designed software (Figure 25).

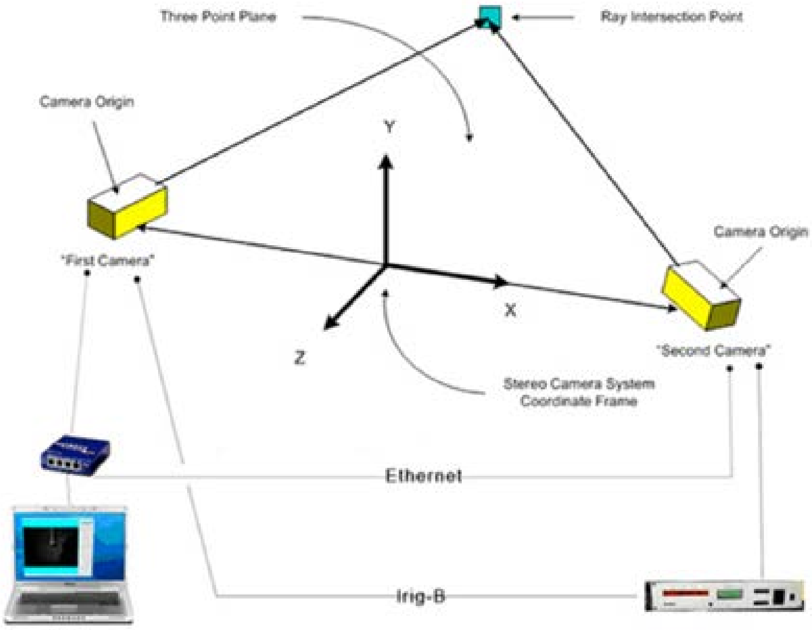


Figure 25 Typical digital image correlation (DIC) set-up

The initial image processing involves defining a unique correlation area known as the area of interest (AOI) across the imaging area. The size of the AOI varies according to the surface area that needs to be monitored. Usually the first image is taken in a non deformed state, while subsequent images are taken at different load stages. These facets are tracked in each successive image with sub-pixel accuracy. Sub-pixels are separately addressed elements of a pixel. To attain tracking with sub pixel resolution, an image-based tracking algorithm is used. Then, using photogrammetric principles, the 3D coordinates of the entire surface of the specimen are precisely calculated. The results are the 3D shape of the component, the 3D displacements and the plane strain tensor.

Tests performed at the Vrije Universiteit Brussel (VUB) to evaluate the feasibility of using this technique in the next half-scale test indicate that it can detect the onset of microcracks with a resolution of approximately 0.0125 mm (Figure 26 & Figure 27). This resolution is high enough to monitor the potential development of microcracks in the half-scale test.

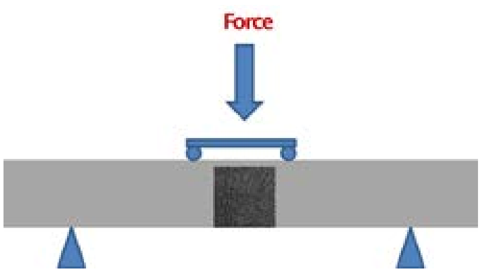


Figure 26 Four-point bending test on reinforced concrete beam showing a 30x30 cm digital image pattern

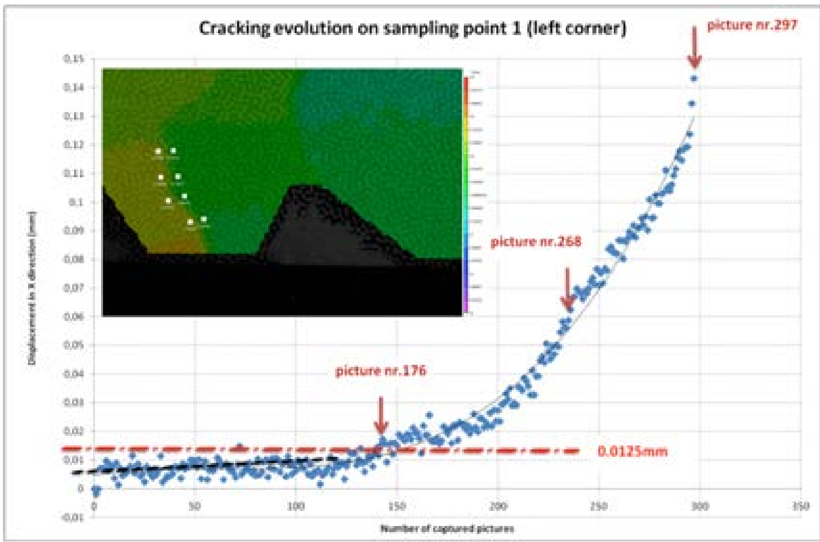


Figure 27 Crack evolution measured on a four-point bending test using DIC showing resolution of cracks of 0.0125 mm

The DIC measurements will use windows specially cut out in the steel mould to allow monitoring of the buffer while the mould is in place (Figure 28), and will be carried out by VUB under a one-year research partnership that includes in-depth analysis and interpretation of the DIC results.

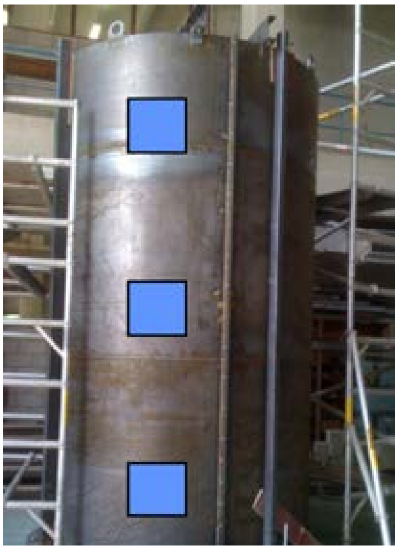


Figure 28 Half-scale test set-up showing three windows to provide access for DIC measurements while the mould is in place

2. Supporting studies

2.1. ATLAS

The small-scale in-situ ATLAS (**A**dmissible **T**hermal **L**oading for **A**rgillaceous **S**torage) tests are performed to assess the thermo-hydro-mechanical (THM) behaviour of the host Boom Clay at the HADES URL.

To broaden the THM characterisation of the Boom Clay on a larger scale and at different temperature levels, the ATLAS test set-up installed in 1993 and 1996 (ATLAS I & II) was extended in 2006 by drilling two additional instrumented boreholes (AT97E and AT98E) (Figure 29). The heater was switched on again from April 2007 to April 2008 with a stepwise power increase, followed by instantaneous shutdown. This phase is called ATLAS III. The extended picture of the temperature field provides clear evidence of the thermal anisotropy. Moreover, three-dimensional coupled THM modelling of the ATLAS III test has been performed. The good agreement between measurements and numerical modelling of temperature and pore water pressure in the horizontal plane of the heater highlights the THM anisotropy of Boom Clay and yields a set of THM parameters. By introducing mechanical anisotropy in the THM coupling model, the numerical simulation predicts an instantaneous but temporary pore water pressure decrease after increasing power, and a temporary pore water pressure increase after cooling in the horizontal plane, but not in the vertical plane. The former phenomenon has been confirmed by in-situ measurements from ATLAS III.

To gain better insight into the anisotropic THM behaviour of the Boom Clay, a new upward, instrumented borehole AT90IU was drilled above the ATLAS heater at the end of 2010 (Figure 30).

The new phase of the ATLAS heater test (ATLAS IV) started on 18 October 2011, using the same heating strategy as for ATLAS III to facilitate interpretation and comparison between the ATLAS III and ATLAS IV tests, and the heater was shut down on 29 November 2012.

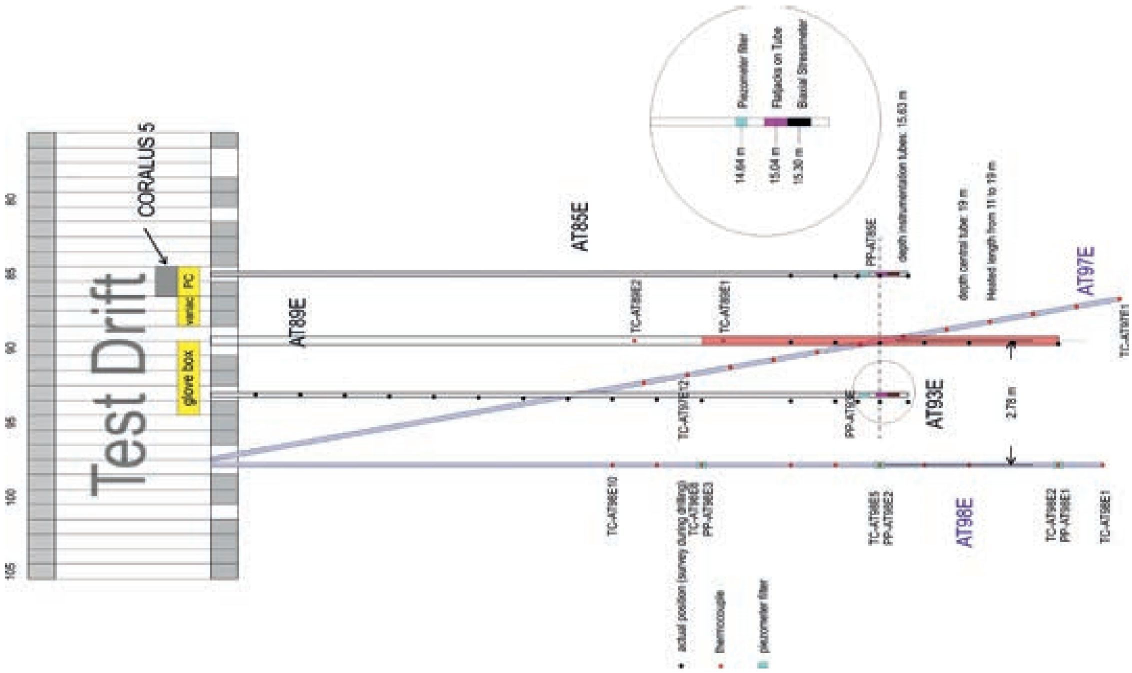


Figure 29 Schematic view of the small-scale in-situ ATLAS test

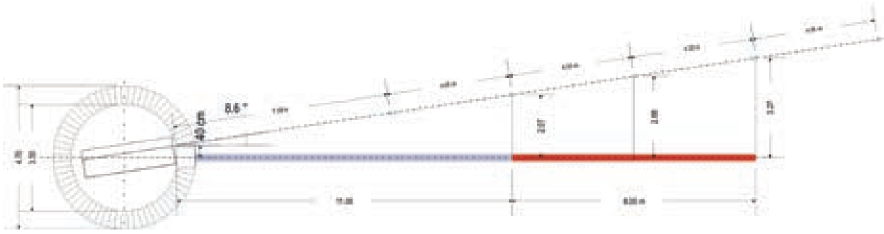


Figure 30 Upward borehole AT90IU drilled above the heater for ATLAS IV

As expected, the available measured variation in the pore water pressure from the new upward borehole was different from that measured from the borehole in the horizontal plane, which confirms the mechanical anisotropy of Boom Clay (Figure 31).

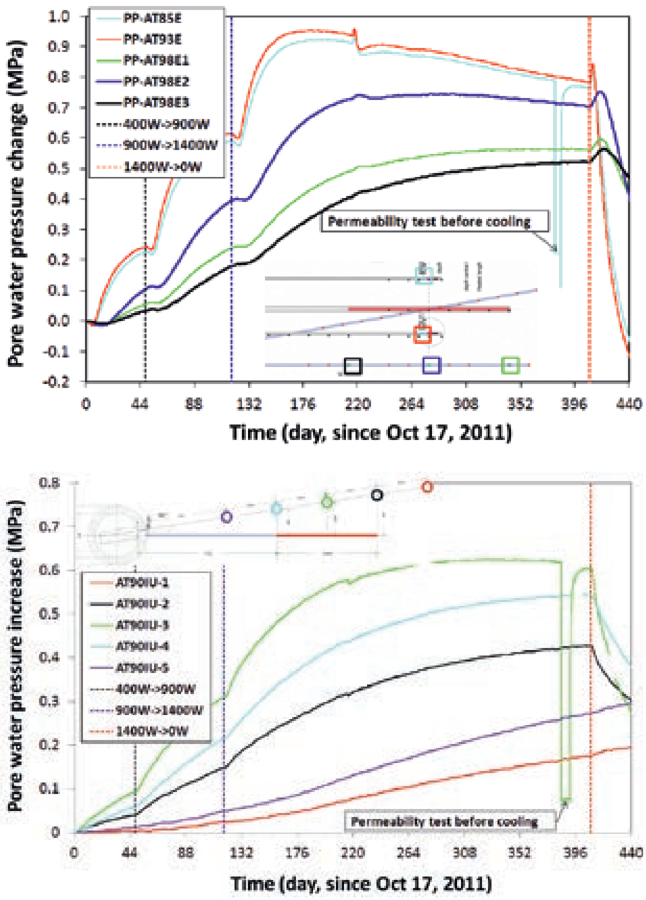


Figure 31 Pore water pressure variation measured from boreholes in the horizontal plane (above) and from the upward borehole (below)

A heating-pulse test is also planned at the end of the ATLAS IV test to determine the "ultimate" heating limit the Boom Clay can withstand.

The ATLAS test described above provides a large set of good-quality, well-documented data on temperature, pore water pressure and total stress, and many interesting observations can be made. The set-up of the tests has a simple geometry, essentially depending on a single material (Boom Clay), and it has well-defined boundary conditions, which facilitates comparison between measurements and numerical modelling. This test also serves as preparation for a full-scale PRACLAY Heater test.

2.2. PhD research

As part of research activities, especially the PRACLAY in-situ experiments, a specific thermo-hydro-mechanical-chemical characterisation programme on Boom Clay was run in parallel with the PRACLAY experiments in collaboration with different universities and laboratories through a PhD programme. EIG EURIDICE is involved in the definition and supervision of the PhD research programme.

Meanwhile, in the context of the ONDRAF/NIRAS research programme for geological disposal to examine potential host formations for HLW disposal, several PhD programmes investigating the thermo-hydro-mechanical-chemical behaviour of Ypresian clays are underway and are being co-supervised by EIG EURIDICE.

CIMNE (Universitat Politècnica de Catalunya, Barcelona (UPC), Spain)

Financed directly by ONDRAF/NIRAS, a new PhD project on the "Laboratory investigation of gas transport processes in Boom Clay" started at the end of 2012. EURIDICE is involved in supervising the project.

This research will focus on a more systematic examination of the gas transport mechanisms and breakthrough processes in Boom Clay at different orientations and stress states (and stress history) using special cells under controlled pneumatic, hydraulic, mechanical and thermal boundary conditions. Simulation-aided techniques (numerical models) will complement the interpretation of these "small-scale" tests in order to make more effective use of the information provided by the measurements and gain a better understanding of coupled processes affecting the response of the material.

IRSM (Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, Wuhan, China)

The project "Research on long-term coupled thermo-hydro-mechanical (THM) behaviour of the Boom Clay" aims to investigate the effect of temperature on the creep and self-sealing capacity of the Boom Clay and to gain knowledge and information for simulating the PRACLAY Heater test. This project started at the end of 2011.

In order to obtain reference data on the effect of temperature on hydro-mechanical behaviour, a series of short-term tests under well-defined THM loading paths were performed as per the test programme. For this purpose, the double linkage HM triaxial test equipment, developed as part of the previous IRSM-EURIDICE cooperation project, was updated by adding the heating system to enable the temperature-controlled triaxial tests to be performed (Figure 32).

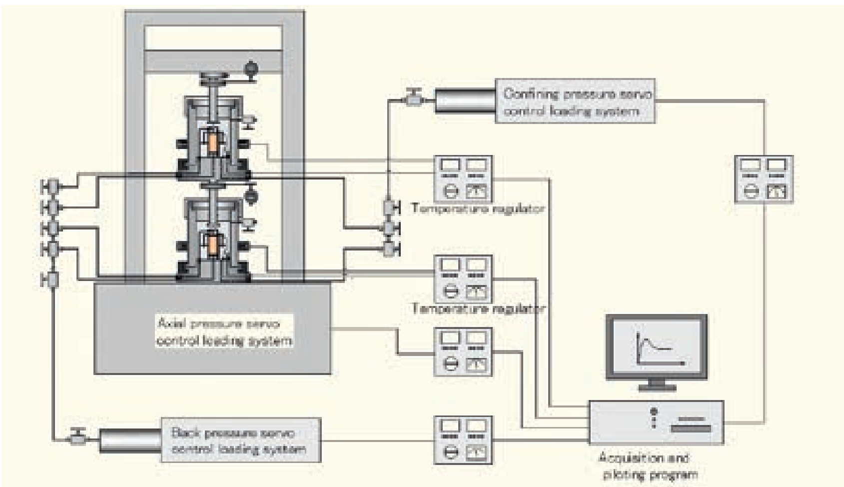


Figure 32 Schematic diagram of the updated double linkage THM triaxial cells

The following observations were made based on the first experimental results obtained during 2012: with the same hydro-mechanical boundary conditions, the shear strength of the Boom Clay decreases by 22%, while the temperature increases from 22°C to 80°C under the confining pressure of 3.7 MPa (Figure 33). Cohesion tends to decrease as the temperature increases from 22°C to 60°C.

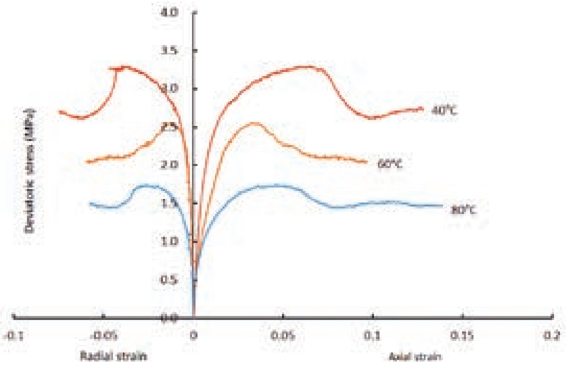


Figure 33 Stress-strain relationship at different temperatures (confining pressure s_3 = 3.7 MPa, back pressure u = 1.2 MPa)

Moreover, in order to investigate the damage process of the natural Boom Clay and to validate the "transversal isotropic elasto-plastic-damage model", undrained triaxial tests with several loading/unloading cycles were performed. An example is given in Figure 34 from which the damage process (for example, Young's modulus evolution with deformation) can be identified according to the proposed constitutive model.

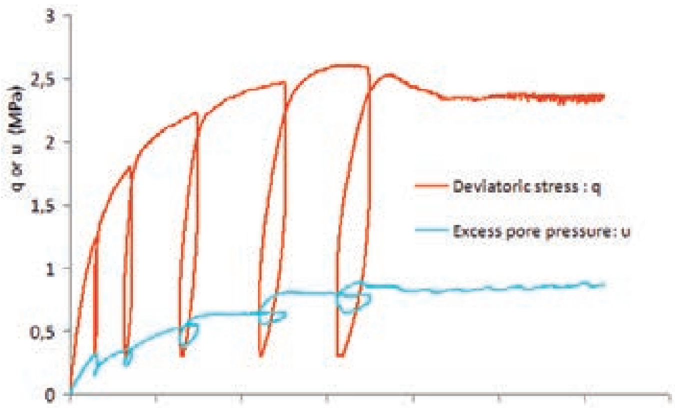


Figure 34 Undrained loading-unloading triaxial test (s_3 = 3.7 MPa, pw = 1.2 MPa, T = 60°C)

Finally, during 2012, numerical work has progressed. A 3D finite element model has been developed in which the PRACLAY gallery is included (Figure 35).

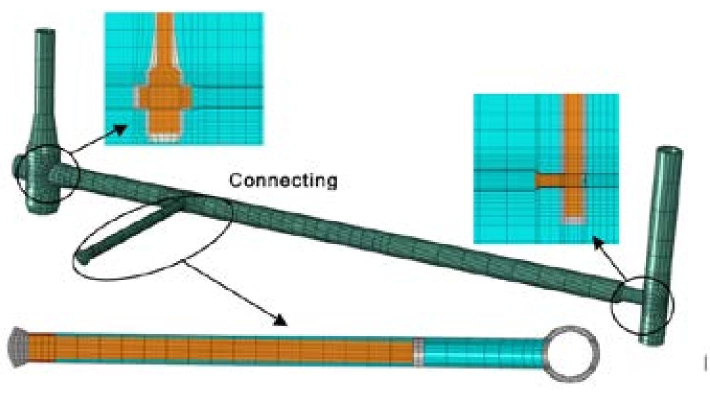


Figure 35 Finite element model of HADES URL

CERMES (Centre d'Enseignement et de Recherche en Mécanique des Sols, France)

THERMO-HYDRO-MECHANICAL-CHEMICAL (THMC) BEHAVIOUR OF YPRESIAN CLAYS AND BOOM CLAY

In 2010 a three-year PhD research programme on "THMC behaviour of Ypresian clays", financed directly by ONDRAF/NIRAS and co-supervised by EURIDICE, was started at CERMES. This PhD thesis forms part of the ONDRAF/NIRAS research programme to examine other potential host formations for high-level waste disposal. The focus is on fundamental THM behaviour characterisation by means of laboratory tests. More attention is paid to the pore water chemistry effects on THM behaviour. In order to provide input for the knowledge transferability study of different clay formations, comparative tests on Boom Clay (on the samples taken from HADES and from the Essen borehole) are also being performed for this PhD thesis.

The microstructure of both clays in their "natural" state was first studied and compared by means of mercury intrusion porosimetry (MIP) and scanning electron microscopy (SEM). The volume change behaviour was studied in both intact and reconstituted states, and under different conditions: under oedometric and isotropic loading, and under loading/unloading loops. The results show that the volume change behaviour is governed by the competition between the physico-chemical effect and the mechanical effect, characterised by a threshold stress that corresponds to the swelling stress in terms of structure changes (Figure 36). A constitutive law was developed to describe this aspect. The permeability was determined, compared with the results in the literature and correlated with parameters such as void ratio. The variation in permeability with depth shows the important role of macro-pores in fluid transfer. The volume change behaviour and permeability of intact Boom Clay and Ypresian clays are also influenced by changes in pore water chemical composition, which modify the diffuse double layer and give rise to the aggregation of clay particles. The elastic parameters, yield curve and failure envelope of Boom Clay and Ypresian clays were identified (Figure 37 and Figure 38). A conceptual elasto-plastic model was developed, accounting for the swelling effects and the competition between the physico-chemical effect and the mechanical effect.

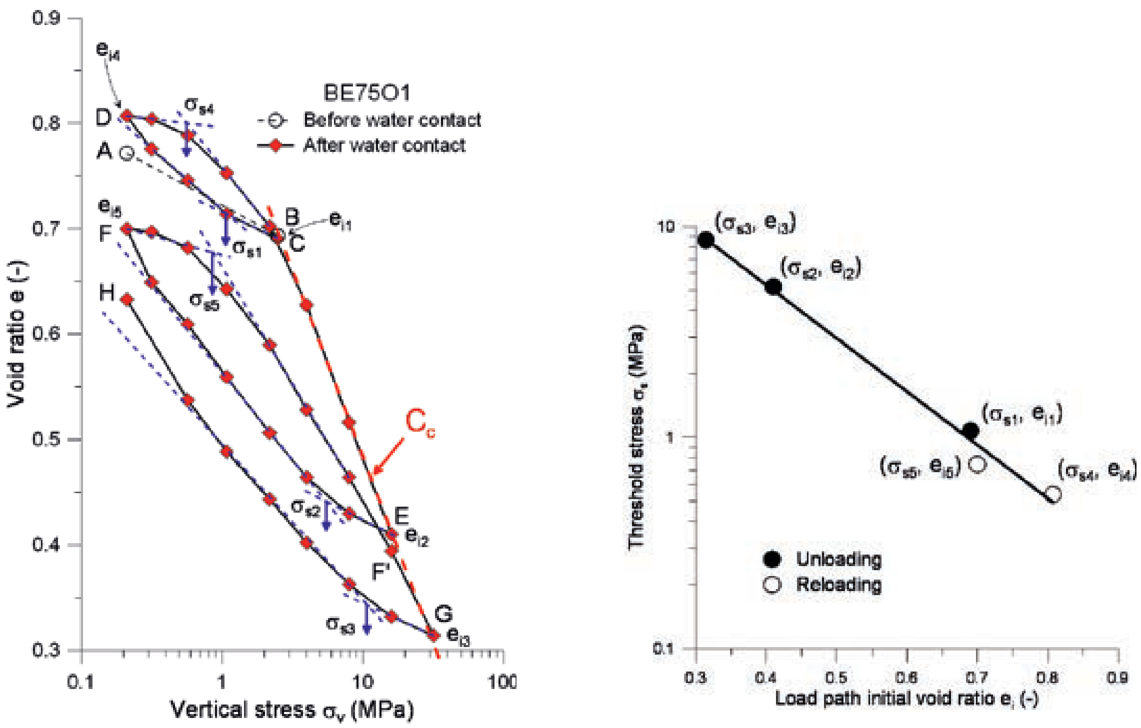


Figure 36 Swelling stress identification (on the Boom Clay sample taken from the Essen borehole)

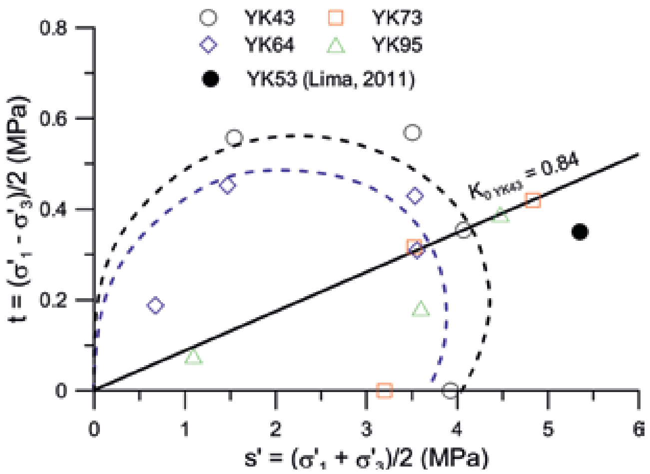


Figure 37 Yield curves for Ypresian clays

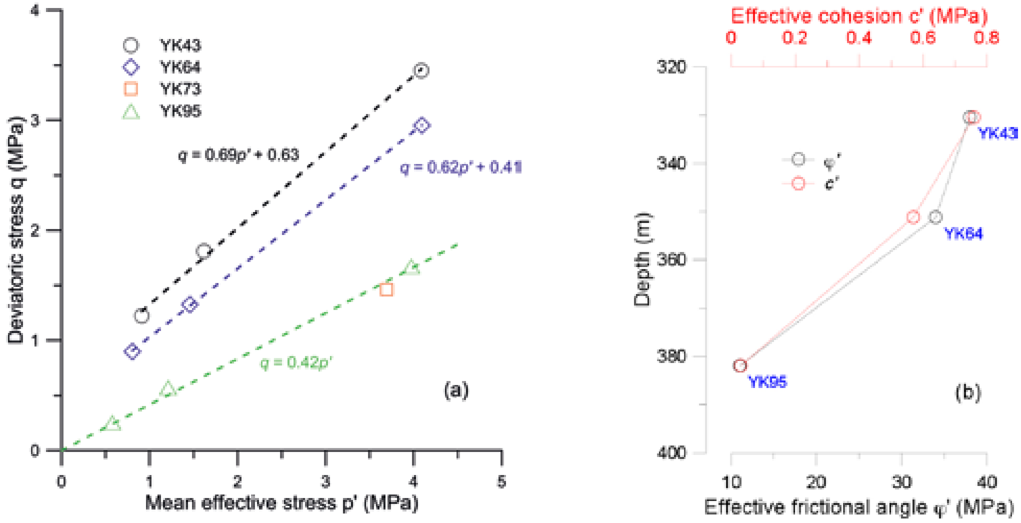


Figure 38 Failure envelopes (left) and shearing strength parameter profiles (right)

The PhD thesis entitled "study of the chemo-hydro-mechanical behaviour of stiff clays in the context of radioactive waste disposal" written by NGUYEN Xuan Phu (in French) will be defended in March 2013.

INVESTIGATION OF ANISOTROPIC BEHAVIOUR OF BOOM CLAY

A new PhD research programme entitled "Investigation of anisotropic behaviour of Boom Clay" started at CERMES at the end of 2011. The European Commission's TIMODAZ project has already highlighted the important anisotropic THM behaviour of Boom Clay and revealed the need for further investigation. This PhD programme comprises three parts:

1. Literature review
2. Experimental study
   - anisotropic hydraulic conductivity determination
   - anisotropic thermal conductivity determination
   - Ko determination (ratio of effective stress to vertical stress)
   - mechanical anisotropy in triaxial cells equipped with bender elements and/or ultrasonic sensors
   - microstructure investigation: initial state and its evolution under different loading paths
3. Constitutive modelling

The thermal conductivity of Boom Clay samples taken from a horizontal borehole in HADES at different depths from the gallery wall (L) was measured by means of a thermal needle probe placed in three directions (samples inclined at 0°, 45° and 90° to the bedding) (Figure 39). The results obtained are shown in Figure 40, from which several remarks can be made: firstly, the thermal conductivity parallel to bedding ($\lambda_{//}$) is higher than that perpendicular to bedding ($\lambda_{\perp}$), with a ratio of $\lambda_{//}$ to $\lambda_{\perp}$ of about 1.5 – 1.7. Secondly, the lower values of thermal conductivity in the zone close to the gallery can be attributed to the effect of the excavation-damaged zone (EDZ), which extends about 2 m from the gallery lining, according to these results.

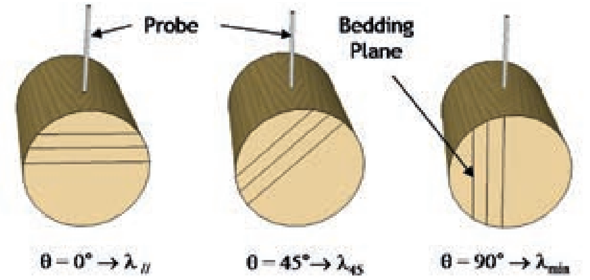


Figure 39 Directions of thermal needle probe to investigate the anisotropy of thermal conductivity

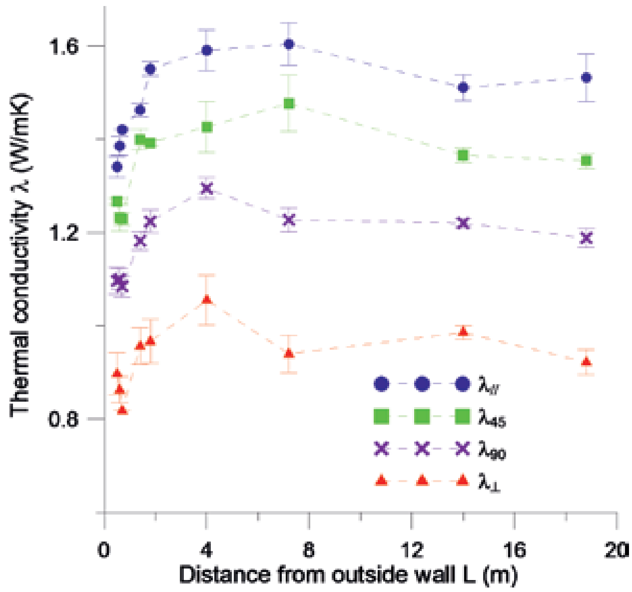


Figure 40 Variation in thermal conductivity with distance from the gallery wall ($\lambda_{\perp}$ is calculated from $\lambda_{//}$ and λ_{90})

The anisotropic hydraulic conductivity of Boom Clay was confirmed by means of the high-pressure oedometer tests performed on samples cored in the different directions with respect to the bedding. However, there is no significant anisotropy in compressibility observed in the test results obtained. Further investigation of mechanical anisotropy is ongoing.

ULg (University of Liège, Belgium)

A new PhD research programme on the EDZ started at the end of 2011 at ULg, focusing on the numerical simulation of the EDZ structure and fractures, based on the strain localisation concept and on short-term behaviour. The challenge will be to reproduce, at least partly, the in-situ observations – displacements, pore pressure evolution, fractures – around recent galleries in HADES. This thesis is financed directly by ONDRAF/NIRAS and will be supervised jointly by EIG EURIDICE and SCK•CEN.

During 2012, firstly triaxial tests on Boom Clay were modelled in order to determine the important parameters (cohesion, dilatancy angle, hardening/softening properties) in the strain localisation of Boom Clay. Afterwards a numerical sensibility analysis of an academic biaxial compression test was realised with a focus on the strain localisation phenomena. This academic test was used since there are no experimental results of biaxial compression tests on Boom Clay. Finally, a first model of the PRACLAY gallery excavation was completed in order to study numerically the development and the characteristics (length, thickness) of the shear bands in fully saturated conditions by considering hydro-mechanical coupling of Boom Clay.

DUT (Dalian University of Technology)

EURIDICE established a scientific cooperation programme with DUT (Dalian University of Technology, China) in 2012 on the "experimental and numerical investigation of the effect of anisotropy of Boom Clay in the EDZ process". The experimental work will be performed in the DUT laboratory, while the numerical part will mainly be carried out by the DUT PhD student (Liu ShiYi), who has received a scholarship from the Chinese government to work at EURIDICE for two years (June 2012 until June 2014). This PhD research will be carried out with financial support from DUT. EURIDICE will provide the Boom Clay samples and supervise the research.

The numerical approach will be based on the finite element (FE) approach combined with the limit equilibrium (LE) method to estimate the conditions and geometry of the fractures induced by excavation.

First, a two-dimensional (2D plane strain) numerical analysis of the excavation of the Connecting gallery has been performed using the commercial FE code "ABAQUS" and an auto-developed LE code STABFEM2D, considering isotropic material behaviour. The fracture pattern obtained numerically is compared with in-situ observations. This preliminary investigation has already highlighted that the anisotropic stresses play an important role in the generation of induced fractures.

In order to consider the effect of anisotropic hydro-mechanical properties of Boom Clay on EDZ generation, a hardening/softening Mohr-Coulomb model considering elastic and plastic cross-anisotropy has been developed and implemented in the ABAQUS code. This anisotropic model is under validation by modelling the laboratory tests.

3. Participation in international research projects

3.1. European Commission projects

TIMODAZ

TIMODAZ officially ended in 2010. As coordinator of the project, EURIDICE – with help from NAGRA and ULg – successfully organised the international post-TIMODAZ workshop on 6 and 7 February 2012 in Mont Terri, as defined in the final dissemination plan of the project. The workshop attracted more than 60 participants and contributions from all over the world, including the United States, Canada, Japan and China. More than two-thirds of the participants were not involved in the TIMODAZ project.

Together with ENPC (France), EIG EURIDICE is also editing a special issue in "Rock Mechanics and Rock Engineering" (Springer, WoS referenced) on the topic of "Thermo-Hydro-Mechanical effects in clay host rocks", which will be published in March 2013.

FORGE

In 2012 EURIDICE continued providing support and follow-up for the FORGE (Fate of Repository Gases) instrumented megapackers. The packers were installed in 2011 under the European FP7 Forge project Work Package 4, which deals with gas transport in-situ tests. The aim of these tests is to simulate on a relatively large scale the expected sequence of phenomena in a medium-level waste (MLW) repository that could lead to gas-driven radionuclide transport.

The large borehole needed for the installation of the packers intercepted a number of septaria and pyrite layers during drilling (2011), which caused difficulties for both the drilling operations and the installation of the packers. The last layer intercepted by the drilling was a large pyrite zone near the end of the borehole. The borehole caved in while drilling through the pyrite zone, causing the drill head to jam. It eventually took eight hours to free the drill head. The efforts needed to free it significantly damaged the borehole, however. One example of the damage was the creation of a large cavity at the end of the borehole. Another was a deviation in both its dip and targeted alignment.

Since the installation the packers have experienced inflation pressure losses, which are thought to be related to leakage in the packers. EURIDICE is working with the packer manufacturer (Solexperts, CH) to seek a solution to the problem and to attempt to stop any further leakage. A first test was performed in Switzerland using a special solution designed to clog potential leakage pathways in the packers. However, this test was not successful due to the difficulty in pumping the product through the narrow injection tubing of the packers. The manufacturer is looking at the possibility of adapting the solution for further testing.

MoDeRn

EURIDICE contributes to the MoDeRn project ("Monitoring Developments for safe Repository operation and staged closure"), a collaborative project co-funded by the European Commission (EURATOM – FP7 – 232598). The project runs from 1 May 2009 to 31 October 2013 (4½ years) and involves 18 partners from 12 countries. ANDRA is coordinating the project. The aim is to provide a framework for the development and possible implementation of near-field monitoring activities and associated stakeholder engagement during relevant phases of the radioactive waste disposal process.

The different Work Packages (WPs) that were defined in this project cover the various approaches to the monitoring issue: scientific-technological developments, demonstration of some selected monitoring techniques under representative conditions and scale, the relevance of monitoring for the different stakeholder groups (including regulators and “lay” stakeholders), and the development of the monitoring strategy into detailed cases (in a salt, hard rock and clay host formation).

The first WP provides a starting point for further monitoring considerations and addresses objectives and strategies, integrating both technical and social developments relevant to the topic. In 2012 the main activity in this WP dealt with the interaction with local and other stakeholders in discussing monitoring issues – and how to put this into practice. An exploratory engagement activity was set up by the WP leader, Antwerp University, with local stakeholders (volunteers from MONA and STORA). The activity consisted of three evening workshops, a site visit to the Swiss URLs (Grimsel Test Site and Mont Terri) and a feedback meeting. EURIDICE participated in this activity as a technical expert. We presented some practical monitoring examples so that the stakeholders had an idea what monitoring was all about (what is monitored and how to deal with data, etc.), and provided technical explanations about the monitoring applications that were shown.

The second WP covers research and technical development activities by different partners. Here, EURIDICE is focusing on fibre optic sensors and on monitoring of cementitious materials. With regard to fibre optic sensors, some custom-made sensors have been developed, specifically sensors for distributed sensing (temperature in the PRACLAY gallery) and Bragg gratings for local strain monitoring. In relation to cementitious materials, innovative monitoring techniques considered include digital image correlation (DIC) for crack detection/characterisation, and different methods for corrosion monitoring. Most of this work is carried out in the context of the Supercontainer feasibility tests (see section 1.2.2.).

The third WP is devoted to the demonstration of some selected monitoring techniques in representative conditions. EURIDICE assesses the performance of some commercially available fibre optic extensometer probes (installed in boreholes around the PRACLAY gallery, as well as inside the gallery to monitor axial deformation), and also a more experimental fibre (installed in the PRACLAY gallery) for distributed sensing of temperature. Additional signal interpretation has also been performed on the seismic monitoring set-up around the PRACLAY gallery to obtain more information from shear waves, for example. This activity also included the development and production of a prototype of a seismic hammer.

The development of different monitoring cases is the subject of the fourth WP. EURIDICE’s contribution covered items such as the selection of parameters based on a safety case, monitoring principles, sensor location and monitoring phases with regard to the different phases of a repository.

EURIDICE participated in two workshops (progress meetings), one in Turku (Finland) and the other in Saint-Ursanne (Switzerland). The results of the work carried out as part of this project were also presented at the 2012 Waste Management conference (Phoenix, USA).

3.2. Other International collaborations

ANDRA (Agence Nationale pour la Gestion des Déchets Radioactifs)

EURIDICE was invited by ANDRA (F) to the LUCOEX workshop in Bure (F) in September 2012. During this workshop, we presented our experience with the seal instrumentation to the other participants (ANDRA, NAGRA, SKB and Posiva – all partners in the LUCOEX project), who also reported on their own experience in different experimental set-ups.

NAGRA (Nationale Genossenschaft für die Lagerung radioaktiver Abfälle)

EURIDICE was invited by NAGRA (CH) and NUMO (J) to a workshop entitled "Defining and implementing Large-Scale Demonstration Experiments", which took place in Switzerland on 14-15 November 2012. During this workshop, EURIDICE gave a presentation on "The PRACLAY experiment at the HADES URL".

IRMM (Institute for Reference Materials and Measurements)

Since 1999, EIG EURIDICE has also delivered services for IRMM's long-standing operation of an ultra-low-level radioactivity lab in support of European Commission policies in the fields of, for example, international standardisation, radioactive waste management and radioprotection. For this purpose, part of the HADES underground research laboratory has been leased to IRMM. The contract is a Service Agreement that can be extended every year, as was done in 2012.

At the end of 2011 this contract was amended to include the lease of extra space in the underground laboratory, on the southern side of shaft 2. During 2012 this extra space was used by IRMM specifically for the testing of high-purity germanium detectors for the GERDA double beta decay experiment (the so-called "Heroica" project).

4. Scientific Advisory Committee (SAC)

The Scientific Advisory Committee (SAC) of EURIDICE is composed of six external experts, three appointed by each of the two constituent members of EIG EURIDICE.

Appointed by SCK•CEN:

- Prof. Hans-Joachim Alheid, Scientific Director, BGR (Bundesanstalt für Geowissenschaften und Rohstoffe - Germany)
- Prof. Robert Charlier, ArGEnCo, GEO3, ULg (University of Liège - Belgium)
- Prof. Geert De Schutter, Magnel Laboratory, UGent (Ghent University - Belgium)

Appointed by ONDRAF/NIRAS:

- Prof. Noel Vandenberghe, Geology Department, KU Leuven (Belgium)
- Dr Piet Zuidema, Division Head, NAGRA (Nationale Genossenschaft für die Lagerung radioaktiver Abfälle - Switzerland)
- Gilles Armand, geomechanical engineer at the Meuse/Haute-Marne underground research laboratory / Head of Fluid and Solid Mechanics Department at the French National Agency for Radioactive Waste Management (ANDRA - France)

The internal rules of the SAC were modified in 2012 in order to extend its activities to all RD&D tasks of EIG EURIDICE (General Assembly, 23 April 2012).

During 2012, two meetings with the Scientific Advisory Committee were organised, focusing on the PRACLAY in-situ experiments. The EURIDICE scientific team presented an update on the PRACLAY project at each of these.

Discussions mainly focused on the following aspects:
- Heterogeneity of the seal swelling;
- Difficulties regarding prediction of the saturation time of the seal;
- Performance of some sensors.

Risk analysis of the PRACLAY seal and possible contingency plans remained important topics of discussion.

In the course of 2012, the SAC members reviewed the report on "The design and installation of the PRACLAY in-situ experiment". Their feedback was incorporated into the final version of the report. On this occasion, the SAC members once again highlighted the importance of knowledge management for the PRACLAY experiments: reporting, use of the logbook, etc.

The SAC members also emphasised the importance of a critical mass of researchers in all EURIDICE R&D fields and underlined the necessity to enhance the manpower of the scientific team in specific areas, taking into account the scale and complexity of the project.

5. Programme committee for underground experiments (POP)

During 2012, the rules and statutory status of POP (Programme committee for underground experiments) were reviewed and updated. The new POP rules were approved by the General Assembly on 23 April 2012.

In the course of 2012, on the basis of the RD&D plan of ONDRAF/NIRAS (in preparation), the POP members carried out a preliminary analysis of the existing experiments: which issues in the R&D plan have been/have not yet been studied in which experiments? It was decided to draw up a detailed inventory of all in-situ experiments (both ongoing and finished) and input them into the GSIS system.

Moreover, the need for a drilling core management procedure and database was discussed by POP. An approach is established to make it possible to track the clay samples sent to third parties and to maintain the link between core samples and the research results though the GSIS system.

6. Management & exploitation of installations

GENERAL

The Statutory Rules define the tasks of EIG EURIDICE concerning the management and exploitation of the installations on the land for which EIG EURIDICE holds a building lease. In 2012 these tasks were properly performed.

The exploitation team continually supports R&D activities in different projects:

- connection of monitoring devices to the data-logging system in HADES;
- re-installation of the steel reinforcement structure and beams (used in the past as a support to start the excavation) at the crossing of the Connecting gallery with the PRACLAY gallery (cf. 1.2.1);
- placement of prisms on the seal and on the PRACLAY gallery lining to be able to monitor any movement of the seal (cf. 1.2.1);
- drilling operations to take Boom Clay core samples, etc.

The exploitation team delivered services related to experiments for the cAt project, such as in-house preparation of the data-acquisition system, installation of instrumentation on site, support, etc. Besides this, requisite maintenance on machinery, site and infrastructure was performed in accordance with the operating licence and applicable legal and regulatory requirements and in line with the ISO 9001:2008 standard. Finally, the necessary support for guiding visitors through the underground laboratory was provided throughout 2012.

To continuously improve reliability and ensure that knowledge is shared in-house, the operation manual is kept updated. This manual contains instructions on how to operate the installations, how to deal with problems, how to remedy breakdowns, how to replace parts, etc. Linked to this operation manual, more and more ideas have been put forward concerning the use of a uniform maintenance log. These ideas will be worked out in 2013.

UNDERGROUND INSTALLATIONS AND ASSOCIATED HOISTING SYSTEMS

The exploitation team and/or AIB Vinçotte carried out the necessary checks on the shafts, cables, hoisting equipment, etc. There were no major defects found. Some minor interruptions in the hoisting systems, shafts, etc. were resolved without creating major problems.

The few problems that occurred during operation were all resolved within an acceptable period of time. Some components became increasingly worn and were replaced in order to avoid further inconvenience.

In 2011 it was decided to start investigating the possibility of renewing the hoisting system of shaft 1. We had planned to launch a public tender in 2012, but were unable to adhere to this schedule due to some ambiguities concerning applicable regulations. We decided to embark on a predesign study of the various hoisting system options and corresponding regulations. This study will be performed by DBE and should help us to reach a better decision on what kind of hoisting system we need in the future and provide an answer regarding which regulations we have to comply with (checks, controls, regulations, etc.), in order to obtain a safe and reliable system.

The ventilation system of shaft 1 was also worn. In the second half of 2012 the old system was disconnected and dismantled. The concrete floor was renewed, and a new ventilation system installed. Some tests were performed at the end of 2012 and the unit can be brought into service at the beginning of 2013. To ensure safe conditions in the underground lab while the work was under way, we refreshed the air using a back-up ventilation system while the main ventilation system was inoperative.

Other standard maintenance and repair work on the hoisting systems, shafts and galleries was performed by the exploitation team in 2012. From time to time, some clean-up activities were undertaken in the HADES URL.

ABOVE-GROUND INSTALLATIONS AND BUILDINGS

The exploitation team carried out standard maintenance and necessary repairs on installations, buildings and infrastructure in 2012.

A clean-up operation was initiated not only underground, but also in the above-ground installations in 2011. This continued in 2012 and also became part of the preparations for the future renewal work on the hoisting system of shaft 1.

Due to new security regulations for nuclear sites and with the aim of being able to welcome visitors more easily, we began to look at the possibility of creating a new visitors' entrance. The main outcome of this exercise is a report that will be presented to the General Assembly early in 2013 to enable a decision to be made on whether to create a new entrance and, if so, which option best suits EIG EURIDICE.

LICENCES

The operating licence is valid until 2024. Nothing changed in this respect in 2012. Jef Leysen was appointed the new Operations & Safety Manager on 29 March 2012.

The nuclear licence of EIG EURIDICE will remain valid until 2021 (in effect from August 2006). All inspections and checks under this licence were carried out by BEL V.

In 2012 EIG EURIDICE continued with the preparations to apply for an environmental licence: inventories were drawn up, old and unusable products were removed from the site, etc. We plan to apply for the licence in 2013.

7. Specific support for the repository technology study of ONDRAF/NIRAS

EURIDICE also supports ONDRAF/NIRAS in its R&D technical feasibility programme of geological disposal. This programme aims to demonstrate the construction and operational feasibility of the proposed concept for geological disposal and the repository design. The next programme milestone is the Safety and Feasibility Case (SFC-1).

The studies under the R&D feasibility programme are subdivided into the following topics:
- fabrication of the waste disposal packages
- construction of the underground repository
- operation and closure of the underground repository

EIG EURIDICE is involved in research on the fabrication of the waste disposal packages through its contributions to the experimental programme on the supercontainer (cf. 1.2.2).

Further support included participation in the research project meetings and review of the reports produced by the project partners.

8. Support for Safety and Feasibility Case 1 of ONDRAF/NIRAS

EIG EURIDICE supports the development of ONDRAF/NIRAS' first Safety and Feasibility Case (SFC-1) with its expertise in the thermo-hydro-mechanical (THM) behaviour of Boom Clay and Ypresian clays.

This also involved supervising several PhDs on the THM behaviour of both clay formations (cf. 2.2).

EIG EURIDICE is also responsible for the synthesis report on the evolution of the disturbed zone around a deep repository for high-level and/or long-lived waste in a clay layer. This report is part of the set of documents supporting ONDRAF/NIRAS' SFC-1.

Activities: PART II

The surface disposal programme for category A waste - cAt Project

Introduction

On 23 June 2006 the Belgian federal government decided that the long-term management of category A waste should take the form of a surface disposal facility within the municipality of Dessel, situated in the northern, Flemish part of Belgium in the province of Antwerp. The government commissioned ONDRAF/NIRAS to carry out this integrated project – i.e. the cAt project. To fulfil its appointed task, ONDRAF/NIRAS works in close collaboration with the STORA and MONA partnerships it has with the municipalities of Dessel and Mol.

An important step in the successful completion of this project is the licence application that ONDRAF/NIRAS is submitting on 31 January 2013 to the Belgian nuclear regulator, the Federal Agency for Nuclear Control (FANC), for the surface disposal facility.

In preparation of the licence application, ONDRAF/NIRAS submitted its safety case to an international peer review by the NEA (Nuclear Energy Agency) in the period between the end of 2011 and mid-2012. The peer review concluded that, from an international perspective, ONDRAF/NIRAS' long-term safety strategy and safety assessment methodology are, in the main, credible and robust and that the disposal programme implements international recommendations and best practices, and is technically mature.

EIG EURIDICE supports the cAt project in the following areas:

- Calculations of the long-term radiological impact of the planned repository;
- Preparation and instrumentation of the planned test cover; and
- Instrumentation of the demonstration test for construction of concrete modules.

1. Radiological long-term safety assessments and quality assurance of models and codes

Radiological long-term safety assessments are a key part of the safety arguments presented in the construction and operating licence application.

In 2011 a broad range of radiological impact calculations was carried out. These calculations involved a sequence of three models: near-field models of the disposal facility, a hydrogeological model and a biosphere model. The models and their computer implementations were extensively qualified and verified before using the results in the licence application. In 2012 the calculations and their verifications were reported on in detail.

These impact calculations have all been based on conservative and envelope assumptions. A likely evolution scenario (LES) has been developed in order to illustrate potential safety margins if more likely assumptions are taken to represent the broadly expected evolution of the disposal system. Calculations with this LES have shown that the maximum radiological impact is 0.001 mSv/year. This is several orders of magnitude below the regulatory dose constraint of 0.3 mSv/year and the dose due to natural sources, which is about 2.1 mSv/year in Flanders. This shows that the surface disposal system at Dessel is radiologically optimised and that long-term radiological impacts will only be a fraction of natural exposures.

Further supporting work for the safety assessments included completeness checks of the scenarios and models with the help of a list of FEPs (features, events and processes) and the documentation of the treatment of uncertainties, as well as justification of the assessment cases considered in the radiological impact calculations.

In 2013 a second version of the reports on FEPs and uncertainty management will be prepared and will be used as input for defining the research, development and demonstration needs for the further category A waste disposal programme. Other work in 2013 will include providing support to ONDRAF/NIRAS in answering questions from FANC on the licence application, and in conducting additional supporting sensitivity calculations as part of these answers.

2. Test cover

After placing waste in a surface-type disposal facility for several decades, a multi-layer cover is installed on top of the disposal modules, with the aim of reducing water infiltration into these modules so as to limit degradation through leaching of the underlying components and to limit leaching of radionuclides from the facility. In the meantime, a long-term test cover programme has been developed to gather information on the technical aspects and the dynamics of a multi-layer cover; the experience gained will form a solid basis for building confidence and experience with multi-layer cover systems to be used in the design, construction and monitoring of the final tumulus.

The technical report entitled “Final cover – Test cover: Design and Implementation”, one of the supporting documents for the licence application, was published in 2011 (NIROND-TR 2011-79 E V1 September 2011).

In 2012 an instrumentation plan for the future test cover was devised by EIG EURIDICE, together with ONDRAF/NIRAS and Tractebel Engineering. A programme subsequently got under way to test the robustness and reliability of the instrumentation under the expected conditions in the test cover. This test programme began under laboratory conditions, with the calibration of time-domain reflectometry (TDR) probes. Prototypes of spatial TDR probes were ordered and tested. The last step of this phase is the implementation of the instrumentation into two experimental set-ups consisting of two 1 m high tumuli composed of sand and clay. In these set-ups, sand and clay will be compacted with the same type of compactor that will be used for the test cover. This will allow the robustness of the instrumentation to be verified before it is implemented in the test cover. This work is planned for early 2013, so that later in the year the technical specifications for construction of the test cover can be drawn up and the tendering process for its construction can start.

3. Demonstration test

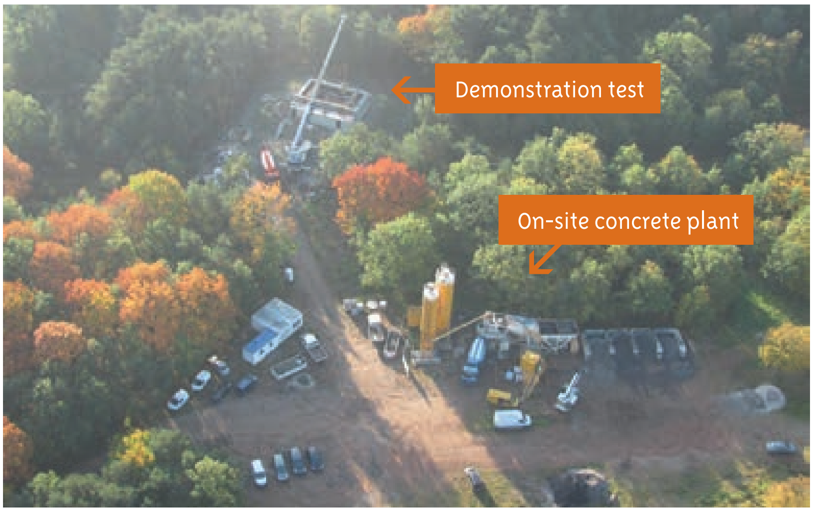


Figure 41 Overview of the demonstration test

In order to assess the technical feasibility of the module construction techniques and the industrial feasibility of the concrete that has been optimised for long-term safety and has been tested on a laboratory scale, a demonstration module construction test for the cAt project was set up and carried out (Figure 41).

EIG EURIDICE, together with ONDRAF/NIRAS and Tractebel Engineering, devised an instrumentation plan for assessing the temperature and stress conditions within the concrete used in the demonstration test.

In 2011 the test module and two test panels were built by ONDRAF/NIRAS and instrumented by EIG EURIDICE. A third panel was built in 2012 and was also instrumented by EIG EURIDICE. Vibrating wire strain gauges and formwork pressure sensors were installed. Reporting on the results will continue in 2013.

Scientific output

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Van Marcke P., Li X., Chen G., Verstricht J., Bastiaens W., Sillen X.- *The PRACLAY Experiment.*- Clays in Natural and Engineered Barriers for Radioactive Waste Confinement.- Montpellier, France, 22-25 October 2012.- [Presentation]

Verstricht J., Dizier A., Bastiaens W., - *Long term loading of the gallery lining in a clay host rock.*- Clays in Natural and Engineered Barriers for Radioactive Waste Confinement.- Montpellier, France, 22-25 October 2012.- [Poster]

Wang Q., Tang A., Cui Y., Li X.- *Microstructure Features of Compacted MX80 bentonite Used for Hydraulic Seal in PRACLAY Heater Test.*- Clays in Natural and Engineered Barriers for Radioactive Waste Confinement.- Montpellier, France, 22-25 October 2012.- [Poster]

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Communication & general management

1. Communication

Communicating about its activities is one of EIG EURIDICE's main tasks. The HADES underground research laboratory (URL) is a powerful tool for explaining the concept of geological disposal and is a perfect starting point to present and explain the research that has been going on for the past 30 years.

To ensure consistency in communication messages and strategies, it is important for all communication activities to be discussed with and agreed upon by both SCK•CEN and ONDRAF/NIRAS. This is mainly managed through the Communication Committee's meetings with ONDRAF/NIRAS and SCK•CEN communication managers.

MEDIA COVERAGE

During 2012, there was almost no media coverage directly reporting on the activities of EIG EURIDICE. On 28 February the VRT news service covered the long-term management of radioactive waste for "Koppen", including filming in the HADES URL and interviews with the Director of EIG EURIDICE, Peter De Preter, and ONDRAF/NIRAS' Communication Manager, Sigrid Eeckhout. The documentary was broadcast on 8 March.

PUBLICATIONS FOR A WIDE AUDIENCE

A special publication on the PRACLAY experiment has been available since September 2012, focusing on the stepwise approach of the experiment, the preparatory work, the status as of 2012 and the next phase of the experiment (Figure 42).

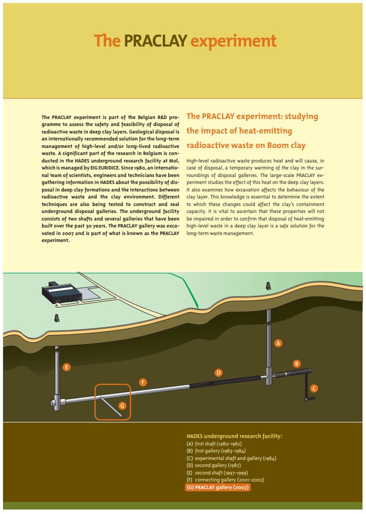


Figure 42 Special publication on the PRACLAY experiment

VISITS

Anyone over the age of 18 can visit EURIDICE and the underground research laboratory in small groups. Sociocultural organisations are looked after by trained guides, who also lead visits at ISOTOPOLIS. Experts on geological disposal, journalists, university students with a scientific background and key political and economic figures are given a guided tour by scientific personnel, the Communication Manager and/or the Director of EURIDICE, sometimes accompanied by ONDRAF/NIRAS or SCK•CEN management.

In 2012 EIG EURIDICE welcomed 1,695 visitors to the HADES URL and the above-ground exhibition on geological disposal; 48 of the 112 visits (925 of the 1,695 visitors) were led by trained tour guides. Of the 112 visits, 66 were Dutch-speaking, 30 English-speaking and 16 French-speaking. At the end of their visit, visitors are asked to give feedback by means of an electronic questionnaire. Overall, people are very positive about their visit to EIG EURIDICE, the quality of the guides and the high standard of the research. They are especially impressed by the tour of the HADES URL. After going underground, people have a more realistic view of what an actual repository might look like.

Besides continual interest from universities offering geological or engineering courses, there was marked interest from politicians. Both the Minister of Economic Affairs, Johan Vande Lanotte, and the State Secretary for the Environment, Energy and Mobility, Melchior Wathelet, visited EIG EURIDICE on 25 July and 3 October respectively (Figure 43).

Figure 43 Visit by Minister of Economic Affairs Johan Vande Lanotte (left) and State Secretary for Energy Melchior Wathelet (right)

The exhibition in the demo hall was upgraded during 2012, the most important new features being two new modules, one on the characteristics of clay and the other on the time perspective of geological disposal (Figure 44).

The module on “Clay” shows visitors the low permeability of clay, its plastic behaviour and sorption of radionuclides and explains how these characteristics are favourable for the safety of a geological repository for the long-term management of radioactive waste. The module on “Time” explains to people that several hundreds of thousands of years of isolation in a deep repository are relatively short compared to the geological stability of Boom Clay during the past several million years.

Figure 44 Upgrade of the demo hall with a module on clay (left) and the geological time perspective (right)

The year 2012 also featured a new introductory film for visitors, explaining the origin of high-level and long-lived radioactive waste and the concept of geological disposal, as well as short films on the excavation history of HADES and clay characteristics.

WEBSITE

After a kick-off meeting at the end of 2011, preparations got under way for the design of the new website. In the spring the wireframes for the different types of content pages were developed by ONE Agency and Bailleul Ontwerpbureau, followed by the design and the look & feel. Over the summer, the content was developed. A first version of the website was presented during the November meeting of the Board. At the end of 2012, a meeting was planned to discuss the feedback from the management of ONDRAF/NIRAS and SCK•CEN.

SCK•CEN OPEN DAYS

During the SCK•CEN open days on 11, 12 and 13 May, 1,600 people were able to visit an exhibition on research into the long-term management of radioactive waste. A poster session together with several installations gave a brief overview of the research activities of EIG EURIDICE, the Waste and Disposal expert group and the Performance Assessments unit. Due to the large number of visitors, it was not possible to visit HADES. Instead, a video link was set up to give people a look at the underground laboratory. By correctly estimating the travel time to and from the laboratory, 10 people won a guided tour of HADES, which took place on 19 December.

2. Personnel

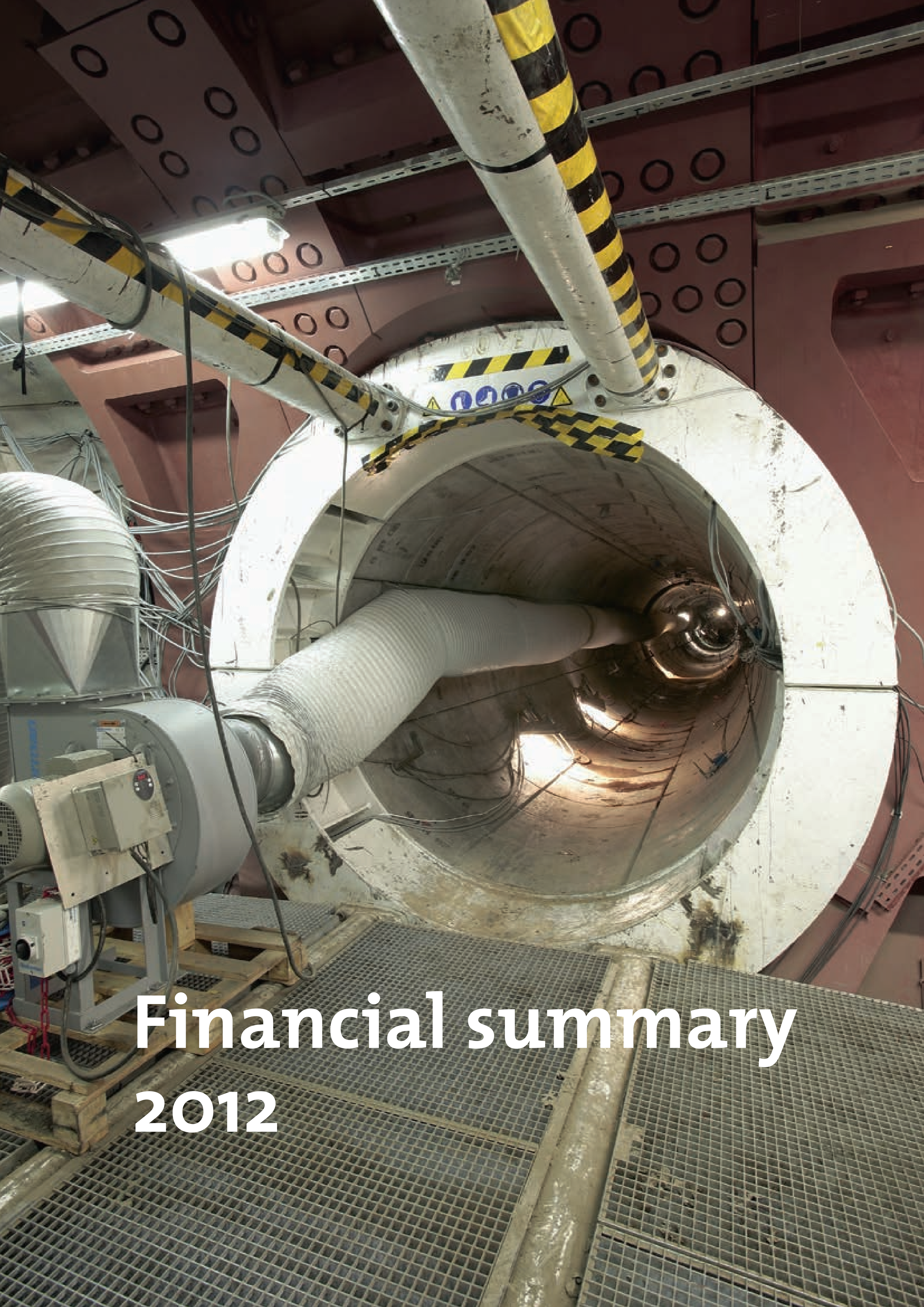
Under its Statutory Rules, EIG EURIDICE has no employees of its own. Personnel working for EURIDICE are under contract to either SCK•CEN or ONDRAF/NIRAS and have operated as the EURIDICE team since 2000, based at the EURIDICE site.

As of 1 January 2012, the EURIDICE team consisted of 15 members. SCK•CEN recruited two new staff members for EURIDICE during 2012. Dr Arnaud Dizier, a geological engineer, took up his post at EIG EURIDICE in March, mainly working on numerical modelling of the in-situ tests. Joannis Troullinos, who has a Master's degree in Chemical Engineering, was recruited in July to support Jan Verstricht in instrumentation & monitoring.

During 2012, SCK•CEN started a recruitment process seeking personnel with technical expertise in instrumentation & monitoring for EURIDICE. The vacancy was published at the end of 2012.

3. Quality Management

Since 2007, EIG EURIDICE has been ISO-certified according to the ISO 9001:2008 standard for Quality Management. An external audit took place on 16 February 2012. There were no major or minor comments. On 18 December 2012 ONDRAF/NIRAS performed a yearly internal audit. No non-conformities were found.



Financial summary 2012

Balance sheet (EUR)

	2012	2011
Amounts receivable within 1 year	1,105,754	1,317,039
Commercial debts receivable	*996,860*	*1,237,924*
Other debts receivable	*108,894*	*79,115*
Cash at bank and in hand	1,018,142	984,557
Current assets	1,144	2,531
Total assets	**2,125,040**	**2,304,127**
Liabilities due within 1 year	2,125,040	2,304,111
Suppliers	*2,114,223*	*2,056,971*
Payments in advance	*5,849*	*247,140*
Additional amounts payable	*4,968*	*0*
Other tangible assets	0	16
Total liabilities	**2,125,040**	**2,304,127**
Company revenue	3,460,264	3,569,270
Turnover	*3,452,620*	*3,553,612*
Other operation income	*7,644*	*15,658*
Operating costs	3,461,414	3,571,602
Cost of services and various goods	*3,457,071*	*3,567,251*
Other operating charges	*4,343*	*4,351*
Financial revenue	1,733	3,351
Financial charges	223	516
Profit or loss on ordinary operation	**360**	**503**
Exceptional revenue	0	0
Exceptional charges	0	0
Pre-tax profit and loss	**360**	**503**
Taxes	360	503
Profit or loss for the finacial year	**0**	**0**

Lexicon

ANDRA	Agence Nationale pour la Gestion des Déchets Radioactifs (FR)
ASC	Applied Seismology Consultants (UK)
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe (DE)
BRIUG	Beijing Research Institute of Uranium Geology (China)
CERMES	Centre d'Enseignement et de Recherche en Mécanique des Sols (FR)
CIMNE	Centro Internacional de Métodos Numéricos en Ingeniería (ES)
CNNC	China National Nuclear Corporation (China)
CTU	Czech Technical University (CZ)
EC	European Commission (BE)
EDZ	Excavation-damaged zone
ENPC	Ecole Nationale des Ponts et Chaussées (FR)
EPFL	Ecole Polytechnique Fédérale de Lausanne (CH)
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit (DE)
IRMM	Institute for Reference Materials and Measurements (BE)
IRSM	Institute of Rock and Soil Mechanics (China)
ITC	School of Underground Waste Storage and Disposal (CH)
KU Leuven	Katholieke Universiteit Leuven (BE)
NAGRA	Nationale Genossenschaft für die Lagerung radioaktiver Abfälle (CH)
NSFC	Natural Science Foundation of China (China)
ONDRAF/NIRAS	Belgian Agency for Radioactive Waste and Enriched Fissile Materials (BE)
NRG	Nuclear Research & Consultancy Group (NL)
RAWRA	RAdioactive Waste Repository Authority (CZ)
SCK•CEN	Belgian Nuclear Research Centre (BE)
THM	Thermo-hydro-mechanical
THMC	Thermo-hydro-mechanical-chemical
UGent	University of Ghent (BE)
UJF	Université Joseph Fournier Grenoble (FR)
ULB	Université Libre de Bruxelles (BE)
ULg	Université de Liège (BE)
UPC	Universitat Politecnica de Catalunya (ES)
URL	Underground Research Laboratory (BE)

EIG EURIDICE is an Economic Interest Grouping involving the Belgian Nuclear Research Centre SCK•CEN and the Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS). It manages the HADES underground research facility and carries out safety and feasibility studies for the disposal of high-level and/or long-lived radioactive waste in a clay host rock.

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