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PROGRESS REPORT OF THE 600 M BOREHOLE PROJECT OF THE CEC PROGRAMME ON MANAGEMENT AND STORAGE OF RADIOACTIVE WASTE

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This report describes the progress of the ECN 600 m borehole project in the period of January - June 1991. The project forms a part of the Radioactive Waste Programme of the Commission of the European Communities, Directorate General for Science, Research and Development, during the period 1990-1994. Contract number: FI2W-CT90-0050 (TSTS), ECN project number 2254.

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1. GENERAL INTRODUCTION

1.1. Title

Experiments in the 600 m borehole in the Asse II salt mine.

1.2. Objective and scientific considerations

In the assessment of the safety of disposal of radioactive waste in salt formations, the thermo-mechanical behaviour of rock salt plays an important role. In previous research programmes models have been developed which need to be verified by in-situ experiments. It has been proven by the COSA project that computations based on laboratory scale experiments do not predict the in-situ measurements. Based on the experiments performed already and on the associated validation work two items were of special concern, viz. the constitutive behaviour of rock salt and the rock pressure in the Asse [1, 2, 3]. A particular problem in the constitutive relations is the elastic or apparent elastic behaviour of rock salt. It appeared that the salt around openings is weaker than could be expected on the basis of laboratory experiments. Possible explanations are primary creep and weakening effects due to micro cracks.

One of the conclusions of the experiments in the 300 m hole experiment was that the lithostatic stress in the Asse salt formation deviates strongly from the primary rock pressure that would be caused by the weight of the overlying sediments. Although this deviation could be explained satisfactory as a consequence of the creep induced stress redistribution around the large excavations [1], the absolute magnitude of the deviation in the salt formation was not known accurately. So some measurements of the rock pressure were desirable because the rock pressure is an important loading in all thermo mechanical experiments. A better knowledge of the rock pressure would improve the interpretations of the HAW project experiment results considerably.

In the research programme discussed here in-situ measurements will be carried out in the Asse II salt mine in the Federal Republic of Germany. The measurements will be carried out in two deep drilled boreholes. In the previous programme which was executed under the

contract titled "Development of a surveillance method during dry-drilling of a 600 m deep borehole and performance of geotechnical measurements in the 600 m hole" (contract nr. FI1W-0084-NL) two measuring devices have been developed. Convergence measuring devices which are able tc measure the time-dependent closure of boreholes at 5 different heights has been successfully demonstrated in a 300 m deep borehole. A Variable Pressure Device (VPD) is developed and installed in a 300 m deep borehole since a 600 m deep borehole was not yet available due to technical difficulties. The development of the drilling technique was part of a bigger programme carried out under supervision of GSF (Gesellschaft für Strahlen- und Umwelt Forschung). After modification of the drilling machine, drilling of a 600 m deep borehole is expected to be completed in 1992.

The experiments which will be carried out in the drilled holes are:

1. Free convergence measurements of the salt wall at five depths in the borehole, i.e. at different salt pressures as soon as a 600 m borehole becomes available.
2. Determination of in-situ elastic and time-dependent response of the salt on pressures changes. The measurements will be carried out with the Variable Pressure Device in the available 300 m hole and will be started in 1991.

The convergence measurements aim to derive the lithostatic pressure, while the experiments with the VPD aim to measure the elastic and time dependent response of rock salt on pressure changes.

The parameters to be measured change slower in the 300 m deep borehole since the rock pressure is lower than it would be in a 600 m deep borehole. The measuring programme therefore needs to be extended for a long time period. This proposed period is two years. The obtained experimental results will be available to predict the behaviour of salt deposits and will give essential information to be used in safety assessment of disposal facilities of radioactive waste in rock salt, especially on the field of elastic behaviour and pressure dependency of creep.

1.3. Working programme

The tasks which need to be conducted during the contracting period are:

1. Maintenance of existing installed experimental equipment;
2. Execution of the experimental programme;
3. Data collection and interpretation of results;
4. Verification of calculations with experimental results.

Maintenance of existing installed experimental equipment

The VPD consists of a pressure unit that is placed in the borehole and a control unit that is placed in a gallery close to this borehole. This is schematically shown in Fig. 1.1. With this device it is possible to vary the pressure in the borehole and to measure the deformation of the hole at the same time. Basically the system consists of a rubber bag that is supported by a stiff steel structure, that can be hydraulically pressurized. The pressure unit is electrically and hydraulically connected to the control unit via a hoist and instrument cable.

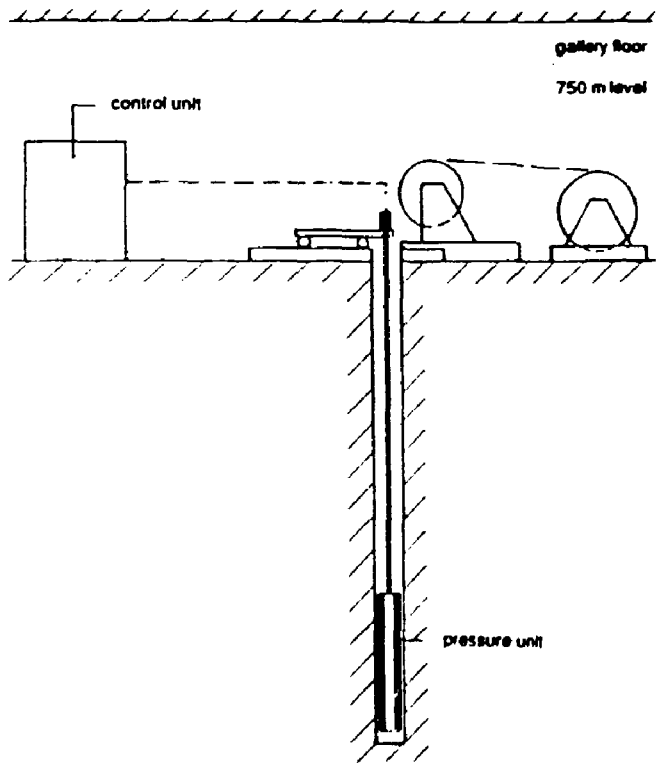

Fig. 1.1. Schematical setup of the Variable Pressure Device.

The control unit contains the pumps, valves and oil reservoirs necessary to apply pressure to the pressure unit and to measure the salt deformation. The system is controlled by an electrical system that can be operated by remote and local control. The transducer signals from this experiments will be collected by computers and transported to ECN.

The measurement of free convergence will not require any system operation. Data are collected by an automatic data aquisition system.

The measuring transducers, electrical power supply system and computer system need to be maintained.

Execution of the experimental programme

The VPD measurements require that parameters (pressures) are changed. These changes can be realised by manipulating switches on the control unit located at the 750 m floor in the Asse mine as well as by remote control from Petten.

Data collection and interpretation of results

The data for both experiments will be collected and stored in a computer system at the experimental site in the Asse II salt mine. At regular time intervals these data are transported to Petten. The data will be interpreted and reported in a data report after validation at the end of the experimental period (see also chapter 4).

Verification of calculations with experimental results

Before the experiments with the Variable Pressure Device start, predictive analyses will be carried out. During the experimental period an evaluation of the measurements will be carried out which also requires analytical work. The evaluation will be reported end 1992. The convergence measurements carried out in the previous phase of the project will be evaluated and reported end 1991.

2. PROGRESS OF THE WORK

2.1. Free convergence measurements

The convergence measurements have been stopped September 18th 1990 because of the Variable Pressure Device had to be placed in the same borehole. The convergence devices have been temporarily stored untill a 600 m deep borehole is drilled by GSF. The drilling machine of GSF will be modified during the first half of 1991 and will be demonstrated in the existing 2nd ECN hole that was drilled up to 347 m. Fig. 2.1. shows the location of the boreholes on the 750 m level. The borehole in which the convergence measurements will be performed is expected to be drilled begin 1992 after which the measurements are planned to start directly.

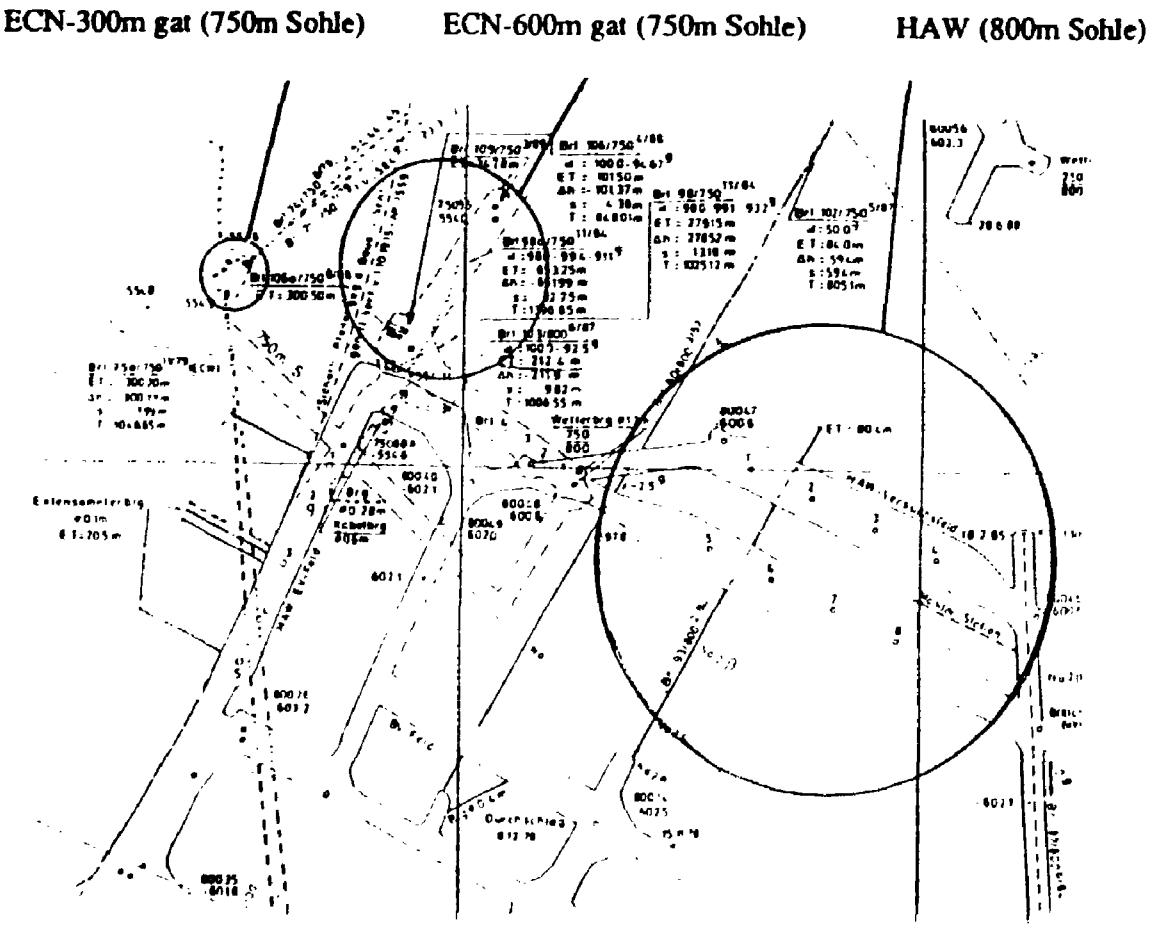

Fig. 2.1. Layout of the boreholes at the 750 m level in the Asse salt mine.

The free convergence data measured in the period 1989-1990 are presented in an interim report [4] that will be issued mid 1991. This report describes the analytical techniques for describing convergence and the measuring devices in detail and gives the measured convergence results.

An evaluation of these results will be made using the reported analytical techniques and will be reported end 1991.

2.2. Variable pressure measurements

The installation of the VPD was completed Januari 14th 1991. The "Betriebsplan" has been approved by the Bergamt and the measurements started March 16th 1991. The time between the installation and the start of the measurements was needed to allow for the salt concrete layers to be tightend into the borehole due to the convergence before applying higher pressures on the VPD.

During the first phase of the experimental programme a pressure of 27 bar was applied on the pressure unit due to the height of the oil column of 300 m from the gallery floor level to the bottom of the hole. The pressure build-up due to convergence of the borehole was to be measured. The measurements, however, gave somewhat different results during the first two months from what was expected. A significant pressure build-up at the gallery floor level was not found, athough two of the four pressure gauges in the borehole indicated a pressure rise of about 5 bars. It was decided to interrupt the measuring programme to analyse the cause of this effect.

Small pressure rises and drops of 2-3 bar (about 1 -2 % of the maximum range) were applied on the system and gave a reaction on all pressure gauges in the same order of magnitude. However, repeating the pressure changes indicated that the difference in oil volume, that was to be pumped into the system to induce the pressure changes, was larger than the expected deformation of the salt due to convergence during the two months period. This could be explained as a kind of hysteresis that was larger than expected based on experiences during the testphase. The pressure gauges that gave the pressure rise were suffering of so-called

"drift". The pressure gauges at the gallery floor were operating accurately and gave no problems.

It thus had to be concluded that the VPD was operating good from a mechanical point of view, but the expected pressure increase (due to compression of the system as a result of borehole convergence) could not be registrated under the given system settirgs. It has to be mentioned that the system is basically designed to work in a borehole of 600 m depth which would give an increase of the convergence rate of the borehole of about 10 times. Due to the appearing hysteresis the accuracy needed for this part of the measurement is not reached. For the mean time the measurement of the processes that slowly change in time is postponed.

Parallel to the mechanical testing FE-analyses were started to analyse in detail the effect of the heat production of the exothermally hardened salt concrete during the installation phase. It can be expected that this has some influence on the creep rate of the salt. The results of the FE-analyses may give some additional information but the results were not available yet for publication in this progress report. This will be worked out further and will be reported later in the pre-test analysis reports for the VPD experiment.
It was decided to concentrate first on higher pressure changes that were originally planned at the end of the experimental period. These pressure changes give better and more accurate results since the pressure changes (from 30 up to 200 bar) are significantly higher.

Modified measuring programme

The modified measuring programme is illustrated in Fig. 2.1. A pressure increase in steps of 25 bars/hour up to 200 bars will be realised. After one week the pressure will be decreased within 1 hour to 30 bar. After evaluation of this step the pressure changes will be repeated at least four times. The measuring program covers a period of at least 10 weeks. This period does not include the evaluation time. After performance of these tests it will be decided whether to repeat the tests with slow pressure variations or to define other measurements with the VPD. The high pressure changes started in July 1991.

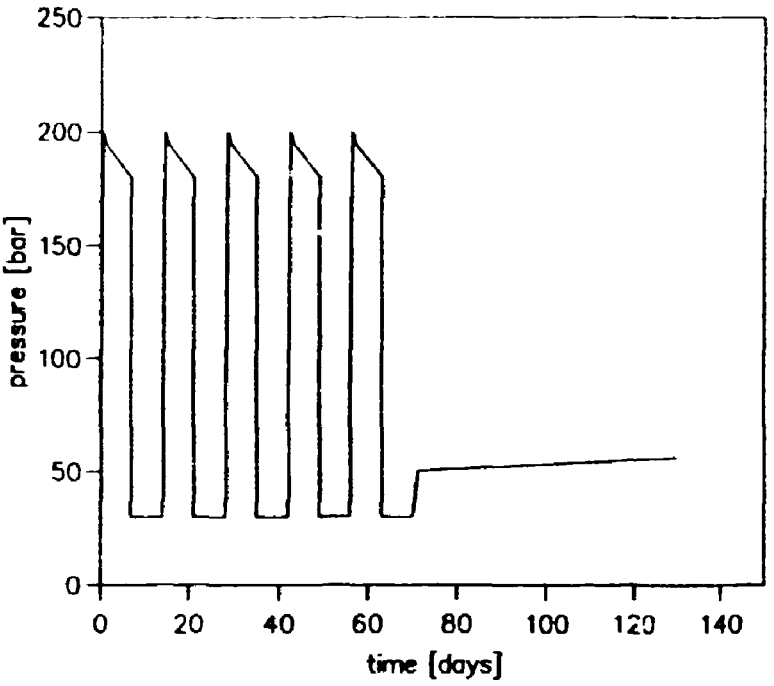

Fig. 2.1. Modified measuring programme.

The first results of the first pressure step indicate that this measurement gives promising and more relizble results. A preliminary conclusion is that the in-situ measured elasticity of the salt is significantly lower than the elasticity measured in the laboratory on small samples, about half or less of the value of 24000 MPa that was measured by the BGR. More detailed analysis of the measurement results and repeated pressure steps, however, are necessary to verify this conclusion and to determine an accurate value for the in-situ elasticity of the salt.

Time schedule

A prediction of the measurement results is being perfomed using Finite Element analyses. Due to the changes in the experimental programme, however, it was not possible to perform the analyses as planned before. The effect of the heat production of the salt concrete layers that are placed on top and below the VPD asked for more attention and more time. The prediction of the reaction of the device on the newly defined pressure steps will be analysed for three different sets of constitutive relations. The report on these predictive analyses, however, will be finished about four months later than originally planned and will therefore be issued end 1991.

The convergence data measured during the period '89 - '90 will be presented in the final report on phase I of the project (August '86 - December 1990) that is expected to be issued September 1991.

An evaluation of the convergence measurements will be performed in the second half of 1991. The convergence measuring devices will be installed in a new 600 m deep borehole begin 1992.

All other activities are on schedule.

3. SUMMARY AND CONCLUSIONS

In the framework of the CEC Programme on Radioactive Waste Disposal (1990-1994), in situ experiments in salt deposits are conducted. The experimental results will be used to validate analytical techniques and computer models for the prediction of salt behaviour. The experiments take place in the Asse II salt mine in Germany. The progress of the work during the first half of 1991 is reported.

Convergence data that is measured during the first phase of the project will be reported in the final report of phase I that will be issued mid 1991. The convergence measurement devices have been removed from the borehole and are temporarily stored to be used in a new 600 m deep borehole that will be drilled begin 1992.

The experiment with the variable pressure device (VPD) has started March 1991. During the first two months it has been shown that the low pressure build-up due to convergence could not be registrated. The system, which is basically designed for higher depths and thus higher convergence rates, showed more hysteresis than was expected on the applied pressure levels. The measuring programme that was defined earlier is therefore modified. It will be concentrated first on high pressure changes which are started in July 1991.
A preliminary conclusion of the first pressure step is that the in-situ measured elasticity of the salt is significantly lower than the elasticity measured in the laboratory on small samples. More detailed analysis of the measurement results and repeated pressure steps are necessary to verify this conclusion.

The predictive analyses that were planned for the first half of 1991 could not be made since the measuring programme was modified. FE-analyses have been concentrated on the interpretation of the measurement result during the first months. The influence of the heat production of the exothermally hardening salt concrete on the behaviour of the borehole is analysed in detail. The predictions of the modified measuring programme (topical report) will be reported later, viz. end 1991.

All other activities are on schedule.

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