ENGINEERING SAFETY ASPECTS OF THE HIGH ACTIVE WASTE (HAW)

TEST DISPOSAL PROJECT IN THE ASSE SALT MINE (FRG)

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ABSTRACT

The High Active Waste (HAW) test field in the Asse salt mine (FRG) will be installed and operated by the Institut für Tieflagerung (GSF/IFT) in close cooperation with the Netherlands Energy Research Foundation (ECN). The transport and handling of radioactive canisters will be demonstrated by loading them in tubelined bore holes. The irradiated rocksalt as well as the thermomechanical test field behavior will be investigated. Because of the retrievability requirement for the canisters throughout the 5 years test period, special canister guiding systems for loading and unloading of the boreholes, as well as borehole tube monitoring systems for following the ovalizing of the borehole tubes will be installed. Prior to loading the holes, the effects of heating a tubelined hole are assessed in two additional electrically heated holes. These safety precautions guarantee that under no condition radioactive material will have to in the HAW test area.

INTRODUCTION

In the FRG, an underground high active (HAW) test field, is being set up in the Asse salt mine, and the equipment to handle the radioactive vitrified sources (canisters) is to be seen as a pilot facility with regard to future final disposal in a national repository. The installation and operation of the pilot plant is to be performed by the Gesellschaft für Strahlen und Umwelt Forschung mbH, München/Institut für Tieflagerung, Braunschweig (GSF/IFT-FRG), in close cooperation with the Netherlands Energy Research Foundation ECN. The HAW test program has as objectives, the investigation of irradiated salt and thermomechanical test field behavior as well as the development of canister transport, and handling systems and different measuring techniques. The subjects for ECN contribution to the HAW-project* are: thermomechanical analyses, engineering in situ safety aspects, special instrumentation for salt pressure determination and crack detection, the data collection system and irradiation effects on rocksalt.

The HAW test field (see Fig. 1) consists of 8 boreholes of which 6 are to be filled with 5 high active canisters per bore hole (1680-2065 W/canister heat generation respectively 200°-250°C salt temperature and 5 x 10^5 R/h radiation dose rate at the salt). In two holes, A1-B1, the canisters are simulated by electrical heaters, which bore holes are incorporated in the test program to serve as reference holes for gas release experiments.

With reference to a more detailed HAW-project** description (K. Kuhn (1)), the high active waste repository, including the technical systems, will be represented as far as possible on a one to one scale with exceptions for borehole depth and borehole tubing. In contrast to the actual repository the holes in the HAW-field are provided with lining tubes to ensure the retrievability of the canisters at any time during the five years test period. The licensee stipulates

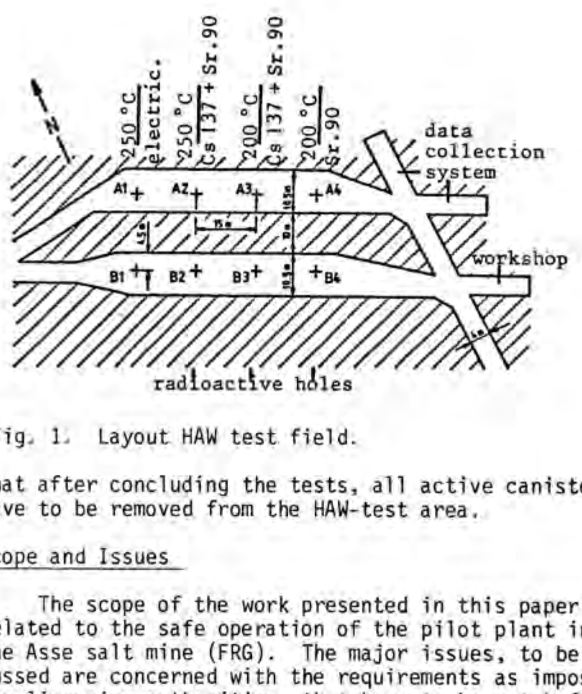

Fig. 1. Layout HAW test field.

that after concluding the tests, all active canisters have to be removed from the HAW-test area.

Scope and Issues

The scope of the work presented in this paper is related to the safe operation of the pilot plant in the Asse salt mine (FRG). The major issues, to be discussed are concerned with the requirements as imposed by the licensing authorities, that have to be met before before commissioning and operation of the test field can take place.

To prevent enclosing of the canisters by the converging salt, the holes in the HAW test field are provided with thick lining tubes (see Fig. 2) with a sufficient wall thickness to withstand the maximum pressure of the surrounding salt and thus to maintain the retrievability of the radioactive canisters at any time during the five years test period. In view of this essential retrievability requirement, in addition to

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** A separate paper, entitled "High level waste disposal project in the Asse salt mine (FRG) T. Rothfuchs, R. Stippler", (GSF/IFT-FRG) is presented at this conference (see Session XI-1).

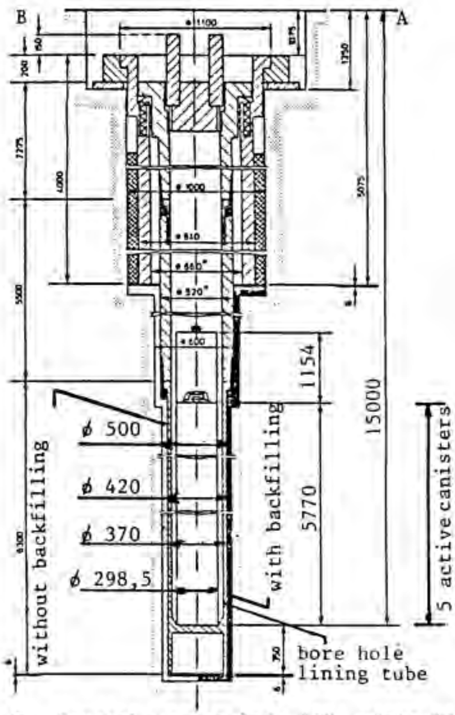

Fig. 2. Borehole types left "B", right "A".

the lining tubes, systems to monitor the tube deformation will be installed. In the unlikely case that the tube deformation exceeds 8 mm on the radius, the canisters have to be retrieved. Furthermore a non-active test, also requested by the licensing authorities will be put in operation, three months before filling the active holes, to assess the actually occurring tube deformation. Reference hole, B1, selected for this so called "one to one" strategy, will be provided with exactly the same equipment for tube deformation measurement as the six "active holes". Borehole A1 on the other hand will be equipped with special instrumentation to obtain salt pressure data for thermomechanical computer code validation.

For ensuring the retrievability of the canisters the following issues have to be considered:

- reliable guiding of the canister and grapple during loading and unloading of the borehole,
- continuous reliable monitoring of the borehole tube deformation,
- reliable prewarning function of the non-radioactive heated borehole B1.

These considerations and requirements lead to the design of the following systems: the Canister Guiding System (CGS), the tube deformation monitoring system (GMS) and the heater for the prewarning borehole, as described in the next paragraphs.

The Canister Guiding System

The canisters are provided with a knob at the *top for* the grapple to grip, and a closely fitting hole in the bottom to accommodate the knob of the canister it is placed upon. The before mentioned retrievability reuuirement leads to the necessity of a canister guiding system (CGS), with the following objectives:

1) To guide the canisters during loading of the boreholes to obtain the right position of the canisters in relation to each other for the hole in the canister bottom to slip over the canister knob already in place,

2) To guide the grapple downwards to the right position to grip the knob of the canister during unloading of the holes, under the most extreme canister/tube position and deformation to be expected.

The CGS, which will be installed between the canisters and the tube wall, has to be designed for functioning during the five years test period under the following conditions: a maximum elliptical tube deformation of 8 mm on the radius, a maximum angle of the tube axis with the vertical, equivalent to 10 cm/15 m, a temperature range of 250°-500°C. Under these conditions (see Fig. 3)

- the misalignment of two canisters, which without the guiding effect of the springs would amount to ~48 mm has to be reduced to a max. misalignment of 7 mm by the CGS.

- in the case of the grapple, reduction of the misalignment to 35 mm by the CGS is sufficient.

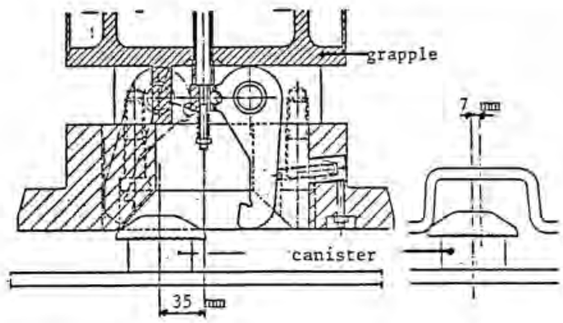

Fig. 3. Max. allowable misalignment. Grapple/Canister: 35 mm; Canister/Canister: 7 mm.

The Canister Guiding System consists of three parallel subsystems, placed 120° apart along the tube perimeter. One subsystem consists of a basic strip with six springloaded guiders located in such a way that each spring touches the top and bottom of the canisters (see Fig. 4). The basic strip is inserted in rails which are welded along the whole length of the tube inner wall.

The springs which have the shape of a bend strip are not strong enough to centralize the canisters that have already been placed in the hole. Hence, the top canister may be in any position in the cross section of the tube with the springs pushing against its upper edge. When the next canister is loaded, it is guided by these springs to the correct position above it. In case of unloading the hole the grapple will be guided by the springs downwards to grip the knob of the canister. The springs are made of Inconel X-750 and covered by a layer of Inconel. The latter is an extra safety precaution to avoid blocking of retrieval, in the highly unlikely case of a broken spring.

CGS Test Facility

Before the canister guiding system will be installed in the boreholes in the HAW-field, both operational conditions: loading and unloading of canisters, will be tested under the most extreme

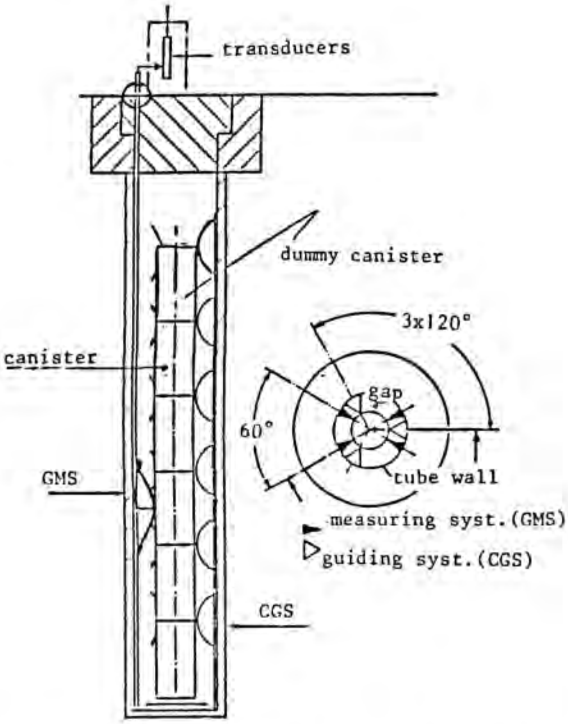

Fig. 4. Schematic layout; Canister Guiding System (CGS); Gap Monitoring System (GMS); 0 passage through borehole lid.

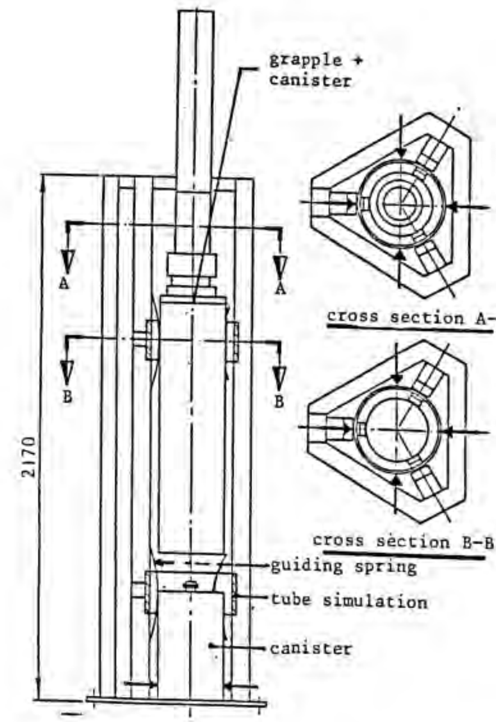

Fig. 5. Test facility for the Canister Guiding System.

expected conditions, in a test rig. This test rig will be set up at ECN in Petten, the Netherlands, and be used to simulate the geometrical conditions as described under CGS design requirements. The test facility (see Fig. 5) consists of a vertical rig of 2 m height, with at two levels a ring simulating the tube wall. The two rings are provided with three sets of rails for the guiding systems, 120^{0} apart circumferential, in which two guiding springs are mounted. In this way two guiding levels are simulated with an axial distance equal to the canister length of 1154 mm. On the bottom plate a canister top is mounted simulating the highest canister of the stack already present in the hole. This top can be placed in different positions. The whole rig is placed under a hoist approximately 10 m above the highest set of springs. A test plan comprising 48 combinations of cross section deformation (8 mm on the tube radius), inclination of the tube axis and different positions of the canister already in place will be carried out, to demonstrate the good functioning of the system for the licensing authorities.

The Gap Monitoring System (GMS)

The deformation of the lining tubes in the boreholes is monitored by the gap monitoring system. If the tube deforms as a result of for instance non-axisymmetric temperature fields around the hole, the cross section of the tube takes on an elliptical shape with the axis in an arbitrary direction. The smallest axis of this ellipse determines for the remaining gap between canister and tube. The GMS must yield this minimum dimension. The GMS is located at the height of the canister stack (see Fig. 4) where the maximum temperature and hence the maximum pressure occur. All holes, except the Al-hole, are provided with a GMS. The GMS has to be designed for the following conditions:

- the maximum allowable tube deformation (8 mm on the radius) to be measured with max. 10% inaccuracy,
- the system must function during the five years test period with interruptions of max. eight hours for replacing a GMS,
- the temperature range is 200^{0}C-500^{0}C and leak tightness requirements for the passages of 10^{-3} mBarliter/sec.

The GMS consists of four individual gap meters at the midheight of the canister stack, located along the circumference of the tube as shown in Fig. 4. The four measurements are required to obtain sufficient information to determine the elliptical deformation and hence the remaining minimum gap at the midlevel of the canister stack. The non-even circumferential distribution of the gap meters is required to avoid insensitivity for certain orientations of the deformation occuring with an even distribution. The assumptions on which the evaluation of the minimal diameter is based are:

- elliptical deformation of the cross section. This is allowed as each higher mode of deformation (triangular, square, etc.) requires much greater pressure differences along the circumference of the tube. These pressure differences will cause creep of the salt and hence the tube will resume its elliptical shape.

- the radial compression of the tube resulting from the average pressure (<450 bar) in the surrounding salt needs not to be measured as its effect can be accounted for in the error analysis.

- the dimensions of the canisters does not vary in time.

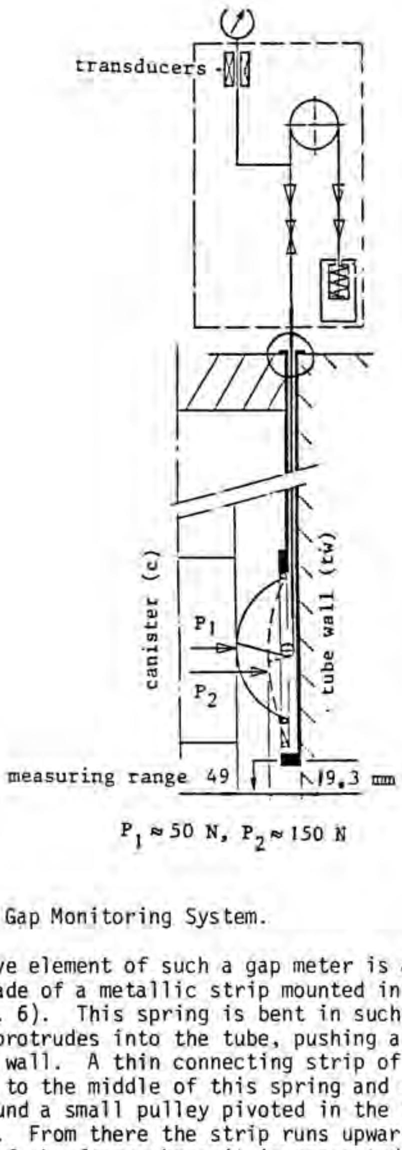

Fig. 6. Gap Monitoring System.

The active element of such a gap meter is a measuring spring made of a metallic strip mounted in a frame (see Fig. 6). This spring is bent in such a way that it protrudes into the tube, pushing against the canister wall. A thin connecting strip of metal is attached to the middle of this spring and runs from there round a small pulley pivoted in the frame of the unit. From there the strip runs upward to the top end of the frame where it is connected to the rod of a push-pull system. This push-pull system consists of a rod in a tube. As the tube is connected to the frame of the unit and the strip to the rod, the relative displacement of rod and tube corresponds to the displacement of the spring to or from the tube wall. The push-pull system extends through a penetration in the borehole lid, which seals off the borehole at the top. The relative displacement of rod and tube is measured in a measuring device located on the borehole lid by means of two redundant electrical linear displacement transducers. The required strength of the spring is determined by the forces needed for good operation. In this connection two different situations have to be considered: the spring moving inward towards the canister and its opposite: the spring being pushed back into the units frame. This distinction is necessary as the direction of the friction depends on the direction of movement. The minimal contact force between spring and canister is set at 50 N. For the friction a force of 50 N has been assumed also, although the actually expected friction is much lower. From this analysis follows that the force required from the spring at its maximum extension of 68.3 mm amounts to 100 N. This relatively high force combined with a range of the gap meter of 19.3-68.3 mm deflexion requires a special spring design with a varying cross section. The improved stress distribution obtained from this varying cross section yields the required flexibility. To prevent blocking of the canisters by parts of the spring in the improbable situation of a broken spring, this spring is also covered by a layer of Inconel keeping the pieces together and out of the way.

The reliability of the GMS is taken into account as follows:

- the mechanical equipment is single fold, but very robust. Failure in that part is very unlikely. From the electrical displacement transducers onwards the system has been installed redundantly. The two signals are fed into two separate branches of the Data Collection System.

- the four gap measurements can also be obtained from mechanical clocks, so that the tube deformation can be computed always, even in case of failure of the Data Collection System. In case of malfunction, the mechanical system of the GMS can be replaced within eight hours.

The required accuracy of the overall deformation monitoring system has been set at 10% of the maximum permitted radial deformation of 8 mm (≈0.8 mm). The error sources can be found in the evaluation of the minimum gap from the four measurements as well as from the gap meters proper, and will result in a toal error of about 8%. Computational errors, errors such as due to compression and thermal expansion of the liner tube and other components as well as strain of components and uncertainty in dimension, are taken into account in the error analysis. Although there is little cause for assuming shift of the systems characteristics, in view of the relatively long test period a method has been designed to recalibrate the system in situ during the functional test.

GMS Test Facility

Before the gap meters will be installed in the boreholes in the Asse-mine, their functioning will be demonstrated in a test facility (see Fig. 7). This test rig will be set up at ECN in Petten, The Netherlands. The test facility has the following objectives:

1) to demonstrate the ability of a single GMS-gap meter to measure the gap width under the conditions as given for the Gap Monitor System, within the required accuracy,

2) to determine the transfer function between gap width and electrical and mechanical (measuring clock) output signal,

3) to demonstrate the reliability of the gap meter in an accelerated test, comprising all movements foreseen in the total test period,

4) to demonstrate that the system can be replaced properly and within the available time,

5) to check the spring characteristics (before and after three).

The testrig has to simulate the conditions as foreseen in the actual situation in the mine, which requires a full size gapmeter unit, a canister simulation, a capability for controlling the gap over the total range (19.3-68.3 mm), heating equipment to simulate the temperature profiles radially (200°C-500°C) as well as axially and a provision to determine the spring characteristics. The test facility built at ECN consists of a vertical simulation of the tube wall with one set of rails attached to it. At the measuring unit level a heater/air cooler combination is provided to establish the required temperature drop across the unit. On top of this furnace a channel is built enclosing the push-pull mechanism completely, simulating the liner tube. The test plan comprises a number of GMS functional tests with different combinations of canister position tube wall deformation, temperature profile as well as demonstration tests for replacibility of the GMS. The tests will be carried out partly under supervision of the licensing authority.

Heater

The active tests will be preceded by inactive test in borehole A1 and B1, of which B1 is the so called prewarning borehole for determining the tube deformation during three months before the active holes will be loaded. The electrical heater has to be designed to produce heat, at the same heat rate and over the same length (5770 mm) as the canister stack in the active holes, continuously throughout the five years test period (max. capacity, 12 kW/heater). The heater consists of a frame on which eight half-circular heating elements are mounted in four pairs above each other, which frame is connected to the borehole lid. To guarantee uninterrupted heat production each heating element has two redundant branches, provided with their own power supply. Under normal conditions with all heaters operable, these two branches work on half load. If one of the branches malfunctions, it is automatically shut-off and the other one is set at full power, thus maintaining the power generation at the desired level, until it can be repaired. Replacement of the heater subcomponents has to be performed within 48 hours.

Conclusion

In conclusion it can be stated that the safety precautions discussed above, namely the canister guiding systems, the gap monitoring systems to determine the tube deformation and the electrically heated prewarning test, guarantee that under no condition radioactive material will have to remain in the HAW test area.

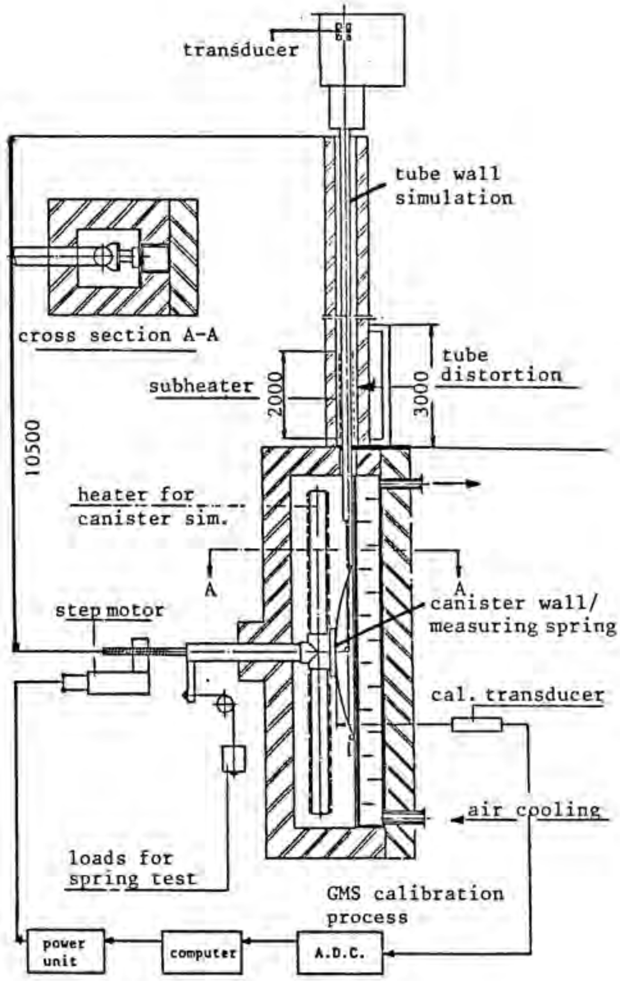

Fig. 7. Test facility for the Gap Monitoring System (GMS).

References

1. K. Kuhn and T. Rothfuchs, "High Level Radioactive Waste Test Disposal", Asse Salt Mine, FRG. Gesellschaft fur Strahlen und Umwelt Forschung mbH, Munchen (GSF/IFT), International Topical Meeting, High Level Nuclear Waste Disposal, Pasco, USA, September 24-26, 1985.