SAFETY ANALYSES FOR THE POST OPERATIONAL PHASE OF FINAL REPOSITORIES OF RADIOACTIVE WASTE

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ABSTRACT

For storing radioactive substances in a salt mine the long term safety of the final repository has to be demonstrated. In case of the undisturbed post-operational phase the conservation of the integrity of the final repository is proved. A considerable release of radionuclides from the final repository to the biosphere is only conceivable after an ingress of brine into the mine. By means of safety analyses it has to be proved that in case of incidents of this type the radioactive load on the biosphere remains below the fluctuation range of natural radioactivity. The computing codes for the analysis of the nuclide migration in the mine and the covering rock are discussed.

DESCRIPTION OF THE FINAL REPOSITORY

In the FRG the final storage of heat producing radioactive waste is planned in the Gorleben salt mine. The final storage is to be located at a depth of 800 m. Two mine wings are planned. One wing is destined for the storage of heat producing highly active waste and part of the medium active waste in drilled bore holes of a depth of 300 m to be sunk at a distance of 50 m from each other. The remainder of the medium active waste and the low active waste are to be stored in the opposite wing.

The bore holes and chambers are filled with crushed salt after receiving their charge and closed with seals. The galleries are also filled with crushed salt and closed with dams. The shafts are closed and sealed as well.

The extension of the final repository are 4500 m along the axis of the salt mine and 500 m in width.

SAFETY ANALYSIS OF THE UNDISTURBED POST-OPERATIONAL PHASE

It has to be proved that even in the post-operational phase inadmissibly high quantities of radioactivities will not be released from the final repository to the biosphere. During the undisturbed post-operational phase the salt mine and the sealed shafts form the high barriers around the repository. A noticeable release of radioactive substances is only possible after a failure of these barriers with a brine ingress into the mine.

The design of the final repository has to be such that the integrity of the natural barriers (salt mine and covering rock) cannot be endangered.

Hence the conservation of the integrity of the final repository for long periods of time has to proved in safety analyses.

For analyzing the thermal mechanic behaviour of the salt mine and the rock GRS used the computer code STEALTH (1), which describes the flow behaviour of the rock salt by means of material equations (2). Fig. 2 shows for example a calculation model for analyzing the final repository with the salt dome and rock. The repository is homogenized and input into the code as an averaged heat source (900 W/HAW mould/charge 1760 moulds per year).

The results of the calculations are amongst others the velocity, pressure, and temperature fields in the salt mine and its surroundings (3). Owing to the heat input materials in the vicinity of the final repository are strongly accelerated as a consequence of thermal mechanic processes. In the initial phase an almost radially symmetric velocity field is formed.

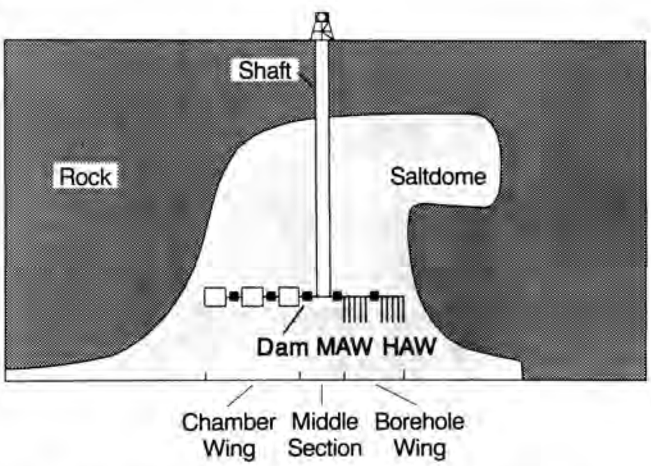

Fig. 1. Planning concept of a Final Radioactive Waste Depository in a Salt Dome.

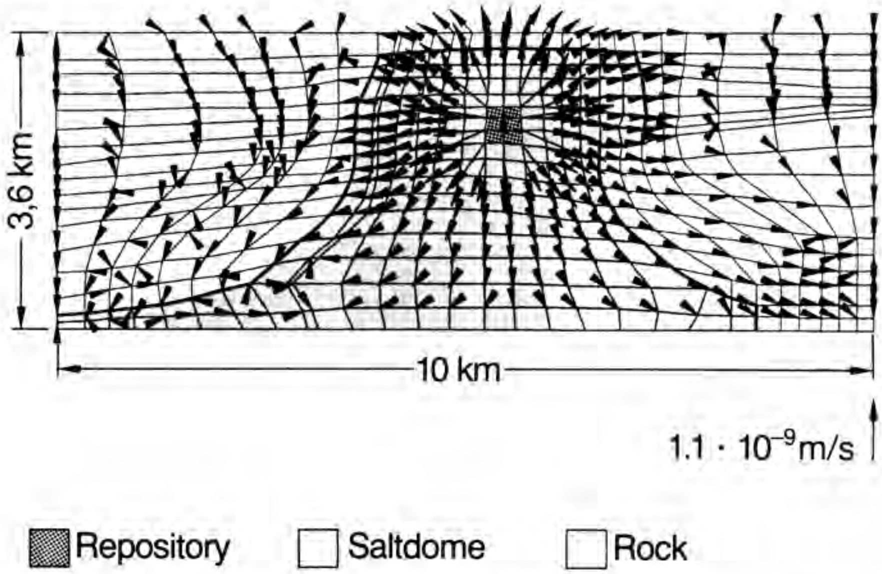

Fig. 2. Calculated Velocity Field 50 Years after Deposition of HAW.

Peak velocities of 30 mm/a may occur then. With the laps of time the velocity field of the salt dome is converted into an upward movement. The temperature of the area of the final repository reaches its maximum value of 170° C after 130 years. At about 3300 years after storage the temperature will have dropped to approximately 41° C.

The upward raising of the surface of the earth is about 1.75 m then. The calculation does not supply any hint that limiting values are exceeded at any point of the system and that its integrity is in danger.

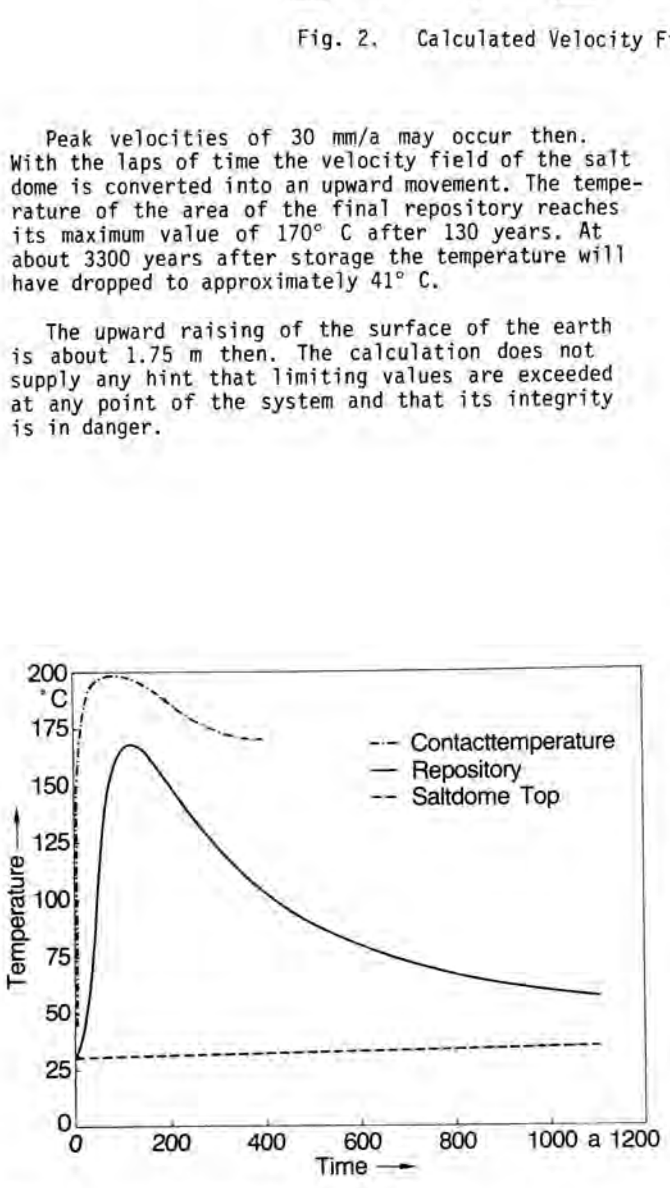

Fig. 3. Calculated Temperature History.

For example the thermodynamic calculations in the near field of a HAW mould show that the maximum temperature of the rock salt remains below 200° C. The aforementioned calculations show as well that the stresses in the salt dome and its surroundings do not reach critical value.

SAFETY ANALYSIS FOR THE DISTURBED POST-OPERATIONAL PHASE

As mentioned above a considerable release of radionuclides to biosphere can be conceived only after a brine ingress into the final repository. In the FRG a deterministic scenario is assumed for such a case. It forms the bases of the safety analysis. For analyzing the brine and nuclide transport in the mine computer codes were developed (e.g. EMOS, MARNIE). For calculating the transport in the covering and adjacent rock codes as SWIFT or NAMMU/NANSOL are used. The latter will be treated by P. Bogorinski in one of the following contribution (6). The transport codes for the mine describe the processes in the multi barrier systems (filled galleries, seals, bore holes, chambers and containers). They take into account the physico-chemical effects upon the different barriers (convergence, temperature evolution, density effects, formation of gases, evaluation of porosity and permeability). In the FRG such a code, namely EMOS (4), was used.

GRS is developing the transport code MARNIE, which is divers to EMOS. It has a modular structure based on an already existing network program.

The network represents the system of galleries, plugs and dams, whilst the locations of storage (chambers, bore holes) are modeled as so called B-Modules. In order to treat these processes in galleries, dams, and plugs the conservation laws of mass, momentum, and components are solved taking into account the physico-chemical processes.

The structure of the code is shown in Fig. 5. It can be seen that in treating the barriers all required effects are available, whose influence on

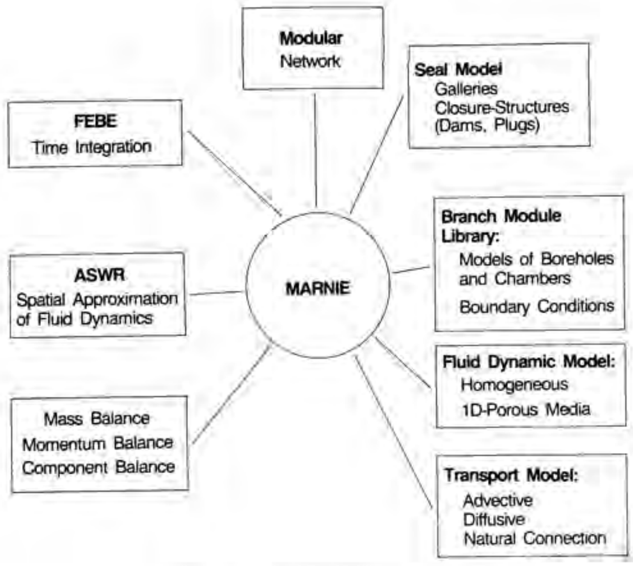

Fig. 4. Flow Chart of MARNIE.

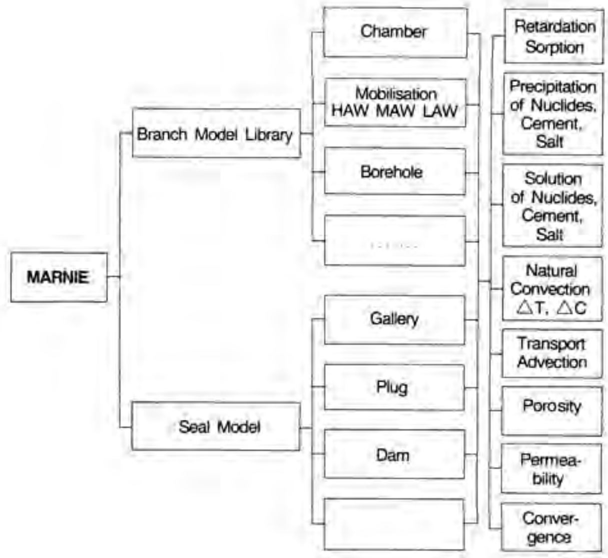

Fig. 5. Configuration of MARNIE.

the results is widely different. Calculations show clearly the strong influence of the convergence of the cavity in the rock salt on the results of the long term safety analysis, i.e. the release of radionuclides from the mine into the covering rock. In Fig. 6 the convergence of a gallery is represented as a function of time. After opening the gallery a strong reduction of its cross section takes place, which decreases with time. After an ingress of brine a hydrodynamic pressure builds up in the gallery so that convergence becomes slower. The gradient, i.e. the rate of convergence, diminishes. The release of radionuclides from the flooded repository itself is strongly affected by the description of those processes. A variation of the rate of convergence before brine ingress from 3 %/a to 1 %/a increases the release by a factor of approximately 20. A similar strong influence results from the solubilitiy limits for nuclides in brine. For nuclides within the limits of solubility a variation of the limits has an effect of the same order of magnitude on the result. Among the barriers the dams are the most important factor of influence (4) followed by seals and backfilled galleries.

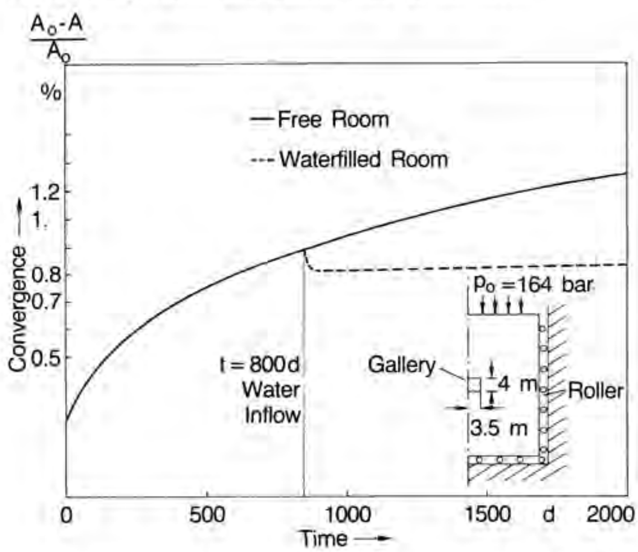

Fig. 6. Calculated Convergence of a Gallery.

ANALYSIS CREDIBILITY

Safety relevant results, especially in the case of long term safety, may only be quantified by the use of computer codes. The degree of confidence of these results is determined amongst others decisively by the quality of the computer codes. Quality assurance of the code requireds apart from documentation work the verification and validation of the code with the help of analytical solutions and benchmark problems.

It has to be assured by model verifications that the computer code solves the mathematical equations correctly, whilst the validation is to assure that the model used in the code is a correct representation of the process or the system.

The degree of qualification of thermal mechanical codes is relatively high. They have been used to reproduce a number of experimental results. The codes STEALTH and ANSALT /4/ have been used successfully in American benchmak calculations. The validation work for the codes describing transport processes are still pending in part.

CONCLUSIONS

In order to improve the reliability of the results of computing codes used in safety analyses further work on model validation is required. In particular the description of the barriers and the occuring effects needs further experimental support. In the case of some of these effects the final validation will be site specific, so that a final qualification may be made only after the exploration of the final repository mine.

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