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DISPOSAL OF SOLIDIFIED HIGH-LEVEL RADIOACTIVE WASTES IN THE ASSE SALT MINE

by

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Kurzfassung

In der Bundesrepublik Deutschland sollen die verfestigten hochaktiven Abfälle im Salzbergwerk Asse endgelagert werden. Eine kritische Überprüfung dieses Konzepts bestätigte seine Durchführbarkeit. Der vorliegende Bericht gibt einen Überblick über die damit im Zusammenhang stehenden Forschungs- und Entwicklungsarbeiten. Neben verschiedenen wichtigen geologischen Daten werden die Resultate von Computer-Berechnungen und Feldexperimenten bezüglich der Wärmeverteilung im Salzgebirge sowie die derzeitigen Vorstellungen hinsichtlich des Transports und der Manipulation der hochaktiven Abfälle diskutiert.

Abstract

A critical review of the German policy confirmed the feasibility to dispose of solidified high-level radioactive wastes in the Asse Salt Mine. From the respective R + D - program some important geological data, some results of computer calculations and field experiments on heat dissipation, and the general idea of the transport and handling system are given in this report.

1. Introduction

Solidified high-level radioactive wastes from fuel reprocessing plants in the Federal Republic of Germany will be disposed of in geological rock salt formations deep underground [1]. No actual disposal of high-level wastes has been carried out up to now but a broad R & D - program is being worked on mainly at the Karlsruhe Nuclear Research Centre, the Technical University Aachen, and at the Asse Salt Mine. This salt mine is in operation by Gesellschaft für Strahlen- und Umweltforschung München as a disposal site for low-level radioactive wastes since 1967 and for intermediate-level wastes since summer 1972.

The project of the United States Atomic Energy Commission to install a National Radioactive Waste Repository for the disposal of solidified high-level radioactive wastes from commercial reprocessing plants in an abandoned salt mine near Lyons, Kansas, has been carefully studied in Germany. Also all public discussions and hearings related to this subject have been followed with great attention. The final decision of the USAEC, not to realize this project was succeeded by a critical review of the German project to dispose of solidified high-level radioactive wastes in the Asse Salt Mine. The result of this review was that there was not any necessity to change the hitherto existing policy.

All main scientific and technical reasons which caused the abandonment of the Lyons project are so closely related to the site of Lyons that they do not result in a coincident abandonment of the general idea of using rock salt formations for radioactive waste disposal. This is indicated by a very recent AEC communication [2], which states that salt formations near Carlsbad, N. M., and also in other parts of Kansas shall be further investigated for this purpose. Furthermore, these reasons can also not be related to the site of the Asse Salt Mine. The local geological and mining situation there is completely different from that near Lyons.

2. Additional geological data of the Asse Salt Mine

The situation, history, and also the general geology of the Asse Salt Mine have been described at an earlier IAEA-ENEA-Symposium [3 ; 4]. Therefore only some additional data shall be given here which are important in respect to the disposal of high-level wastes.

The salt of the Asse Salt Mine has been evaporated from the ocean in the geological Permian age that means 220 to 200 million years ago. About 110 million years before the present time the originally bedded salt masses were folded up by tectonic processes into the present form. The geologic structure of the Asse is relatively simple compared to many other salt domes in Northern Germany or along the coast of the Gulf of Mexico. It does not have the typical cross-section of a mushroom with overhanging flanks, disturbed overburden strata, and heavily folded salt masses within itself. And so, it is not a real salt dome but a salt anticline (Fig. 1). Nevertheless, the salt within this anticline is very pure as in a salt dome for nearly all interbedded layers of e. g. shale, anhydrite, or dolomite which are normally encountered in bedded salt deposits have been left in the depth during the tectonic folding due to their relative hardness and brittleness compared to the plasticity of salt.

This geological genesis results in four properties which are specially favourable for the use of the Asse Salt Mine for the disposal of high-level radioactive wastes.

The first one is the purity of its rock salt which is important with regard to rock mechanical behavior and to heat dissipation around high-level wastes disposed of in the salt.

The second one is the depth of the salt anticline. The base of the salt is situated at least at 1500 m below the surface, and probably deeper. The exact figure is not known up to now but from geophysical investigations and from other salt domes of the same age in Northern Germany it can be concluded that the base is somewhere between 2000 and 3000 m below the surface. This will be investigated in the near future. The horizontal area available in a salt anticline for disposing of high-level radioactive wastes is relatively small compared to bedded salt deposits. But with the anticline becoming wider with growing depth and by using deep boreholes for the storage of the solidified high-level wastes this disadvantage can be compensated for, and so too, large salt masses can take the heat originating from the waste.

The third positive property of the Asse Salt Mine are the basement rocks underlying the salt. They consist of paleozoic rocks which are highly consolidated. This geological consolidation accounts for the fact that an earthquake has never been recorded in the basement rocks underlying Northern Germany, for earthquakes are strictly connected to tectonic processes and almost everytime originating from big fracture zones in the earth' s crust. Both conditions do not exist in this region and consequently, there is also no probability of an earthquake within the next some tenthousand years.

The fourth point is that the anticline is covered with impermeable strata of anhydrite and shale on its flanks. So there is no direct contact between the salt and groundwater which might eventually be present in the overburden strata. In 1969 a geological borehole was drilled into the top of the anticline. This borehole proved that the caprock consists of a mixture

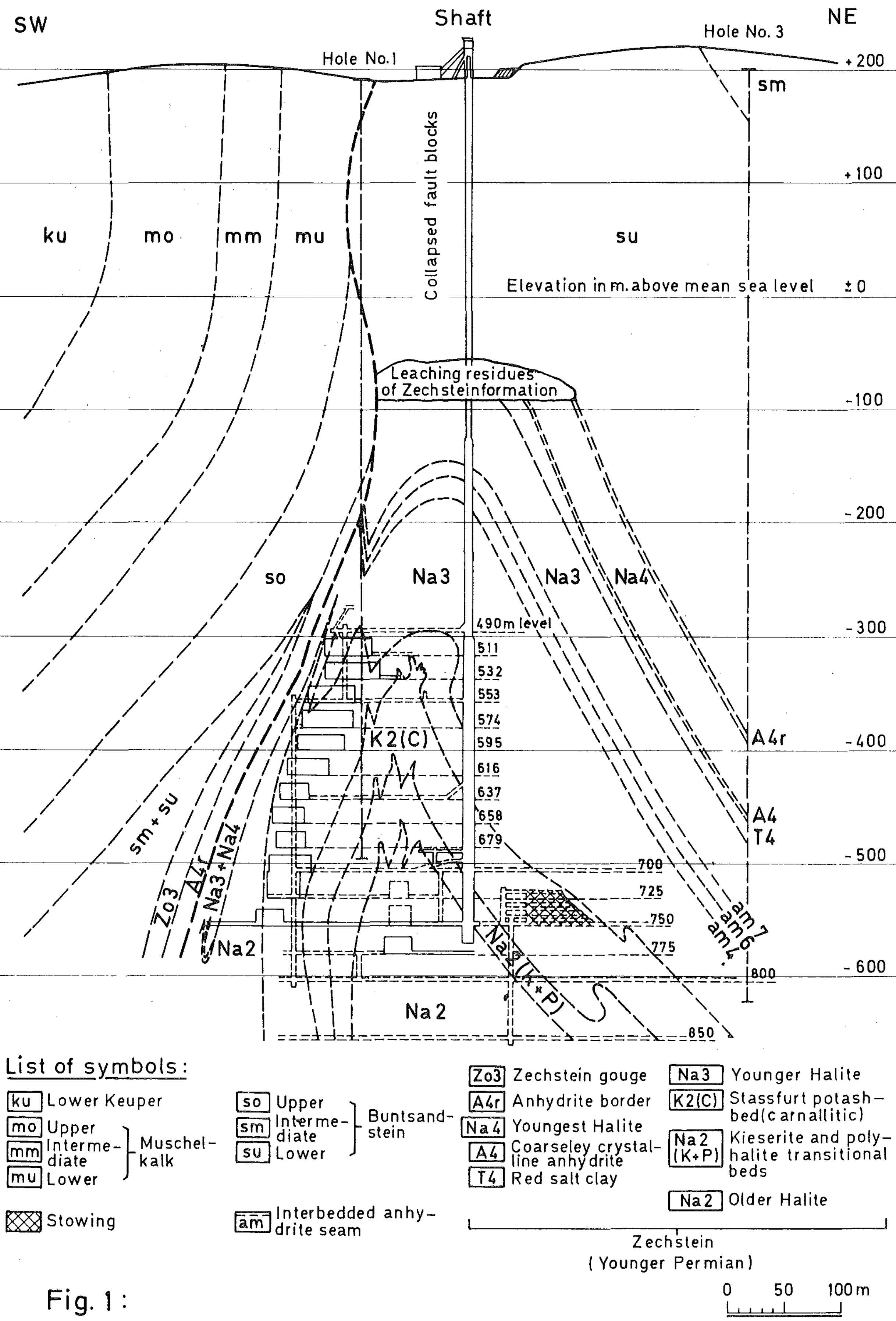

Fig. 1:
Cross section through the anticline of Asse

of siltstone, gypsum, and anhydrite, to be completely dry. Also the surface of contact between the salt and the overburden, the so-called "Salzspiegel", was without any brine or water.

During the operation time of the mine from 1908 to 1964 more than 100 large rooms have been excavated in the rock salt of the Younger Halite (Fig. 2). None of these rooms, side by side and one upon the other on 13 levels is suitable for the disposal of solidified high-level wastes. They are and will be used for the storage of low- and intermediate-level radioactive wastes [5]. The area chosen for the disposal of high-level glass blocks is situated in the very depth of the mine. In this part of more than 775 m depth no old mine workings exist, so the dimensions for the charging rooms can be properly designed. They are mainly governed by rock mechanical aspects and by the size of equipment. As already mentioned the large mass of compact rock salt available to the depth offers to use boreholes several ten meters deep and to stack several blocks of solidified high-level waste on top of each other in a borehole.

3. Heat dissipation problems

Precondition for the safe and also for the economic disposal of high-level wastes is the optimum harmonizing of

- nature of solidified wastes
- disposal geometry
- disposal technology.

The most important parameters for these studies and calculations are :

1. Physical properties of solidified waste and of salt,
2. Maximum admissible temperature in solidified waste, in sheating material, and in salt,
3. Specific heat production of self heating waste,
4. Geometry of waste cans and boreholes, distance and depth of boreholes,
5. Time dependence of heat production.

In order to determine optimal values for temperatures and storage geometry, investigations are being carried out as well with computer calculations as with field experiments in the mine.

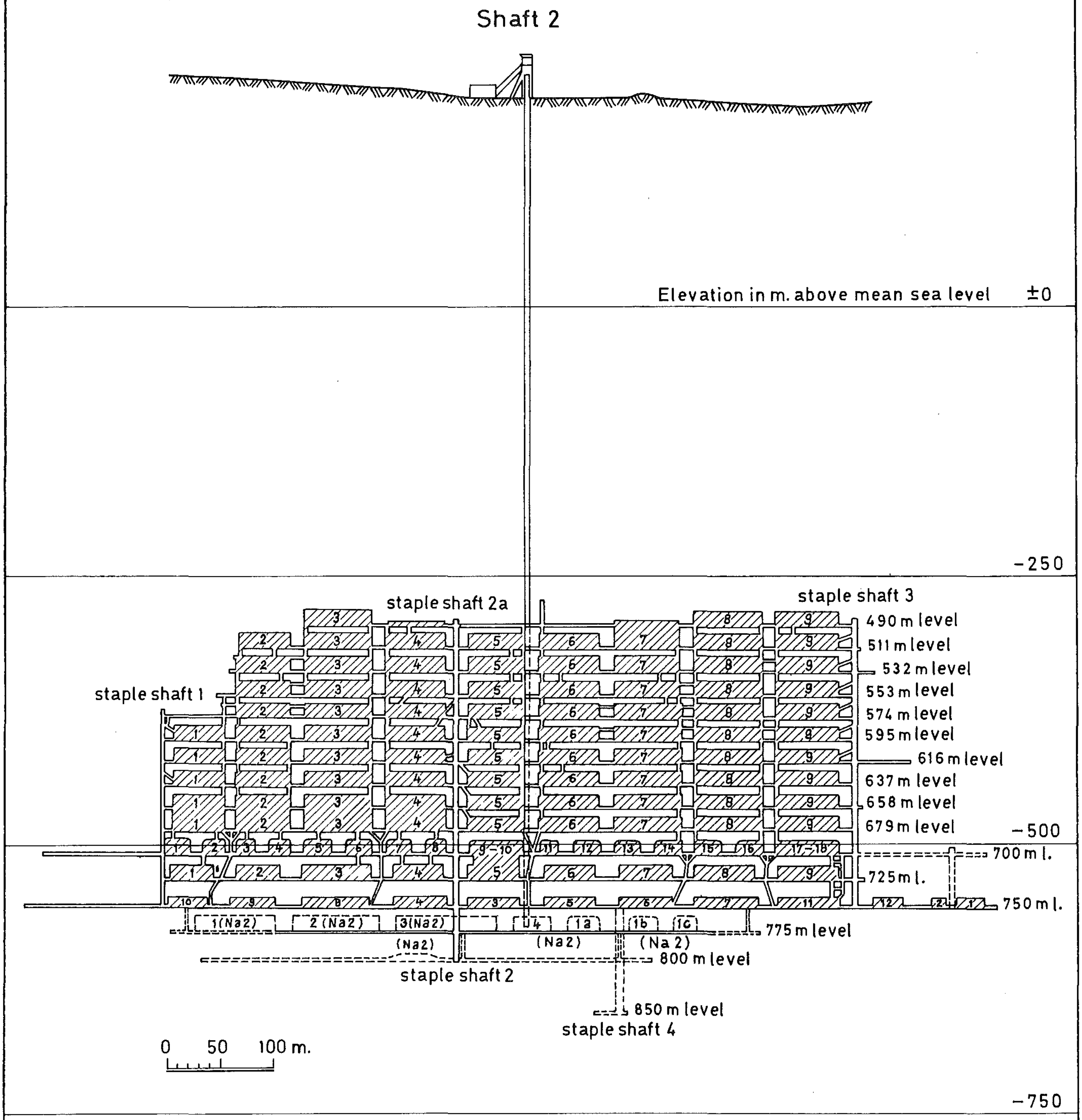

Fig. 2:
Longitudinal cross section of the Asse Salt Mine

3.1 Computer calculations

From the extensive computer calculations which have been done at the Technical University Aachen only very few results can be given here. As one example the qualitative influence of some parameters on the maximum temperature in the centre of the cylinders is discussed.

1. The time-dependent temperature course near a source remains independent from neighbouring sources over relatively long periods (10^3 - 10^4 hours).

2. Therefore variation of the source distance (Fig. 3) or variation of the source length (Fig. 4) do not influence the first phase of heating. From Figure 3 it can be seen that an increase of the source distance to more than a certain value will not increase the maximum temperature. From Figure 4 it can be extrapolated that no unlimited source lengths are possible in a large field of sources.

3. Every variation of parameter results in a time displacement of the maximum temperature.

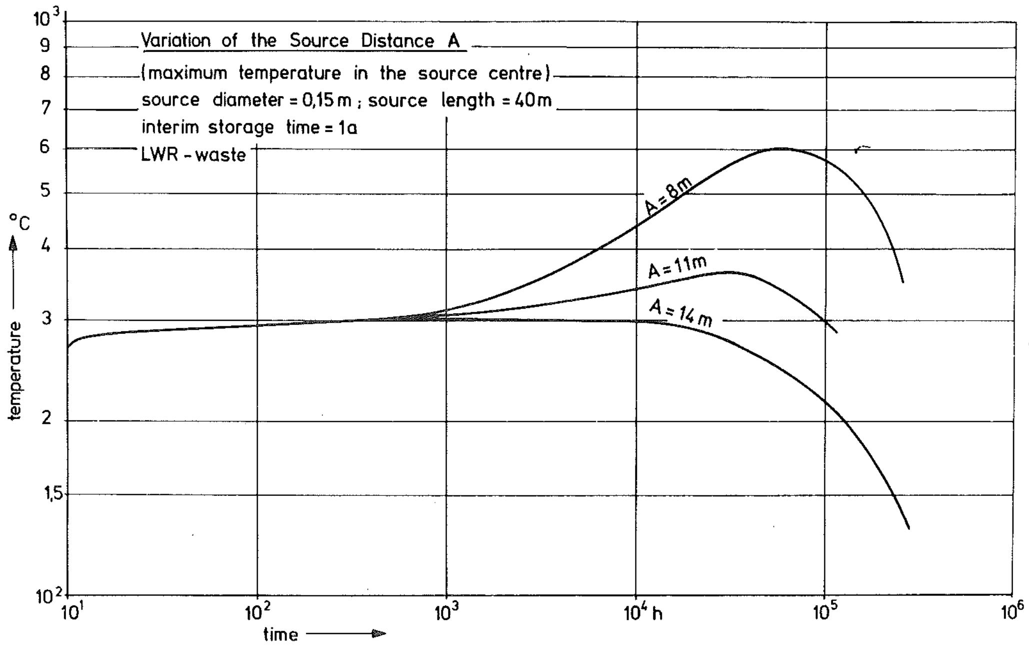

Fig. 3 : Maximum temperature in the source centre with variation of the source distance A

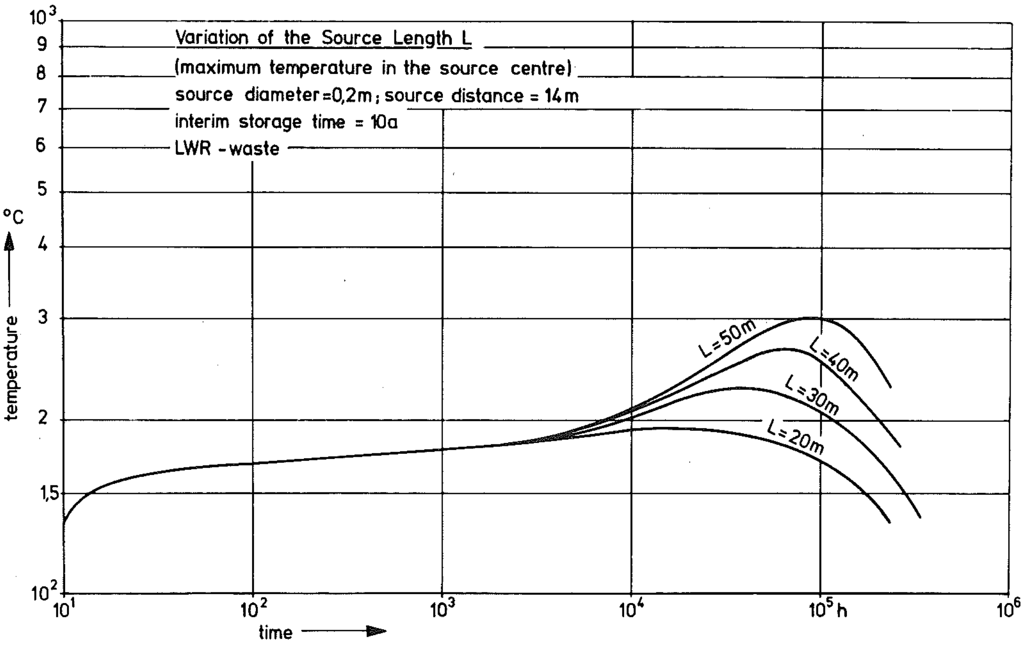

Fig. 4 : Maximum temperature in the source centre with variation of the source length L

In evaluating the temperature calculations the single temporal maximum temperatures are combined in a set of graphs with several parameters. Such an example is shown in three dimensions in Figure 5.

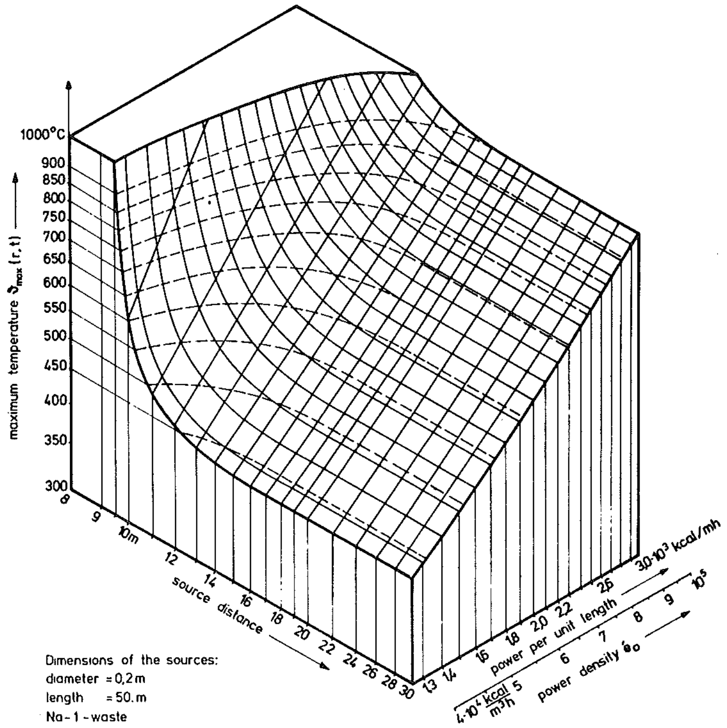

Fig. 5 : Temporal Maximum Temperature in the Centre of the Sources

3.2 Field experiments

Field experiments have been and will be performed in the mine by means of electrical heaters. In order to get detectable results of heat dissipation in the rock salt within reasonable time power density of the electrical heaters had to be chosen relatively high compared to that of actual high-level glass blocks. Whereas the maximum power density of high-level wastes at the time of vitrification will be about 100 Watt/litre that one of the electrical heaters in the most recent field experiment was three times higher, i.e. 300 W/l. The maximal temperature achieved on the surface of these electrical heaters was about 380 °C. They were of cylindrical form with a diameter of 10 cm and a length of 110 cm. The electrical power was 3 kW per heater at the begin of the experiment and was decreased with time thus simulating the decay of fission products. In this experiment the heaters were buried vertically 5 m into the salt so that the central plane of the cylinders was situated 4.5 m below the floor.

Heat dissipation around the three electrical heaters was recorded with about 70 resistance thermometers and another 40 thermocouples. Only a few results shall be given here.

At the central plane the maximum temperatures in the annulus around the heaters and on the wall of the boreholes were only little lower than those on the heaters, that means 350 - 330 °C. A very steep temperature decrease was recorded within the first meter of compact salt. 20 cm of salt dropped the maximal temperature to about 130 °C. In a distance of 50 cm from the borehole the temperature did not rise above 90 °C. In a distance of 3.5 m the maximal temperature was only 6 to 8 °C higher than normal rock temperature which is 31 °C at this mine level.

Seven temperature control points had been installed only 10 cm below the floor at various distances. At no one the temperature was higher than 37 °C though the nearest one was only 10 cm apart from the heated borehole. In this gallery there surely was a certain amount of heat exchange with the mine air though there was no special ventilation. Nevertheless heat diffusion in the salt was really spherical which is proven by another control point also only 10 cm apart from the borehole but situated another 3.5 m below the central plane. At this point, too, the temperature never was higher than 40 °C.

Agreement of results of computer calculations and of field experiments is relatively good but both have to be continued in order to find as well the maximum admissible temperatures in glass and in salt as to figure out the optimal storage pattern.

4. Transport and handling system

In the same way as it was demonstrated with the disposal of low- and intermediate-level radioactive wastes in the Asse Salt Mine [5], as well the transport and handling system for the disposal of high-level waste as the total storage technology will be proved in a first test phase. This means that the first technology may be altered before it becomes the one which will be used for routine disposal.

This statement is backed up by another very important factor. In the first years of operation beginning in 1976/77 only a small quantity of about 50 to 100 glass blocks will have to be disposed of per year. These glass blocks will originate from the prototype solidification plant VERA which will vitrify the high-level wastes from the reprocessing plant WAK in Karlsruhe [6]. Transport and handling and storage technology will certainly have to be modified or even newly designed when large quantities of vitrified waste blocks from a commercial reprocessing plant will have to be disposed of.

For the above mentioned small annual number of glass blocks, however, a transport and handling system is being designed which is restricted to the already existing equipment in the mine. The most important consequence of this idea is that no special shaft will be sunk or drilled for the transportation of high-level wastes into the mine. Furthermore all operation in the mine will be done without hot cells, unloading or reloading facilities, or remote equipment. So it is necessary to transport the high-level glass cylinders within a shielded cask through the existing shaft into the mine.

The limiting factor for this operation is the capacity of the hoisting equipment in the shaft which is 9.8 tons. According to this limit a shielded cask is being designed which will have a shielding thickness of about 37 cm of steel [7].

It will only be possible to transport one glass cylinder at a time in this shielded cask from the solidification plant at Karlsruhe to and into the Asse Salt Mine. These glass cylinders will have dimensions of 20 cm in diameter and 1 m in length which results in an effective volume of about 25 l. The total β-γ-radioactivity will be in the range of 250,000 Ci/cylinder [6].

The transport and handling system for the solidified high-level radioactive wastes in the mine will be very generally, similar to that already being used for transport and handling of intermediate-level radioactive wastes [5]. After lowering the shielded container within the hoisting cage to the bottom of the shaft at 750 m below the surface it will be picked up by a jib-crane and put on a transport vehicle. This is just being designed.

The transport vehicle will bring the shielded container from the shaft to the storage level at 775 m through a declining tunnel. In the charging room the shielded container can be positioned on top of a radiation protection cover on the respective borehole just to be filled. This radiation protection cover has to be opened together with the bottom glider of the shielded container. The glass cylinder can then be lowered into the borehole with full radiation protection. When the foreseen number of glass blocks has been stacked in a borehole this will be closed by filling it up with concrete plugs and salt.

5. Summary

All efforts of the R & D - program preparing the first disposal of solidified high-level radioactive wastes in the Asse Salt Mine must be continued and intensified within the next few years. Some important geological data, results of computer calculations and field experiments on heat dissipation, and the general idea of the transport and handling system for the glass cylinders have been reported in this paper.

Another field which is very important for the disposal of solidified high-level wastes in a salt mine are rock-mechanical questions. Because of their very specific character they shall only be mentioned here without giving any details. Nevertheless this field is also being worked on in the laboratory as well as in the mine at normal and elevated temperatures.

The aim of the complete R & D - program is to be ready for operation in 1976/77 .

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