DISPOSAL OF LOW- AND MEDIUM-LEVEL RADIOACTIVE WASTES BY MEANS OF IN-SITU SOLIDIFICATION

H. H. Homann
NUKEM GmbH, D 6450 Hanau 11, FRG

R. H. Kraemer
KfK GmbH, D 7500 Karlsruhe, FRG

ABSTRACT

The in-situ solidification concept for the disposal of LLW and MLW is in development in the FRG since 1976. This concept consists of two main components: 1) preconditioning of raw wastes by granulation and, 2) production of a free flowing grout and vertical transport into an underground cavern.

The paper covers the second subject and describes an inactive demonstration plant producing grout with a capacity of max. 5 m^3/h. The grout is fed into a vertical pipeline of 960 m length installed in the ASSE saltmine and after a residence time of 30 min. disposed of by in-situ solidification in the prototypcavern.

Results of the first campaign with the production of 146 tons of grout which were realized through the pipeline within 16 hours are reported. Detailed information is given on the transient behavior of the system and its automatic control.

INTRODUCTION

Radioactive wastes in the FRG are to be disposed of in geological formations of the deep underground in order to be isolated safety on a long-term basis from the biosphere.

One disposal technology is the so-called "In-situ Solidification" which is currently in the R&D demonstration phase. Originally developed for the storage of low- and medium-level radioactive wastes, it can also be applied for the disposal of other environmentally toxic wastes.

In contrast to the disposal technologies tested and implemented in the past, by means of which the solidified waste is disposed of in containers, the in-situ solidification process is based on a containerless disposal of the waste. When applying this process LLW-MLW concentrates, dried salts, ashes, ion exchanger resins and other solid wastes that have been preconditioned to granules are mixed with liquid wastes, for example tritiated water, and cement to form a free-flowing product (grout) which is then transported through a vertical pipe from ground level directly into the underground cavern (Fig. 1).

Due to the characteristics of the hydraulic binder, the product solidifies underground to a quasimonolithic block which ultimately fills the underground cavern almost completely.

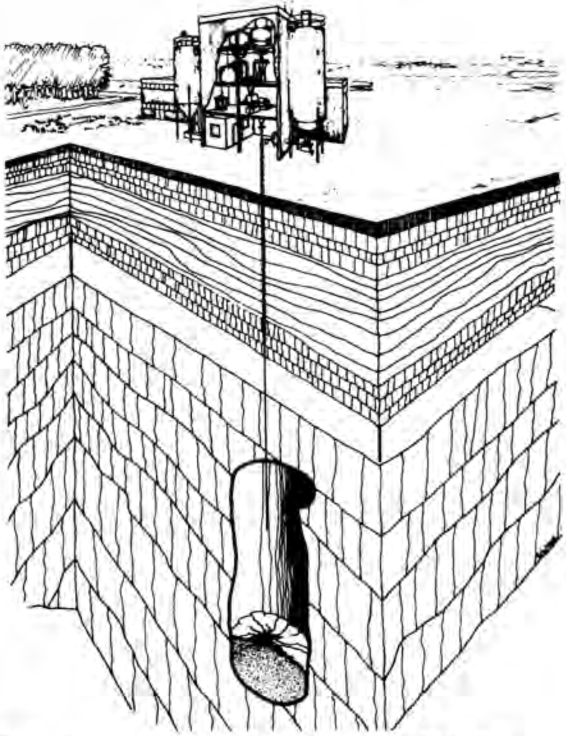

Fig. 1. In-Situ Solidification of MLW/LLW.

In comparison with established disposal technologies, the in-situ solidification is distinguished by a number of advantages, e.g. with a relatively short operation time of one or two decades, the open cavern space is refilled by a stable waste product, which restabilizes the rock formation; also the low specific surface of the monolith is a positive factor with regard to possible leaching in case of accidental intrusion of groundwater. The high degree of refilling means optimum utilization of the cavern and thus an increase in the economy of the disposal facility. Finally, the elimination of manual underground storage procedures results in reducing the radiological exposure of operating personnel and the environment.

These, as well as other advantages were the stimulus for a program sponsored by the Federal Ministry of Research and Technology with respect to the development and testing of the in-situ solidification process. Work on this program started in 1976. A first status report was presented at the Waste Management '82[1]. The program covers two main subjects:

- preconditioning of the raw wastes by granulation[2], and
- producing a free flowing grout and vertical transport into the cavern.

This paper is devoted to the second subject.

BASIC RESEARCH

Many efforts were spent to the selection of a suitable transportation system. Based on the extensive experience acquired in pumping concrete, through pipelines, a transportation process adapted from the mining sector was to be applied which avoids the known disadvantages of pump operation such as cavitation and the resulting dissociation and clogging as well as reliability problems.

The transportation principle is a continuously operating process without forced mechanical conveying but driven only by gravity. The flow rate, as an equilibrium relationship between wallfriction and gravity, adjusts itself to a certain materialflow which is liable to the pipe cross section and the rheological parameters of the grout. The system operates without overpressure and does not require pumps thus offering high inherent operational safety. Due to the relatively low flowspeed compared with free fall abrasion of the pipeline and the grout itself is held to a minimum.

As there was no literature available on the rheological characteristics of a granule-filler suspensions in a gravity driven flow, it was necessary to establish by experiment the feasibility of the process as well as the design of the transportation system with a reference throughput of 3-5 m^3/h.

After a first series of experiments, the maximum granule loading with adequate flowability of the product was determined to be about 60%. The transportation capacity as a function of diameter was determined on a test stand with a vertical pipeline of about 8 m. The observed flowrate was determined to be 1.8 m^3/h and 7.8 m^3/h for a pipe with an internal diameter of 52 mm and 82 mm respectively[3]. The basic feasibility of the process was thus confirmed. In a further step, a larger test facility was built consisting of a dosing and mixing device followed by a vertical pipeline with a length of about 50 m (Fig. 2). In more than 30 individual experiments, the transportation process with the preceding mixing operation was tested, and the process engineering parameters for the design of a full-scale system were evaluated.

DESCRIPTION OF THE DEMONSTRATION PLANT

Based on the results of the preceding experiments, a prototype demonstration plant was constructed with the following characteristics:

Length of the vertical pipeline: 960 m

Inner diameter of the pipeline: 47.4 mm

Grout transportation capacity:
max: 5.0 m^3/h
= 11.000 kg/h

min. 3.0 m^3/h
= 6.600 kg/h

Grout formula:

granules : 60% by wt.

cement : 27% by wt.

water : 13% by wt.

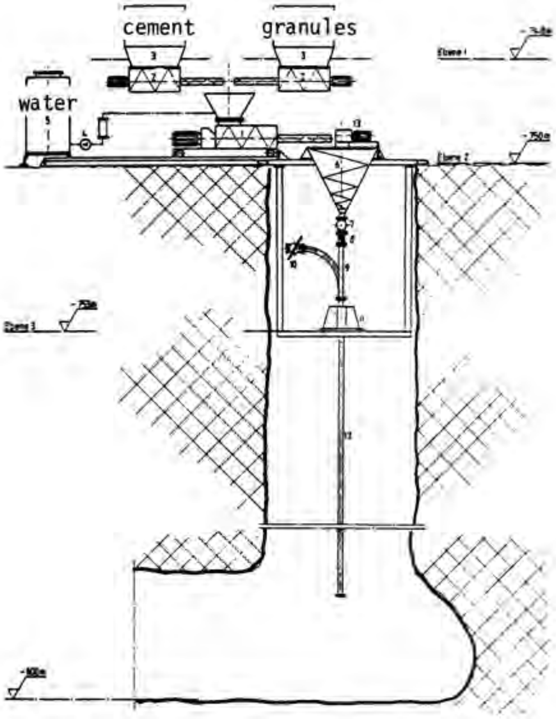

Fig. 2. Test Facility with 50 m Pipeline.

Figure 3 shows the engineering flowsheet of the plant. The cement is transferred from a silo truck into the cement storage silo B 31. This silo is equipped with an auxiliary discharge device in order to avoid the formation of bridges. The cement is delivered by means of a pneumatic conveyer mechanism to the feed hopper for cement dosing B 41.

The granules are unloaded from big bags into the vibrating screen S 17 where oversized granules i.e., 5 mm are separated out. The remaining granules are conveyed by means of an elevator into the supply silo B 11. From this silo, the granules are transported gain by means of an elevator into the feed hopper B 21 fpr the granule dosing device D 21. The feed hoppers B 21, B 41 are refilled automatically. The mixing water is combined with the necessary additives in the preparation tank B 51 according to the formula specified and is conveyed into the feed hopper B 61 for the water dosing device D 61. The dosing of the mixture constituents, i.e., granules, cement and water into the continuously operating mixer M 71 in accordance with the specified formula, is carried our with gravimetric feeders whereby the water dosing feeder is used as master feeder.

The mixer likewise continuously conveys the mixed product into the transportation feed hopper B 71. After a mean residence time of about 0.5 hours, the product is emptied into the vertical pipeline.

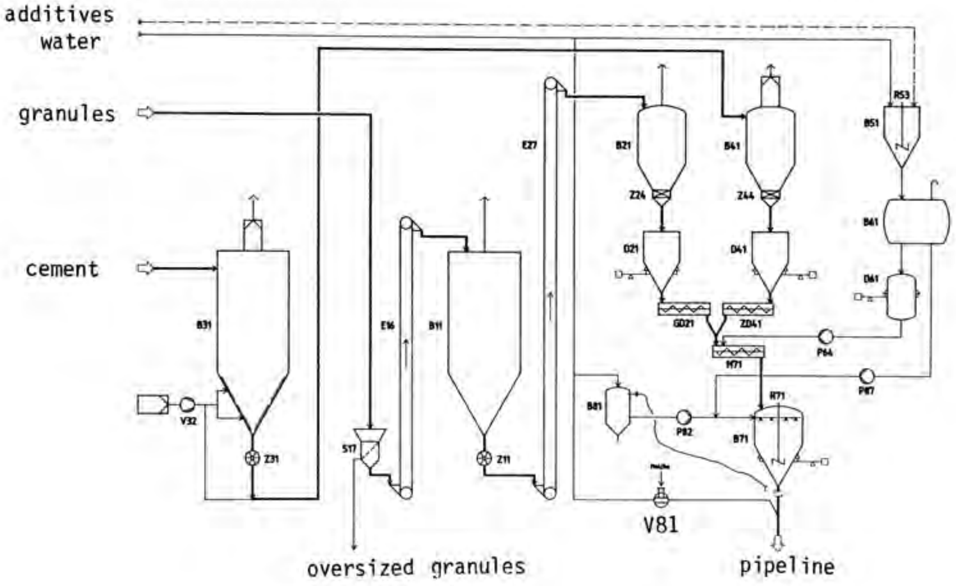

Fig. 3. Engineering Flowsheet of the Demonstration Plant.

It was adequately well known from the preceding experiments that changes in the characteristic of the ingradients such as, e.g., the fineness of grinding of the cement or the grain spectrum of the granules, could result in major changes of the flowability ranging up to clogging of the pipeline. In order to avoid these effects, the system was equipped with automatic control as follows: the level of the mixture in the transportation feed hopper was monitored through a measurement of weight. The output signal generated from this measurement acts inversely proportional on the master feeder. As a result, the level of the feed hopper remains constant. This is necessary because the torque developed by the agitator in the transportation feed hopper is monitored and is used as a measure for the flowability. This means if the characteristics of the ingredients change, the flowability also changes, as recorded by the rise or fall of the level of the grout in the transportation feed hopper. This change in level then acts on the feeders which compensate the deviation in level corresponding to the predetermined nominal value. As corresponding conditions apply for the torque measurement, this signal is directly proportional to the flowability. Brief fluctuations in the ingradients which result in reducing the flowability can be compensated by feeding additional water. Major changes must be compensated by changing the grout formula used in the process.

B 81 and P 82 represent a water recycling system with which the feed hopper can be cleaned after each campaign. Through a pig valve V 81, the pipe-line can be cleaned during and after operation. Figure 4 shows a planning model of the system while Fig. 5 shows already the completed demonstration facility.

RESULTS OF THE FIRST OPERATING RUN

During two phases of initial operation in April and June 1984, the individual functional groups were optimized with respect to their process engineering parameters, before the system was adjusted for operation. In October 1984, the first storage operation was carried out. During 16 operations hours, 145 tons of the grout were mixed and transported through the pipeline into the underground cavern at a depth of

Fig. 4. Model of the demonstration plant.

Fig. 5. Completed Demonstration Plant.

about 1.000 m. The operating performance of the system under various functional conditions will be described below on the basis of the operating records.

Preparations for Start-Up

The preparations for start-up covered the production of lubricant suspension consisting of water and cement in the relationship of W/C = 0.44. This phase served at the same time for checking and fine adjustment of the overall system. The lubricant suspension was used to lubricate the pipeline and thus to establish adequate conditions for the following transportation of the grout according to the specified formula. Figure 6 shows this phase.

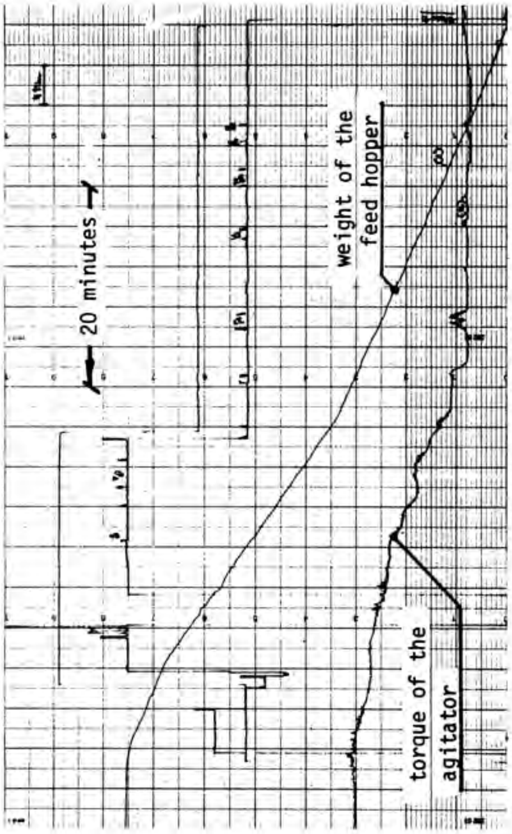

Fig. 6. Record of the Initial Filling Phase of the Feed Hopper.

In order to have adequate time for the start-up preparations, the dose rate of the master feeder was initially limited to 60% and was raised later on to 80%. The continuous rise of the weight curve from the feed hopper and the rise of the torque line could be distinctly recognized. Having reached the specified nominal value for the weight of 4.500 kg, the feeders were switched off by the controller. The lubricant mixture was agitated for about 15 minutes for the purpose of homogenization before it was released through the vertical pipeline.

Start-Up Operation

Figure 7 shows a record of the start-up operation beginning with the opening of the main valve which connects the transportation feed hopper with the vertical pipeline. Simultaneously with the opening of the valve, all three feeders were started and production of the reference mixture began. Figure 7 shows this part of the operational phase.

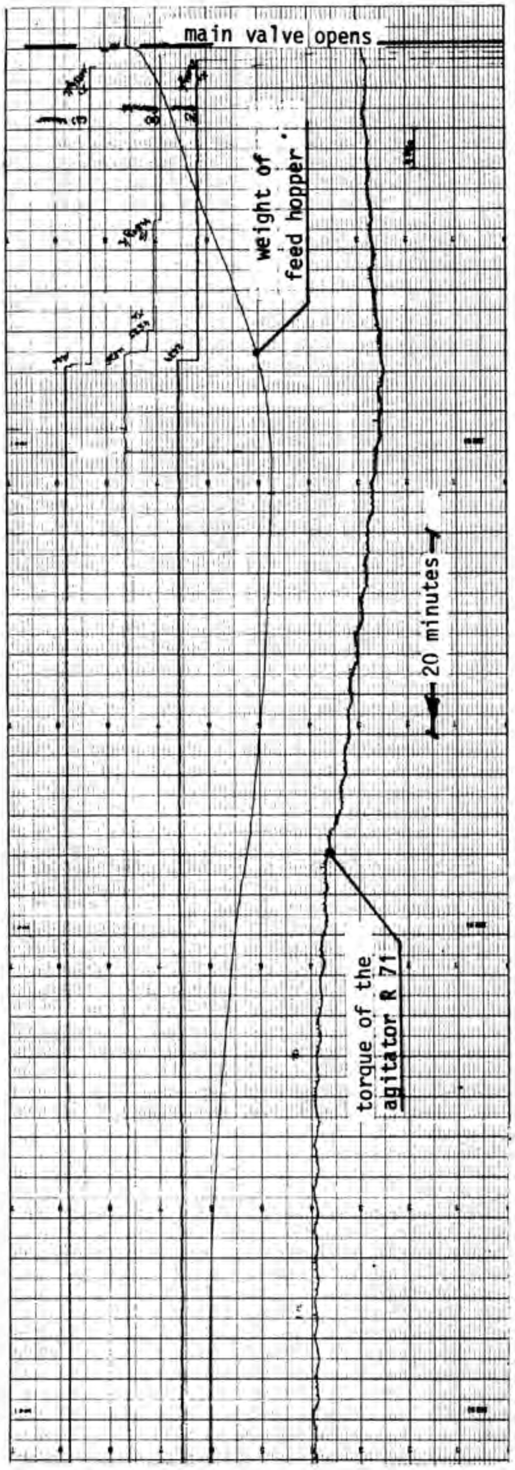

Fig. 7. Record of the Start-Up Operation.

Due to the empty pipeline and the good flowability of the lubricant, a high throughput of more than 15.000 kg/h and arrived to 10.700 kg/h after 3 more minutes. After remaining constant at this level for almost 25 minutes, the throughput dropped only minimally with a gradient of about 7 kg/min to 8.200 kg/h and then slowly rose again to a constant transportation rate of

8.650 kg/h. After a total of 120 minutes, the system was in equilibrium, i.e., the flowrate and the doserate were balanced.

Of special interest in this transient phase, is the observation of the torque curve. It reflects the same behavior as the weight curve, but with a distinctly less gain. The two curves pass through the minimum relatively close to each other with a difference of about 8 minutes. However the torque curve reaches the maximum about 25 minutes earlier which corresponds to the residence time of the lubricant in the pipe. Therefore, with the help of the weight curve and the torque curve, a good possibility for interpreting the transportation process and adequate latitude for taking control measures are provided.

Operating Phase 1 - Malfunction

During the start-up operation represented in Fig. 6 and 7, the system was operating under automatic control. At that time, the grout had not yet reached the specified granule concentration of 60%. Therefore, the flow rate and the doserate were in balance at a lower hopper inventory than specified for nominal operation. In order to attain nominal operating condition, the flowability of the product was reduced through an increase in the granule-and-cement concentration which is recognizable from the increase in the hopper weight (Fig. 8).

As these efforts were made, a malfunction in the cement feeder occurred. During the course of this malfunction, when returning the feeders to operation, an uncontrolled change in the grout formula occurred recognizable from the spontaneous rise in the torque curve with only a slight rise in the weight curve.

In order to reach correct operating conditions and to improve the flowability of the grout 16 liters of water were dosed directly into the transportation feed hopper by means of the auxiliary water pump. The result of this operation was a step-by-step reduction in the torque. After a total of 18 minutes, the system was readjusted, i.e., the effectiveness of the emergency subsystem feeding auxiliary water to control changes in the flowability was impressively proven. With the addition of only slight amounts of water, in this case 16 liters to a total of about 4.800 kg

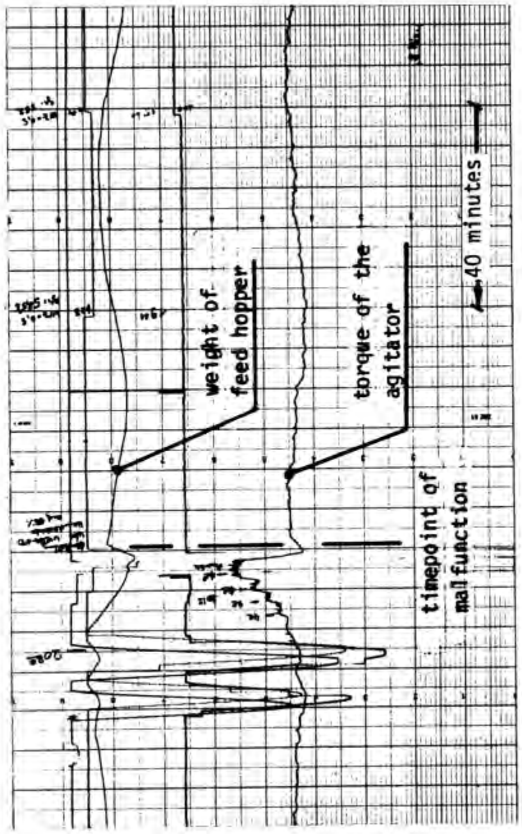

Fig. 8. Record of Operating Phase 1.

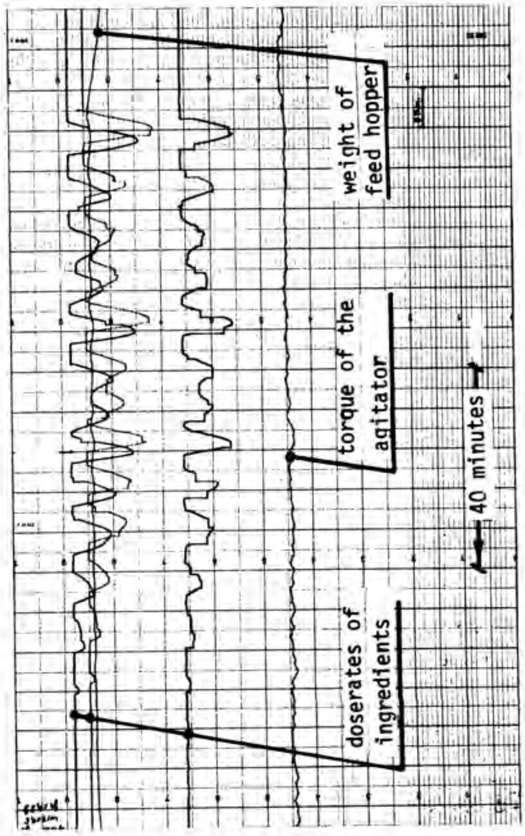

Fig. 9. Record of Operating Phase 2.

of product, the flowability of the product could be readjusted to provide controlled operation.

Operation Phase 2-Controlled Operation

As mentioned above, the system was to be shifted into the controlled mode of operation by an increase in the solid material loading. Figure 9 shows the system under controlled operation. While the weight curve deviated only by about ± 30 kg from the specified nominal value, the controller reacted at that time with inadequately damped control actions in the doserates. Neverless, this shows that the system is capable of meeting the requirements of stable process control. The control must still be optimized with respect to its gain and damping factor.

CONCLUSIONS

Regarding the results of this first storage campaign it can be stated, that the vertical transport of the reference product through a pipeline of 960 m driven only by gravity is feasible. Moreover the transient behavior of the system meets the requirements of stable control. The design data evaluated from the preceding experiments could be confirmed by the full scale demonstration facility.

With respect to the process itself, it should be remarked that its operational performance was excellent, that even in critical situations, the process engineer was able in adequate time to recognize changes in the flow characteristics and to initiate remedial measures.

Further storage operations with the system will be carried out for the purposes of testing components and optimizing details, in brief, to acquire operating experience. However, since this work does not exert a critical influence to the overall system, this process can be applied for the large scale disposal of radioactive and other environmentally toxic materials.

REFERENCES

1. R. H. Kraemer and R. H. Kroebel, "A Containerless Wastes Disposal Concept by In-Situ Solidification of MLW/LLW in Salt Caverns". Waste Management '82, Vol. 2, p. 75.

2. W. Guber, W. Zimmer, R. H. Kraemer, "Industrial Demonstration Plant for Granulation of Simulated Radioactive and Toxic Wastes". Proc. of Waste Management '85.

3. M. Weber, Y. Dedegil, H. H. Homann, "Transport of Waste into Caverns by Vertical Flow of Concrete Suspensions". Scientific Basis for Nuclear Waste Management V, Berlin 1982, p. 873.