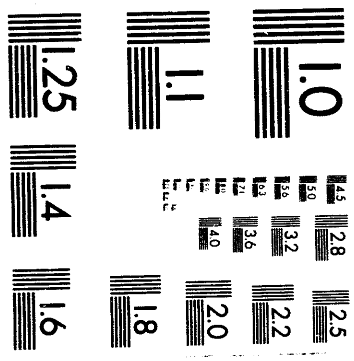
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6

Conf-940553--11

LA-UR- 94-715

Title: SIMULATED WASTE PACKAGE TEST IN SALT

Author(s): H. N. Kalia

Submitted to: Int'l Radioactive High-Level Waste Management
Las Vegas, NV
May 22-26, 1994

MASTER

Los Alamos
NATIONAL LABORATORY

Form No. 836 R5
ST 2629 10/91

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

SIMULATED WASTE PACKAGE TEST IN SALT

Hemendra N. Kalia
Los Alamos National Laboratory
101 Convention Center Drive, Suite 820
Las Vegas, Nevada 89109
(702) 794-7094

ABSTRACT

The Salt Repository Site Characterization Project Office (SRPO), of the U.S. Department of Energy (DOE) Office of the Civilian Radioactive Waste Management (OCRWM), in cooperation with Federal Republic of Germany (FRG), simulated a waste package test at Asse Salt Mine (Asse). The purpose of this test was to determine the effect of heat produced by the decay of High-Level Radioactive Waste (HLW) on:

o Migration of brine moisture;
o Thermomechanical response of the salt;
o Geomechanical response of the room mined in salt;
o Corrosion on potential HLW waste package container materials; and
o Generation of gases.

This paper describes the test performed, results obtained, and the performance of instruments and data acquisition system deployed.

INTRODUCTION

Before Congress amended the Nuclear Waste Policy Act of 1982[1], in December of 1987, three geologic locations were being characterized as potential hosts for HLW from civilian nuclear reactors (spent fuel) and HLW from defense facilities. The three projects were: Salt Repository Project (SRP), Basalt Waste Isolation Project (BWIP), and Yucca Mountain Site Characterization Project (YMP), known at that time as the Nevada Nuclear Waste Storage Investigation (NNWSI). The SRP was supported by Battelle Project Management Division (BPMD), of Battelle Memorial Institute (BMI), Columbus, Ohio. This test was performed under a DOE and FRG Bilateral Agreement.

The test was conducted at Asse to simulate the effect of heat produced by the decay of HLW on (1) the migration of brine moisture; (2) the thermomechanical response of the salt; (3) the geomechanical response of the room mined in salt; (4) the extent of corrosion on the potential waste container materials; and (5) generation of gases, pressure, and composition.

Planning for the test was initiated in 1980 and was completed in 1981[2]. Mining for the test room, which was located 800 m below the surface in a bed of halite, began in December 1981. The test room was 60 m long, 20 to 40 m wide, and 10 to 15 m high3. The room was mined by a continuous miner. Figure 1 shows the general layout of the test.

TEST PARAMETERS

Major test objectives3 were to: (1) observe the effects of heat and gamma radiation on migration of brine (moisture) present in salt; (2) qualify test methods and equipment for tests to be performed later in the Exploratory Studies Facility (ESF) to characterize the Salt site and to assist characterization of potential German HLW repository site; (3) monitor conditions in the test boreholes resulting from the interactions between salt and materials in the boreholes due to radiolysis, corrosion, and gas generation, etc; (4) observe and monitor thermomechanical behavior of the salt; (5) monitor pressure buildup due to the release of gases generated, and (6) use the data gathered to validate predictive models to establish the response of salt under radiation and thermal loads.

TEST CONFIGURATION

Four separate similar sets of test equipment were installed. Each set consisted of a central heater borehole 43.5 cm in diameter, a sleeve 5 m long, 8 guard heaters, and 3 thermocouple boreholes. Figure 2 shows the vertical cross section of the non- radioactive test assembly. Figure 3 shows the horizontal cross section of the test assembly near the heater. The lower 2 m of the borehole was electrically heated. In experiments with cobalt 60, the cobalt 60 sources were placed at the lower 2 m of the heated boreholes. Heat produced by the decay of cobalt was considered in applying the electric load to heat the salt. To achieve a maximum salt temperature of 210o C and a temperature gradient of 3o C/cm, at the central borehole wall, total power output for the central heater was set at 3 Kw, and total output from the guard heaters was set at 7.22 Kw.

TEST CHRONOLOGY

The mining for the test room was initiated in December of 1981, and completed in March of 19822. Drilling to install the instruments began in June of 1982, and was completed in December of 1983. Test equipment was installed during the months of March through May of 1983. Heaters were energized on September 12, 1983. Cobalt sources were inserted in December of 1983. The heating phase and data acquisition continued through November of 1985.

To terminate the test, cobalt sources were removed during the months of October and November 1985. To minimize cracking of the salt, as it cooled, the temperature was gradually reduced in seven identical steps. The testing was terminated at the end of November 1985 or 918 days after the heating cycle was started.

TEST INSTRUMENTATION

The central borehole wall temperature for the test was measured at five elevations and three azimuthal locations for a total of 15 locations (Figure 4). The temperature of the lower sleeve was measured at three elevations and three azimuthal locations for a total of nine locations per experiment. The temperature was also measured by a temperature probe at five elevations along three azimuthal locations. Instruments were installed to monitor failure of power at the central and guard heaters.

Displacement and power switches were installed to detect the collapse of the borehole walls and to quickly retrieve the radioactive sources should the borehole collapse. Heater sleeve deflections were measured at six locations at the same plane.

The temperature was monitored by grounded junction chromel-alumel type K thremocouples with 1 mm diameter Inconel 600 sheathes. These thermocouples had a temperature range of (250 to 3500).

The room deformations were monitored by installing three point extensometers. In all, nine extensometer stations were installed. The horizontal closure of the room was monitored by measuring between the extensometer heads.

The floor heave was measured by installing 25 survey leveling stations. Floor cracking or propagation of fractures, as the floor temperature increased, were detected by acoustic monitoring devices.

The stresses induced by deformation and thermal loading were measured by Glotzl direct reading stress cells and strain gauge stress meters developed by Sandia National Laboratories.

To measure corrosion, several metallic coupons (table 1) were attached to the spring clips used in the borehole wall temperature monitoring assembly. The specimens were distributed at circumferential intervals of 120 degrees at three elevations in the heated and irradiated zones.

Moisture and brine migration detection was accomplished by installing a moisture collection system.

For this test a closed cycle system2 was used. In the closed system, the gas exiting from the borehole is used as a carrier. The moisture is removed in cold traps and the gas is recycled. At Asse a single refrigerator was used to collect water from the four test locations.

This method doesn't collect all of the water/brine produced. Some of the moisture having low partial pressure and hydrated product remain in the borehole. This liquid was collected at the completion of the test.

The moisture collection system also consisted of monitoring borehole gas pressure, collecting released gases, low-flow alarm switches on each loop, and pressure difference monitors across each pump.

PRE-TEST ACTIVITIES

Critical test site characteristics were obtained at the beginning of the test. The test room was geologically mapped. Several salt samples were taken and tested to obtain salt properties, such as water content, chemical composition, mineralogical characteristics, uniaxial compressive strength, tensile strength, dynamic elastic modulus, shear strength, modulus of rigidity, and time dependent creep properties. Table 2 provides average mineralogical composition of Asse salt moisture content and its thermal conductivity.

DATA ACQUISITION

The data collection was accomplished by a Data Acquisition System (DAS) having a capacity to monitor 1000 channels. Two hundred channels per experiment were required.

The DAS had three basic functions: (1) measure and record selected test parameters; (2) monitor selected test parameters and identify unusual performance with alarm; and (3) monitor current to electrical heaters and automatically switch to the backup power supply in the event of power failure. The DAS scanned all of the channels and checked for out-of-limit conditions every two minutes.

TEST RESULTS

There were no significant problems encountered once the test heaters were turned on. The test performed as designed for about two and a half years. For the entire period, the test instrumentation performed satisfactorily and yielded acceptable test results.

The quantity of moisture/brine collected during the test was slightly less than predicted. A large influx of moisture occurred when the cool down phase was implemented.

Thermomechanical response of salt at each test location were comparable to the pre-test prediction. The power level for the heaters had to be increased during the test because the in situ thermal conductivity was found to be higher than that used for pre-test calculations.

Observed geomechanical response of the room was accurately predicted by the models for ambient conditions. However, the displacements under predicted for heated rooms.

Corrosion coupons recovered from the test showed very little corrosion. It is conceivable that the test duration or the amount of brine was not enough to initiate corrosion.

Prior to the start of heating, the boreholes were purged with dry nitrogen. Gas samples were taken every four weeks thereafter from the boreholes and analyzed for composition. Hydrogen gas was observed in tests with and without radioactive sources.

Out of the four tests, only two of them: location 1 and 3 were designed as sealed systems. Test location 1 operated satisfactorily and gas pressure increased with time. Minor leaks occurred. However, it was possible to seal these leaks. However, during the cool down phase, the borehole lost pressure, presumably because of the fractures around the borehole as the salt cooled.

Test location 3 operated as a sealed system for over 200 days and then developed a leak. This leak could not be fixed.

In general, it was difficult to maintain seals. Nevertheless, during the period that the test locations were gas tight, gas samples were successfully taken and analyzed.

POST-TEST ACTIVITIES

This activity consisted of retrieving cobalt sources and returning them to suppliers, obtaining material samples (salt, fluids, corrosion coupons), and instruments for post-test evaluation.

The DAS and the power controllers were covered with several millimeters of salt. Although no failure occurred during the test, should the test had continued, the components would have failed. In fact, the DAS did fail when the test was being terminated.

Test assemblies were removed from test locations 1, 2, and 4. However, the test assembly from location 3 could not be extracted. A ramp was driven from the floor level to expose the equipment at test location 3.

The irradiated salt had changed in color to honey and blue. The change in color is attributed to the formation of colloids. At the maximum color change, the radiation dose absorbed by the salt was 2x10E8 rads. At the heated midplane, where the salt temperature was 2100 C, the maximum radiation dose was 4.6x10E8 rads. In the region of maximum salt temperature, the color changed to honey. There was no significant change in the observed geomechanical properties of the salt.

All of the corrosion coupons
attached to the thermocouple cage showed some corrosion. Gamma radiation from the cobalt source seems to have had very little impact on the corrosion of the test samples.

CONCLUSIONS

When the actual field data were incorporated into the computer models to predict the test behavior, the test results were in close agreement. Major test objectives were achieved. The brine was successfully collected and volume obtained, though less than predicted, the trend of release was consistent with the model prediction. The thermomechanical response was consistent with the predicted results. The geomechanical response of the room was consistent with the prediction. The room response was under predicted when heated. The instrumentation, with the exception of strained gaged stressmeter, performed as desired. The stress gaged meter could not be calibrated, and therefore, a suitable conversion from volts to stress could not be achieved.

The affect of radiation on the salt properties was not significant, nor did it seem to accelerate the corrosion of test coupons or the assembly.

It was difficult to maintain sealed systems to collect released gases. The gas samples collected, while they were sealed, were analyzed for composition.

The DAS, while functioned as designed for most of the test duration, did fail in the end because of accumulation of salt on the connectors.

All other test hardware (heaters, brine collection system, excavation and drilling equipment, extensometers, etc.) performed satisfactorily.

It can be concluded that the brine migration, thermal stress/strain behavior of the salt at Asse can be considered as validated.

ACKNOWLEDGEMENT

The work described in this paper was sponsored by the Salt Repository Site Characterization Project office as a part of the Civilian Radioactive Waste Management Program. The Project was managed by the U.S. DOE, Salt Repository Project. This Project was performed under DOE and

FRG Bilateral Agreement. The data used in preparing this paper is based on existing and published data i.e., no new data was used in preparing this paper.

REFERENCES

1. United States Congress, Nuclear Waste Policy Act, Public Law 97- 425, as amended December 21, 1987; Omnibus Reconciliation Act of 1987 Conference Report HR 3545

2. Rothfuchs, T; Wieczorek, K; Federson, H.K; Staupendhal, G; Coyle, A.J; Kalia, H; Eckert, J; Brine Migration Test, Final Report, GSF-Bericht 6/88. Gesellschaft fur Strahlen - und- Umweltforshung mbh Nunchen, Federal Republic of Germany, 1988

3. Klein, F.F; Leroch, M.J; Kehrman, R.F; Brine Migration Test for Asse Mine Federal Republic of Germany. Westinghouse Electric Corporation, Waste Technology Services Division, Madison, Pennsylvania. WTSD-TME-026, January 1986

Figure 1 - Brine Migration Test Room

Figure 2 - Vertical Section of non Radioactive Test Assembly

Figure 3 - Horizontal Section of Test Assembly Near Heater Midline

Figure 4 - Thermocouple Location

Table 1 - Chemical Composition of Asse Halite and its Thermal Conductivity

Table 2 - List of Corrosion Coupons

MINERALOGIC COMPOSITION AND WATER CONTENCT OF SALT AT ASSE MINE

EXPT #	MINERALOGICAL COMPOSITION (WEIGHT%)			WATER (WEIGHT)	
	HALITE	POLYHALITE	ANHYDRITE	TOTAL	ABSORBED
1-1C	99.99 ± 5.30	2.93 ± 1.43	2.580 ± 4.17	0.23 ± 0.22	0.05
1-1T1	94.00 ± 6.60	3.27 ± 2.88	2.730 ± 4.15	0.22 ± 0.17	0.02
1-1T2	96.58 ± 2.87	2.95 ± 2.34	0.457 ± 0.77	0.28 ± 0.27	0.10
1-1T3	92.47 ± 7.03	3.01 ± 1.48	4.520 ± 5.80	0.21 ± 0.10	0.03
2-2C	95.13 ± 4.88	4.12 ± 3.86	0.750 ± 1.18	0.23 ± 0.21	-
2-2T1	92.85 ± 5.81	6.68 ± 5.22	0.470 ± 0.90	0.44 ± 0.35	0.04
2-2T2	93.01 ± 7.32	6.28 ± 5.77	0.710 ± 2.04	0.31 ± 0.25	-
2-2T3	93.41 ± 8.30	3.52 ± 2.56	1.770 ± 3.09	0.20 ± 0.15	-
3-3C	94.85 ± 2.77	2.90 ± 2.80	2.200 ± 2.02	0.18 ± 0.18	0.01
3-3T1	94.13 ± 3.68	2.44 ± 0.63	3.430 ± 3.45	0.13 ± 0.04	-
3-3T2	94.99 ± 3.39	2.26 ± 1.41	2.850 ± 1.97	0.16 ± 0.11	0.02
3-3T3	94.87 ± 5.36	4.10 ± 3.23	1.110 ± 2.26	0.26 ± 0.24	0.01
4-4C	95.73 ± 3.62	1.88 ± 1.41	2.340 ± 2.81	0.12 ± 0.10	0.01
4-4T1	96.16 ± 2.21	2.07 ± 1.24	1.970 ± 1.30	0.14 ± 0.14	0.02
4-4T2	95.25 ± 4.63	2.33 ± 1.95	2.410 ± 3.06	0.16 ± 0.11	0.02
4-4T3	92.00 ± 9.68	2.52 ± 1.98	5.480 ± 7.99	0.13 ± 0.09	-

THERMAL CONDUCTIVITY OF ASSE SALT

TEMPERATURE C	25	50	100	200	300
THERMAL CONDUCTIVITY IN W/mK	5.5	4.9	4.4	3.3	2.7

TABLE 1

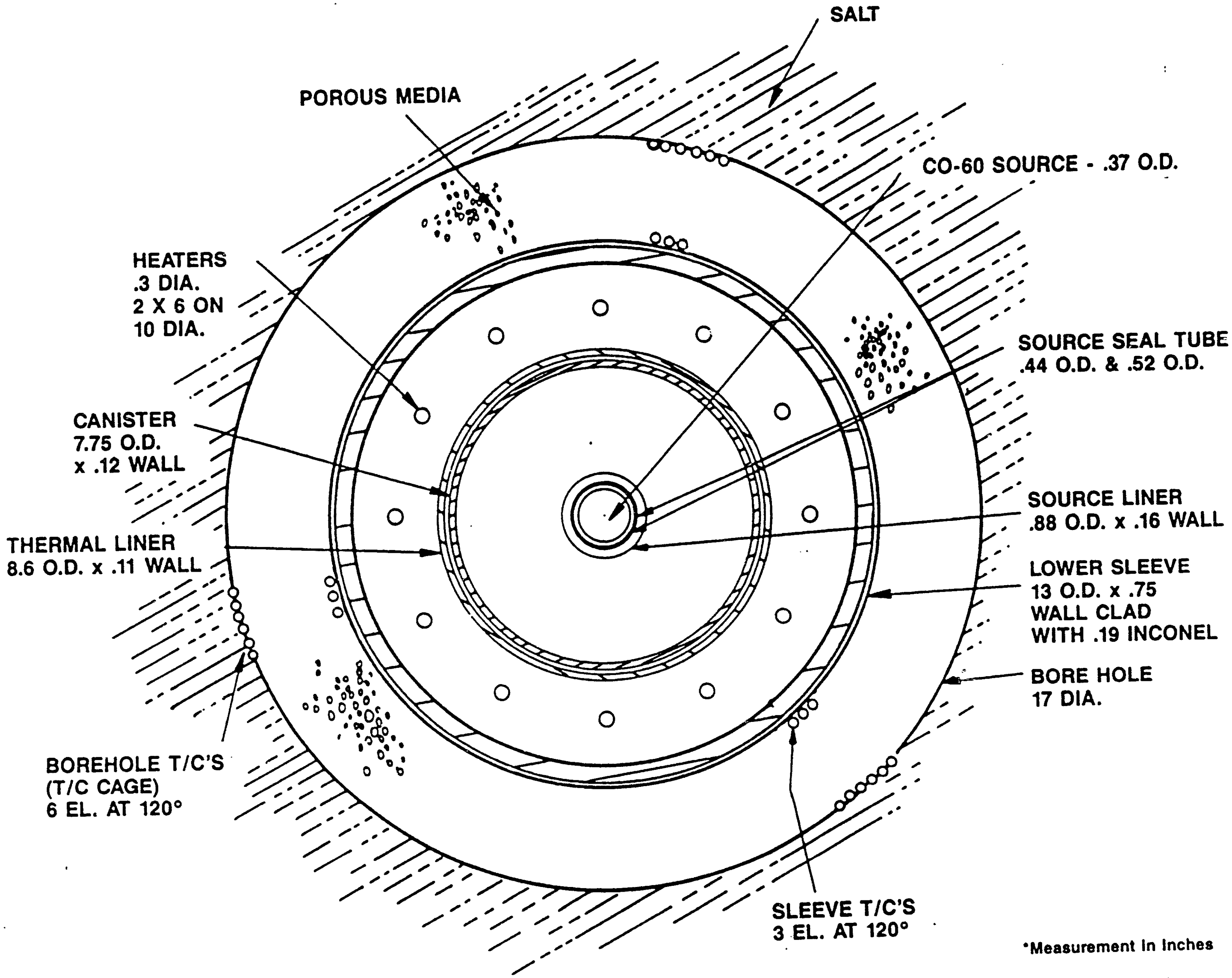

Figure 1 - Horizontal Section of Test Assembly Near Heater Midline

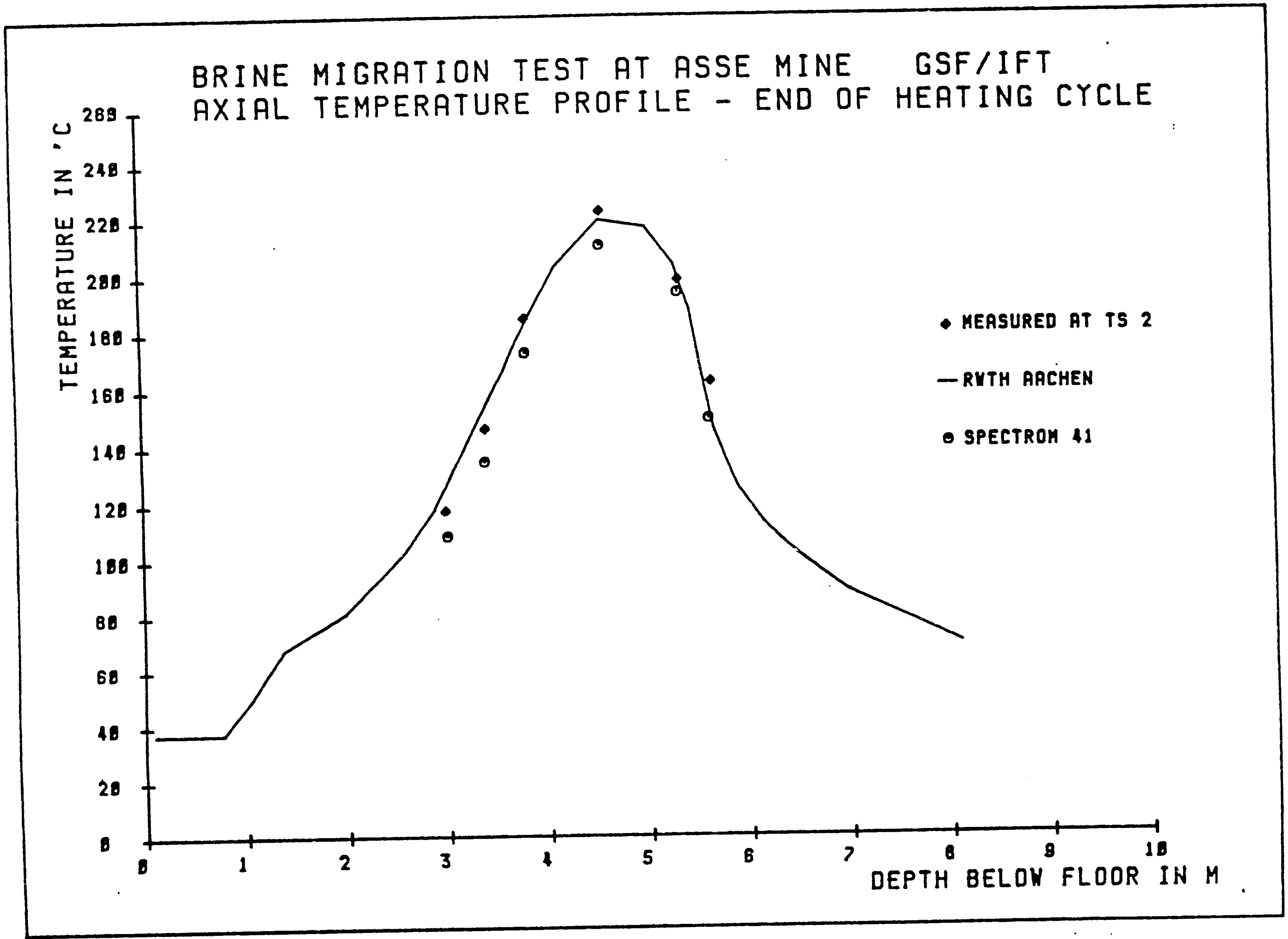

Figure 2 - Comparison of the Measured Borehole Wall Temperature at Test Site 2 and the Post - Test Calculation Results

DATE
FILMED

4/11/94

END