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IN SITU EXPERIMENTS TO SUPPORT DEVELOPMENT OF THE WASTE ISOLATION PILOT PLANT (WIPP)*

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The main thrust of the WIPP in situ activities will be those associated with the WIPP early shaft complex to be planned and developed in the FY80-81 time frame. In this early shaft complex, there will be significant geological investigations. There will also be complexes for the following:

Large-scale rock mechanics design verification
Drifts with the heat load of anticipated waste
Experiments to address technical issues of:¹

TRU waste emplacement and retrieval (without radioactivity)
Non-radioactive high-level waste interactions
Thermal structural experiments
Stable nuclide migration
Brine migration
Permeability
Borehole plugging
Operation and design
Instrumentation development and monitoring

Waste interaction investigations include corrosion, getter (multibarrier) development, nuclide transport (stable nuclides), i.e., those areas where preliminary information can be obtained without radioactivity. This project is (10/79) in the early planning and layout phase.

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The borehole plugging program, largely independent of the early shaft, is continuing in southeastern New Mexico for the next few years. Initial activities centered about sealing a plug against the high-pressure Bell Canyon aquifer (FY79). Activities in FY80 include potash core tests, a shallow wellbore test bank, and media quantification experiments in southeastern New Mexico.

In the short term, activities are currently underway at the Avery Island mine (in cooperation with ONWI) that include instrumentation development (hole closure device) and in situ performance verification of Sandia-developed stress gages for salt and heater development. Future activities at Avery Island will include scanning of intact salt with radar, a joint Sandia/ONWI investigation of brine migration (shutdown of ONWI heater at Site B) and possibly other activities.

For some WIPP experiments, use of the tunnels at the Nevada Test Site are being considered. At present these include particulate and telemetry equipment experiments that are planned for FY80.

Some limited access to southeastern New Mexico mines is also being investigated. Tentatively, our efforts at such mines would include a brine migration experiment, some hole closure, scanning of intact salt (radar and resistivity) and whatever other activities that could be arranged with the mine.

Finally, bench scale activities continue and new activities are planned centering around a joint Battelle PNL/Sandia bench scale experiment with real waste in salt.

Most of the in situ activities now underway or in planning are summarized in Table 1. An asterisk denotes an activity where experimental work is underway. In these noted cases, results have been obtained from work at southeastern New Mexico mines, from the ONWI-run Avery Island facility in Louisiana, and large bench scale experiments at Sandia. The field work and results to date are briefly mentioned below.

THERMAL/STRUCTURAL

Bench Scale Experiments. A large block of salt, 1 m high and 1 m diameter, was instrumented with a heater in its center with surrounding thermocouples. Information was obtained on:²

Thermal conductivity—isotropic for this block of bedded salt. Strict control must be obtained on external boundary conditions of experiments of this type in order to model adequately. More material data are needed for crushed salt for adequate modeling.

TABLE 1

	Relevance to WIPP			
	WIPP Oper	WIPP Design	WIPP Expts	WIPP Monit
<u>TRU CHARACTERIZATION (Simulation)</u>				
<u>HLW INTERACTIONS</u>				
Corrosion material and leaching coupons in heater fields			Yes	Yes
Bench-scale experiments			Yes	
<u>THERMAL/STRUCTURAL</u>				
Bench-scale experiments*			Yes	
Hole closure--ambient and heated*		Yes	Yes	
Single heater experiments			Yes	
Mine deformation experiments*	Yes	Yes	Yes	Yes
Heated room			Yes	
Heated pillar			Yes	
<u>NUCLIDE MIGRATION</u>				
None (stable isotopes possible in heater fields)			Yes	
Getter experiments*			Yes	
<u>PERMEABILITY</u>				
In situ permeability in mine	Yes	Yes		
Nitrogen gas pocket analysis			Yes	
<u>BRINE MIGRATION</u>				
Bench-scale experiments*			Yes	
In situ heater experiments			Yes	
<u>BOREHOLE PLUGGING</u>				
Salt plug tests at mine level		Yes		
Media quantification		Yes		
<u>OPERATION AND DESIGN</u>				
Drilling studies	Yes			
Simulated Storage and retrieval/TRU	Yes			
Simulated TRU operation	Yes			
Simulated retrieval of HLW forms	Yes	Yes		
Radiation background*	Yes			
Mine ventilation studies	Yes	Yes	Yes	
Scanning of intact salt*	Yes		Yes	
Moisture exchange/mine vent system/outside air*		Yes	Yes	
Coring in hot salt			Yes	
<u>INSTRUMENTATION DEVELOPMENT</u>				
Thermal probe*		Yes		Yes
Stress and deformation sensors*		Yes		Yes
Borehole closure devices*		Yes		Yes
Heater development*		Yes		

Instrumentation techniques--Thermocouples with stainless steel sheaths or inconel sheaths gave the same reading side by side. Material used to fill thermocouple holes (suerisen cement or crushed salt) did not affect the readings.

Corrosion coupons--Fourteen corrosion candidate coupons, in a special hole in the block, were picked to represent a wide range of classes. Included were the following: (1) titanium C.P., (2) titanium-6V-4Al, (3) Hastelloy C-276, (4) Inconel 600, (5) zirconium, (6) Zircaloy-2, (7) Zircaloy-4, (8) SS-20Cb3, (9) SS-Nitronic 50, (10) SS-304, (11) 17-4 pH stainless steel, (12) 70-30 brass, (13) aluminum 6061, and (14) 1018 mild steel. The temperature at the bottom of the coupon hole was maintained between 100°C and 150°C for about ninety days. Examination of all coupons confirmed that nothing corroded. The 70-30 brass, 1018 steel and 304 stainless steel coupons had a thin, nonadherent oxide film on the polished surface. The weight change was below experimental detection limits.³

Deformation Experiments--Pillar Collapse. The structural deformations following an ongoing mining operation in salt/potash were measured. Information was obtained on:

Structural deformation of rooms and pillars following sequential mining.

Instrumentation techniques--It was necessary to develop instrumentation to measure large deformations and to develop an absolute level gage to distinguish floor heave from ceiling motion; the first field test of sandia-developed stress gages for salt was made.

Hole Closure. Hole closure data for a given hole depth, as a function of time, are being taken in conjunction with testing a developmental closure gage.

NUCLIDE MIGRATION

Bench-scale measurements of thermal conductivity and contact resistances for WIPP HLW backfill barrier material (clays, sands, salt) are in progress. Results obtained have confirmed that the thermal probe used in this study is accurate and repeatable. Calculated maximum probable errors for all values of thermal conductivity are about 5 percent. Dry backfill compositions and a compaction technique for the backfill mix have been identified. Corresponding thermal conductivities at room temperature were about 0.5 W/m °K, a value that is

large enough to justify further consideration of these materials. (This will be presented as part of a separate paper.)

PERMEABILITY

Field data were taken from WIPP horizons from the AEC-7 borehole in support of laboratory data. In these tests compressed air was injected into the borehole and the resulting flow rates into the formation were measured. These flow rates were interpreted in terms of formation permeabilities. A series of tests were conducted using the Systems, Science and Software-designed guarded straddle packer system capable of measuring permeabilities down to 0.1 microdarcy. In these interval permeability tests, 100-foot lengths of borehole were isolated and the permeability of the surrounding formation examined. Tests were conducted at depths of 2270 feet and 1870 feet.

Interval permeability test results indicate the 100-foot-thick salt layer centered at the 2264-foot-depth has an in situ permeability between 12 and 21 microdarcies. Constant pressure flow measurements yield permeabilities ranging between 18 and 21 microdarcies. These tests were conducted for 6- to 8-hour periods during which time the air flow should penetrate to a radial distance of approximately 10 feet. Constant pressure flow measurements indicated the 100-foot-thick salt layer, centered at a depth of 1869 feet, had a permeability of 3 microdarcy (gas penetration approximately 3 feet). When this test interval was shut in, there was no observable pressure decay. This later response is not resolved at this time.⁴

BRINE MIGRATION

A bench-scale experiment⁵ consisted of a large salt block, 1 m high and 1 m in diameter, with heater in the center. The heater core was flushed with nitrogen gas and the water content in the exhaust was instrumented with two independent techniques. Water release from the heated borehole was measured by continuously purging the sealed borehole with very dry nitrogen gas and measuring the water content in the exhaust gas with two independent techniques. Data was automatically recorded by a computer-based data-acquisition system. The heating of the salt block started on November 28, 1978, and terminated on April 16, 1979, after a series of steps at decreasing heater power. At the maximum heater power of 1.5 kW, the maximum temperature and temperature gradient at the surface of the heater hole were approximately 200°C and 12° C/cm, respectively.

The total amount of water released from the heater hole during the course of the experiment was about 110 grams—a small fraction of the estimated 2 to 8 kilograms of water present in the salt block. Over 40 percent of the total water released occurred during the shutdown phase. The average and peak rates of moisture release during this phase were much higher than either during "power up" or the "steady state" phases. A similar surge of moisture was observed during a thirty-minute power outage. During the 69-day period when the heater power was held at 1.5 kilowatts, moisture was released at a monotonically decreasing rate.

Complete data analysis and analytical modeling of Salt Block II have not been completed. Analyses using both fluid inclusion migration and vapor phase transport are being used. The former may be able to predict moisture release quantities during "power up" and "steady state" but cannot explain release rates during shutdown. The latter may be more appropriate to these transients.

Mineralogical post-mortem analyses of Salt Block II are underway. In one examination a slab of rock 1-cm thick was cut from a 4-inch core taken adjacent to the heater hole. Transmitted-light optical microscopy revealed the presence of elongate tracks of fluid inclusions, oriented radially with respect to the heater hole. Many of these tracks are terminated (at the "heated" end) with structures resembling nail-heads, walking-stick heads, and spindles. These tracks, together with the occurrence of carnallite encrusting the heater-hole surface, indicate that a significant fraction of the 111 grams of water recovered in the Salt Block II experiment made its way to the heater hole in the liquid phase.

OPERATION AND DESIGN

Radiation background. Background radiation measurements were taken in potash and salt mines. Data are being analyzed.

Scanning of intact salt. (By resistivity and radar techniques) The resistivity techniques center on ideas taken from the Asse mine. The first resistivity measurements using four-point probe revealed the potential of the method.⁶ Resistivities vary from less than 100 OHM-meters, when "wet" salt or salt with clay impurities is present, to more than 60,000 OHM-meters where dry salt is encountered. Preliminary radar scanning measurements using reflected radiation, under controlled conditions, could reveal voids, brine, and metal in intact salt. In this first measurement, the ranges were short, approximately 50 feet or less, but they will be increased in subsequent measurements.

Moisture exchange. Moisture exchange between the mine ventilation system and the outside air have been done under different conditions. In one instance, temperature pressure and relative humidity measurements have also been taken underground near the bottom of the inlet and exhaust shafts during the period from February through April 1979. The humidity and temperature in the exhaust air showed little variation—essentially remaining constant around 35 percent and 23.5°C, respectively. The intake air showed some variation during the course of the experiments, and a range of 23 percent to 61 percent was observed on the relative humidity. The temperature at the mine level in the intake showed only a modest variation between February and April (11° to 23°C), and the daily variation was only 3° to 4°C. Because of the influence of salt particles in the air, proper experiment techniques for relative humidity were not easily developed—especially for the dewpoint hygrometers. These measurements and an earlier measurement show that certain mines in south-eastern New Mexico can give up moisture to the outside, at least at certain times of the year. Various configurations of filters were investigated, ultimately establishing a reproducible, well-calibrated system. In another instance, manual measurements were made at Avery Island for about a year for intake and exhaust air. The main variations are, as expected, on the inlet side. Data from these activities will ultimately yield heat transfer coefficients for typical shafts as well as flow coefficients when surface meteorological data is factored in. The data also suggest that conditioning of inlet air may be impractical.

Particulate Studies. The air particulate studies were performed during mining activities in a SENM mine and at a surface drill site during drilling operations.⁷ The underground data were collected about 2 km from the mining operations, while the surface measurements were made on the drill pad adjacent to the rig. Particle size distribution and total suspended material were measured. Data were taken using Anderson impactor samplers. The average particulate load on the surface (approximately 150 microgram/m³) was less than that observed underground (approximately 340 microgram/m³). Yet, during very dusty conditions, the surface level was observed to exceed 800 micrograms/m³. The surface site measurements could represent particulates ingested by the mine ventilation system under certain conditions.

INSTRUMENTATION DEVELOPMENT

Thermal probe. A simple thermal probe, to measure thermal conductivities, has been tested in the laboratory and in situ data are being analyzed.

Stress and deformation sensors. A Sandia-modified IRAD gage and a Sandia strain gage stressmeter are undergoing in situ verification tests after earlier successful preliminary testing both in the laboratory and the field.⁸

Borehole closure devices. Two types of borehole closure devices have been developed: mechanical and capacitive. The early version of the mechanical gage, mainly for ambient closure measurements, is being tested at Avery Island and appears to be quite successful (see Hole Closure). A conceptual version of the capacitive gage, to be used for on-line closure measurements in a heater experiment (modeled after the one used at Asse), has been built, but field testing must await the design of a specific heater test.

Heater development. A new heater concept, using quartz lamps, will be tested at Avery Island. Moisture collection apparatus may be included in that test as a target of opportunity.

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