WIPP Small Scale Seal Performance Tests – Status and Impacts

R. E. Finley, J. R. Tillerson

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-76DP00789
SAND91-2247
Unlimited Release
Printed January 1992

Distribution
Category UC-721

WIPP Small Scale Seal Performance
Tests - Status and Impacts

by

R. E. Finley
J. R. Tillerson
Repository Isolation Systems Division 6346
Sandia National Laboratories
Albuquerque, New Mexico

Accepted for Presentation at the
Solution Mining Research Institute (SMRI) Conference
October 28-29, 1991
Las Vegas, Nevada

* This paper has been accepted for publication in the designated
category UC-721 conference proceedings or journal, but may differ from its present form
when it is published therein.
WIPP SMALL SCALE SEAL PERFORMANCE TESTS - STATUS AND IMPACTS

by

Ray E. Finley  
Joe R. Tillerson  
Repository Isolation Systems Division  
Sandia National Laboratories  
Albuquerque, NM 87185

Abstract

Numerous small-scale in situ seal experiments have been emplaced in boreholes up to 38 in. in diameter at the WIPP. Seal materials include expansive salt concrete, bentonite, and crushed salt. Emplacement techniques stressed conventional technology and the use of available site personnel. Preliminary evaluation of the performance of these seals has been completed by using structural data from embedded instrumentation and fluid flow data from gas and brine flow measurements. Preliminary results suggest that submicrodarcy permeabilities can be obtained using these materials and that structural performance is satisfactory.

1.0 Introduction

1.1 Background

The U.S. Department of Energy is developing the Waste Isolation Pilot Plant (WIPP) facility in southeastern New Mexico to demonstrate the safe disposal of Transuranic (TRU) radioactive wastes arising from the defense activities of the United States. The WIPP waste disposal horizon lies in a bedded salt formation approximately 2150 ft (656 m) below the ground surface. The salt is interspersed with thin clay and anhydrite layers. Figure 1 is a schematic of the WIPP facility, including the locations of major underground and surface features.

1.2 Sealing Program at WIPP

The sealing program at the WIPP is intended to develop and demonstrate technology such that seals can be designed to limit the release of radionuclides to the accessible environment. Current plans call for placement of seals in panel-access drifts for the TRU waste storage areas and in the four shafts accessing the WIPP (see Figure 1). Seal materials under consideration for use at the WIPP include concrete, crushed salt for long-term seals, and swelling clays for short-term seals. Information regarding the seal designs currently planned for the WIPP is given in Nowak et al. (1990). SNL is currently planning and performing major experiments intended to provide information that can be used to support actual WIPP facility seal designs. These experiments include Thermal-Structural Interaction (TSI) Tests, Large-Scale Seal Tests, Small Scale Seal Performance Tests (SSSPT), Disturbed Rock Zone (DRZ) characterization, and brine inflow tests. This paper discusses only the SSSPT program.

The SSSPTs are in situ experiments that are intermediate in scale between full-scale in situ seal tests and laboratory tests. The SSSPTs utilize materials and geometries similar to those currently planned for
Figure 1. Sectional View of WIPP Facility.
large-scale seal tests and seal emplacements; however, direct comparisons between the SSSPT and full-scale seals must be carefully evaluated because many of the measurements are scale dependent. These geometries, especially those intended to simulate sealing in shafts, provide demonstrations of technologies and confirmation of in situ processes that influence seal performance. This information may be useful for sealing other openings such as boreholes accessing solution mined caverns. The primary objectives (Stormont, 1985) of the Small-Scale Seal Performance Tests are as follows:

1) to determine in situ fluid flow performance for various seal systems, including evaluating flow paths, the difference between gas and brine permeabilities, and size effects,
2) to determine in situ mechanical performance of the host rock and seal materials, including material interfaces and size effects,
3) to assess seal emplacement techniques, and
4) to support the development of numerical predictive capabilities

A considerable body of work has been completed to date. This paper summarizes selected results. Many references will cite the original work.

2.0 SSSPT Test Description

The plans for the SSSPTs were developed in 1985 and are described in detail in Stormont (1985). The SSSPTs are a series of in situ experiments designed to evaluate the performance of various candidate seal materials emplaced in boreholes from 6 in. (15.2 cm) to 38 in. (96.5 cm) in diameter. The emplacement holes are oriented both vertically into the floor and horizontally into the ribs. The seal system is comprised of the seal, seal/rock interface, and the rock adjacent to the seal. Table 1 briefly describes the SSSPTs conducted to date, including a description of the primary seal material, orientation, and types of measurements made. In addition, all of the various test series utilize a similar test configuration. Figure 2 shows generalized configurations for the test series conducted to date (see Table 1). In general, an emplacement hole and an access hole (if used) are drilled either in the rib or floor of the opening. The seal material, in some cases containing instrumentation, is emplaced over a predetermined interval in the emplacement hole. A four packer fracture flow tool (FPFFT) capable of using brine or gas can be placed in the access hole (where used), and the interval beneath the seal can be pressurized for fluid flow measurements.

The emplacement techniques employed in the SSSPT test program emphasized conventional technology and the use of available personnel at the WIPP site. The seal materials used in the SSSPTs include expansive salt-based concrete, and blocks compressed from 100% crushed salt, 50/50% crushed salt/bentonite, and 100% bentonite. The blocks were pressed into workable sizes using a modified adobe block making machine (Sandia block machine) (Stormont and Howard, 1987). The manufacture and emplacement of the seal materials for each of the test series were accomplished without major difficulty, although placement of the expansive salt based concrete (SSSPT-A, SSSPT-B) required the use of chilled water and retarding admixture (sodium citrate) to maintain workability during transport underground. In addition, optimization studies to determine the most durable blocks were performed prior to the manufacture of crushed salt blocks (SSSPT-C Phase 1, SSSPT-D Phase 1), 50/50% salt bentonite blocks (SSSPT-C Phase 1), and 100% bentonite blocks (SSSPT-C Phase 2, SSSPT-D Phase 2).

3.0 Test Results

Test results for the SSSPT program are discussed in terms of the material used in the seal. The SSSPT program provides both operational information (relating to construction and materials) and performance information (relating to system response). The operational information is of a qualitative nature, whereas the performance information is obtained from direct measurements such as hole closure or gas and brine flow.

The emplacement of seals with embedded instrumentation added complexity to relatively simple seal designs. For instance, embedded instrumentation requires cabling to the surface for data acquisition. The cabling presents a potential pathway through the seal during gas and brine testing. Many of the seals tested in test series A and B showed obvious leakage along the instrumentation cable bundle when
Figure 2. Generalized Test Configurations.
<table>
<thead>
<tr>
<th>Test Series</th>
<th>Seal Material</th>
<th>Seal Emplacement Orientation</th>
<th>Emplacement Date</th>
<th>Measurements*</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Salt-Based Concrete</td>
<td>Vertical</td>
<td>7/85</td>
<td>Seal Pressure; Displacement and Temperature; Gas and Brine Flow</td>
</tr>
<tr>
<td>B</td>
<td>Salt-Based Concrete</td>
<td>Horizontal</td>
<td>2/86</td>
<td>Seal Pressure; Gas and Brine Flow</td>
</tr>
<tr>
<td>C</td>
<td>Salt and 50/50% Salt/Bentonite Block</td>
<td>Horizontal</td>
<td>9/86</td>
<td>Seal Pressure; Brine Flow</td>
</tr>
<tr>
<td>Phase 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Bentonite Block</td>
<td>Horizontal</td>
<td>12/90</td>
<td>Seal Pressure; Brine flow</td>
</tr>
<tr>
<td>Phase 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Salt Block</td>
<td>Vertical</td>
<td>1/88</td>
<td>Seal Pressure; Hole Closure; Floor Heave; Gas Flow</td>
</tr>
<tr>
<td>Phase 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Bentonite Block (short-term)</td>
<td>Vertical</td>
<td>9/89</td>
<td>Seal Pressure; Brine Flow</td>
</tr>
<tr>
<td>Phase 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: Instruments include strain gages, stress meters, thermocouples, pressure cells, borehole displacement gages, Multiple Point Borehole Extensometers (MPBX), and the Four Packer Fracture Flow Tool (FPFFT) for fluid flow measurements.
permeability testing was performed (Peterson et al., 1987). As a result, later test series included uninstrumented seals to evaluate the influence of instrumentation on seal performance.

EXPANSIVE SALT CONCRETE SEALS

SSSPT Series A and B utilized nine emplacement holes located in the floor of the D Room Alcove and in the west rib of Room M. The seal material, an expansive salt concrete developed for SNL by Waterways Experiment Station (WES) (Wakeley and Walley, 1986), was underlain by crushed salt. The aspect ratio of the seal ranged between 2:1 to 1:1. Key results from the expansive salt concrete seal tests are as follows:

EMPLACEMENT

- Emplacement of expansive salt concrete seals was successfully demonstrated as evidenced by the emplacement of nine seals in vertical and horizontal orientations using standard equipment and personnel (Stormont, 1986; Stormont and Howard, 1987)
- Standard commercial equipment and techniques were used successfully for vertical and horizontal emplacements (Stormont, 1986; Stormont and Howard, 1986)
- Concrete met emplacement criteria for slump, limited bleed, segregation, limited air entrapment, self-leveling behavior, and workability (Stormont, 1986; Stormont and Howard, 1986)

PERFORMANCE

- Submicrodarcy initial permeability was measured during brine flow testing (Peterson et al., 1987)
- A reduction in flow path size was observed by a decrease in tracer arrival times measured within a year of seal emplacement (Peterson et al., 1987)
- Brine flow rates of about 200 ml/day (Figure 3) corresponding to submicrodarcy permeabilities were measured for 91-cm-diameter seals (Peterson et al., 1987)

![Flow Data from SSSPT](image-url)

Figure 3. Comparison of Typical Brine Flow Data from SSSPT Seals.
• Structural performance of the expansive salt concrete seals was satisfactory as evidenced by the seals withstanding 1.8 MPa back pressure during brine flow testing (Stormont, 1987; Van Sambeek and Stormont, 1987; Labreche and Van Sambeek, 1988).
• The expansivity of the concrete (0.12% in the lab) provided a sufficient interface between the seal and the rock to limit fluid flow at early times (Wakeley and Walley, 1986; Peterson et al., 1987; Stormont, 1987).
• There was little evidence of thermal cracking of the concrete during cooling (Stormont, 1987).
• Thermomechanical data during early times agreed well with numerical modeling predictions, however, questions remain as our ability to predict mechanical behavior and the interactions with the surrounding salt at later times (Labreche and Van Sambeek, 1988).

100% BENTONITE BLOCKS

SSSPT-C Phase 2 and SSSPT-D Phase 2 utilize four seals constructed using blocks of 100% bentonite pressed in the Sandia block machine (Stormont and Howard, 1987). The blocks were arranged in the seals in a manner that would minimize the potential for flow along a continuous interface. Key results from the 100% compressed bentonite block seal tests are as follows:

EMPLACEMENT

• Emplacement of 100% bentonite blocks in vertical and horizontal boreholes was successfully demonstrated by the completion of four seals in a confined space although construction was very labor intensive (Torres, 1987; Torres and Howard, 1989; Torres et al., in prep).
• High density (80% of intact bentonite) durable blocks could be consistently fabricated using modified available technology (Torres and Howard, 1990).
• Seal density of >75% of intact bentonite density can be achieved in a 3-ft bentonite core (Torres and Howard, 1990).

PERFORMANCE

• Microdarcy permeability was measured after about two months of brine testing.
• The only 100% bentonite seal tested showed a marked decrease in brine flow due to bentonite swelling from about 1800 cc/day to about 20 cc/day after 150 days of testing (see Figure 3) (Torres and Howard, 1990).
• Pressure measurements show a roughly twofold increase in seal pressure after about 300 days of brine testing up to values near 0.7 MPa (Torres and Howard, 1989).

50/50% SALT/BENTONITE SEALS

SSSPT-C Phase 1 utilized blocks comprised of a mixture of 50% crushed salt and 50% bentonite. The blocks were laid so as to minimize the potential for flow along a continuous joint. Key results from the 50/50% salt/bentonite block seal tests are as follows:

EMPLACEMENT

• Emplacement of 50/50% crushed salt/bentonite block seals in horizontal boreholes was successfully demonstrated by the completion of five seals in a confined space although construction was very labor intensive (Stormont and Howard, 1987).
• High density (>77% of salt/bentonite intact density) durable blocks of 50/50% crushed salt/bentonite could be consistently fabricated using modified available technology (Stormont and Howard, 1987).

PERFORMANCE

• Millidarcy permeability was measured after about 6 months of brine testing (Torres and Howard, 1989).
• The brine flow results for the two 50/50 salt/bentonite seals indicate a flow of about 250 ml/day after about 250 days (see Figure 3) (Torres and Howard, 1989).
• Structural measurements (Stormont and Howard, 1987) suggest that the salt/bentonite block seals do not behave significantly differently than do 100% salt block seals over the time periods discussed.

• Long-term permeability of the seal can possibly be tailored using different proportions of materials.

An additional emplacement-related observation is that one of the 50/50% salt/bentonite seals emplaced for SSSPT-C Phase 1 failed by piping as a result of adding brine too rapidly. The rapid brine input did not allow the bentonite adequate time to take up water and swell to effectively seal potential flow paths. This seal failure was not related to instrumentation cabling. The seal was dismantled, inspected, and replaced. Subsequent slow input brine testing did not result in a piping failure (Stormont and Howard, 1987).

100% CRUSHED SALT BLOCK SEALS

SSSPT Series C Phase 1 and Series D Phase 1 utilized seven seals: four horizontally emplaced and three vertically emplaced. The seals were constructed using blocks of 100% crushed salt pressed in the Sandia block machine. The blocks were arranged in the seals to minimize the potential for flow along a continuous joint. Key results of the 100% salt block seals are as follows:

EMPLACEMENT

• Emplacement of 100% crushed salt block seals in vertical and horizontal boreholes was successfully demonstrated in seven seals in a confined space although construction is very labor intensive (Torres et al., in prep; Torres, 1987; Stormont and Howard, 1987).

• High density (>82% intact salt) durable blocks of 100% crushed salt could be consistently fabricated using modified available technology (Stormont and Howard, 1987).

• Tamped-in-place crushed salt can be emplaced to >75% of host rock density, suggesting a possible alternative to block seals (Howard, 1988).

PERFORMANCE OF 100% CRUSHED BLOCK SEALS

• Gas flowrate within a few months after seal emplacement exceeded the measuring capability of the equipment (Torres et al., in prep).

• Structural measurements including seal pressure and borehole displacements agree with laboratory and modeling predictions that the crushed salt seals will provide little resistance to closure and little resistance to flow until the crushed salt has achieved 90 - 95% of the intact salt density (Holcomb and Shields, 1987; Sjaardema and Krieg, 1987).

4.0 Discussion

The Small Scale Seal Performance Tests have provided preliminary information on the performance of expansive salt concretes, crushed salt, crushed salt/bentonite mixtures, and 100% bentonite as seal materials for the Waste Isolation Pilot Plant. Seals using these materials have been successfully constructed and emplaced with conventional technology and available personnel at the WIPP. The preliminary results suggest that expansive salt concretes and bentonite seals can provide seals against brine flow during early time periods, with permeabilities in the microdarcy range. The performance of 50/50% crushed salt/bentonite mixtures is inconclusive at this time; however permeabilities in the millidarcy range have been achieved. Crushed salt seals have been successfully emplaced and are currently being monitored to evaluate the long-term behavior of such seal materials for the WIPP. Information obtained to date does not contradict laboratory and modeling predictions that crushed salt must reconsolidate to 90 - 95% of the in situ density before significant reduction in fluid flow and resistance to closure occur.

The impacts of the SSSPTs on the sealing program at the WIPP are significant. The SSSPTs have provided critical information on seal materials and performance that has been used in the development of preliminary designs for the WIPP seals. The SSSPTs have also identified limitations of our knowledge of seal material performance. For instance, it is not clear from the SSSPTs whether thermal strains from cooling will induce fractures in larger expansive salt concrete seals that may be used in the WIPP. Also,
test durations for the SSSPTs are so short that longer term behavior of the seal materials is unknown. Future goals for the SSSPT program will be to address these issues. It is clear that the existing SSSPT seals should be retested to evaluate time dependence on the seal performance.
5.0 References


### DISTRIBUTION

**Federal Agencies**

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Attn: Deputy Director, RW-2</td>
<td>Associate Director, RW-10</td>
</tr>
<tr>
<td></td>
<td>Office of Program Administration and Resources Management</td>
</tr>
<tr>
<td></td>
<td>Associate Director, RW-20</td>
</tr>
<tr>
<td></td>
<td>Office of Facilities Siting and Development</td>
</tr>
<tr>
<td></td>
<td>Associate Director, RW-30</td>
</tr>
<tr>
<td></td>
<td>Office of Systems Integration and Regulations</td>
</tr>
<tr>
<td></td>
<td>Associate Director, RW-40</td>
</tr>
<tr>
<td></td>
<td>Office of External Relations and Policy</td>
</tr>
<tr>
<td>Forrestal Building</td>
<td>Washington, DC 20585</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>US Department of Energy (4)</th>
<th>WIPP Project Integration Office</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attn: W.J. Arthur III</td>
<td>L.W. Gage</td>
</tr>
<tr>
<td>L.W. Gage</td>
<td>P.J. Higgins</td>
</tr>
<tr>
<td>D.A. Olona</td>
<td></td>
</tr>
<tr>
<td>PO Box 5400</td>
<td></td>
</tr>
<tr>
<td>Albuquerque, NM 87115-5400</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>US Department of Energy</th>
<th>Attn: National Atomic Museum Library</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albuquerque Operations Office</td>
<td></td>
</tr>
<tr>
<td>PO Box 5400</td>
<td></td>
</tr>
<tr>
<td>Albuquerque, NM 87185-5400</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>US Department of Energy (4)</th>
<th>WIPP Project Site Office (Carlsbad)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attn: R. Becker</td>
<td>V. Daub</td>
</tr>
<tr>
<td>J. Lippis</td>
<td>J.A. Mewhinney</td>
</tr>
<tr>
<td>PO Box 3090</td>
<td></td>
</tr>
<tr>
<td>Carlsbad, NM 88221</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>US Department of Energy</th>
<th>Research &amp; Waste Management Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attn: Director</td>
<td></td>
</tr>
<tr>
<td>PO Box E</td>
<td></td>
</tr>
<tr>
<td>Oak Ridge, TN 37831</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>US Department of Energy</th>
<th>Attn: E. Young</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room E-178</td>
<td></td>
</tr>
<tr>
<td>GAO/RCED/GTN</td>
<td></td>
</tr>
<tr>
<td>Washington, DC 20545</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>US Department of Energy</th>
<th>Office of Environmental Restoration and Waste Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attn: J. Lytle, EM-30 (Trevion II)</td>
<td></td>
</tr>
<tr>
<td>Washington, DC 20585-0002</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>US Department of Energy (3)</th>
<th>Office of Environmental Restoration and Waste Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attn: M. Frei, EM-34 (Trevion II)</td>
<td></td>
</tr>
<tr>
<td>Washington, DC 20585-0002</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>US Department of Energy</th>
<th>Office of Environmental Restoration and Waste Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attn: S. Schneider, EM-342 (Trevion II)</td>
<td></td>
</tr>
<tr>
<td>Washington, DC 20585-0002</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>US Department of Energy</th>
<th>Office of Environment, Safety and Health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attn: C. Borgstrom, EH-25</td>
<td></td>
</tr>
<tr>
<td>R. Pelletier, EH-231</td>
<td></td>
</tr>
<tr>
<td>Washington, DC 20585</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>US Department of Energy (2)</th>
<th>Idaho Operations Office</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Processing and Waste Management Division</td>
<td></td>
</tr>
<tr>
<td>785 DOE Place</td>
<td></td>
</tr>
<tr>
<td>Idaho Falls, ID 83402</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>US Department of Energy</th>
<th>US Environmental Protection Agency (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation Programs (ANR-460)</td>
<td></td>
</tr>
<tr>
<td>Attn: R. Guimond</td>
<td></td>
</tr>
<tr>
<td>Washington, DC 20460</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>US Geological Survey</th>
<th>Water Resources Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attn: K. Peters</td>
<td></td>
</tr>
<tr>
<td>Suite 200</td>
<td></td>
</tr>
<tr>
<td>4501 Indian School, NE</td>
<td></td>
</tr>
<tr>
<td>Albuquerque, NM 87110</td>
<td></td>
</tr>
</tbody>
</table>
US Nuclear Regulatory Commission  
Attn: H. Marson  
Mail Stop 623SS  
Washington, DC 20555

NM Environment Department (1)  
WIPP Project Site  
Attn: P. McCausland  
PO Box 3090  
Carlsbad, NM 88221

Defense Nuclear Facilities Safety Board  
Attn: D. Winters  
Suite 700  
625 Indiana Ave., NW  
Washington, DC 20004

Nuclear Waste Technical Review Board (2)  
Attn: D.A. Deere  
S.J.S. Parry  
Suite 910  
1100 Wilson Blvd.  
Arlington, VA 22209-2297

Advisory Committee on Nuclear Waste Regulatory Commission  
Attn: R. Major  
7920 Norfolk Avenue  
Bethesda, MD 20814

State Agencies  

Environmental Evaluation Group (3)  
Attn: Library  
Suite F-2  
7007 Wyoming, NE  
Albuquerque, NM 87109

NM Bureau of Mines and Mineral Resources  
Socorro, NM 87801

NM Energy, Minerals, and Natural Resources Department  
Attn: Library  
2040 S. Pacheco  
Santa Fe, NM 87505

NM Environment Department (3)  
Secretary of the Environment  
Attn: J. Espinosa  
1190 St. Francis Drive  
Santa Fe, NM 87503-0968

Battelle Pacific Northwest Laboratories (2)  
Attn: H.C. Burkholder, P7-41  
R.E. Westerman, P8-37  
Battelle Boulevard  
Richland, WA 99352

Savannah River Laboratory (3)  
Attn: N. Bibler  
M.J. Plodinec  
G.G. Wicks  
Aiken, SC 29801

INTERA Inc.  
Attn: J.F. Pickens  
Suite 300  
6850 Austin Center Blvd.  
Austin, TX 78731

INTERA Inc.  
Attn: W. Stensrud  
PO Box 2123  
Carlsbad, NM 88221

IT Corporation (2)  
Attn: P. Drez  
R.F. McKinney  
Regional Office - Suite 700  
5301 Central, NE  
Albuquerque, NM 87108

Los Alamos National Laboratory  
Attn: B. Erdal, CNC-11  
PO Box 1663  
Los Alamos, NM 87544

RE/SPEC, Inc.  
Attn: W. Coons  
Suite 300  
4775 Indian School, NE  
Albuquerque, NM 87110-3927

RE/SPEC, Inc.  
Attn: J.L. Ratigan  
PO Box 725  
Rapid City, SD 57709
Southwest Research Institute (2)  
Center for Nuclear Waste  
Regulatory Analysis  
Attn: P.K. Nair  
6220 Culebra Road  
San Antonio, TX 78228-0510

SAIC  
Attn: G. Dymmel  
101 Convention Center Dr.  
Las Vegas, NV 89109

SAIC  
Attn: H.R. Pratt,  
10260 Campus Point Drive  
San Diego, CA 92121

Tech Reps Inc. (3)  
Attn: J. Chapman  
R. Jones  
E. Lorusso  
5000 Marble, NE  
Albuquerque, NM 87110

Westinghouse Electric Corporation (5)  
Attn: Library  
G. Cox  
L. Fitch  
R. Kehrman  
L. Trego  
PO Box 2078  
Carlsbad, NM 88221

Universities  
University of New Mexico  
Geology Department  
Attn: Library  
Albuquerque, NM 87131

University of Washington  
Attn: G.R. Heath  
College of Ocean and Fishery Sciences  
583 Henderson Hall  
Seattle, WA 98195

Individuals  
D.W. Powers  
Star Route Box 87  
Anthony, TX 79821

Libraries  
Thomas Brannigan Library  
Attn: D. Dresp  
106 W. Hadley St.  
Las Cruces, NM 88001

Hobbs Public Library  
Attn: M. Lewis  
509 N. Ship Street  
Hobbs, NM 88248

New Mexico State Library  
Attn: N. McCallan  
325 Don Gaspar  
Santa Fe, NM 87503

New Mexico Tech  
Martin Speere Memorial Library  
Campus Street  
Socorro, NM 87810

New Mexico Junior College  
Pannell Library  
Attn: R. Hill  
Lovingston Highway  
Hobbs, NM 88240

WIPP Public Reading Room  
Carlsbad Public Library  
Attn: Director  
101 S. Halagueno St.  
Carlsbad, NM 88220

Government Publications Department  
General Library  
University of New Mexico  
Albuquerque, NM 87131

National Academy of Sciences, WIPP Panel  
Charles Fairhurst, Chairman  
Department of Civil and Mineral Engineering  
University of Minnesota  
500 Pillsbury Dr., SE  
Minneapolis, MN 55455-0220

Howard Adler  
Oak Ridge Associated Universities  
Medical Sciences Division  
PO Box 117  
Oak Ridge, TN 37831-0117

Dist.-3
Foreign Addresses

Studiecentrum Voor Kernenergie
Centre D’Energie Nucléaire
Attn: A. Bonne
SCK/CEN
Boeretang 200
B-2400 Mol, BELGIUM

Atomic Energy of Canada, Ltd. (3)
Whiteshell Research Estab.
Attn: B. Goodwin
M. Stevens
D. Wushke
Pinewa, Manitoba, CANADA R0E 1L0

Francois Chenevier, Director (2)
ANDRA
Route du Panorama Robert Schumann
B.P.38
92266 Fontenay-aux-Roses Cedex
FRANCE

Jean-Pierre Olivier
OECD Nuclear Energy Agency
Division of Radiation Protection
and Waste Management
38, Boulevard Suchet
75016 Paris, FRANCE

Claude Sombret
Centre D’Etudes Nucleaires
De La Vallee Rhone
CEN/VALRHO
S.D.H.A. BP 171
30205 Bagnols-Sur-Ceze, FRANCE

Bundesministerium fur Forschung und
Technologie
Postfach 200 706
5300 Bonn 2, GERMANY

Gesellschaft fur Reaktorsicherheit
(GRS) (2)
Attn: B. Baltes
W. Muller
Schwertnergasse 1
D-5000 Cologne, GERMANY

Bundesanstalt fur Geowissenschaften
und Rohstoffe
Attn: M. Langer
Postfach 510 153
3000 Hanover 51, GERMANY
Hahn-Meitner-Institut für Kernforschung  
Attn: W. Lutze  
Glienicker Strasse 100  
100 Berlin 39, GERMANY

Institut für Tieflagerung (2)  
Attn: K. Kuhn  
Theodor-Heuss-Strasse 4  
D-3300 Braunschweig, GERMANY

Physikalisch-Technische Bundesanstalt  
Attn: P. Brenneke  
Postfach 3345  
D-3300 Braunschweig, GERMANY

D.R. Knowles  
British Nuclear Fuels, plc  
Risley, Warrington, Cheshire WA3 6AS  
1002607 UNITED KINGDOM

AEA Technology  
Attn: J.H. Rees  
D5W/29 Culham Laboratory  
Abingdon, Oxfordshire OX14 3DB  
UNITED KINGDOM

AEA Technology  
Attn: W.R. Rodwell  
O44/A31 Winfrith Technical Centre  
Dorchester, Dorset DT2 8DH  
UNITED KINGDOM

AEA Technology  
Attn: J.E. Tinson  
B4244 Harwell Laboratory  
Didcot, Oxfordshire OX11 ORA  
UNITED KINGDOM

Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle (NAGRA) (2)  
Attn: S. Vomvoris  
P. Zuidema  
Hardstrasse 73  
CH-5430 Wettingen, SWITZERLAND

Shingo Tashiro  
Japan Atomic Energy Research Institute  
Tokai-Mura, Ibaraki-Ken  
319-11 JAPAN

Netherlands Energy Research Foundation ECN  
Attn: L.H. Vons  
3 Westerduinweg  
PO Box 1  
1755 ZG Petten, THE NETHERLANDS

Svensk Karnbransleselorsjning AB  
Attn: F. Karlsson  
Project KBS  
Karnbranslesakerhet  
Box 5864  
10248 Stockholm, SWEDEN

Sandia Internal

1502  
J.C. Cummings

3141  
S.A. Landenberger (5)

3145  
Document Control (8) for DOE/OSTI

3151  
G.C. Claycomb (3)

6000  
D.L. Hartley

6119  
E.D. Gorham

6119  
Staff (10)

6121  
J.R. Tillerson

6121  
R.E. Finley (5)

6121  
Staff (7)

6300  
D.E. Miller

6302  
T.E. Blejwas, Acting

6303  
W.D. Weart

6303  
S.Y. Pickering

6341  
A.L. Stevens

6341  
Staff (6)

6341  
Sandia WIPP Central Files (10)

6342  
D.R. Anderson

6342  
Staff (20)

6343  
T.M. Schultheis

6343  
Staff (2)

6345  
R.C. Lincoln

6345  
Staff (9)

6347  
D.R. Schafer

8523-2  
Central Technical Files

9300  
J.E. Powell

9305  
M.J. Navratil