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Borehole Plugging Program Status Report October 1, 1978 – September 30, 1979

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ONWI/SANDIA
BOREHOLE PLUGGING PROGRAM
STATUS REPORT*

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This report summarizes the activities conducted to date in support of the ONWI-funded, Sandia-implemented Borehole Plugging Program. This program activity emphasizes the requirements of the Waste Isolation Pilot Plant (WIPP) proposed for southeastern New Mexico.

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TABLE OF CONTENTS

	<u>PAGE</u>
I. INTRODUCTION	1
A. Background	1
B. Publications	2
II. CURRENT YEAR ACTIVITIES	3
A. Management	3
B. Materials	3
C. Instrumentation	5
D. Field Test	6
III. PROPOSED FY80 ACTIVITIES	8
A. Management	8
B. Materials	8
C. Instrumentation	9
D. Field Test	9
APPENDIX A - SUMMARY OF BHP EVENTS TO DATE	A-1
APPENDIX F - REFERENCES	B-1

I. INTRODUCTION

A. Background

The Borehole Plugging Program (BHP), under ONWI sponsorship, was initiated in FY79 by Sandia to provide a basis for laboratory and wellbore data collection in support of the Waste Isolation Pilot Plant (WIPP) proposed for installation in southeast New Mexico (SENM). This report is based on an annual report to ONWI which summarizes the results of the first year's activities and provides the basis for ongoing program development. For a more comprehensive report of the program, refer to the BHP Program Description.¹

The four major BHP categories are listed below along with a brief description of the responsibilities within each category.

Management: Responsibilities include overall program management, budgeting, direction, and coordination. Included in this category is the assessment of available technology and expansion as required to achieve specific results; analysis of the effects of wellbore fluid migration in a consequence assessment program; determination of experiment and plug design requirements and incorporation of a quality assurance policy into the program elements.

Materials: Responsibilities involve materials research and development responsive to BHP design requirements, including extensive cementitious materials laboratory research, testing compatibility of these materials with host-rock formations, analysis of interface bonding and sealing parameters, development of field emplacement techniques and requirements, and the determination of alternate plugging materials.

Instrumentation: Responsibilities involve determination of instrumentation availability, adequacy, and development responsive to BHP design requirements, laboratory research and development of breadboard prototypes, and the conversion to fieldable instrumentation systems.

Field Testing: Responsibilities include the translation of program test plans into the field operational procedures required to meet and satisfy BHP objectives. A careful and precise melding of the various program elements into a cohesive whole in the form of a field test requires coordination of budgets, schedules, QA procedures, and data collection validity.

To date the BHP has been concerned only with cementitious materials as plug candidates and small-diameter wellbores. Expansion to other materials and large-diameter shafts is intended as the program develops and the data base improves. Activities within each category to date are described in Section II, with a synopsis of planned activities included in Section III. Appendix A contains a record of historical events within the BHP to date. Appendix B contains the list of references.

B. Publications

1. Publication activities conducted during the year include the following Sandia reports:
 - a. Development of the Borehole Plugging Program document¹
 - b. Development of the WIPP Quality Assurance Plan²
 - c. Development of program test plans for the Bell Canyon Test (BCT)³, the Potash Core Test (PCT)⁴, the Surface Wellbore Test Bank (SWTB)⁵
 - d. Initiation of the test plan for the Media Quantification Experiment (MQE) (intended for publication in 1980)
 - e. Preparation of a field activities paper for presentation in October 1979, at ONWI, Columbus, OH⁶
 - f. Destructive and non-destructive test data of candidate plug mixes⁷
 - g. Report of plugging ERDA-10⁸
 - h. Preparation of the Borehole Plugging Program Instrumentation Development Report⁹

II. CURRENT-YEAR ACTIVITIES

A. Management

1. The summary of current technology is contained in a report by D'Appolonia for ONWI¹⁰ and is in the process of review for application and inclusion in the BHP.
2. Consequence assessment activities have been directed by J. P. Brannen, Sandia Laboratories, in conjunction with a similar program at ONWI. Efforts to date involve conservative modeling of possible leak path scenarios.
3. Quality assurance procedures have been developed and applied to the field test program.
4. Meetings were scheduled to conduct peer reviews of intended activities for the Bell Canyon Test (January 1979) and for a mid-year program review (April 1979). Additional meetings (most recent--August 7, 1979) were conducted to define requirements and assign responsibilities for an ONWI-sponsored geochemical program. A summary of historical events within the BHP is contained in Appendix A.
5. Initial steps in developing a plug design modeling and testing capability were established utilizing Systems, Science and Software (S³) as a contractor to Sandia. Test design criteria were established for the Bell Canyon Test, and data obtained will be compared to predictions.

B. Materials

1. Results obtained from the Duval plug 217 analysis are contained in references 11 and 12.

2. The grout development program for borehole plugging was initiated at the Army Corps of Engineers Waterways Experiment Station (WES) in FY76. Laboratory development mixtures have been studied and exposed to water simulating the underground water at the WIPP site for more than two years. Samples of grouts cast in the field during the plugging of ERDA-10 have also been exposed to a brine water, including some at elevated temperature for more than a year.

Development of grout mixtures was continued during the year. A coarser cement was selected to increase the density by lowering the water/cement ratio (w/c) and to reduce permeability and porosity. Class H cement was used with an expansive additive to improve bonding at the grout/rock interface in a drill hole.

3. Grout development work culminated in the grout mixture BCT-1-FF which was placed in the borehole ABC-7 at the WIPP site to form a short plug. The early work used a salt brine mixing water and developed a suitable mixture with a high-density compressive strength and push-out shear-bond strength (to pipe and anhydrite rock cores), and low permeability for water flow. Late in the year the interface between the salt grout and anhydrite rock was found to be porous with a high permeability even though the push-out resistance remained high. Subsequent development work utilized fresh mixing water and showed satisfactory low permeability at the grout/anhydrite interface for the grout mixture BCT-1-FF. The grout was a 70/30 percent by volume class H cement/flyash mixture with a self-stress additive to achieve expansion of about 0.1 percent. Compressive strength was greater than 70 Mpa, and water permeability is about 1 microdarcy or less. The fluid density of 2.11 gm/cm^3 was achieved by the use of a water-reducing or turbulence-inducing compound and a defoaming agent.
4. Equipment for a materials field laboratory was procured and shipped to the WIPP site. The field quality control of the grouting

operation was supervised by WES personnel. Field samples were taken during the batching, field mixing, and placement operations. The samples were cured at elevated temperatures in brine water from the AEC-7 hole. After a week of curing and expansion data, the field samples were shipped to the WES laboratory at Vicksburg, MS, for testing and long-term exposure studies.

5. The WES lab received samples of a grouted hole (Duval plug 217) in potash ore for analysis. The age of the grout was about 17 years. The results of a petrographic analysis indicated that the hardened grout was relatively competent with regard to permeability and shear-bond resistance.¹¹ These data for a high w/c of about 0.1 were considered to be evidence of the suitability of plugging boreholes with cement grouts for sealing and long-term durability. The current technology for achieving placeable cement grouts with low w/c of about 0.3 or less should show marked improvements.

C. Instrumentation

1. Development and Laboratory Evaluation

- a. Conductivity probe - A conductivity probe, which operates as a four-terminal resistor to eliminate line effects, has been designed. Carbon electrodes are used to minimize interactions between the probe and the liquid being measured. During the initial laboratory tests, it was found that AC excitation of the probe was required to preclude the electrolyte from reacting to the excitation current. Sixty hertz to 20 KHz excitation frequencies were found to be satisfactory. Considering line loading problems at the higher frequencies, 1 KHz was selected for probe excitation. The probe gives reliable readings for tap water, saturated brine, and various mixtures. It has been used to measure simulated samples of the Delaware and Culebra aquifers. The conductivities of the two samples differed by a factor of 5, thereby permitting positive identification.

- b. Water level indicator - The primary method for monitoring the change in liquid level above a borehole plug will be a commercial pressure transducer. However, since the pressure transducer has limited resolution and its output is dependent on liquid density, an independent discrete liquid level indicator has been designed. The discrete liquid level indicator utilizes a resistance ladder and carbon contacts for the circuit value changes. One pair of signal leads provides indications of four different levels. The distance between levels can be varied from .5cm to many meters. One KHz excitation is used.
- c. Signal conditioning circuitry - To record the 1 KHz outputs of the conductivity probe and the discrete liquid level indicator on a conventional data logger, the signals have to be converted to DC. Circuitry has been designed and incorporated in the system.
- d. In-plug transducers - Development has been initiated on two probes which can be grouted in place to monitor the leakage of brine past the plug. The two probes are a Wenner probe and a monocoil inductance probe. The Wenner System will probe varying volumes which include the plug, interface, and region outside the plug by using a multiple probe array. A prototype has undergone preliminary laboratory tests. The inductance coil is a backup approach. The primary advantage of the inductance coil is that it does not require good electrical contact with the plug material.

D. Field Tests

- 1. The Bell Canyon Test (BCT)³ was completed on September 26, 1979, through the plug emplacement phase, with subsequent unloading to essentially atmospheric pressure above the plug by October 11, 1979. Plug integrity was ascertained and plans are in progress for long-term plug evaluation.

2. Samples obtained during the BCT coring operation to deepen the wellbore were shipped to Waterway Experiment Station (WES), Pennsylvania State University (PSU), Oak Ridge National Laboratory (ORNL), and Dowell Corporation for compatibility testing with BCT plug grout. Unused cores are stored at Carlsbad by Sandia.
3. The AEC-7 wellbore was used to conduct in situ permeability measurements at the salt zone to develop and refine the measuring techniques for the BHP plug design task, consequence assessment, and Sandia's research in support of the WIPP Waste Acceptance Criteria Steering Committee.
4. The AEC-7 wellbore was utilized to conduct upper zone hydrology testing for subsequent data analysis (to be published).
5. Progress was made in the development and refinement of field activities required to conduct the Bell Canyon test such as improving experience in packer setting techniques, depth control techniques, nitrogen systems for unloading wellbores, wellbore logging techniques, and application of quality control procedures to these tasks.
6. Initial steps were taken leading to the development of design criteria and procurement activities directed at establishing an in-house logging capability.
7. Similar steps were initiated leading to the development of requirements for establishing a wellbore closed circuit television logging capability.
8. Field operations included the acquisition of the sample borehole plug 217 for laboratory testing as noted in Section IIB, Materials.^{11,12}
9. Field activities refined development of and experience in obtaining support and services not normally utilized in routine oil field

operations, including modification of these services to be responsive to specific field test needs. This latter capability represents a significant contribution to the Borehole Plugging Program since normal oil field practices are not conducted to satisfy laboratory-type requirements. Development of the understanding and support required to accomplish the RCT with the existing service organizations represents a major achievement of the field test program and is largely due to the efforts of R. D. Statler, manager of the Santa Fe field program at the WIPP site.

III. PROPOSED FY80 ACTIVITIES

A. Management

1. Activities planned include publication of test plans for the Surface Wellbore Test Bank (SWTB), the Media Quantification Experiment (MQE), and a preliminary analysis and report of BCT data.
2. Continue evaluation and development of current technology assessment.
3. Continue consequence analysis of WIPP site-specific scenarios.
4. Continue development of plug design requirements including field testing of aquifer zones and determination of feasibility techniques for liquid in situ permeability measurements.
5. Peer review meetings will be scheduled as required.

B. Materials

1. Laboratory cast specimens and field samples of grout mixtures will be tested and evaluated. Some samples are more than three years old and have been exposed to water (simulating the ground water at the WIPP site) at both ambient and elevated temperatures. The data will be included in the third report of a series on the materials development program. Additional studies will be undertaken of the contact area between grouts, with and without salt in the mixing water, and various rocks including anhydrite. Rock plug petrographic examinations will be required at differing ages to evaluate the permanence of the interface in matching that of the grouts and the host rock.

2. Cementing materials reasonably available to the WIPP site will continue to be tested and evaluated. Contacts with contractors in the cement industry will continue in order to obtain the latest information on new materials in addition to the development work underway at WES.
3. The Potash Core Test field core samples of the grouted hole will be shipped to the WES and other laboratories for testing and evaluation. These studies will add to knowledge of the in situ properties of cement plugs and the host rock.

C. Instrumentation

1. Development and Laboratory Evaluation
 - a. Wire line system - The water conductivity, water level indicator, pressure, and temperature probe designed for the original BCT will be adapted to a wire line system which can be installed inside 2-5/8"-diameter tubing.
 - b. In-plug transducers - Further development of the Wenner probe and the monocoil inductance probe will be pursued.
 - c. Hardwire systems for transmission of data from below a borehole plug will be evaluated and tested.
 - d. If the proper field conditions are available, in situ inclusion stressmeters will be evaluated.

D. Field Tests

1. Conduct the Potash Core Test (PCT)⁴
2. Initiate plug emplacement phase of the Surface Wellbore Test Bank (SWTB)⁵

APPENDIX A
SUMMARY OF BHP EVENTS TO DATE

<u>DATE</u>	<u>EVENT</u>
August 7-8, 1978	BHP Workshop - Battelle, Columbus
August 25, 1978	BHP outline submitted by Sandia
October 12, 1978	AEC-7 recommended as DHT (BCT) test bed See January 20, 1979, entry
November 1, 1979	17-year-old potash plug 217 obtained for analysis--shipped sample to WES/PSU
November 9, 1978	Official funding received
December 22, 1979	Program plan and description (final draft) dated January 1, 1979
January 11-12, 1979	BCT (Bell Canyon Test) final design meeting and preliminary geochemical stability of grout meeting
January 15, 1979	Reentry and deepening authority approval requested for AEC-7 from DOE/BLM
January 20, 1979	DHT changed to Bell Canyon Test (BCT) due to conflict with another DOE program name
February 28-March 1, 1979	BHP Program midyear review
March 1, 1979	Formal acceptance by ONWI of Sandia QA Program
March 20, 1979	Drill rig in place for Bell Canyon Test
March 23, 1979	Approval to use P-4 for PCT obtained within Waste Management Technology Department, Sandia
April 2, 1979	Whole hole permeability measurements completed Set up to deepen AEC-7 to Bell Canyon Formation
April 5, 1979	Commence coring operation to Bell Canyon
May 3, 1979	First setting of Bottom Hole Packer. Dry run.
May 7, 1979	Demob drill rig. Phase I BCT complete.

May 17, 1979	Mobilize workover rig; prepare for straddle packer permeability tests. Commence Phase II BCT.
June 6, 1979	Complete straddle packer tests for upper zone permeability measurements.
June 7, 1979	Obtained 200K supplemental funding from RLO (dtd June 1, 1979) for Phase II operations. Commenced hydro testing of AEC-7. Phase II operations suspended pending results of hydro tests.
June 15, 1979	Final version of BCT Test Plan published.
June 25, 1979	Program planning meeting with RLC/ONWI at ALQ, Albuquerque.
July 5, 1979	Bottom Hole Packer removed from AEC-7, completing in-hole dry run of bottom instrumentation package.
July 7, 1979	Complete hydro testing. Phase I, BCT complete.
July 11, 1979	Decanning of Bottom Hole Instrumentation package indicates satisfactory performance. Analysis of film records in progress.
July 17, 1979	Final planning meeting for BCT plug emplacement.
July 18, 1979	Final planning meeting with ONWI for BCT execution including casing option due to upper zone fluid production.
July 25, 1979	Interface problem disclosed using brine mix for BCT plug. Selection of alternate fresh water mix made and testing initiated.
August 6, 1979	Remob rig for BCT Phase II plug emplacement. Possible problem disclosed with fresh water plug mix. Review meeting for BCT plug mix impact planned.
August 7, 1979	Accidental disconnect during emplacement of Packer and Instrumentation package for BCT Plug Zone Integrity Test.
August 10, 1979	Packer and Instrumentation package recovered. Demob rig pending system evaluation and cement work results.

August 14, 1979	Plug mix evaluation meeting at WES. Preliminary plans to proceed with BCT Phase II plug emplacement pending cement work results due September 4, 1979.
August 27, 1979	Remob rig for BCT Plug Zone Integrity Tests and plug emplacement.
September 6, 1979	Fresh water mix lab testing indicates satisfactory performance.
September 26, 1979	Fresh water cement plug emplaced in ABC-7. Prepare for BCT monitor operations.
October 9, 1979	Set BCT plug differential pressure at 1200 PSI. Monitor INFLOW rate.
October 10, 1979	Set BCT plug differential pressure at 1850 PSI. Monitor INFLOW rate.
October 11, 1979	Gross BCT plug integrity established. Prepare plans to monitor tracer gas #2 release on October 30, followed by additional plug testing and wellbore casing.

APPENDIX B

REFERENCES

1. Christensen, C. L. and Hunter, T. O. Waste Isolation Pilot Plant (WIPP), Borehole Plugging Program Description, January 1, 1979. SAND79-0640, Sandia Laboratories, Albuquerque, NM 87185, August 1979.
2. Waste Isolation Pilot Plant (WIPP) Quality Assurance Program Plan (QAPP), Sandia Laboratories, Albuquerque, NM, April 1979 (controlled distribution).
3. Christensen, C. L., Test Plan, Bell Canyon Test, WIPP Experimental Program, Borehole Plugging. June 1979, SAND 79-0739, Sandia Laboratories, Albuquerque, NM 87185.
4. Christensen, C. L., Test Plan, Potash Core Test, WIPP Experimental Program, Borehole Plugging. July 1979, SAND 79-1306, Sandia Laboratories, Albuquerque, NM 87185.
5. Christensen, C. L. and Goodwin, R. H., Test Plan, Surface Wellbore Test Bank, WIPP Experimental Program, Borehole Plugging. July 1979, SAND 79-1306, Sandia Laboratories, Albuquerque, NM 87185 (to be published).
6. Christensen, C. L., Field Test Programs of Borehole Plugs in Southeastern New Mexico, SAND 79-1634C, for presentation at ONWI, October 1979.
7. Gulick, C. W., Jr., Borehole Plugging - Materials Development Program, Report No. 2, SAND79-1514, Sandia Laboratories, Albuquerque, NM 87185, 1979 (to be published).
8. Gulick, C. W., Jr., Borehole Plugging Program, Plugging of ERDA-10 Drill Hole, June 1979, SAND79-0789, Sandia Laboratories, Albuquerque, NM 87185, June 1979.
9. Cook, C. W., Borehole Plugging Program Instrumentation Development, Report, SAND79-0789, Sandia Laboratories, Albuquerque, NM 87185, 1979 (to be published).
10. The Status of Borehole Plugging and Shaft Sealing for Geologic Isolation of Radioactive Waste, January 1979, Report No. ONWI 15, D'Apponia.
11. Buck, Alan D., and Burkes, J. P., Examination of Grout and Rock from Duval Mine, New Mexico; Miscellaneous Paper SL-79-16, Structures Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MI, July 1979, Final Report.
12. Scheetz, B. E., et al. Unnumbered ONWI report, draft, July 1979. Materials Research laboratory, The Pennsylvania State University (to be published).