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Instrumentation Development for the Waste Isolation Pilot Plant (WIPP) Borehole Plugging Program (BHP)

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INSTRUMENTATION DEVELOPMENT FOR THE
WASTE ISOLATION PILOT PLANT (WIPP) BOREHOLE PLUGGING PROGRAM (BHP)

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ABSTRACT

This report discusses the instrumentation development needs of the borehole testing program as it now exists. Although requirements may change as the program progresses, the items indicated are basic to any borehole plugging program. Instrumentation is discussed both for the plug environment and for the plug itself. For the plug environment, a probe for measuring the disturbed region and a coordinate logging tool are required. For the plug itself, instrumentation includes measurements above, within, and below the plug. Instrumentation for most measurements above the plug is currently available; for measurements within and below the plug, however, further development is required. Specifically, resistivity, induction, and acoustic probes; an in situ stressmeter; and a hardware, feedthrough system need to be developed.

1116

TABLE OF CONTENTS

	<u>Page</u>
Introduction	3
Development	3
Plug Environment Assessment	3
Logging	4
In Situ Stress	4
In Situ Permeability	5
Plug Assessment	5
Above-Plug Transducer Development	5
In-Plug Transducer Development	6
Below-Plug Transducer Development	6
Recommendation for Plug Instrumentation Development	7
Plug Deterioration	7
Core Structural Testing	7
Summary	8
References	10
Bibliography	10

INSTRUMENTATION DEVELOPMENT FOR THE WASTE ISOLATION PILOT PLANT (WIPP) BOREHOLE PLUGGING (BHP) PROGRAM

Introduction

One objective addressed by the WIPP BHP Program description document¹ is to develop materials, techniques, and instrumentation for determining the adequacy of plug designs in keeping well-bore leakage comparable to leakage along natural migration pathways.

To achieve this objective, instrumentation that provides data for the assessment of any borehole environment and the validation of plugging techniques is required. Before plug emplacement, borehole conditions and the properties of the surrounding media need to be determined. After emplacement, the integrity and performance of the plug need to be certified. This report presents an instrumentation development plan to provide the required data based on needs identified by the BHP document. The primary emphasis is on instrumentation to acquire data from emplaced cementitious plugs rather than from laboratory tests. Laboratory testing of plugging techniques will be complementary and parallel.

The instrumentation development plan assesses both the existing borehole environment (which characterizes the borehole and the properties of the host rock) and borehole plug in place performance.

Development Plan

Plug Environment Assessment

The borehole plug environment to be defined includes both the actual borehole characterization and the properties of the host rock. Borehole characterization encompasses a determination of the surface condition of the wall as well as the degree and extent of the disturbance caused by drilling, hole conditioning, and preparation. The host rock needs to be characterized in terms of thermomechanical and geochemical properties and permeability. To provide a baseline, the host-rock properties should be those of the least-disturbed in situ material.

Instrumentation to characterize the borehole environment can be defined in the general-use assessment categories of logging, in situ stress, and in situ permeability.

Logging--State-of-the-art logging techniques can be used for most of the borehole characterization and evaluation. As part of the environment characterization, core samples will be taken and cataloged from the areas of interest. The one area in which existing logging equipment may not be adequate is that of measuring the disturbed region around the borehole.

Development of logging tools is required to determine the extent of the disturbed region of a borehole. The most likely techniques for these measurements are acoustic and/or electromagnetic probes. The possibility of miniaturizing probes to a 50-mm diameter will be pursued during the development of scanning probes that can penetrate geologic formations. Current long-range planning suggests that some boreholes may be plugged with an open-center plug. With this type plug, scanning probes may prove useful for evaluating plug deterioration and the plug-to-wall bond, as well as the disturbed region.

In experiments with satellite holes, it is important to determine the coordinates of all measurement locations. A logging tool that accurately locates measurement coordinates is needed to operate in holes with diameters between 70 and 210 mm and at depths of 5 to 1500 m.

In Situ Stress--The modification of the local stress field by drilling and subsequent relaxation of the borehole needs to be determined. An approximation of the fracturing and increased permeability caused by stress relief can be ascertained through modeling. Any restoration of the stress field and subsequent healing may require monitoring after plug emplacement.

Sandia has developed extensometers and inclusion stressmeters² that can be applied to shallow holes (~20 m deep). These instruments may be placed in either the main borehole or in nearby satellite holes.

Further development of this instrumentation will be required for deep holes. A first step in this evaluation is to apply existing technology in test holes ~15 m deep that are located in a mine. Following successful completion of this phase, modifications for deep-hole applications should be developed. Acoustic techniques may also provide a nondestructive test for in situ stress.

In Situ Permeability--A measurement of the permeability of the host rock is required to determine the minimum permeability requirement for the borehole plug.

Currently the experience of Systems, Science, and Software (S³) is being used in this area. S³ uses tracer-gas/pressurization techniques to assess the porosity and permeability of geological media. More details on the techniques used can be found in Reference 3. Further development of in situ permeability instrumentation is planned.

Plug Assessment

The purpose of a borehole plug is to minimize the transport of fluids through the borehole. The emplaced plug is adequate if the permeability of the plug and the plug/host interface is less than that of the in situ host rock. If this ideal condition cannot be achieved, any departures can be determined by measurement. A consequence analysis from these data is necessary to determine the adequacy of the plug. Further, the integrity and performance of emplaced plugs may need to be monitored for long periods to detect any deterioration or changes. Plug deterioration could result in loss of mechanical properties (strength, bond to host rock, etc) and/or an increase in permeability.

Above-Plug Transducer Development--Instrumentation probes developed for the Bell Canyon Test (BCT)⁴ essentially satisfy the requirement for above-the-plug measurements. Sandia has developed a probe for measuring water level, and conductivity, pressure, and temperature above a borehole plug.⁵ The conductivity probe provides a rough

measure of dissolved salts that can be useful in identifying the source of the water. S³ also devised for the BCT a method of measuring permeability through the plugged region that uses time-released tracer gases. The BCT will determine if further instrumentation development is required for future tests.

In-Plug Transducer Development--When plugs with thicknesses greater than a few metres are installed, measurements have to be made within the plug. Sandia has started the development of two probes that can be grouted in place to monitor the leakage of brine past the plug. These two probes, a Wenner resistivity probe and a monocoil inductance probe, will be available in 1980. The Wenner probe uses a multiple-probe array to probe varying volumes that include the plug, interface, and region outside the plug. A prototype model of this probe has undergone preliminary laboratory tests. The monocoil inductance probe is a backup approach that is also intended to monitor brine leakage past the plug. The primary advantage of the inductance coil is that it does not require good electrical contact with the plug material. Both probes will require further laboratory evaluations before they can be fielded.

Other transducers that may prove useful within the plug are an inclusion stressmeter and an acoustic probe. The stressmeter would monitor loading changes on the plug, and the acoustic probe would detect changes in the integrity of the plug.

Below-Plug Transducer Development--The transmission system for transducer data from below the borehole plug will be investigated to determine whether to use wireless or hardwire methods. Hardwire systems will be evaluated and tested to determine if methods can be developed to overcome the inherent disadvantages of this method (leakage paths through the plug, cable breakage, and environment-induced deterioration). The short-term potential of this method appears greater than that of a wireless transmission system. Wireless transmission⁶ will be investigated to determine if adaptation is achievable for this application. The long-term serviceability of electronics components used by this system is considered to be unpredictable.⁷

Because of the costs of development and evaluation and the potential problems of the two systems, the hardwire system is the prime candidate for this application.

Recommendations for Plug Instrumentation Development--In-Plug.

Development and evaluation of the Wenner and inductance probes should be completed. Studies using the inclusion stressmeter and acoustic probes should also be initiated.

Below-Plug. Laboratory tests need to be run to develop cable feed through technology. Past underground test experience at the Nevada Test Site can serve as a starting point. It needs to be established that a hardwire feedthrough is not the weak link in an emplaced plug. Once this has been done, hardwire systems should be developed for use in and below emplaced plugs.

Plug Deterioration--Plug deterioration will be determined indirectly by observing changes in leakage rate or permeability using the instrumentation recommended in the preceding section. The reason for plug deterioration will have to be determined from laboratory tests of plug samples.

Core Structural Testing

Laboratory structural tests of various grout mixtures are typically run using grout core samples. It is desirable to run some of these tests on full-size plugs in rock samples, with the actual downhole environment (confining pressure and temperature) simulated. Other full-scale plug tests may also be needed. It appears that some full-scale laboratory tests can probably be run in the large test facility at the University of California, Berkeley. This facility is currently being used on an ONWI contract.⁸

SUMMARY

The instrumentation development discussed in the preceding sections resulted from the needs of the borehole testing program as it now exists. Instrumentation requirements will probably change as the program progresses, but the items indicated are fairly basic to any borehole plugging program. For conciseness, the instrumentation development plan is summarized in Table 1.

Table 1

Summary of Instrumentation Development Plan

<u>Item</u>	<u>Design Responsibility</u>	<u>Design Phase</u>	<u>Ready for Fielding</u>
water level and conductivity	SLA	complete	now
tracer (gas)	S3	complete	now
resistivity probe	SLA	10/78	3/80
induction probe	SLA	10/78	3/80
in situ stress	SLA	complete	now (shallow hole)
hardwire feed-thru	SLA	8/79	6/80
disturbed region probe	to be decided		
coordinate logging tool	to be decided		
acoustic in-plug probe	to be decided		
full-scale plug test	to be decided		

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