LEGIBILITY NOTICE

A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although a small portion of this report is not reproducible, it is being made available to expedite the availability of information on the research discussed herein.

LA-UR -88-3961

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W 7405-ENG-36

LA-UR--88-3961

DE89 003603

TITLE

APPLICATION OF ROCK MELTING TO CONSTRUCTION OF STORAGE HOLES FOR NUCLEAR WASTE

AUTHOR(S)

Joseph W. Neudecker, Jr.
Group WX-11, Analysis and Testing

SUBMITTED TO

Society of Mining Engineers
P. O. Box 625002
Littleton, Colorado 80162-5002

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes.

The Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

[illegible]

MASTER

Abstract. Rock melting technology can provide in-situ glass liners in nuclear waste package emplacement holes to reduce permeability and increase borehole stability. Reduction of permeability would reduce the time and probability of groundwater contacting the waste packages. Increasing the stability of the storage boreholes would enhance the retrievability of the nuclear waste packages. The rock melting hole forming technology has already been tested in volcanic tuff similar to the geology at the proposed nuclear waste repository at Yucca Mountain, Nevada.

Background

Rock melting penetrators were developed at the Los Alamos National Laboratory during the years 1970-1975 to drill holes in rock and soil by progressive melting rather than by chipping, abrading, or spalling. The wide range of experiments carried out at that time, both in the laboratory and in the field demonstrated the feasibility and the advantages of the rock melting excavation technology.

Two important characteristics of the holes formed by rock melting offer particular advantages to the storage holes for the emplacement of nuclear waste packages. Creating holes by rock melting results in the in-situ material being converted to a glass, and the walls of the holes are formed with this glass. The glass is much denser than the in-situ material, has much less permeability, and is also much stronger than the in- situ material. All of these characteristics provide advantages to emplacement holes for the storage of nuclear waste packages.

The rock melting technology development program at Los Alamos resulted in the construction and extensive field testing of several different sizes and types of rock melting tools, and the technology is readily adaptable to the hole reaming and hole wall conditioning requirements of the storage holes for nuclear waste repositories. Many of the successful experiments were carried out in volcanic tuff that is very similar to the geology at Yucca Mountain, Nevada where a nuclear waste repository is planned to be constructed.

Characteristics of Melted Rock Hole Liners

To best characterize the liner material, physical and mechanical tests were performed on hole liners derived from melting volcanic tuff. These tests were carried out at the facilities of Terratek Corporation, Salt Lake City, Utah, and the test results are presented below.

Density Measurements

The dry and grain densities measured for parent tuff and liner are summarized in Table 1. It is interesting to note that the grain density of the lining material is less than that of the parent tuff. The densities and porosity values obtained for the tuff are typical of other tuffs, for example the Nevada Test Site tuff reported by W. [illegible] (see References).

Table 1. Density and Porosity Data

	DRY DENSITY (gm/cc)		GRAIN DENSITY (gm/cc)	
MATERIAL	AVERAGE OF FIVE SAMPLES	STANDARD DEVIATION	AVERAGE OF THREE SAMPLES	POROSITY (%)
TUFF	1.39	.03	2.54	45
TUFF	1.50		2.54	41
LINING	2.23	.04	2.40	7

Permeability of Liner Material

Permeability as a function of effective stress (confining pressure) was measured on several radial samples of glass liner material using air as the permeating fluid. The results of several tests are shown in Figure 1. As expected the permeability decreases as the effective stress increases. There is a large sample variability at low effective stress but this appears to be reduced at effective stress on the order of 30MPa. Note that on unloading, the permeability did not completely recover. It is significant that the permeability values were generally 1.0 milidarces or less at very modest confining pressures, and that the lining material was formed routinely, without special care being taken to improve the liner glass quality, as would be done if a special hole reaming rock melting tool were used.

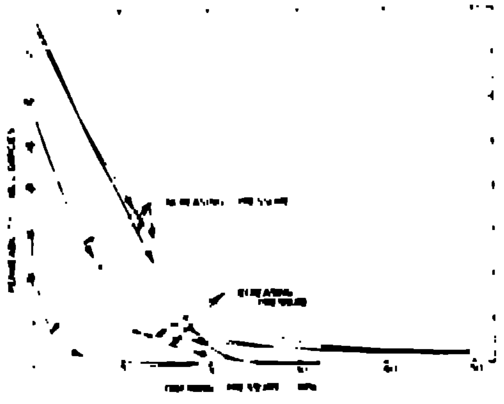

Figure 1. Permeability of Liner Samples

Mechanical Properties

Compression and tension tests were performed on both parent tuff and glass lining at confining pressures ranging from 0 to 5 MPa. Since the lining material was much stronger than the parent tuff the strength data is shown on separate figures. Figure 2 shows the failure envelopes in compression and tension for the lining material and Figure 3 shows the failure envelopes for the parent tuff.

Collapse Tests

A schematic of the collapse tests is shown in

Figure 4. A thick-walled, jacketed, hollow cylinder is exposed to external pressure until failure occurs. The sample was not exposed to any axial stress. This loading condition is most typical of the service loads that a nuclear waste storage hole would have to sustain. Hence the test results shown in Table 2 below are significant.

Table 2. Collapse Test Data

TEST	MATERIAL	INSIDE DIAMETER (mm)	OUTSIDE DIAMETER (mm)	SAMPLE LENGTH (mm)	PRESSURE AT FAILURE (MPa)
1	Lining	51	92*	127	34*
2	Lining	51	92	127	46
3	Lining	51	92	127	46
4	Dry Tuff	48	95	127	17.9
5	Wet Tuff	48	95	127	2.6
6	Composite	51	180**	457	>70***

*Failed at a thin edge adjacent to end cap -- Tests 2 and 3 are better indications of true strength

**Outside diameter of glass lining was 92 mm - the rest of the material was parent tuff

***Sample was subjected to a capacity pressure of 70 MPa and did not fail. The capacity pressure was dictated by the stress in the rod holding the ends apart

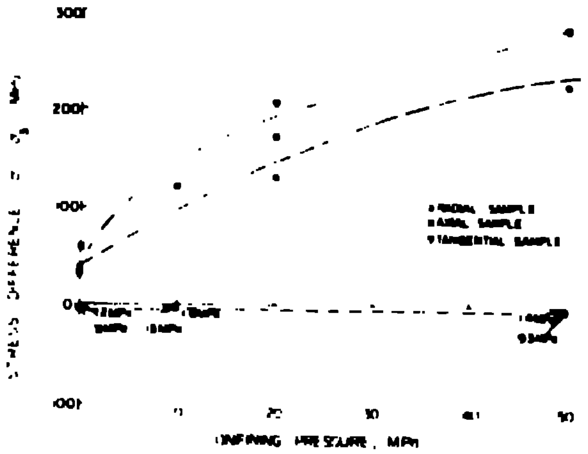

Figure 2. Failure Envelopes in Tension and Compression for Lining Materials

Figure [illegible]. Failure Envelopes for Saturated and Dry Tuff

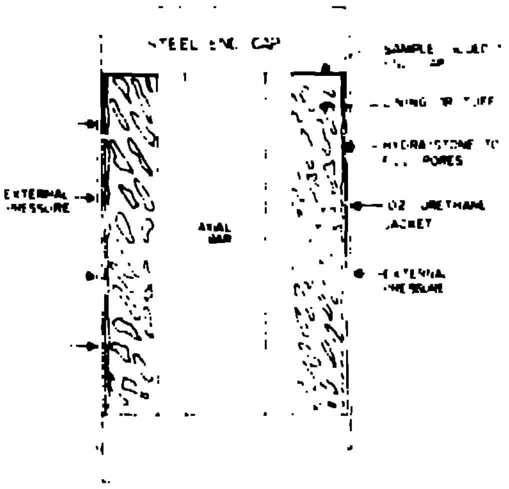

Figure 4. Schematic of Collapse Test

Rock Melting System Hardware

Penetrator Tests

A wide variety of rock melting penetrators have been tested. An adaptation of a melting consolidation mode penetrator would be used for forming a strong, impermeable glass liner in volcanic tuff. In this mode, which is applicable to porous rock or soil, all the melted rock is consolidated into a rock glass lining, and it is not necessary to remove any debris or "cuttings" from the hole.

Assuming that the waste repository storage hole had already been drilled by a boring machine, then the reaming and glass forming advance rate would be very fast and limited only by the thermal requirement dictated by the volume of tuff to be converted to the glass lining.

The tests carried out at Los Alamos proved that the primary factor regulating the glass forming rate is the power available for melting. A relatively small axial thrust load is applied to overcome friction and keep the penetrator moving, but this load influences the penetration rate very little if at all.

Glass Lining System Configuration

Although the detailed design of the reaming and glass lining system is beyond the scope of this paper, it is possible to outline the basic hardware system configuration.

The system will be built around an annular shaped heated penetrator operating in the melting consolidating mode. Figure 5 is a schematic of this system showing the melting zone, the glass liner and the placement of the essential system components.

The penetrator body is assumed to be 1.0 meter diameter, fabricated from either tungsten or molybdenum, and heated by an internal electric heater. This size of penetrator body would be assembled from approximately thirty individual segments, each having its own internal heater. The electric power required to heat each segment is estimated to be 5.0 kw, for a total penetrator electric power requirement of 150 kw.

A simple pipe stem would supply the cooling air and contain the electric power cable

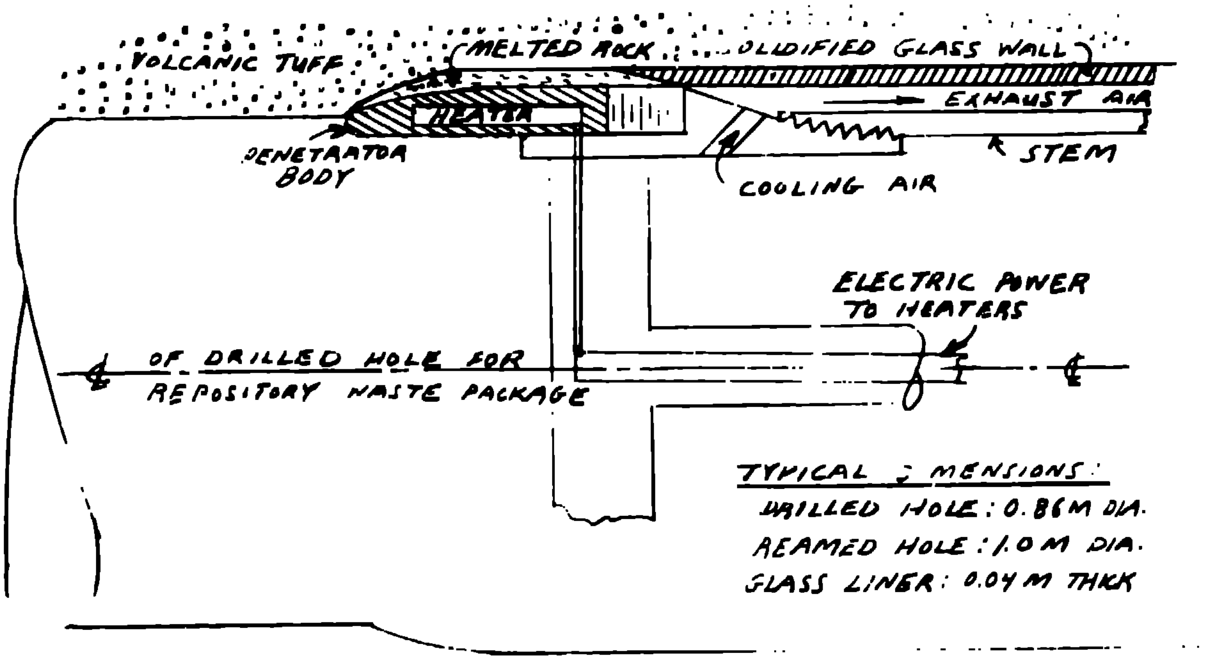

Figure 5. Schematic Diagram of Rock Melting Glass Liner Tool

The surface support components would consist of a drilling rig to apply a small thrusting load to the pipe stem, an electric generator for the heater power, and an air compressor for the cooling air supply.

All essential components of the system, with the exception of the segmented penetrator body, were tested successfully during the Los Alamos rock melting program.

Summary and Conclusions

In-situ glass liners created by rock melting reaming of bored holes for nuclear waste storage packages would provide a protective layer of strong and relatively impermeable material around the storage containers.

Laboratory tests have shown that crushing strengths have been doubled and permeability reduced by factors of three or more for the glass liner material as compared to the in-situ volcanic tuff.

The rock melting technology exists to make the glass liners by reaming the drilled emplacement holes using an electrically heated rock melting penetrator system. Such systems have been developed and extensively field tested by Los Alamos National Laboratory.

Acknowledgments

This work was supported by the U.S. Department of Energy to which the author expresses his grateful appreciation.

References

Reports

1. Nielson, R., Abou-Sayed, A., and Jones, A., 1975,"Characterization of Rock Glass Formed by the LASL Subterrene in Bandelier Tuff", TR-75-61, Terratec Inc., Salt Lake City, Utah.

2. Neudecker, J., 1973,"Design Description of Melting-Consolidating Prototype Subterrene Penetrators", LA-5212MS. Los Alamos National Laboratory, Los Alamos, New Mexico.

3. Neudecker, J., 1974,"Conceptual Design of a Coring Subterrene Geoprospector", LA-5517-MS, Los Alamos National Laboratory, Los Alamos, New Mexico.

4. Gido, R., 1973,"Description of Field Tests for Rock Melting Penetration", LA-5213-MS, Los Alamos National Laboratory, Los Alamos, New Mexico.

5. Williams, R., 1973,"Development and Construction of a Modularized Mobile Rock Melting Subterrene Demonstration Unit", LA-5209-MS, Los Alamos National Laboratory, Los Alamos, New Mexico.

6. Butters, S.,1975,"Material Properties Testing in Support of the Nevada Test Site Nuclear and High Explosive Test Program", TR-75-27, Terratec Inc., Salt Lake City, Utah.