Radioactive Waste Isolation in Salt: Peer Review of the D'Appolonia Report on Schematic Designs for Penetration Seals for a Repository in the Permian Basin, Texas

D. F. Hambley, J. C. Stormont, J. E. Russell, D. F. Edgar
D. F. Fenster, W. Harrison, and M. W. Tisue

ARGONNE NATIONAL LABORATORY
Energy and Environmental Systems Division

Operated by
THE UNIVERSITY OF CHICAGO for U. S. DEPARTMENT OF ENERGY
Under Contract W-31-109-Eng-38

8504080197 850222
PDR WASTE
WM-16 PDR

Argonne National Laboratory, with facilities in the states of Illinois and Idaho, is owned by the United States government, and operated by The University of Chicago under the provisions of a contract with the Department of Energy.

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, expressed 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.

This informal report presents preliminary results of ongoing work or work that is more limited in scope and depth than that described in formal reports issued by the Energy and Environmental Systems Division.

Printed in the United States of America. Available from National Technical Information Service, U. S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

ANL/EES-TM-261

RADIOACTIVE WASTE ISOLATION IN SALT: PEER REVIEW OF THE D'APPOLONIA REPORT ON SCHEMATIC DESIGNS FOR PENETRATION SEALS FOR A REPOSITORY IN THE PERMIAN BASIN, TEXAS

by

D.F. Hambley, J.C. Stormont,* J.E. Russell,** D.E. Edgar,
D.F. Fenster, W. Harrison, and M.W. Tisue

Energy and Environmental Systems Division
Geoscience and Engineering Group

September 1984

work sponsored by
U.S. DEPARTMENT OF ENERGY
Salt Repository Project Office
Office of Civilian Radioactive Waste Management

*Sandia National Laboratories
**Texas A&M University

Department of Energy
Chicago Operations Office
Salt Repository Project Office
505 King Avenue
Columbus, Ohio 43201-2693

July 9, 1984

NOTICE TO READERS

At the request of the Salt Repository Project Office, Argonne National Laboratory carried out a review of a report entitled "Schematic Designs for the Penetration Seals for a Repository in the Permian Basin."* Argonne was asked to consider the assumptions, the interpretation of data, the adequacy of materials, the future activities, the behavior of crushed salt and the sealing design in general. It was our hope that the review panel might identify any deficiencies in material properties or in the designs that may been present.

The review report prepared by the Argonne panel has been given to OWMI for their consideration and for transmittal to D'Appolonia.

R. C. Wunderlich
Acting Chief
Engineering and Technology
Salt Repository Project Office

*A microfiche copy of the reviewed report is attached to the inside back cover of this report.

FOREWORD

Documents are being submitted to the Salt Repository Project Office (SRPO) of the U.S. Department of Energy (DOE) by Battelle Memorial Institute's Office of Nuclear Waste Isolation, by D'Appolonia Consulting Engineers, Inc., and by other contractors to satisfy milestones of the Salt Repository Project of the Civilian Radioactive Waste Management Program. Some of these documents are being reviewed by multidisciplinary groups of peers to ensure DOE of their adequacy and credibility. Adequacy of documents refers to their ability to meet the standards of the U.S. Nuclear Regulatory Commission, as enunciated in 10 CFR Part 60, and the requirements of the National Environmental Policy Act and the Nuclear Waste Policy Act of 1982. Credibility of documents refers to the validity of the assumptions, methods, and conclusions, as well as to the completeness of coverage.

Since late 1982, Argonne National Laboratory has been under contract to DOE to conduct multidisciplinary peer reviews of program plans and reports covering research and development activities related to siting and constructing a mined repository in salt for high-level radioactive waste. The present report summarizes Argonne's review of a September 1983 draft report by D'Appolonia Consulting Engineers, Inc., entitled *Schematic Designs for Penetration Seals for a Repository in the Permian Basin.*

Argonne was requested by DOE to review the report on March 6, 1984 (see App. A). The review procedure involved obtaining written comments on the report from two extramural and four Argonne experts in relevant research areas. The peer review panel met at Argonne on April 4, 1984, and reviewer comments were integrated into this report by the review session chairman, with the assistance of Argonne's core peer review staff. All of the peer review panelists concurred in the way in which their comments were represented in this report (see App. B), a draft of which was sent to SRPO on April 13, 1984.

PREVIOUSLY PUBLISHED REPORTS IN THE SERIES

"RADIOACTIVE WASTE ISOLATION IN SALT"

ANL/EES-TM-242 Peer Review of the Office of Nuclear Waste Isolation's Geochemical Program Plan (Feb. 1984)

ANL/EES-TM-243 Peer Review of the Office of Nuclear Waste Isolation's Socioeconomic Program Plan (Feb. 1984) (revised July 1984)

ANL/EES-TM-246 Peer Review of the Office of Nuclear Waste Isolation's Plans for Repository Performance Assessment (May 1984)

ANL/EES-TM-254 Peer Review of the Office of Nuclear Waste Isolation's Reports on Preferred Repository Sites within the Palo Duro Basin, Texas (April 1984)

ANL/EES-TM-256 Special Advisory Report on the Status of the Office of Nuclear Waste Isolation's Plans for Repository Performance Assessment (Oct. 1983)

ANL/EES-TM-258 Peer Review of the Office of Nuclear Waste Isolation's Plan to Decommission and Reclaim Exploratory Shafts and Related Facilities (July 1984)

ANL/EES-TM-259 Peer Review of the Office of Nuclear Waste Isolation's Report on the Organic Geochemistry of Deep Groundwaters from the Palo Duro Basin, Texas (Aug. 1984)

ANL/EES-TM-260 Peer Review of the Texas Bureau of Economic Geology's Report on the Petrographic, Stratigraphic, and Structural Evidence for Dissolution of Upper Permian Bedded Salt, Texas Panhandle (Aug. 1984)

ANL/EES-TM-261 Peer Review of the Office of Nuclear Waste Isolation's Report on Functional Design Criteria for a Repository for High-Level Radioactive Waste (Aug. 1984)

CONTENTS

PEER REVIEW PANEL MEMBERS viii

SUMMARY OF RECOMMENDATIONS 1

1 INTRODUCTION 2

2 GENERAL COMMENTS 3

2.1 Assumptions and Limitations 3
2.2 Technical Soundness 3
2.3 Performance Requirements 4
2.4 Future Activities 4
2.5 Seal Designs 5
2.6 Consolidation Behavior of Crushed Salt 5

3 SPECIFIC TECHNICAL ISSUES 6

3.1 Excluding Salt from Shaft Sealing Concepts 6
3.2 Keys for Bulkheads 7
3.3 Borehole Seal Designs 8
3.4 Cementitious Materials 8
3.5 Stratigraphy 9
3.6 Sealing Schedule and Retrievability 9
3.7 Sealing the Dockum Group and the Ogallala Formation 9
3.8 Interface Grouting 10
3.9 Disturbed Zone 10
3.10 Number of Bulkheads in the Shaft 10
3.11 Dense Structural Backfill 10
3.12 Crushed Salt Consolidation Analysis 11
3.13 Prediction of Creep Rate 11

4 REGULATORY ISSUES 12

5 PAGE-BY-PAGE COMMENTARY 13

REFERENCES 18

APPENDIX A: U.S. Department of Energy Letter Requesting Peer Review 21

APPENDIX B: Concurrence Sheet 25

APPENDIX C: Credentials of Peer Review Panel Members 29

• • •

A microfiche copy of the following unpublished report is attached to the inside back cover of this report: P.C. Keisall et al., *Schematic Designs for Penetration Seals for a Repository in the Permian Basin*, D'Appolonia Consulting Engineers, Inc., Albuquerque, N.M. (Sept. 1983).

PEER REVIEW PANEL MEMBERS

*Dr. Dorland E. Edgar
Geoscience and Engineering Group
Energy and Environmental Systems Division
Argonne National Laboratory

*Mr. David F. Fenster
Geoscience and Engineering Group
Energy and Environmental Systems Division
Argonne National Laboratory

‡Mr. Douglas F. Hambley
Geoscience and Engineering Group
Energy and Environmental Systems Division
Argonne National Laboratory

**Dr. Wyman Harrison
Associate Director for Geoscience and Engineering
Energy and Environmental Systems Division
Argonne National Laboratory

Dr. James E. Russell
Texas A&M University
College Station, Texas

Mr. John C. Stormont
Waste Management Technology Department
Sandia National Laboratories
Albuquerque, New Mexico

Ms. Mary W. Tisue
Geosciences Editor
Energy and Environmental Systems Division
Argonne National Laboratory

The credentials of panel members are summarized in App. C.

---

*Member of core peer review staff.

‡Review session chairman and member of core peer review staff.

**Review panel chairman and member of core peer review staff.

RADIOACTIVE WASTE ISOLATION IN SALT: PEER REVIEW OF THE D'APPOLONIA REPORT ON SCHEMATIC DESIGNS FOR PENETRATION SEALS FOR A REPOSITORY IN THE PERMIAN BASIN, TEXAS

by

D.F. Hambley J.C. Stormont, J.E. Russell, D.E. Edgar,
D.F. Fenster, W. Harrison, and M.W. Tisue

SUMMARY OF RECOMMENDATIONS

The following recommendations for improving the D'Appolonia Consulting Engineers, Inc., report entitled *Schematic Designs for Penetration Seals for a Repository in the Permian Basin* have been abstracted from the body of this report. The authors of the reviewed report should:

1. State the major assumptions of the study in Sec. 1.1 rather than later in the report.

2. Consider using salt for the shaft seals in salt horizons.

3. Reconsider whether keys are needed for the bulkheads.

4. Provide for interface grouting. Use of expansive cement will not guarantee that interfaces will be impermeable.

5. Discuss the sealing schedule and, where appropriate, consider what needs to be done to ensure that emplaced radioactive waste could be retrieved if necessary.

6. Describe in more detail the sealing of the Dockum and Ogallala aquifers.

7. Consider an "as low as reasonably achievable" approach to performance requirements for the initial design phase.

8. Address the concerns in the 1983 U.S. Nuclear Regulatory Commission document entitled *Draft Technical Position: Borehole and Shaft Sealing of High-Level Nuclear Waste Repositories.*

9. Cite the requirements for release of radioactivity by referring to specific clauses in the regulations of the U.S. Environmental Protection Agency.

10. Provide further explanation in the outline of future activities about materials development and verification testing. More emphasis on development of accelerated testing programs is also required.

1 INTRODUCTION

The report prepared by D'Appolonia Consulting Engineers, Inc., for the Office of Nuclear Waste Isolation (ONWI) entitled *Schematic Designs for Penetration Seals for a Repository in the Permian Basin* references schematic seal designs for a repository in bedded salt to the stratigraphy of the Permian Basin in the Texas Panhandle. The peer review of the D'Appolonia report conducted by Argonne National Laboratory involved obtaining written critiques of the report from two extramural and four Argonne experts in relevant research areas. A core group of four Argonne panelists met on April 4, 1984, to review and discuss all of the written comments, after which the review session chairman drafted the present report. Panelists did not contact ONWI or D'Appolonia personnel, and none of the panelists have been involved in any programs sponsored by the U.S. Department of Energy (DOE) or directed by ONWI such that their participation in the review process could be construed as a conflict of interest.

No specific guidance was provided to Argonne by DOE on how to conduct the review. However, DOE did ask that the panelists respond to the following questions and request for comment (see App. A).

1. Are D'Appolonia's assumptions and the limitations of its analysis adequately and clearly stated?

2. Is the technical interpretation of the data presented correct?

3. Do the materials recommended for seals and backfill meet the performance requirement?

4. Are the future activities outlined in the report appropriate for meeting the objectives of the sealing program?

5. Comment on the sealing design and the consolidation behavior of crushed salt.

2 GENERAL COMMENTS

2.1 ASSUMPTIONS AND LIMITATIONS

The assumptions made by D'Appolonia and the limitations of its analysis are for the most part adequately and clearly stated in the report. The overall approach for developing seal designs is discussed in Sec. 1.3, with the specific elements of the approach listed on page 5. As discussed in Sec. 1.4, the performance requirements for the seals have been divided into design goals and design bases. Design goals are defined as "statements of the overall required performance." Design bases are "the qualitative limits on performance of various aspects of a seal system, specified such that if these bases are met the design goal will be met automatically."

The assumed reference conditions are given in Sec. 2.0. The assumed repository layout described in Sec. 2.1 is based on Stearns-Roger (1983) conceptual designs for a repository in bedded salt in the Permian Basin. The assumed site geology given in Sec. 2.2 is based on Stone and Webster (1982). The assumed physical, mechanical, and thermal properties of the host rocks are discussed in Sec. 2.3, and the assumed in situ stresses and temperatures are given in Sec. 2.4. The report mentions that hydrostatic conditions are assumed for the salt but that the stresses in nonsalt rocks are unknown. The assumptions for the crushed salt consolidation analysis and the limitations of that analysis are given in Sec. A.6.1. If these assumptions have been idealized, the authors have been careful to point it out.

Nonetheless, the report would be improved by listing the major assumptions in Sec. 1.1 and changing the section title to "Objectives, Scope, and Assumptions." Some of the major assumptions to be included in Sec. 1.1 are:

1. The repository layout described in Sec. 2.1 is from Stearns-Roger (1983).

2. The stratigraphy as presented in Sec. 2.2 is from Stone and Webster (1982).

3. Retrievability needs to be considered only with respect to panel bulkheads and backfilling the storage rooms.

4. Mining should be carried out so as to minimize damage to the surrounding rock.

2.2 TECHNICAL SOUNDNESS

Although the material presented in the report is for the most part technically sound, several technical issues requiring further attention are discussed in Sec. 3 of this report. More generally, panelists wished to emphasize that several aspects of salt behavior are rather controversial. One of the more controversial of these is the rate of time-dependent deformation around mine openings. Some researchers, notably Baar

(1977) and Mraz (1976), are of the opinion that creep prediction models based on laboratory experiments may yield misleading results. However, others rely heavily on laboratory data. The authors of the D'Appolonia report used laboratory-based data generated by RE/SPEC, Inc. (Pfeifle et al., 1983), but state that there is "uncertainty in predicting long-term room closure rates" (p. 33). They also indicate that further analyses will be required to confirm their assumptions. Although such analyses may be helpful, final confirmation will be possible only when the repository has been constructed and in situ behavior has been monitored for a period of time.

2.3 PERFORMANCE REQUIREMENTS

Performance requirements are not explicitly spelled out in the report, a deficiency that should be remedied. Section 1.4 (Performance Requirements) discusses the terminology and concepts to be used in the design process. From this discussion, the term "design goal" (p. 9) appears to be equivalent to "performance requirement." These topics should be presented more clearly.

The "overall design goal for penetration seals" is defined in terms of U.S. Environmental Protection Agency (EPA) limits, that is, the "maximum allowable release from the site as a whole." The report states on page 9 that "the total allowable site release allotted to the seal system should be in the range of 5 to 10 percent." This argument has two weaknesses. First, the basis for selecting this range is not stated, except to say that the range is "an order of magnitude less than the maximum acceptable repository release" (p. 9). Although this approach appears intuitively logical for the schematic design phase, it is subject to criticism for being subjective. If possible, supporting arguments for this selection criterion should be expanded and the numerical EPA standards or limits should be presented. Second, at this stage of the design process, it is not clear how to objectively and quantitatively evaluate the performance of the schematic seal designs in terms of the overall design goal or in terms of the qualitative performance requirements contained in 10 CFR Part 60 (U.S. Nuclear Regulatory Commission, 1983a). In fact, there may not be an absolute technical requirement for such evaluation at this schematic design stage. However, without such evaluation, the panelists could not judge the ability of the materials or design to meet the stated performance requirement.

At this stage, it might be better to approach this problem from the "as low as reasonably achievable" (ALARA) perspective and defer quantitative expression of performance until additional site-specific data and detailed repository design information are available. In any case, this portion of the design and evaluation process will be subject to criticism because of the uncertainties surrounding the problem.

2.4 FUTURE ACTIVITIES

Section 4.0 (Future Activities) seems particularly well thought out and should provide the basic framework for successful completion of the entire penetration seal program. However, more details could be provided for such topics as salt consolidation

and fracture healing (item 4 on page 80), materials development, verification testing, and accelerated testing.

Panelists questioned whether existing schedules for developing penetration seals (e.g., Kelsall et al., 1982) allow sufficient time for the various activities described in Sec. 4.0. Also, several of the subsections in App. A refer to additional work that may be difficult or impossible to accomplish within the limited time available.

2.5 SEAL DESIGNS

Some of the schematic designs presented in the report incorporate relatively complicated concepts and designs, and it is not obvious that such designs are superior to simpler ones. This high level of complexity could result in unnecessary developmental work and excessive costs. It may also complicate verification of emplacement and evaluation of subsequent performance. The design of borehole seals and the use of extensive keyways are discussed further in Sec. 3 of this report.

2.6 CONSOLIDATION BEHAVIOR OF CRUSHED SALT

The state of knowledge is rather primitive with respect to the consolidation behavior of crushed salt. A relatively extensive laboratory program to explore creep consolidation will probably be needed. The presence of brine and its response to temperature gradients will likely be emphasized. However, as discussed in Sec. 2.2 of this report, it is difficult to replicate in situ loading conditions in the laboratory. Nonetheless, predictions of salt behavior based on the results of laboratory tests may provide a rough estimate of actual deformation.

3 SPECIFIC TECHNICAL ISSUES

Whereas the majority of the review panelists considered most of the D'Appolonia report to be technically sound, panelists occasionally disagreed with the authors on a technical point or felt that certain topics should be discussed at greater length. The more important of these problem areas are:

- Excluding salt from shaft sealing concepts,
- Keys for bulkheads,
- Borehole seal designs,
- Cementitious materials,
- Stratigraphy,
- Sealing schedule and retrievability, and
- Sealing of the Dockum Group and Ogallala Formation.

3.1 EXCLUDING SALT FROM SHAFT SEALING CONCEPTS

According to the report, salt or salt-based materials are not suitable for sealing the shafts (pp. 35, 41, and 54) because of possible contact with freshwater and subsequent dissolution. Panelists disagreed and recommended that salt not be excluded from shaft sealing concepts at this stage of the design process. In fact, salt may be the most appropriate medium, particularly in the lower portions of the shaft. Because cost is given as a factor in the choice of seal materials (p. 36), it should be noted that the cost of salt blocks may be much less than the cost of cement-based seals.

No given or referenced analysis demonstrates that groundwater will reach the lower portion of the shaft in sufficient quantity to dissolve emplaced salt before it can reconsolidate. Actually, current plans call for sealing the shaft in the vicinity of the aquifers so that flow is kept "as low as is reasonably and economically feasible" (p. 12). By not using any salt in the shaft, the principle of "using salt as the major seal material and by relying on creep closure to seal the penetrations by consolidating and recrystallizing the salt" (p. 12) is violated, and the sealed shaft becomes an anomalous (i.e., chemically and mechanically unmatched) conduit between the aquifers and the repository. If the nonsalt seals fail with time, water will most likely infiltrate the repository horizon.

On the other hand, if salt placed in the lower portions of the shaft reconsolidates into a mass with properties comparable to undisturbed salt, the repository horizon will be isolated from the water sources above by intact salt. This configuration seems more desirable, as the premise for emplacing waste in salt beds is that salt will provide

long-term stability and exclusion of water. Further, "the effective consolidation of crushed salt might relax the required longevity of other seal components [from at least 10,000 years] to 1000 years or less" (p. 86). Proving that seal components will be effective over a period of 10,000 years is technically much more difficult.

If the emplaced salt reconsolidates into essentially intact salt, any "evidence" of the shaft below this point would be lost. If freshwater eventually migrates down the sealed shaft, a dissolution front would proceed spherically from the point at wh n intact salt is encountered. If salt is not used for sealing the shaft, this point would be at the repository horizon; if salt is used, this point would be above the repository horizon, thereby providing additional isolation of the radioactive waste from water.

Analyses of stress buildup in bulkheads at the base of the shaft indicate that because the "radial stress reaches 50% of the initial in situ stress in less than 1 to 5 years[,]...it can be reasonably concluded that any fractures in the salt adjacent to the penetration should be at least significantly closed if not totally healed at this level" (p. A-34). The report also states that "the joints between the bricks, and between the bricks and the penetration wall, should heal forming an homogeneous mass indistinguishable from undisturbed salt" (p. 53). Because the sealing concepts presented for the upper portions of the shaft where water is present should result in low flows for at least five years, there should be sufficient time for the salt blocks to form a mass indistinguishable from undisturbed salt.

In summary, until more is known about material properties, costs, and water flow through the shaft, excluding salt from consideration for shaft seals is not defensible and certainly not dictated by the concepts presented in the report.

3.2 KEYS FOR BULKHEADS

The report states that "bulkheads will be keyed into the walls of the shafts and tunnels in order to intersect the interface and part of the disturbed zone, and to provide additional shear resistance" (p. 51). This idea is based on standard practice in constructing dams or bulkheads for water control, where stoppings are keyed into the host rock to provide shear resistance and to lengthen the pathway for seepage water. Mine ventilation stoppings, on the other hand, are constructed to fill the opening but are rarely keyed in. Thus, while some keying may be necessary, always requiring keys may be neither necessary nor desirable. Before keys are incorporated into any design, there should be proof that the advantages outweigh the disadvantages.

Constructing keyways does not eliminate the interfaces between the rock and seal. Also, although a keyway will lengthen the flow path along the interface, the increase may well be insignificant. If disturbed zones are present, excavation of a keyway may merely extend the disturbed zone. In fact, if the disturbed zone is proportional to the radius of the excavation as suggested on pages 51-52, keyways will result in larger volumes of disturbed rock. There is no evidence that the disturbed zone will be reduced if excavation immediately precedes bulkhead emplacement. As more than half of the disturbed zone results from stress relief "regardless of the excavation method used" (p. 52), it is not clear how "low-energy excavation methods" (p. 52) will result in a less extensive disturbed zone.

The need for additional shear resistance is not obvious, as fills tend to transfer vertical loads to the surrounding host rock and may not require substantial support (National Coal Board, 1982). Cylindrical plugs in both laboratory and field studies have exhibited strong resistance to shear stresses (Gulick et al., 1980; Stormont and Daemen, 1983). Further, keys may induce unfavorable stress concentrations in the rock near the loaded plug end.

In summary, keys will not only be expensive, but they may be difficult and dangerous to construct, especially in the shafts. Because careful investigation will be required to demonstrate that keys are necessary, they should be considered, but not mandated, in the report.

3.3 BOREHOLE SEAL DESIGNS

The proposed borehole sealing design outlined in 10 steps on page 76 will undoubtedly be subject to stringent quality assurance requirements. On the basis of one panelist's experience with a borehole plugging operation performed under strict quality assurance control, the panel believes that the specified procedures are going to result in a very difficult and costly operation. In particular, in-place compaction of clay and carefully cleaned borehole walls may not be practical because of variations in borehole size and shape caused by washouts.

Unless the need for such a relatively elaborate plugging system can be demonstrated, a simpler operation would make more sense. The authors actually state that 100 m of open hole should be enough to form "an adequate plug" (p. 74). They also state that "with prudent repository siting and exploration practices, there should be few, if any, boreholes connecting the ground surface and the repository that are not coincident with a shaft location or contained within a pillar of undisturbed rock" (p. 71). Therefore, it is imprudent to advance a design that will be costly and difficult to develop, emplace, and verify, unless absolutely necessary.

3.4 CEMENTITIOUS MATERIALS

The report states that concretes developed from BCT-1F and BCT-1FF grouts will be "relatively stiff" (p. 45). If this statement means stiff relative to the host rock, it is not correct. The elastic moduli are essentially the same for these grouts and rock salt (Gulick et al., 1980).

The next paragraph on page 45 states a need to develop a "low-modulus, fracture-resistant concrete (or grout)." The argument appears to be that creep closure of the salt adjacent to a "rigid" bulkhead will result in stresses large enough to fracture the bulkhead. This conclusion is contradicted by the authors' own analysis. Figure A-9 shows that radial pressure buildup on a concrete bulkhead will approach lithostatic pressure, about 2400 psi. Yet, the BCT-1F and BCT-1FF grouts have unconfined compressive strengths on the order of 7,000-10,000 psi (Gulick et al., 1980). Also, it is not clear how development of a concrete that would "creep in response to stress" (p. 45) would be beneficial, as known creep rates of concretes are much less than those of salt.

3.5 STRATIGRAPHY

The general stratigraphy of the Upper Permian section in the Palo Duro Basin in Deaf Smith and Swisher counties is adequately described for the report's purposes. Also, Fig. 2-2 is adequate as a generalized stratigraphic section. However, one important problem is that the thick salt unit of Lower San Andres (LSA) Unit 5 does not meet the minimum thickness requirement. As shown on an isopach map of LSA Unit 5, this unit meets the old 75-ft criterion in Deaf Smith County, but not the revised 125-ft minimum (Office of Nuclear Waste Isolation, 1983a, p. 52; 1983b, pp. 62 and 66). A revised working draft of the report that screens from preferred locations to preferred sites does not consider the LSA Unit 5 salt as a potential repository horizon (Office of Nuclear Waste Isolation, 1984, p. 12). Isopach maps of LSA Unit 5 salt indicate that the thickness data presented in lines 7-9 on page 18 of the D'Appolonia report are misleading and apparently refer to the entire LSA Unit 5, which includes anhydrite or dolomite, shale, limestone, and salt strata (Office of Nuclear Waste Isolation, 1983a, Fig. 4-5, p. 10; 1983b, Fig. 5-2D, p. 66).

It is an oversimplification to describe the Dockum Group and Ogallala Formation in one sentence (p. 18). The Dockum is a well-lithified rock unit, which is water-bearing in parts, whereas the Ogallala Formation consists principally of loose to well-cemented sands and gravels.

Finally, why do the authors refer to wells in Deaf Smith County when discussing a potential repository in the LSA Unit 4 salt in Swisher County (p. 20)? Data from DOE borings in Swisher County are available and should be used for such analyses.

3.6 SEALING SCHEDULE AND RETRIEVABILITY

One unstated assumption of the report is that the U.S. Nuclear Regulatory Commission (NRC) will allow DOE to close the repository before placement of the seals begins. However, storage rooms will likely be backfilled and panel bulkheads will probably be emplaced during the operational period. And performance objectives for the operational period require that the option of retrievability be maintained (U.S. Nuclear Regulatory Commission, 1983, 10 CFR 60.111[b]). This requirement is not mentioned in the report and is alluded to only once in the appendix. A section in the introduction should discuss the sealing schedule, including the need for retrievability.

3.7 SEALING THE DOCKUM GROUP AND THE OGALLALA FORMATION

Because the Ogallala Formation and Dockum Group are important aquifers, impermeable shaft linings will extend below these strata. Furthermore, it is likely that chemical seal rings will be placed in the shaft linings so that these aquifers will be completely isolated. Experience with chemical seal rings is insufficient to guarantee their long-term efficacy, but they are well proven as short-term seals in several potash mine shafts. In our opinion, it would be extremely imprudent to remove the shaft lining during the shaft sealing process. Also, as pointed out in the report, freezing of a ring of ground surrounding the shaft would be required -- a costly and time-consuming process.

3.8 INTERFACE GROUTING

The report states that grouting the interface between bulkheads and the country rock will not be required because expansive concretes will be used (pp. 62 and 67). Yet, at the same time, interface flow is identified as a primary concern (pp. 55 and 69) with regard to bulkhead performance. Successful bulkhead emplacements at the Nevada Test Site and in deep South African gold mines have shown that interface grouting may be the single most effective way to reduce overall flow (Garrett and Campbell-Pitt, 1956, 1961). Further, interface grouting may reduce the concern about tensile stresses at the rock/seal interface (Daemen et al., 1983). Interface grouting should be identified in the report as a probable treatment.

3.9 DISTURBED ZONE

It states on page 51 that "the disturbed zone may consist of a destressed zone extending several radii from the shaft or tunnel wall in which permeability may be increased due to loosening of the crystal structure." This speculative statement should be strongly qualified as far as its implication of increased permeability extending so far into the rock. Evidence suggests that sampling effects (e.g., drilling core) make it difficult for laboratory measurements of permeability to predict a stress-permeability relationship in situ (Cooley and Butters, 1979; Sutherland and Cave, 1979).

In addition, the report repeatedly mentions blast-induced damage. Yet, it states on page 13 that "all excavation will be by means of continuous miners or roadheader-type tunnel boring machines." While this statement does not refer to the shafts, the possibility exists that they will also be drilled. However, it is prudent to include the possibility of blast-induced damage, provided that the extent of the disturbed zone around the shafts is clearly the subject.

3.10 NUMBER OF BULKHEADS IN THE SHAFT

"Seven bulkheads [for the shaft sealing system] are sufficient to provide both a cost-efficient reduction in system permeability and some redundancy in the event that some of the bulkheads may not perform to specification" (p. 67). No basis is given for this statement.

3.11 DENSE STRUCTURAL BACKFILL

"A dense structural backfill is located immediately above and below each bulkhead...to absorb or deflect stresses away from the bulkhead proper" (p. 67). Yet, elsewhere in the report the authors give the advantages of stress buildup associated with the bulkheads (p. 51 and App. A). These contradictory positions need to be resolved.

3.12 CRUSHED SALT CONSOLIDATION ANALYSIS

The authors took great care to identify the assumptions and limitations of the crushed salt consolidation analysis. The nature and number of those assumptions and limitations, however, call into question the relevancy of the analysis. The analysis would be much more useful once further laboratory work addresses some of the fundamental uncertainties, such as the creep rate for crushed salt undergoing consolidation. Until that time, the degree of uncertainty associated with the analysis severely limits its application. However, App. A should remain in the report but with the revisions detailed in Sec. 5 of this report.

3.13 PREDICTION OF CREEP RATE

Equations A-5 and A-6 on pages A-17 and A-18, respectively, are not adequate for modeling the closure rate in underground openings in a repository in salt because the assumptions made in deriving these equations are not in accord with expected repository conditions. These assumptions, most of which are not stated in the report, can be commented upon as follows:

1. Only steady-state creep is considered, even though temperature and stress conditions will be changing throughout the time period considered.

2. The assumed circular shape of the model opening is not adequate for noncircular storage rooms, haulageways, and other repository openings.

3. More detailed thermal analysis studies have shown that temperature gradients, which are assumed to be irrelevant in these equations, are significant.

4. Because this analysis assumes a single opening in an infinite medium, the influence of adjacent openings is ignored.

As stated on page A-18, variations have been observed in laboratory-determined values of steady-state creep parameters for salts from different locations. This observation does not mean, however, that similar variations will be observed in the values for salt samples from any particular site. Furthermore, the observed variability does not mean that the best available methods of analysis should not be used.

4 REGULATORY ISSUES

The schematic design, as presented, appears to be logically directed toward the overall content of 10 CFR 60 (U.S. Nuclear Regulatory Commission, 1983a), including the required criteria for shaft and borehole seals (Sec. 60.134 [a]) and their materials and placement methods (Sec. 60.134 [b]). However, the overall treatment of NRC regulations and guidance should be expanded, even though some aspects of 10 CFR 60 have been specifically addressed (p. 72).

Although the difficulty in evaluating compliance at the schematic design stage was noted in Sec. 2.3 of this report, the applicable regulations should still be stated explicitly, including the relevant sections of both 10 CFR 60 and 40 CFR 191 (U.S. Environmental Protection Agency, 1984). Magnitudes specified in the regulations for limits on radioactive releases should also be given.

More specifically, the design should be explicitly compared to and evaluated for compliance with the guidance presented in U.S. Nuclear Regulatory Commission (1983b). It appears that the majority of the guidance and requirements of NRC are addressed, either directly or indirectly, by the schematic design and proposed future activities contained in the report. However, an additional section or a subsection for inclusion in Sec. 4 could explicitly present the major requirements, issues, and guidance as formulated by NRC and the particular activities within the seal design program that will satisfy each of them. This information should be summarized in tabular form (cf. Table 4-1) so that gaps in data and design requirements could be readily identified and obviated. This form of presentation would illustrate how program activities are directed toward providing NRC with the information necessary to evaluate the adequacy of the design for licensing.

5 PAGE-BY-PAGE COMMENTARY

Page(s)	Line(s)	Comment
2	27	Insert the word "conceptual" before the word "designs."
10	12-15	This sentence should be revised to read: "maximum allowable groundwater flow and minimum allowable groundwater travel time through the seals..." The minimum groundwater travel time from the repository to the accessible environment is stipulated in 10 CFR 60.122(b)(2)(iv).
10	20-21	This sentence would be clearer if it were worded: "For example, it is not logical to design a seal system that is significantly less permeable than the host rock."
11	6-7	This sentence implies that the backfill will not have compacted over the time period, that is, that it will remain highly porous.
33	28-31	The authors are to be commended for stating the uncertainty in predicting "long-term room closure rates" and relating those uncertainties to the variability in test data resulting from laboratory tests designed to measure creep properties.
33-34	31-32; 1-2	The authors also recognize that consolidation and recrystallization of the salt backfill, and the time required for them to take place, are contentious issues.
35	14-16	Baar (1977) claims that salt is essentially impermeable below a depth of about 1000 ft.
37	22-24	How was the sample loaded -- hydrostatically or triaxially?
39	1-4	Intuitively, consolidation should be slower at the corners of the room; however, the rate will depend on the magnitude of the stress difference as compared with that at adjacent locations.
39	15-16	The authors should explain that the creep rate will depend on the temperature and that the temperature is higher near the radioactive waste canisters.
40	7-18	Although rather controversial, the effects of the presence of brine and of brine migration need to be considered.

Page(s)	Line(s)	Comment
42	1-6	Sealing boreholes with cementitious materials is also well established in the mining industry.
42	32-37	Research into sealing is also taking place at the University of Arizona.
46	6-7	The interface between the concrete and the host rock is very important. Testing at the University of Arizona indicates that, even with an expansive cement, shrinkage can occur upon curing and drying. Such shrinkage could result in a pathway along this interface.
47		References should be provided for the various curves in Fig. 3-1. Also, the two curves labeled "smectite" should be labeled "montmorillonite."
48	5-7	"Smectite" is a generic term for swelling clays. This sentence should conclude with: "...small proportions of montmorillonite or by larger proportions of illite."
52	15-18	This concern has also been expressed by NRC. Furthermore, the interface between the host rock and the seal material could serve as a preferred pathway.
59	19-22	A reference is required for the densities possible with pneumatic stowing. What was the assumed moisture content of the backfill?
60	12-18	Why would crushed salt be used for a bulkhead?
64-65	16-32; 1-2	These two paragraphs presumably refer to the earth fill although it isn't as clear as it should be.
65	13-19	Because the Ogallala and Dockum units are aquifers, the lining of the shaft through them will likely be designed to be relatively impermeable and resistent to corrosion. The type of lining used will also depend on the method used to construct the shaft. If the lining were to be removed, freezing would definitely be required.
67	7-10	This sentence should be revised to read: "...there is a diminishing return in including additional low-permeability components in a shaft seal system whose seal components act in series."

Page(s)	Line(s)	Comment
69	5-7	The polymer referred to is presumably the Dowell Chemical Seal Ring (CSR)™ or a similar formulation. Such seals have been in use for about 20 years.
70	6-10	If possible, accelerated tests should be devised to evaluate the durability under expected repository conditions of various candidate materials.
72	6-9	Deviation of boreholes can be controlled by careful drilling, frequent hole surveys, and redirection.
73	1-9	This discussion assumes that conventional methods of sinking shafts will be used. At the Waste Isolation Pilot Plant at Carlsbad, N.M., current practice is to drill a pilot hole and then slash by conventional drill-and-blast methods.
73	15-20	It is not true that horizontal holes can't be sealed adequately. The more important problem is to keep long horizontal holes from deviating, although the U.S. Bureau of Mines has had some success with this in coal mines. In any case, the holes should be kept relatively short.
77-78	25-33; 1-5	This discussion doesn't indicate that horizontal holes can't be grouted -- only that considerable care is required. This position is apparently contradicted by the statement on page 73, lines 15-20.
86	6	The third bullet is especially important.
88	11-15	The acceptability of such relaxation remains to be proven, although such a change in the requirements would seem logical.
88	32-33	Accelerated tests are definitely necessary.
90	18-20	This sentence should be deleted -- a generic test facility is no longer planned.
A-6	13-14	The definition of mean stress ($\sigma_m = \sigma_1 + \sigma_2 + \sigma_3$) conflicts with that given in Fig. A-1.
A-10	1-17	The information presented on the strength tests is insufficient. To evaluate the tests, readers need details on temperature, stress and/or strain rates, sample size, grain size distribution, etc.

Page(s)	Line(s)	Comment
A-12; A-14	9-36; 1-6	Greater correspondence is needed between the description of the analysis in the text and the flowchart on page A-13. The boxes in the flowchart should have the same numbering system as in the text.
A-14	7-9	The authors should justify their selection of time steps of one year.
A-15-A-17		Several assumptions in Sec. A.4 have not been stated. For example, are all of the infinite strip sources turned on simultaneously? Also, the locations at which temperatures are overestimated are not given. This type of analysis underestimates the temperature at the wall of the emplacement hole.
A-17	3-5	Is neglecting the heat loading from transuranic waste justifiable?
A-17	29	What assumptions are implicit in Eq. A-5? Is this a plane-strain model? Has incompressible flow been assumed?
A-18	26-29	Some practitioners, especially Baar (1977) and Mraz (1976), have found that using laboratory data to predict creep closure can give very misleading results, mainly because of the difference in loading conditions and resultant behavior. The only truly reliable means of determining creep behavior is to monitor closure underground in a full-scale repository. However, laboratory-derived values can be used in an analysis program to provide a first rough estimate.
A-19		In Table A-3, what is the temperature range for the given activation energies?
A-20	1-26	The effects of neglecting the transient response that results from changing the stress during a creep test should be discussed.
A-23	3	Why is the notation used for the bulk modulus different from that used in Eq. A-2 on page A-5.
A-23	18-19	What is the source of Eq. A-8?
A-23	30-31	If the backfill is dry, it is possible to use pneumatic stowing techniques to achieve initial densities of up to 83% of the density before excavation.

Page(s)	Line(s)	Comment
A-24		An additional implicit assumption is that the backfill will be homogeneously placed and will respond uniformly.
A-25	7-8	Temperature gradients have been shown to be significant in more detailed analyses.
A-29	2-33	Although the conclusions appear realistic, not allowing for the presence of brine is a deficiency. The behavior of brine inclusions is a rather controversial subject. Further research is needed.
A-30	1-3	If the storage room were backfilled during the 50-year retrievability period (10 CFR 60.111[b]), compaction would not be wise, as it would make removal of the backfill more difficult. The incentive for compacting the backfill is to minimize ultimate surface subsidence and general site disturbance.
A-30	16-19	The low stress levels are not surprising because the deformation modulus of the crushed material will be low.
A-33	15-18	How conservative is it to use Young's modulus rather than a constrained modulus?
A-33	28	Why are thermoelastic stresses ignored?

REFERENCES

Baar, C.A., *Applied Salt Rock Mechanics - I*, Elsevier Scientific Publishing Co., Amsterdam (1977).

Cooley, C.H., and S.W. Butters, *Pressure and Time Effects on Permeability of Salt Cores*, Terra Tek, Inc., Salt Lake City, Report No. 79-45 (1979).

Daemen, J.J.K., et al., *Rock Mass Sealing — Experimental Assessment of Borehole Plug Performance, Annual Report, June 1982-May 1983*, prepared by Department of Mining and Geological Engineering, University of Arizona, for U.S. Nuclear Regulatory Commission, NUREG/CR-3473 (1983).

Garrett, W.S., and L.T. Campbell-Pitt, *Design and Construction of Underground Bulkheads and Water Barriers*, Transactions 7th Commonwealth Mining and Metallurgical Conf., South African Institute of Mining and Metallurgy, Johannesburg, 3:1283-1301 (1961).

Garrett, W.S., and L.T. Campbell-Pitt, *Tests on Experimental Bulkhead for High Pressures*, J. South African Institute of Mining and Metallurgy, 59(4):123-143 (1958).

Gulick, C.W., et al., *Bell Canyon Test (BCT) Cement Grout Development Report*, Sandia National Laboratories Report SAND 80-1928 (1980).

Kelsall, P.C., et al., *Schematic Designs for Penetration Seals for a Reference Repository in Bedded Salt*, Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio, ONWI-405 (1982).

Mraz, D., *Theoretical Predictions Confirmed by In Situ Rock Behavior in Deep Potash Mines*, Proc. 19th U.S. Rock Mechanics Symp., Y.S. Kim, ed., University of Nevada-Reno, pp. 468-475 (1978).

National Coal Board, *The Treatment of Disused Mine Shafts and Adits*, Mining Department, London (1982).

Office of Nuclear Waste Isolation, *Identification of Preferred Sites within the Palo Duro Basin: Vol. 1 — Palo Duro Location A, and Vol. 2 — Palo Duro Location B*, Battelle Memorial Institute, Columbus, Ohio, unpublished manuscript (Jan. 1984).

Office of Nuclear Waste Isolation, *Permian Basin Location Recommendation Report*, prepared for the U.S. Department of Energy, Technical Report DOE/CH/10140-2 (1983a).

Office of Nuclear Waste Isolation, *Identification of Preferred Sites in Palo Duro Locations*, Battelle Memorial Institute, Columbus, Ohio, unpublished manuscript (1983b).

Pfeifle, T.W., et al., *Preliminary Constitutive Properties for Salt and Nonsalt Rocks from Four Potential Repository Sites*, Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio, ONWI-450 (1983).

Stearns-Roger Services, Inc., *Deaf Smith/Swisher Counties, Texas: Repository Design Concepts and Costs*, Denver (1983).

Stone and Webster Engineering Corp., *Area Geological Characterization Report for the Palo Duro and Dalhart Basins, Texas*, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio, ONWI-292 (1982).

Stormont, J.C., and J.J.K. Daemen, *Axial Strength of Cement Borehole Plugs in Granite and Basalt*, prepared by Department of Mining and Geological Engineering, University of Arizona, for U.S. Nuclear Regulatory Commission, NUREG/CR-3594 (1983).

Sutherland, H.J., and S.P. Cave, *Gas Permeability of Southeastern New Mexico (SENM) Rock Salt*, Sandia National Laboratories Report SAND 78-2287 (1979).

U.S. Environmental Protection Agency, *Report on the Review of Proposed Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes*, Code of Federal Regulations, 40 CFR 191 (1984).

U.S. Nuclear Regulatory Commission, *Disposal of High-Level Radioactive Wastes in Geologic Repositories: Licensing Procedures*, Code of Federal Regulations, 10 CFR Part 60 (1983a).

U.S. Nuclear Regulatory Commission, *Draft Technical Position: Borehole and Shaft Sealing of High-Level Nuclear Waste Repositories* (1983b).

APPENDIX A

U.S. DEPARTMENT OF ENERGY LETTER REQUESTING PEER REVIEW

Department of Energy
Chicago Operations Office
Salt Repository Project Office
505 King Avenue
Columbus, Ohio 43201-2693

RECEIVED
W. HARRISON
MAR 07 1984
ACTION:
COPIES:
COMPLETED:

March 6, 1984

Wyman Harrison, ANL
9800 South Cass Avenue
Argonne, Illinois 60439

Dear Dr. Harrison:

SUBJECT: REVIEW OF REPORT ENTITLED "SCHEMATIC DESIGNS FOR PENETRATION SEALS FOR A REPOSITORY IN THE PERMIAN BASIN"

We would appreciate your forming a panel to review the attached D'Appolonia report entitled "Schematic Designs for the Penetration Seals for a Repository in the Permian Basin." The review should include, but need not be limited to, the following points:

1. Are their assumptions and limitations adequately and clearly stated?
2. Is the technical interpretation of the data presented correct?
3. Do the materials recommended for seal and backfill meet the performance requirement?
4. Are the future activities outlined in the report appropriate to meeting the sealing program objectives?
5. Comment on the sealing design and consolidation behavior of crushed salt.

Please complete the review and submit your comments to SRPO by April 13, 1984 and sooner if possible. If you have any questions, please contact Roger Wu at FTS 976-2916 ext. 13.

Sincerely,

Leslie A. Casey

for R. C. Wunderlich
Chief
Engineering and Technology
Salt Repository Project Office

SRPO:KKW:1568A

ST# 351-84

cc: S. Matthews, ONWI
D. Kingsley, ONWI
J. Moody, ONWI
S. Hanley, ONWI

APPENDIX B

CONCURRENCE SHEET

APPENDIX B

CONCURRENCE SHEET

I concur that the Argonne National Laboratory review of the D'Appolonia Consulting Engineers, Inc., report entitled *Schematic Designs for Penetration Seals for a Repository in the Permian Basin* fairly represents my comments, where incorporated, to the peer review panel.

Dorland E. Edgar

Dorland E. Edgar

Hyman Harrison

Hyman Harrison

David F. Fenster

David F. Fenster

James E. Russell

James E. Russell

Douglas P. Hambley

Douglas P. Hambley

John C. Stormont

John C. Stormont

APPENDIX C

CREDENTIALS OF PEER REVIEW PANEL MEMBERS

Dorland E. Edgar

Central Missouri State University: B.S., Geology (1968)
Colorado State University: M.S., Geology (1973)
Purdue University: Ph.D., Geology (1976)

Dr. Edgar joined the Geoscience and Engineering Group of the Energy and Environmental Systems Division of Argonne National Laboratory in 1978. Since that time he has worked as a geologist and hydrologist on programs related to waste management and energy and mineral resources development. From 1981 through 1983, he participated in studies of the geologic setting of crystalline rocks of the northeastern and Lake Superior regions of the United States for the purpose of assessing their suitability as sites for a high-level radioactive waste repository. His primary areas of responsibility on this project were surface-water and groundwater hydrology, geomorphology, and surficial geology.

From 1978 to 1981, Dr. Edgar was affiliated with Argonne's Land Reclamation Program and Environmental Control Technology Program, where he studied the relationships between surface mining and reclamation activities, and geomorphic processes, hydrology, water quality, and erosion and sedimentation. Dr. Edgar also served as a U.S. Department of Energy representative to an interagency group that reviewed comments and drafted revised regulatory guidelines for the U.S. Office of Surface Mining.

Before coming to Argonne, Dr. Edgar was employed at Oak Ridge National Laboratory, where he conducted research on surface and subsurface hydrologic and geologic conditions, and their relationship to the shallow land disposal of low-level radioactive waste. One project involved the study of the hydrologic and geomorphic processes involved in transporting radionuclides from burial sites through an instrumented watershed. Dr. Edgar's graduate research was directed primarily toward the relationships between hydrology and the geomorphic processes operating within alluvial stream channels and drainage basins.

Dr. Edgar has published approximately 25 scientific and technical publications, and is a member of two professional societies.

David F. Fenster

City College of the City University of New York: B.A., History (1967)
University of Illinois: M.A., History (1968)
Queens College of the City University of New York: M.S., Geology (1975)
Certified Professional Geologist, No. 4668, American Institute of Professional Geologists
Certified Professional Geologist, No. 85, State of Indiana

Mr. Fenster joined the staff of the Geoscience and Engineering Group of the Energy and Environmental Systems Division of Argonne National Laboratory in 1982. He is currently Technical Project Manager and member of the multidisciplinary core peer review staff, which is reviewing technical documents for the Salt Repository Project Office of the Civilian Radioactive Waste Management Program. He also served as a technical reviewer for parts of Argonne's Lake Superior regional report related to siting repositories for high-level radioactive waste in crystalline rocks.

Prior to coming to Argonne, Mr. Fenster was Project Geologist with Dames & Moore, Park Ridge, Ill. He had been with Dames & Moore since joining the staff of the Cranford, N.J., office in 1974. During his tenure with Dames & Moore, Mr. Fenster acquired extensive experience in seismotectonics, structural geology, radioactive and hazardous waste disposal, regional geology, engineering geology, hydrogeology, and general geologic field mapping. For example, Mr. Fenster was Principal Investigator for Stratigraphy for the Generic Environmental Impact Statement concerning disposal of radioactive waste in bedded salt, granitic rocks, and argillaceous formations for Oak Ridge National Laboratory. He also worked on a revised draft (unpublished) of a national screening document concerning selecting sites for repositories in crystalline rocks for isolating high-level radioactive waste.

Mr. Fenster also worked on geologic investigations related to nuclear power plant siting and licensing. He is familiar with U.S. Nuclear Regulatory Commission review and licensing procedures, having worked on early site reviews, preliminary safety analysis reports, final safety analysis reports, and detailed fault investigations.

Mr. Fenster has published on the siting of repositories for high-level radioactive waste, midcontinent tectonics, and structural geology in the Northeast, and has worked on more than 30 consulting reports. He is a member of five professional societies, including the Association of Engineering Geologists.

Douglas F. Hambley

Queen's University at Kingston: B.Sc., Mining Engineering (1972)
Lewis University: MBA candidate
Registered Professional Engineer, No. 18026014, Province of Ontario, and
No. 062-039201, State of Illinois

Mr. Hambley has more than 10 years experience in mining, tunneling, and underground construction. He joined the staff of the Geoscience and Engineering Group of the Energy and Environmental Systems Division of Argonne National Laboratory in 1984. Prior to working at Argonne, Mr. Hambley was employed as a Senior Mining Engineer for nearly four years by Engineers International, Inc., a mining/tunneling consulting firm located in Westmont, Ill. In addition to designing several large tunnels for various purposes, he spent over two years as Project Engineer on U.S. Nuclear Regulatory Commission contracts to assess retrievability from repositories for high-level radioactive waste and to provide technical assistance for repository design reviews.

Between 1972 and 1980, Mr. Hambley held various technical positions with major Canadian mining companies, including Denison Mines Ltd. and Falconbridge Nickel Mines Ltd. During his employment at Denison (1977-1980), he was responsible for several major projects, including (1) a tripartite (Denison/Rio Algom/CANMET) regional stability study; (2) investigation, specification preparation, and tender evaluation for Stanrock Mine dewatering and shaft rehabilitation; (3) design of the backfill system for a pillar recovery scheme; and (4) design of the underground garage and supply station for diesel fuel at No. 1 shaft.

Mr. Hambley has published on retrievability of high-level nuclear waste, design of shafts and tunnels, computer modeling of mine openings, and raise boring cost estimation. He is active in several technical societies.

Wyman Harrison

University of Chicago: S.B., Geology (1953), after three years of undergraduate work at Stanford University
University of Chicago: S.M., Geology (1954)
University of Chicago: Ph.D., Geology (1956)
Registered Geologist, No. 2476, State of California
Certified Professional Geologist, No. 134, American Institute of Professional Geologists, and No. 487, State of Virginia

Dr. Harrison is Associate Director for Geoscience and Engineering for Argonne National Laboratory's Energy and Environmental Systems Division. He directs a 25-person group that performs analytical and experimental studies related to management of energy and mineral resources and to development and deployment of related technologies. Major activities of the group include (1) acquisition of geophysical and geotechnical data bases, (2) analysis of the data of geoscience to support design and deployment of energy technologies, and (3) development of physical and mathematical models of geophysical/geotechnical systems.

Dr. Harrison's group recently completed comprehensive surveys of geoscience data pertaining to crystalline rock complexes in the northeastern and Lake Superior regions of the United States to help assess their potential as possible sites for repositories for high-level radioactive waste. Dr. Harrison has conducted numerous other geological and geotechnical studies at Argonne, ranging from estimating the petroleum resources of selected basins in the Soviet Union to determining near-shore circulation in Lake Michigan.

From 1971 to 1975, Dr. Harrison was Professor of Geography (Associate Department Chairman) at the University of Toronto, where he specialized in geophysical studies related to slope stability in sedimentary terrains and the siting of supertanker ports. Prior to that, he was Associate Director for Physical, Chemical, and Geological Oceanography at the Virginia Institute of Marine Science and a Professor of Marine Science at the University of Virginia. Dr. Harrison was Director of Environmental/Science Services Administration's (now National Oceanic and Atmospheric Administration's) Land and Sea Interaction Laboratory from 1964 to 1968. Before that he was on the faculty of Dartmouth College's Department of Geology and a geologist with the Indiana Geological Survey.

An author of over 100 papers, reports, reviews, and books, Dr. Harrison was made Senior Scientist at Argonne in 1976.

James E. Russell

South Dakota School of Mines and Technology: B.S., Civil Engineering (1963)
South Dakota School of Mines and Technology: M.S., Civil Engineering (1964)
Northwestern University: Ph.D., Theoretical and Applied Mechanics (1966)

Professor Russell joined the faculty of Texas A&M University in 1978 as Professor of Mining Engineering and Geophysics, and has been a Brockett Professor of Engineering since 1982. He has had extensive experience in the analytical/numerical, laboratory, and field rock mechanics aspects of mining, underground construction, and underground storage. Much of his research has involved in situ experiments related to waste repository design, radioactive waste isolation in salt, creep models for salt, thermal loading in waste repositories in salt, benchmark problems in salt using different numerical methods, coal gasification, and lignite mining.

Dr. Russell currently serves as rock mechanics consultant to ONWI and Oak Ridge National Laboratory; resource consultant for rock mechanics to the Overview Committee for the Basalt Waste Isolation Project; coinvestigator of an ONWI-sponsored project at Texas A&M University to develop constitutive equations for salt; and member of the Performance Constraints Working Group for RE/SPEC, Inc., and ONWI. During 1979 he served as a member of the Peer Review Group for DOE, Nevada Nuclear Waste Storage Investigations.

From 1977 to 1978, just prior to accepting the position at Texas A&M, Professor Russell was the Project Manager for Rock Mechanics at the Office of Waste Isolation, Union Carbide Corporation. From 1972 to 1976, he was Vice President and Resident Consultant at RE/SPEC, Inc. From 1967 to 1976, Dr. Russell served as Assistant Professor of Civil Engineering; Associate Professor of Civil Engineering, Mining and Civil Engineering, and Mining Engineering; and Professor of Mining Engineering at the South Dakota School of Mines and Technology. From 1966 to 1967, he was Senior Research Engineer at Southwest Research Institute.

Professor Russell has published extensively in the fields of rock mechanics, mining engineering, lignite mining, coal gasification, and waste isolation. He is a member of six professional and honorary societies, and has served on 11 national committees.

John C. Stormont

University of Wisconsin, Madison: B.S., Mining Engineering (1980)
University of Arizona: M.S., Mining Engineering (1983)

Mr. Stormont has more than three years research experience in mining, rock engineering, and nuclear waste repository design. Since 1981, he has been involved in research and development activities concerning the sealing of rock masses at underground nuclear waste repositories -- as a Research Assistant at the University of Arizona and later at Sandia National Laboratories. Since joining the Experimental Programs Division of Sandia National Laboratories in 1983, he has worked on the Waste Isolation Pilot Plant (WIPP) project, being responsible for its plugging and sealing development program.

After obtaining his Bachelor's degree in 1980, Mr. Stormont worked as a Field Assistant to Dr. Bezalel Haimson. His duties included logging drill core and measuring in situ stresses using hydraulic fracturing. He also worked summers as a Junior Engineer with Climax Molybdenum Co. (1979) and as Assistant City Engineer for the City of Monroe, Wis. (1978).

Mr. Stormont has published several reports on stress measurement techniques in salt and on the plugging and sealing of boreholes for geologic repositories, including the program plan for the WIPP plugging and sealing program.

Mary W. Tisue

Beloit College: B.S., Geology (1961)
Yale University: M.S., Geology (1963)

Ms. Tisue has been employed since 1976 as a technical editor for the Energy Environmental Systems Division of Argonne National Laboratory. From 1981 thru 1983, she was part of a research team that gathered geologic information on crystalline rocks of the northeastern and north-central United States, with a view assessing their suitability as sites for repositories for high-level radioactive waste. Other projects have involved the editing of reports, journal articles, conference papers and proposals on such topics as transportation, decision analysis, particulate control, industrial process energy conservation, economics of gasohol, chemistry of synthetic fuel process waters, environmental studies of ocean thermal electric conversion, recycling, petroleum geology and resource assessment, and socioeconomic impact of energy development.

Prior to accepting a position at Argonne, Ms. Tisue worked as a technical writer and marketing assistant for an instrument company and as an editor for the Metals Research Laboratory of what was then the Olin-Mathieson Chemical Corporation.

Ms. Tisue is a member of the Society for Technical Communication and the Association of Earth Science Editors.

SALT REPOSITORY PROJECT OFFICE

Page 1 of 1

Document Transmittal Record

(Transmittal Date)

SALT REPOSITORY PROJECT

To:	From:
Bill Altman (Name)	Jerry Reese (Name)
NRC (Organization)	DOE-SRPO (Organization)

ITEM	REV.	DATE	NO. OF COPIES	COPY NO.
PNL Report 2955, Reference Site Initial Assessment for a Salt Dome Repository	-	June, 1982	1-Vol. I 1-Vol. II	File Copies
				-

Remarks	RETURN COPY TO SENDER
Please sign receipt w/ estimated return date; these are file copies. Thanks, J.R.	Material listed on this transmittal has been received. An estimated return date to SRPO is _____. (Signature) (Date)

5675B