PEER 23 - Independent Technical Review of Bin and Alcove Test Programs

DOE/EM-0130T

Independent Technical Review of the Bin and Alcove Test Programs at the Waste Isolation Pilot Plant

December 1993

Conducted by the
U.S. Department of Energy
Office of Environmental Restoration
and Waste Management
Washington, D.C. 20585

THIS PAGE

LEFT BLANK

INTENTIONALLY

TABLE OF CONTENTS

THIS PAGE

LEFT BLANK

INTENTIONALLY

PREFACE

This report documents an Independent Technical Review (ITR) by the Department of Energy (DOE), Office of Environmental Restoration and Waste Management (DOE-EM) of a transuranic (TRU) waste test program at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. The review was performed at the request of the Director, Office of Waste Management Projects (EM-34) through the Office of Technical Support, Office of Waste Management (EM-35).

Information for the review was drawn from documents provided to the ITR Team by the WIPP Project Integration Office (WPIO), the WIPP Project Site Office (WPSO), Sandia National Laboratories (SNL), Westinghouse Waste Isolation Division (WID), and others; and from presentations, discussions, interviews, and facility inspections at the WIPP Site and Albuquerque, New Mexico during the weeks of July 26-30 and August 30-September 3, 1993. During the week of September 7-10, 1993, the ITR Team developed consensus assessments and recommendations.

The ITR Team consensus assessments and recommendations form the core of this report, and are supported by associated descriptions and discussions. The report is an independent assessment of information available to, and used by, WIPP personnel. Repetition of information to support assessment discussions is not meant to imply discovery of the information by the ITR Team. ITR Team members, however, acting as independent reviewers, may have assessed the information from a perspective that differs significantly from that of WIPP personnel.

This report is based on information obtained and conditions observed during the review interval of July 26 to September 3, 1993. The ITR Review process and normal site work activities usually result in changes in knowledge and organization at the site during report preparation subsequent to the review interval. This document does not comment on evolution of the WIPP program subsequent to the review interval.

A Technical Oversight Board (TOB), composed of senior level individuals with extensive experience in the development, execution, management, and evaluation of large, technically complex projects, is chartered to review all aspects of the ITR Team's activities. In its Charter, the TOB is directed to review the assessments and recommendations prepared by the ITR Team. The WIPP Charter and review plan were discussed with the TOB at a meeting on July 21, 1993 in Albuquerque, New Mexico. The results of the review were then discussed with the TOB on October 14, 1993 in Salt Lake City, Utah. Guidance of the TOB has been used in the preparation of this report.

ITR EXECUTIVE SUMMARY

iii.1. Review Synopsis

This Independent Technical Review assessed the need for and technical validity of the proposed Bin and Alcove test programs using TRU-waste at the WIPP site. The ITR Team recommends that the planned Bin and Alcove tests be abandoned, and that new activities be initiated in support of the WIPP regulatory compliance processes. Recommendations in this report offer an alternate path for expeditiously attaining disposal certification and permitting.

iii.2. Background

To support compliance demonstration, the WIPP program has proposed two types of underground tests with TRU waste: (1) Bin Tests, using instrumented containers called bins located in a large, easily accessible room; and (2) Alcove Tests, using 1050, 55-gallon drums placed in a sealed room.

Bin Tests use two types of bins: (1) Type I bins hold the contents of six 55 gallon drums of nearly dry waste at ambient pressure, and (2) Type II bins hold the contents of five drums of humid or brine saturated waste at up to 10 atmospheres pressure. Seven Type I and twelve Type II bins are planned to measure the amount of gas generated over one or more years.

Alcove tests use a more realistic emplacement of waste in drums and if design goals are achieved, could allow sampling and analysis of volatile organic compounds and other waste produced gases.

The stated justification for the Bin and Alcove tests has been the need to provide experimental data on gas generation by decomposition of TRU waste and its packaging. Gas generation studies have been proposed because it is postulated that gas generated by metal corrosion, organic biodegradation and radiolysis could create pressure sufficient to fracture the geologic formation allowing nonregulated gases to carry regulated contaminants, such as volatile organic compounds, to the unit boundary. In the event of human intrusion, it is further postulated that gas from the repository or pressurized brine pockets could move regulated contaminants to the accessible environment. These hypotheses have yet to be validated by rock mechanics or other performance assessment techniques. The ITR Team reviewed the ability of the Bin and Alcove Tests to provide the required gas generation data.

Information was drawn from both published and draft WIPP documents and from interviews with WIPP personnel. In addition, ITR team members listened to representatives of oversight and stakeholder groups, including the National Academy of Science (NAS), the Environmental Evaluation Group, the Southwest Research and Information Center, Concerned Citizens for Nuclear Safety, the NM Office of the Attorney General, and Southeast NM stakeholders, to gain an understanding of their values and opinions of the Bin and Alcove tests.

iii.3. Principal Assessment

The review team concluded that: **there is no scientific, regulatory, or operational imperative to perform the Bin or Alcove tests at WIPP with radioactive waste.** Other tests can and should be performed at WIPP and elsewhere to confirm information used for regulatory compliance demonstration and certification. This is an assessment of the technical justification for the tests, not of the ability of site personnel to perform the tests or of the repository to accept TRU waste.

iii.4. Path Forward Recommendation

Preparation and submission of compliance and permitting packages at the earliest possible date are the foundation of the recommended path forward. All other near term work elements should support these activities. All regulatory permits, approvals, and certification should be acquired before any in situ confirmatory or operational tests are performed in WIPP with radioactive waste.

A lack of clear guidance from cognizant regulators on specific requirements for regulatory compliance should be the only source of future delay in operating WIPP as a TRU waste repository. While most, although not all, of the relevant regulations exist, no clear statement of what constitutes acceptable submissions has been produced by the regulatory bodies. Submission of the regulatory packages, with consequent responses from the regulators, is required to create unequivocal end points for field and laboratory investigations, computer modeling, and performance assessments. DOE/EM and Environmental Protection Agency (EPA) upper management should set the foundation for implementing the proposed path forward. The ITR Team believes that delay will be minimized by making the regulators part of the process through early submission of the regulatory packages.

Although all regulations do not exist and existing regulations may change, the ITR Team believes that sufficient gas generation information is available to complete the performance assessments and other elements required to prepare and submit compliance and permitting packages within 18 months. The recommended conceptual compliance and permitting process will allow the TRU waste disposal phase to begin in three years if specified milestones are met.

Laboratory and field tests currently in progress should be continued if they can confirm assumptions in performance assessment models and calculations used to support regulatory submittals. Ongoing and new tests may be required to reduce unacceptable uncertainties identified by the regulators in review of the submittals. The choice of tests to be continued or initiated will require informed judgment, based on the state and requirements of the regulatory process.

Bench-scale laboratory tests using simulated and/or actual waste should be continued or completed, and additional tests initiated if required. Results of bench-scale tests will not only explain individual gas generation mechanisms but also the synergistic effects of combined mechanisms. Such tests are necessary to confirm (1) that radiolysis has negligible synergistic effects on other processes, and (2) to support the validity of tests that use nonradioactive simulated waste.

Large-scale laboratory tests (multi-drum volume) using nonradioactive, simulated waste should be initiated as required. Large-scale tests should investigate gas generation processes in heterogeneous waste under simulated repository conditions. These tests can be performed above ground, at WIPP or elsewhere, unencumbered by mine safety regulations.

Phased preparation for disposal operation must occur at WIPP while the regulatory permitting and certification process is underway. Current engineering and operations testing should continue to rapid completion. Within a year the site should begin a cold commissioning phase (non-radioactive operations) to test and perfect waste operations, without the encumbrance of radioactivity. When regulatory certification is obtained and permits issued, hot commissioning can begin by introducing increasing amounts of TRU waste into the operations. Phased commissioning, comparable to startup of operations in industrial plants, will ensure an effective operating team and safe transition to disposal operation.

The WIPP mission should be allocated among the principal organizations (DOE, SNL, and Westinghouse), leading to a program that functions along clear lines of communication, authority and responsibility. The principal DOE WIPP office should maintain project vision. Site operations should be supported by a DOE site office that is a functional branch of the principal WIPP office. Regulatory compliance organizations in SNL and Westinghouse, including performance assessment, should be collocated.

I. SUMMARY ASSESSMENTS

1.1. Introduction

The objective of this independent technical assessment of proposed TRU waste experiments at WIPP, as stated in the Charter (Appendix F), is to:

> "Review the need for, and technical validity of, the Bin and Alcove test programs, as defined in the Test Phase Plan, the Technical Needs Assessment Document, and individual test plans."

Chapter I summarizes assessments of the task areas defined in the Charter:

- Regulatory Interpretation and Compliance,
- Technical Performance Assessment,
- Test Implementation and Approach,
- Test Integration,
- Associated Test Issues, and
- Recommendations.

These assessments are an objective view of the test programs, not a critique of individuals, organizations, or past decisions. They support change to an alternate WIPP certification and permitting strategy such as that presented in Chapter II. Detailed discussion of the assessment basis is presented in Chapter III, and in topic-specific Appendices A through D.

The ITR Team observed three principal unresolved technical questions during their review of the tests:

- The rate and quantity of non-regulated gases generated by metal corrosion and biodegradation of organics in heterogeneous waste at repository conditions remains uncertain.

- Gas interaction with repository geological constituents remains uncertain. Gases generated in sufficient rate and quantity may reach hydrostatic (pore-brine) or lithostatic pressure. As a consequence gas may: drive brine out of the repository possibly limiting further gas generation; fracture the geologic formation allowing gas flow; and transport regulated contaminants toward the unit boundary at repository depth exposing them to possible biological and/or hydrolytic degradation.

- Mechanisms which might move regulated materials to the accessible environment remain speculative. Trapped gas from waste or brine pockets, tapped by future well drilling for example, may move regulated contaminants to the accessible environment.

1.2. General Assessment

There is no scientific, regulatory, or operational imperative to perform the Bin or Alcove tests at WIPP with radioactive waste. The proposed in situ Bin and Alcove tests cannot adequately quantify or characterize the gas generation phenomena, nor do they duplicate repository conditions.

1.3. Regulatory Approach Assessment

The WIPP program does not have an adequate regulatory compliance program. Regulatory requirements have changed over time, and the WIPP program has not responded to many of these changes in a timely manner. Effective response by WIPP project personnel to regulatory criteria is hampered by inconsistent requirements, and their nonstandard interpretation throughout the program. Although a regulatory strategy document has recently been drafted, documents to support its implementation have not yet been prepared.

DOE has not demonstrated that the proposed Bin and Alcove tests are needed to support compliance determination. Information derived from the Bin and Alcove tests is considered to be confirmatory. Bin and Alcove test data and modeling results, however, may be difficult to correlate. The information presently planned for compliance determination will come from first principles modeling and from bench scale lab tests. Without a direct tie to the compliance determination, the rationale for the Bin and Alcove tests is weak.

RCRA, mine safety, and other regulations governing the generation of new waste, the manipulation of existing waste, and the presence of explosive gases make it in essence impossible to perform sound laboratory tests underground at WIPP. Occupational safety requirements limit the conditions under which waste materials can be examined at WIPP. Appropriate facilities and/or equipment do not exist at WIPP to inspect, analyze or characterize waste before and after testing. Current safety and design considerations do not allow fluids in the bins and drums to be sampled. Design constraints on Type 1 bins limit the maximum flammable gas concentration to 50% of the lower flammability limit. Therefore, bins will be purged with inert gas as this limit is approached. The proposed Type 2 bin design does allow potentially flammable gas mixtures; the test is not designed, however, to reach lithostatic pressure. This limitation may prevent the system from reaching a natural equilibrium mixture of gases under conditions relevant to those anticipated during the repository disposal phase and thereafter. If waste cannot be subjected to realistic conditions and inspected before and after testing, germane information cannot be obtained.

Program staff do not have a common understanding of compliance requirements. Communication between regulatory compliance and performance assessment personnel is extremely limited. Although a recent effort has been made by program management to define regulatory roles and responsibilities, the number of experienced staff may be insufficient to fill the defined roles. Efficient preparation of a compliance package is further hampered by the physical separation of performance assessment and compliance personnel.

1.4. Assessment of Performance Assessment

Performance Assessment (PA) is not closely coupled to other aspects of the WIPP program. PA output, such as a definitive list of data needs and associated Data Quality Objectives (DQOs) for laboratory and in-situ tests, is not used to provide detailed guidance to the WIPP test program. The most recent detailed sub models and all available experimental data are not yet incorporated into the currently used high-level PA model.

Many of the PA sub-models are first-principles process models calibrated using homogeneous bench scale experimental data. Additional testing may be necessary to confirm that the existing sub-models and data adequately predict gas effects.

Although imperfect, the existing PA total system model is adequate for the preparation of the mid-1995 regulatory compliance packages. Current PA models and the existing WIPP project database can be used to perform PA analyses required to demonstrate regulatory compliance. Deficiencies noted by the regulators during review of the compliance packages can be addressed by future models and experimental data. Periodic PA progress reports discussing calculations based on improved models and confirmatory data from laboratory and field studies will build confidence in modeling and reduce uncertainties in performance measures.

1.5. Bin Test Assessment

Planned Bin tests will provide marginal confirmation of gas generation models because they will not address interaction mechanisms. The Bin tests are not designed to complement laboratory test programs, and are not tied to compliance demonstration.

Radiolysis will be a minor contributor to gas generation in WIPP waste. The presence of radioactive contaminants in the bins will have little measurable effect on the gas generation processes, and will make test activities more complex. Regulations and handling techniques which govern the performance of experiments, particularly those related to underground testing, will make it difficult, if not impossible, to assess gas generation processes and synergistic or inhibiting interactions among gas generation mechanisms. The presence of TRU-waste materials in the Bin Test waste is an inadequate justification for performing these tests.

Waste for the proposed Bin tests is being characterized at INEL. The rate of characterization is very low, about seven bins in two years, but INEL is commended on the video and conventional documentation of the process. Nevertheless, the level of chemical and physical characterization is insufficient to support the data quality objectives necessary for the tests to confirm PA model predictions.

The design of the tests and the hardware is inadequate to provide data relevant to waste disposal and post-closure conditions. The test environment provided for the Bin tests at WIPP does not adequately simulate repository conditions. Regulatory requirements (Section I.3) limit interaction between the bin contents and the surrounding repository environment. The underground test site has no scientific or technical basis, and it limits test conditions.

The Type 2 bin design is conceptual, and incomplete. Conceptual bin seals, for example, may be inadequate to prevent the infiltration of oxygen into the bins, preventing the attainment of anoxic conditions. In addition, outgassing of oxygen from the waste material during the relatively short duration of these tests may also prevent simulation of oxygen free post-closure conditions.

Although many instruments are located on the bins, several are omitted. Corrosion rate monitoring instruments and methods to determine the presence or growth of biological organisms are not included. This is unacceptable because corrosion and biological processes are thought to be primary mechanisms for gas generation.

1.6. Alcove Test Assessment

The planned Alcove test will not provide defensible or cost effective data to demonstrate compliance with 40 CFR 268 or 40 CFR 264 Subpart X. It will provide no knowledge of the volatile organic compound (VOC) source term. Measurement of gas production will be inaccurate because of unmeasurable gas loss into the Disturbed Rock Zone. Gas loss around seals is difficult to estimate and also unmeasurable. Results will not be readily extrapolated to disposal room conditions for use in predicting repository response to stored waste.

II. PATH FORWARD STRATEGY

II.1. Basis for Recommendations

The WIPP Mission, as defined in Public Law 96-164 and repeated in the WIPP Land Withdrawal Act, is "to provide a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission." Extensive interim storage of high-liability TRU waste throughout the defense complex provides the motivation for completing the WIPP compliance process.

The recommendations outlined in Chapter II are based on the ITR Team's consensus that a focused path forward strategy can bring the WIPP Mission to the disposal stage within three years without implementing the proposed Bin and Alcove Tests. Alternative large-scale laboratory tests using nonradioactive simulated waste, and bench-scale tests using radioactive materials are proposed. By providing technical information for the permitting process without introducing radioactive waste into WIPP, the new path forward can avoid the time delay, cost and complexity associated with EPA's review and approval of the proposed radioactive Test Phase Plan required by the LWA for in situ radioactive tests.

Based on observations and assessments of the state of the WIPP Program, and using existing WIPP work elements, the ITR Team developed a framework for a new path forward through certification and permitting to disposal. The success of this path forward depends on completing attainable milestones to meet the regulatory requirements of the EPA and the LWA. To this end, assuming a flat future funding profile, all project participants must commit to completing their tasks within budget and schedule constraints.

In support of WPIO efforts to develop a new organization, the proposed path forward allocates certain tasks among the principal organizations (DOE, SNL, and Westinghouse WID) and provides a work flow for following this structure.

Many WIPP oversight and stakeholder groups understand the technical documentation of WIPP plans and recognize the tenuous tie between the Bin and Alcove tests and the regulatory process. The break from the old path can form a new basis for more open and cooperative interactions that are consistent with present DOE policies and attitudes.

II.1.1. Motivation

WIPP is a part of a coherent solution to the TRU-waste-disposal problem that was created by the past national mandate for a nuclear arsenal. TRU wastes now residing at generator storage sites collectively represent a large national problem that transcends the local environmental problem envisioned by individual sites. Because all nuclear weapons manufacturing within the defense complex has ceased, significant production-related TRU waste probably will not be generated. Decontamination and decommissioning (D&D) of existing weapons facilities, however, will continue to generate waste. Although the volume of existing waste can be estimated from observations and historical records, the amount of future waste is difficult to predict with confidence. At Rocky Flats, for example, the amount of waste generated by decontaminating a room to a level sufficient to store waste drums has been estimated to exceed the volume of the room cleaned. Many environmental restoration activities cannot proceed without a certified permanent disposal site such as WIPP.

At present, waste from past defense work and cleanup activities is stored retrievably in interim facilities, but the potential for degradation of the waste containers increases over time. Interim remediation of degraded containers increases the costs associated with their storage without providing added value.

Personnel at generator sites cannot successfully carry out D&D activities without a destination for the waste products. Inability to successfully complete these work elements reduces productivity, increases personnel frustration, and causes qualified, motivated people to seek more stimulating jobs. Failure to start TRU disposal activities while funds and personnel are available will leave many facilities in unstable, deteriorating condition.

WIPP is an excellent location for permanent, safe disposal of TRU waste because it has excellent geological characteristics and strong Carlsbad community support. The Carlsbad community believes that their opinions on safety, the local economy, and other societal issues should be weighed heavily because of their proximity to WIPP. They agree that technical personnel should select, design and perform tests necessary to determine repository suitability. Local support is, however, contingent on demonstrable progress toward regulatory compliance.

II.2. Path Forward Strategy

II.2.1. Introduction

The path forward concept shown in Fig. II.1 consists of three elemental time phases: Permit/Certification, Disposal, and Decommissioning. The WIPP Program is presently in the first phase. The end of the first phase and the beginning of the second are the subject of the path forward strategy. The third phase is not considered in this review.

The integrated path forward for the WIPP program is centered on compliance with regulations. Regulatory certification and permitting should precede any underground testing with TRU waste. Tests with radioactive waste are not required to satisfy the Code of Federal Regulations, Land Withdrawal Act, state regulations, or local regulations. The ITR team believes that not performing in-situ tests with TRU wastes will greatly simplify the path forward and make the regulatory approach technically more defensible. The alternative tests proposed can provide data of equivalent or better quality than the planned TRU-waste tests. After certification and permitting, the Disposal Operations section of the LWA applies, and real waste can gradually be introduced into the repository in a Hot Commissioning phase.

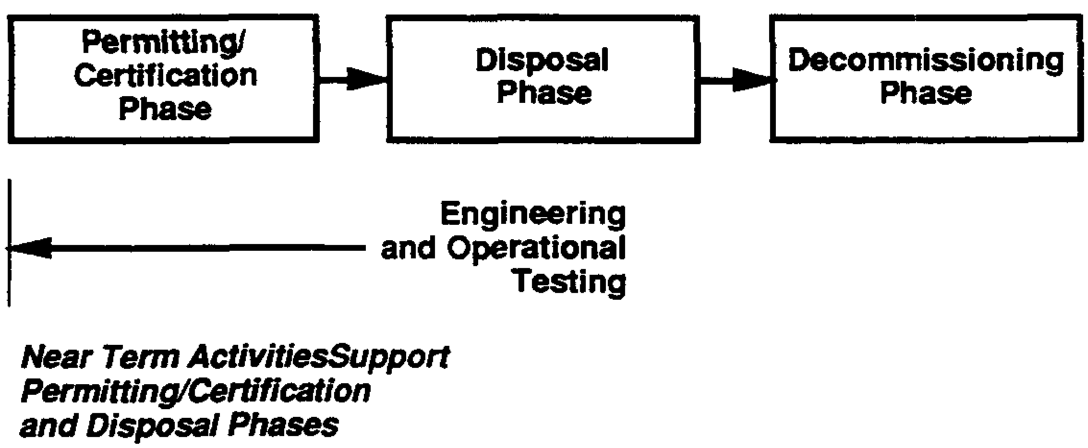


Fig. II.1. WIPP Program Phases

DOE-EM senior management should set the foundation for attaining this compliance goal by establishing a framework for interaction among WIPP regulatory personnel, the EPA and NMED. The programmatic vision and mission must be consistent with the mission stated in the Public Law. Decision makers should commit to the major elements of the path forward. They should commit their organizations to the success of the project and ensure that the lower-level managers are of the highest caliber and share the commitment to the success of the program.

The DOE should also commit to coordinated, active, and open interaction with stakeholder groups by assigning specific, senior-management responsibility for this role. Interactions with stakeholder groups should center on understanding their values related to jobs, economic development, storage of waste in their communities, transportation of waste, societal values attached to land, and other basic issues. Decision makers should consider these values when guiding the program, and should be prepared to explain how the values are incorporated.

The more detailed near-term path forward, shown in Fig. II.2, focuses on the end of the Permit/Certification Phase and the beginning of the Disposal Phase. It depicts broad components, and is not intended to capture the full complexity of testing, compliance, or operational activities. On this path, disposal can be initiated sooner than the current plans propose.

In Fig. II.2, time is shown in elapsed years. The work elements shown on the figure are logically dependent on each other but are not tied to a specific start date. Within this presentation time will be described in elapsed months or years. Where actual dates add clarity to the discussion, they will be place in parentheses next to the elapsed time, based on an assumed start date of October 1, 1993.

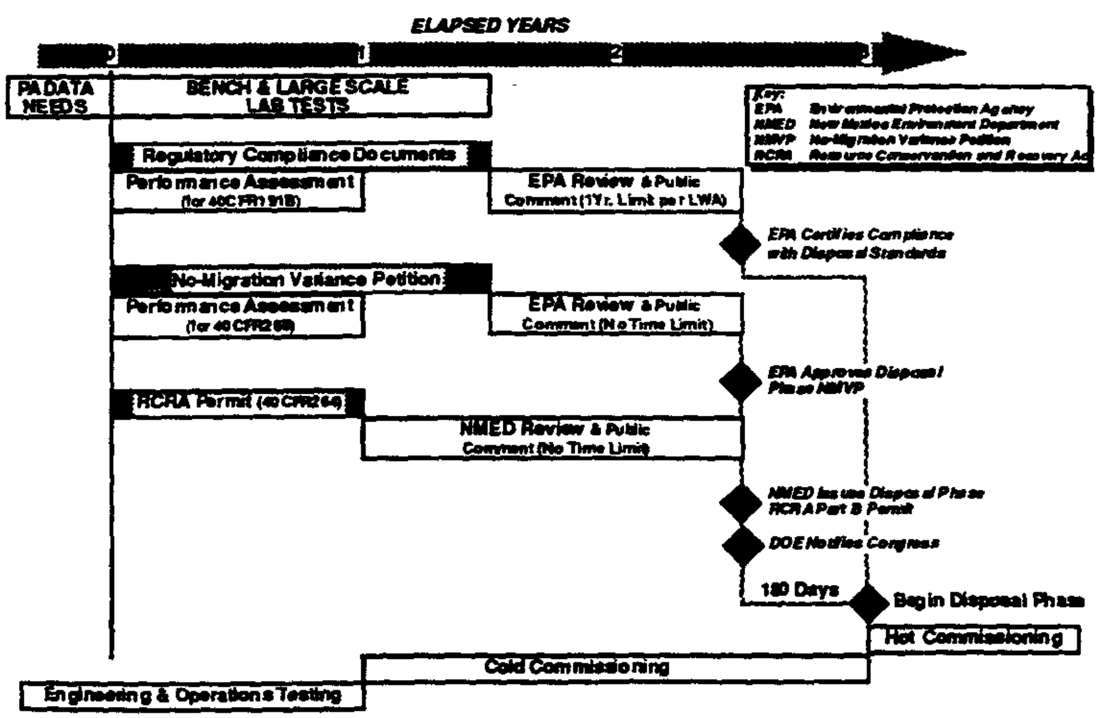


Fig. II.2. WIPP Near-Term Path Forward

The time line focuses on three major activities: (1) lab tests in support of the regulatory process, (2) compliance and permitting paths, and (3) operational and commissioning phases. Hot commissioning should commence immediately after certification and permitting. Diamonds represent major programmatic milestones.

Achievement of the disposal phase milestone within three years requires management of the review and comment processes by cognizant regulators. EPA review and public comment on 40 CFR 191 compliance documents is limited by the Land Withdrawal Act to one year, which is included in the schedule. EPA review and public comment on the no-migration variance petition is not bounded but a year has been allowed in Fig, II-2. NMED review and public comment on the RCRA permit is allowed 18 months. The actual time for these review and comment processes is beyond project control, but can be influenced by improved interactions among personnel from the project, regulatory agencies and stakeholder groups. Success in achieving this milestone is controlled by EPA and NMED.

WIPP personnel should develop the detailed schedule of the proposed near-term path forward. The schedule should consist of discrete work activities with finite scope, fixed cost, bounded schedule, and fixed milestones. The ITR Team recommends that scheduled activities have first funding priority, and that other activities should be funded at a lower priority or be demobilized.

II.2.2. Regulatory Component

Where full knowledge does not exist, speculation about potential regulatory responses to WIPP compliance packages appears to drive WIPP decisions. The ITR proposed regulatory path forward assumes first pass success in all areas even though the team recognizes that incomplete knowledge might require subsequent, additional information to be provided. The philosophy of first pass success was adopted to drive clarification by the regulators of uncertain areas, thereby assuring rapid, ultimate success.

The ITR Team recommends that complete regulatory compliance packages (permits, petitions, certifications, etc.) be prepared to demonstrate compliance with 40 CFR 264, 40 CFR 268 and 40 CFR 191 using existing data, PA methods and models. These compliance packages should be completed and submitted to the regulators within 18 months (mid-1995) as shown in Fig. II.2, and should address all requirements of each cognizant regulatory agency, especially on waste analysis and migration of contaminants. The following specific recommendations support the preparation of these packages on the timelines of Fig. II.2.

- To improve communication and coordinate work required to meet the schedule, the ITR Team recommends collocating all personnel responsible for regulatory compliance documents and performance assessment analyses.

- A strategy for submitting compliance packages to all appropriate regulatory agencies within 18 months (mid-1995) should be immediately developed. Packages should use existing waste and site characterizations and experimental data to substantiate the best possible bounding case analysis, using PA methods and models. The compliance packages submitted within 18 months should include the maximum inventory that can be supported by PA analysis. The package should address uncertainties and should include strategies to ensure that all TRU waste allowed by LWA (section 7 and 16), including mixed waste, will be certifiable for disposal.

- The proposed accelerated schedule assumes that the final EPA certification criteria (40 CFR 194) are not significantly different from the current draft. Currently available data specifically related to gas-generation issues are sufficient to support a defensible PA, and the PA analyses should be completed using existing data bases. Tests that are now underway and any future tests should be used to confirm PA input and assumptions.

- An open dialogue should be quickly established with waste generators to foster appropriate integration of their waste characterization knowledge and methodologies into the preparation of the WIPP regulatory compliance packages.

- Interactions should begin immediately between the DOE and the EPA, at senior management and working levels, to accurately define regulatory compliance package requirements. These interactions should strive to stabilize the regulatory arena and resolve ostensible regulatory incompatibilities, such as the definitions of the accessible environment and site boundaries.

- Negotiations for developing RCRA Part B permit applications should begin immediately with the New Mexico Environment Department, specifically emphasizing waste analysis plans and waste characterization.

- Absence of a well-defined and articulated regulatory strategy for WIPP has allowed some oversight and special interest groups to divert effort toward issues that may not be primary to the overall WIPP Mission. The ITR Team recommends a management function to solicit input from public groups, to incorporate their input into Project decision-making, and to communicate the decisions and their rationale to these groups. This will help not only to define a long-term strategy but also to follow the strategy to its conclusion.

In the event that the first pass is not fully successful, then specific guidance for full acceptability should be provided by the regulators. Subsequent testing, modeling, and regulatory submissions should be in conformity with this guidance.

II.2.3. Performance Assessment

PA analysis required for regulatory compliance should be completed within 15 months (mid-1995) using the best set of conceptual models, computer codes, parameter ranges, and actual data available in early CY 1994. Detailed process models should be integrated into the PA total system model expeditiously so that the analysis reflects the current state of program knowledge. No new experimental activities should begin until the need for the data is defined by PA analysis performed in response to regulatory feedback to the WIPP regulatory submittals, as discussed in Section II.2.2. Regarding gas generation, recent laboratory tests have confirmed that gas-generation rates and quantities that will be used as input to the PA analyses for the regulatory compliance packages are reasonable estimates. New data are not needed for a defensible performance assessment. New data, however, may be needed if regulations under 40 CFR 194 contain unanticipated requirements, or to reduce uncertainties in PA calculations or gas generation models as part of the regulatory compliance packages to be submitted in mid-1995.

Figure II.3 illustrates the relationship between compliance demonstration and data development (Lab/Field Activities etc.). In Fig. II.3 data flows from technical activities to compliance, and data need flows in the opposite direction i.e., PA defines the need for data. Compliance demonstration is a requirement before waste can be disposed at WIPP. To meet this requirement, performance assessment calculations must be performed demonstrating compliance with appropriate regulations. Sensitivity and uncertainty analyses are performed, with models and results from PA analyses, to define additional data needed to resolve issues preventing compliance demonstration. Similar sensitivity and uncertainty analyses can also be used to develop performance-based Waste Acceptance Criteria. The WIPP organizational work flow should reflect this process.

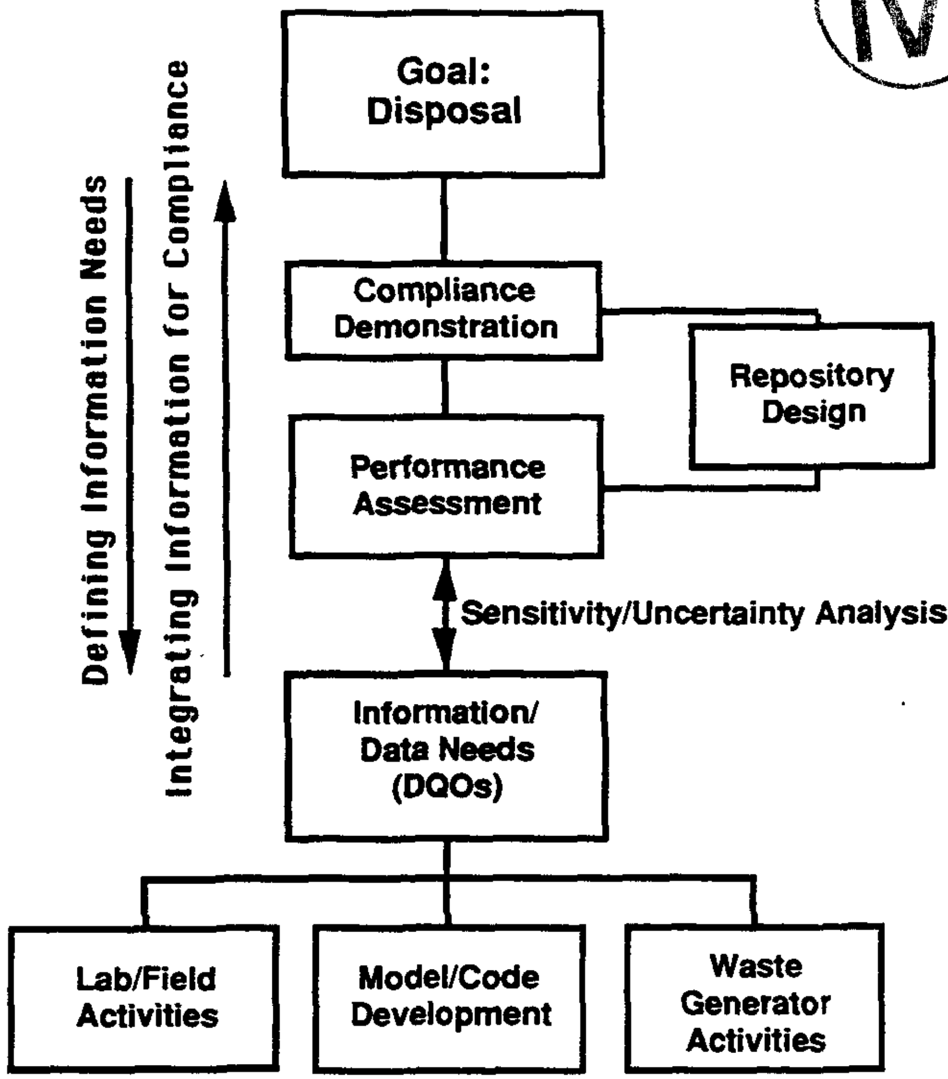


Fig. II.3. Relationship between Regulatory Compliance and Data Collection

The current PA model makes it impossible to perform parameter sensitivity studies rapidly and conveniently, because it does not handle coupled processes and parameters well. The ITR Team recommends that the high level PA model be developed further for performing bounding calculations and sensitivity/uncertainty analyses to focus data collection and to guide the regulatory strategy. This high-level model should be capable of evaluating coupled processes.

II.2.4. Gas Generation Tests

Gas generation phenomena can be evaluated with bench-scale and large-scale laboratory tests.

II.2.4.1. Bench-Scale Laboratory Tests.

PNL and BNL are carrying out bench-scale waste tests (corrosion and microbial, respectively) that fulfill the PA need for a gas generation model. These tests should continue, with completion scheduled in 15 months (end of CY 1994). New tests should be undertaken only if PA sensitivity and uncertainty analyses identify the need.

The ITR Team recognizes that the PA must use current gas generation data, that does not incorporate the results of ongoing tests, to complete compliance and permitting documents in 18 months. Ongoing tests should, however, confirm present estimates of gas generation, add confidence and reduce uncertainties in the gas model, and explain gas generating mechanisms.

Incomplete understanding of the potential interactions among waste, brine, gas, and the surrounding rock yields a conservative response to regulatory compliance. Hold-up of volatile organic compounds through dissolution in brine, adsorption by geologic materials, and biodegradation may help compliance with 40 CFR 268.6. These processes are not considered in a prediction which estimates whether sufficient carrier gas is produced to form pathways to the repository boundary. Consideration should be given to a focused laboratory study of VOC transport, although it is not recommended that it be placed on the critical path for submission of compliance documents.

II.2.4.2. Large-Scale Laboratory Tests.

The proposed Bin Test Program should be abandoned. The ITR team recommends alternative tests be used to meet unfilled data needs. Large-scale laboratory tests using nonradioactive simulated wastes are an alternative. Like the Bin Tests, these alternative tests should contain several drum-equivalents of waste. The volume is not critical but should be large enough to allow testing of representative waste forms and types. The proposed tests can be performed above ground at WIPP or any location where suitable facilities exist. Large scale tests should increase understanding of the effects of scale by examining:

- The effects of waste volume and heterogeneity to support the extrapolation of bench-scale test results to repository volume.

- The effects of synergisms or probable antagonisms, such as metal passivation by microbial gas generation.

Tests and equipment should have the following attributes to meet the data needs:

- Test vessels should be capable of operating at lithostatic pressure to better represent long-term, in-situ repository conditions.

- Test vessels should be fabricated from materials such as those found by PNL to be appropriate for bench-scale tests. The vessels should be hermetically sealed to minimize oxygen infiltration during the long duration of the proposed tests. Provision for in-test gas and liquid sampling should be provided if appropriate.
- Either off-the-shelf or custom built vessels may be used. Scheduling constraints will be a major consideration in this choice.
- Wastes should be characterized before and after the tests to a level similar to that for bench scale tests.
- Instrumentation options should be thoroughly explored and should include in-situ corrosion sensors and pH sensors.

Results from these tests are expected to confirm the conservative nature of previous assumptions about gas generation and are not needed for preparation of the 1995 compliance documents. The tests should be initiated as quickly as possible, however, so that at least one year of data can be collected before the EPA responds to a permit, variance, and/or certification application.

II.2.4.3. VOC Emission from Waste.

The proposed Alcove Test Program should also be abandoned. Data on VOC emissions from waste drums is available from tests that are already being performed at INEL. Test methods may be adapted to increase the value of the data. For example, continuous collection of gases from the drum filters may be feasible. The ITR Team recommends that WIPP participate in analyzing the data, which should form the basis for predicting VOC concentrations and operational releases from the repository. Data collected from waste-storage buildings at generator sites should fulfill WIPP data needs at least as effectively as an Alcove Test.

II.3. Repository Engineering

The ITR team recommends that operational experience be formalized as part of a specifically planned commissioning phase. This phase will serve to focus the transition of WIPP from a scientific project to an operating facility.

The recommended approach is standard practice in engineering project management. It provides for a period of operational testing of system components, cold (nonradioactive) commissioning of the total disposal system and hot (radioactive) commissioning before full scale disposal. No TRU waste should be introduced into the repository until all disposal phase approvals have been obtained. The ITR Team believes that such an approach will satisfy regulators regarding operational safety and will provide a demonstration to stakeholder groups that WIPP has been soundly engineered.

II.3.1. Design and Engineering

Most design and engineering tasks have been completed. These include most of the facility infrastructure, TRUPACT II, and waste-container-handling systems. Some components of these systems remain undeveloped, however, partly because the emphasis has been on bin handling rather than on drum handling as a result of the Bin Test program. The ITR Team recommends developing and testing the remaining components before the completion of compliance documents.

Engineering operations testing, which covers component and engineering subsystem testing, virtually has been completed. New or re-engineered components should be tested within their subsystem within one year.

II.3.2. Cold Commissioning

The purpose of cold commissioning is to test the total disposal system under realistic loads. Handling drums and Standard Waste Boxes at typical disposal phase rates will confirm the design and operation of safety systems. The system should be run at operational capacity for several weeks, transferring weighted drums underground, emplacing, and backfilling them. Retrieval of drums may also be tested. No operational or safety reason could be found for using radioactive waste during this phase. Cold commissioning should be completed at the time of certification and permitting to allow immediate start of the hot commissioning phase.

II.3.3. Hot Commissioning

Hot commissioning will involve handling, storing, and backfilling TRU waste at rates gradually approaching those anticipated during disposal. Hot commissioning will begin after compliance approvals. All health physics and other radiation safety systems will be tested within the proven waste-handling system. The concept of a sealed and thoroughly monitored disposal room similar to that proposed for the Alcove Test may be valuable as the first activity. The sealed room could: be monitored to provide data for compliance verification reports; have a capability for dose monitoring; and have a high level of containment for the first waste emplaced. The room must be allowed to respond naturally to stresses and movements in the rock mass, however, and not be artificially supported beyond the need for worker safety during emplacement. Eventually the roof will collapse and the waste will be retrievable only at high cost. A well defined and managed hot commissioning phase can assure both the operator and oversight groups that unexpected problems can be readily identified and mitigated.

II.4. Allocation of Mission and Work Flow

To establish clear lines of authority and accountability, DOE should define the roles and responsibilities of all project participants. This will give DOE the opportunity to trim positions or activities that are not needed to support this focused schedule.

Each principal WIPP participant owns a portion of the WIPP mission. Figure II-4 illustrates a possible allocation of tasks based on observed and mandated activities, as follows:

- The DOE should: (a) provide policy and programmatic guidance to the Science Advisor and to the M&O Contractor, (b) interact with stakeholders, and (c) be the formal government signatory to regulatory compliance documents. The DOE should set and communicate clear stable directions to all organizations having an interest in the success of WIPP.

- The Science Advisor (SNL) would: (a) guide the DOE and the M&O on scientific aspects of the program, (b) develop the PA model and perform calculations for demonstration of regulatory compliance, (c) do research and development tasks to support certification and permitting, and (d) manage and report on the research done by its scientific subcontractors.

- The M&O contractor (Westinghouse WID) would: (a) manage and operate the WIPP facility, (b) develop and implement regulatory compliance documents and activities under the guidance of DOE, (c) be a formal signatory to the RCRA compliance documents, and (d) be responsible for design, engineering, and commissioning activities.

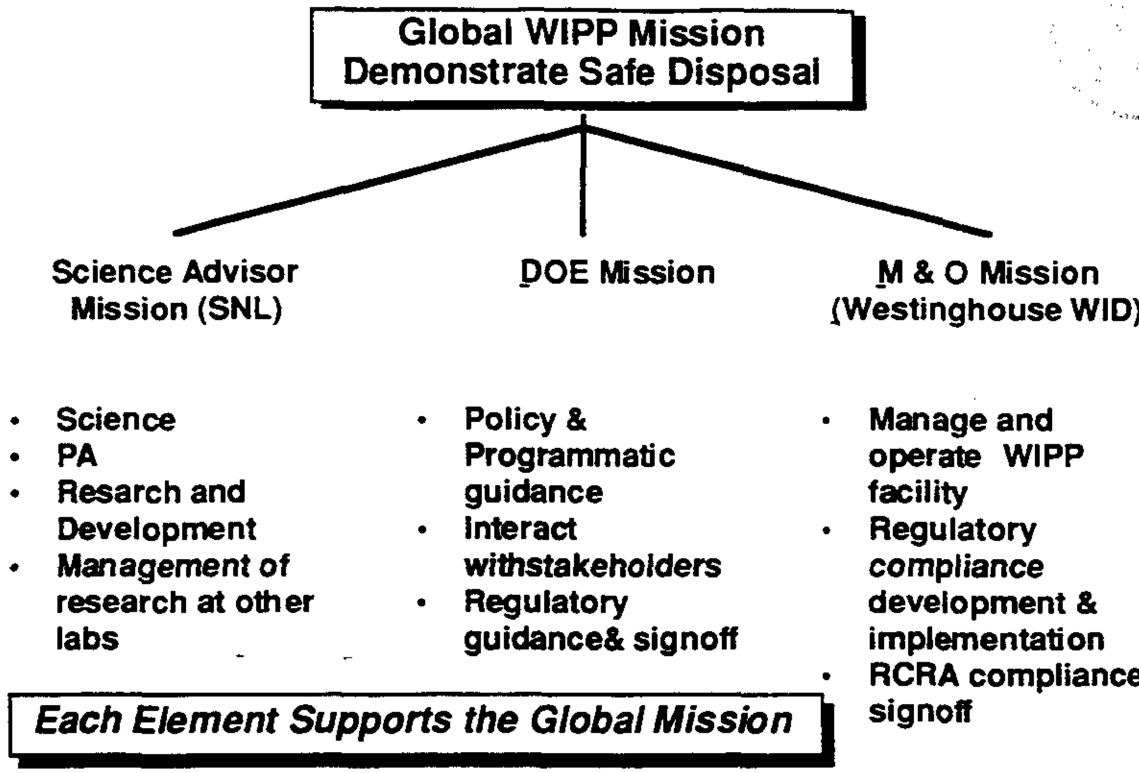


Fig. II.4. Allocation of Mission

Successful mission completion requires an integrated work flow among the participants, as illustrated in Fig. II-5. A functional organization should be developed to reflect this work flow. The recommended structure can provide better focus and improve communications. This structure must not, however, be interpreted as precluding direct interactions among the various organizations when such interactions would best serve the Project mission.

The present principal WIPP Office, WPIO in Albuquerque, owns the DOE portion of the mission. It should function as corporate headquarters, not as a funnel for communication among project participants.

Site operations should be supported by a DOE site office that is a functional branch of the principal WIPP Office. The authority and responsibilities of such an office should be consistent with its role of client's representative overseeing site operations and testing.

The DOE, Westinghouse, and SNL groups supporting compliance and PA-related activities should be collocated. Because demonstrating regulatory compliance is currently the work focus at WIPP, communication among the groups must be straightforward and effective. Good communication is difficult to achieve with the current geographic distribution of offices.

Management priorities at WIPP should begin to reflect the necessary shift in the general focus of work from research to WIPP site operations. This implies that the role of the Science Advisor would diminish or change and that the center of activity, and thus management responsibility, will begin shifting to the WIPP site. Management should also become more active in setting goals for completing discrete tasks within time and budget constraints. Contractor incentives should be considered such that successful completion of tasks or attainment of milestones is rewarded.

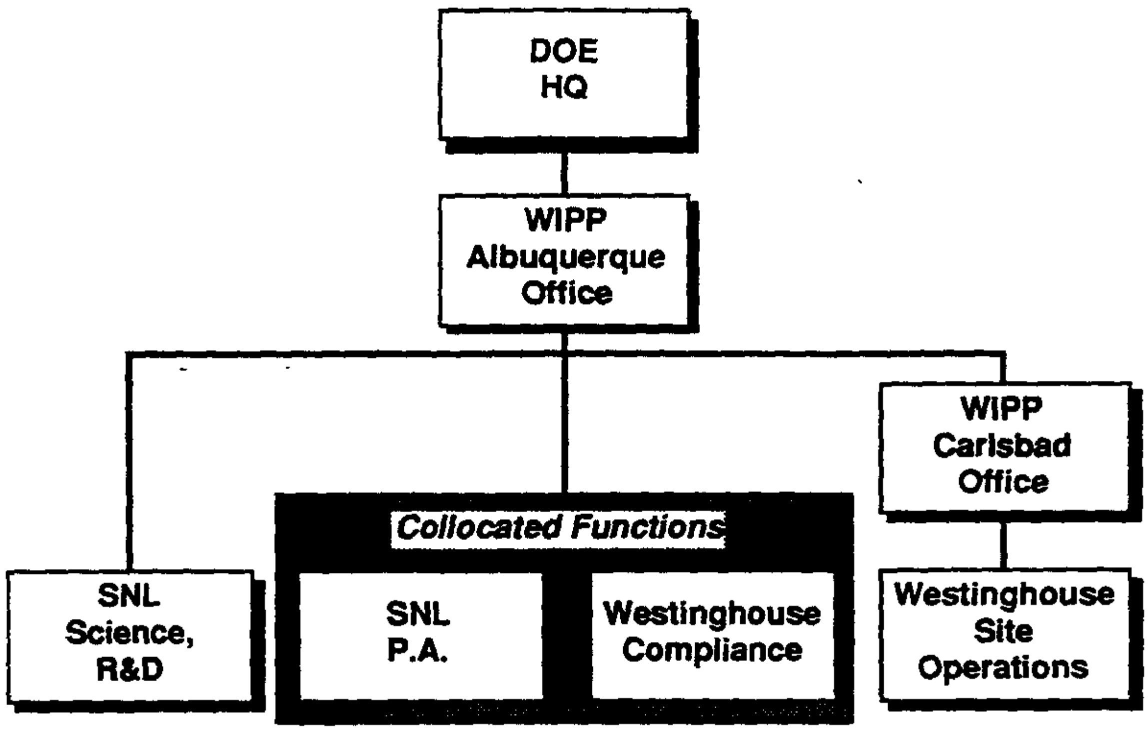


Fig. II.5. WIPP Work Flow

II.5. WIPP Project Management Plan

The present Project Management Plan for WIPP is in draft form. It should be completed consistent with the WIPP Mission, the Path Forward, the Allocation of Mission, and the Functional Work Flow. It will constitute an agreement or contract on work to be performed. It should be agreed to by EM-1 and other major participants, and shared at stages in its preparation with regulators and stakeholders. The draft PUREX/UO3 Deactivation Management Plan, prepared for the US Department Of Energy Office of Environmental Restoration and Waste Management by the Westinghouse Hanford Company in Richland, Washington (WHC-SP-1011, September 1993) is an example of such a plan, and the process used to involve stakeholders and regulators.

III. TECHNICAL EVALUATIONS

III.1. Introduction

The Waste Isolation Pilot Plant (WIPP) project is currently tasked with demonstrating compliance with three major regulations designed and promulgated to protect public health and safety for current and future generations. These regulations are:

- 40 CFR Part 191, Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes,
- 40 CFR Part 264, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities, (Subpart X, Miscellaneous Units) and
- 40 CFR Part 268, Land Disposal Restrictions (Part 268.6, Petitions to allow land disposal of a waste prohibited under subpart C of part 268).

In order to demonstrate regulatory compliance, the WIPP project must show that it can safely manage and handle wastes during disposal operations, and demonstrate that releases of radioactive transuranic and hazardous waste constituents do not exceed release limits set by the regulations for the next 10,000 years. Although demonstration of operation and handling can be observed and certified, demonstrating long-term compliance will mean modeling the performance of the repository based on the current understanding of geologic and chemical processes, combined with a knowledge of the waste inventory for disposal. Such modeling must assess, with adequate confidence, whether or not the WIPP will comply, which will require predicting release mechanisms of radioactive and hazardous waste constituents, transport mechanisms of these constituents, and transport pathways to various regulated boundaries, either existing or induced.

Gas generation occurs via three mechanisms: corrosion of metal drums in which waste will be disposed, as well as waste metals by interacting with brine from the geologic environment; microbial degradation of waste; and radiolysis of organic matter contaminated with radioactive constituents. In addition to the bounding mechanisms, interactions (synergistic or antagonistic effects) amongst these three mechanisms are possible, but not currently well known--hence, total gas generation and generation rates can be either enhanced or retarded.

The Bin and Alcove Tests proposed by the WIPP project are intended to provide confirmatory data to the gas generation model. In order to evaluate the need for, and the adequacy of the Bin and Alcove Tests, the ITR team was required to evaluate aspects of the entire WIPP project, including the approach to regulatory compliance, overall performance assessment methodology, the gas generation model, tests for gas generation mechanisms, and specifics of the Bin and Alcove tests themselves. Observations, assessments and recommendations on these aspects follow.

III.2. Regulatory Interpretation and Compliance

A brief summary of primary governing regulations is provided in Appendix A.1.

III.2.1. Regulatory Compliance Approach

Observations: The regulatory framework surrounding WIPP has been unstable since its authorization under the Nuclear Energy Authorization Act of 1980, as historically described more fully in Appendix A.2. The changes that contributed to the shifting environment included DOE acknowledging that its facilities were subject to the RCRA; issues related to compliance with the Land Disposal Restrictions in 40 CFR 268; initially unclear authority and responsibility to regulate mixed wastes; the promulgation of radioactive waste standards (40 CFR 191) by EPA without compliance criteria for managing and disposing of spent nuclear fuel, high-level and TRU wastes; and implementation of the Land Withdrawal Act (LWA) of 1992[1].

Because the regulatory requirements of 40 CFR 191 and 40 CFR 268 were developed under different statutory authorities, they have different objectives and thus actions required under one regulation may be inconsistent with actions required under the other. The regulations within 40 CFR 191, under authority of the Atomic Energy Act of 1954 and the Nuclear Waste Policy Act of 1982, provide applicable standards for protecting the general environment from radioactive material. The regulations found in 40 CFR 260-268 were promulgated under authority of RCRA and are intended to "protect human health and the environment" from the effects of hazardous wastes being discharged to the environment. The breadth of the regulatory differences is described more fully in Appendix A.3. Beyond the obvious difference between radioactive materials and mixed waste, the differences can be summarized to focus on the application of points about compliance and approaches to PA.

To date, little progress has been made in resolving potential conflicts between these regulations. Nevertheless, WIPP intends to develop a single compliance approach for securing a variance from 40 CFR 268 and a certification under 40 CFR 191. The WPIO states, "[T]hese regulations are fundamentally similar and have compliance provisions and requirements that are equivalent or substantively similar." [2]

On August 9, 1993, the DOE submitted a document defining the roles and responsibilities among the DOE, the M&O Contractor (WID) and the Scientific Advisor (SA). The policy assigns the M&O Contractor as the organization responsible for the overall regulatory compliance package. SNL, on the other hand, is assigned the responsibility for all PA modeling efforts. However, DOE has not clearly defined effective lines of responsibility among DOE-HQ, the WIPP Project Integration Office, the DOE Albuquerque Operations Office (DOE-ALO), and the WIPP Project Site Office (WPSO).

Communications among the EPA and the DOE's SA and DOE's M&O Contractor have been tightly controlled by DOE.

Assessments: The WIPP Project has not been guided by an adequate regulatory compliance strategy and program. Several factors contributing to the lack of an adequate compliance strategy include regulatory instability and regulatory conflicts between 40 CFR 191 and 40 CFR 268, which are somewhat beyond the Program's direct control. Yet, the lack of clearly defined roles and responsibilities among WIPP Project participants, as well as inadequate interaction with the EPA, have also contributed to the lack of a regulatory compliance strategy.

DOE has been ineffective in settling frequent differences between the M&O Contractor (Westinghouse/WID) and the SA (SNL) regarding regulatory compliance strategies. Out of this confusion, the M&O Contractor emerged as the lead for RCRA compliance (40 CFR 264/268), and SNL took the lead in 40 CFR 191 compliance issues. The two contractors appear to work independently despite the DOE's goal to have a common approach for demonstrating compliance with both regulations.

The lack of access to the regulator on the part of the SA and the M&O Contractor has further thwarted progress towards establishing an appropriate compliance strategy and program.

Recommendations: DOE should immediately strengthen its interactions with EPA and NMED to negotiate an appropriate regulatory approach and to resolve potential differences between the regulations. A framework providing more open dialogue with the regulating agencies and the WIPP Project should be established that does not compromise DOE's fiscal or policy responsibilities.

III.2.2. WIPP's Regulatory Strategy

Observations: DOE appears to have been guided by a policy objective of "getting waste underground." This undocumented policy objective appears to have undermined efforts to develop a comprehensive regulatory compliance strategy for the WIPP Disposal Phase. Efforts have been primarily focused on the WIPP Test Phase, specifically on the Bin and Alcove Tests, rather than later activities.

Significant regulatory accomplishments have been achieved in support of the WIPP Test Phase. A conditional No-Migration Determination was approved by EPA in November 1990, which allows untreated wastes to be received at WIPP, although only for the Test Phase. Further, the State of New Mexico Environment Department (NMED) issued a draft permit under RCRA on August 26, 1993, which would allow the receipt of TRU mixed wastes at WIPP although only for the Test Phase. However, the time-consuming process of permitting Type 1 bins, Type 2 bins and Alcoves has diverted both the regulator's and DOE's resources primarily to the Test Phase. As a result of this emphasis, little effort was spent on developing a comprehensive regulatory compliance strategy for the WIPP Disposal Phase.

DOE has recently recognized the need to develop a comprehensive compliance strategy for the Disposal Phase. In August 1993, DOE prepared a draft "WIPP Regulatory Compliance Strategy and Management Plan." This draft document defines an approach and strategy but does not provide sufficient detail to implement an effective regulatory compliance program. According to Section 4.3 of the draft document, DOE explains that "the 'technical approaches' to be used . . . [to] prepare the necessary permit and Certification Applications will be documented in detailed plans and procedures." These documents have not yet been prepared.

The draft WIPP Regulatory Compliance Strategy and Management Plan describes a "Compliance Demonstration and Recertification/Reapplication Process" that is driven by a performance-based waste inventory. This approach involves the development of waste acceptance criteria based upon results derived from the PA analyses needed for regulatory compliance.

Assessments: The regulatory strategy currently being pursued lacks integration and a firm scientific link between the proposed Bin and Alcove Tests and demonstration of regulatory compliance.

Recommendations: A complete regulatory compliance package should be prepared based on PA. Existing waste characterization and experimental data should be used to substantiate a bounding case analysis. The WIPP Project should perform the PA, based upon a best estimate of the total waste inventory. PA calculations should then be performed using subsets of that inventory, if necessary, in demonstrating compliance with the radionuclide requirements of 40 CFR 191, and the mixed waste requirements of 40 CFR 268.

It is recognized that the compliance package will be submitted to different regulating agencies, but it should be submitted as an integrated, comprehensive package. The compliance package should include three major compliance documents, each consistent with the WAC:

- the 40 CFR 191 Compliance Document will be submitted to the EPA Office of Radiation and Indoor Air (EPA-ORIA);
- a No-Migration Variance Petition will be submitted to the EPA Office of Solid Waste (EPA-OSW) to satisfy the requirements of 40 CFR 268.6; and
- a RCRA Part B Permit application will be submitted to the State of New Mexico Environment Department (NMED) to fulfill 40 CFR 264 requirements.

Based upon the results of the PA, the WIPP waste acceptance criteria can be finalized. PA-based WAC will modify the existing WAC, which were developed in response to existing regulations applicable for waste transportation and handling. These pre-closure regulatory criteria should be evaluated in light of the PA results, because additional waste acceptability criteria may be needed to meet post-closure requirements.

DOE should immediately begin negotiations with each regulating agency to identify any issues requiring further clarification before final certification and permitting, such as interacting with NMED to determine what degree of waste characterization data will be required to receive TRU wastes at WIPP.

A regulatory review schedule should be negotiated. The WIPP LWA requires that EPA-ORIA make a determination on DOE's 40 CFR 191 Compliance package within one year from submission; however, there is no mandated time limit for the EPA-OSW and the NMED to review the No-Migration Variance Petition and the Part B Permit application, respectively. Such a negotiated review schedule would facilitate the timely completion of all relevant activities.

III.2.3. Regulatory Compliance and Technical Information Needs

Observations: The EPA and others have developed the concept of the DQO process within the regulatory framework. This process, although not unique to RCRA and CERCLA investigations, uses the regulatory requirements that the program must meet to derive data requirements and therefore testing requirements. By using this process, experimental programs are defined by the nature, precision, accuracy, and imposed conditions derived from the regulatory compliance criteria and standards. Experimental programs that satisfy these requirements can be shown to be clearly necessary for compliance. Interviews with WIPP personnel at all levels confirmed that the DQO process has not been implemented.

Assessments: There is no apparent connection between SNL's in-progress and planned experimental programs with program compliance requirements, and their need or sufficiency for regulatory compliance cannot clearly be demonstrated. Experimental programs that provide data on sensitive parameters or processes identified by PA studies are not tied to quantification requirements established to meet PA/compliance needs.

Recommendations: The DQO process should be implemented in identifying and defining experimental programs. A combined compliance/PA analysis should be performed to identify compliance requirements needing specific and quantitative information. From this effort, experimental programs can be designed, if necessary, to generate the information and satisfy the requirements to the extent possible. Existing and planned experiments should be reviewed to determine if they are necessary and sufficient to meet the technical information needs. Experimental designs may need to be modified, some new experiments may need to be designed, and some currently active or planned experiments may be canceled if they do not meet compliance or operational requirements.

A more intensive effort to integrate regulatory compliance and PA analyses, including sensitivity and uncertainty analyses, should be initiated as soon as possible to make experimental programs conform to program needs with maximum cost-effectiveness.

III.2.4. Bin and Alcove Tests and the Definition of Directly Relevant

Observations: If the Bin and Alcove Tests are to be initiated, then the DOE must submit to the EPA a Test Phase Plan. This plan shall, per the LWA:

> ". . . provide a detailed description of how the test phase activities will provide information *directly relevant* to a certification of compliance with the final disposal regulations or to compliance with the Solid Waste Disposal Act (42 U.S.C. 6901 et seq.); and include justifications for all such activities. " (PL 102-579, Section 5 (b) (3) and (4), emphasis added).

The EPA, in turn, shall

> ". . . approve the test phase plan, or any modification to the plan, in whole or in part, if the Administrator determines that the experiments

will provide data that are *directly relevant* to a certification of compliance with the final disposal regulations or to compliance with the Solid Waste Disposal Act (42 U.S.C. 6901 et seq.)." (PL 102-579, Section 5 (d) (2) (A))

Neither the LWA nor EPA define the term "directly relevant". Although the DOE asserted that the test phase i.e., the Bin and Alcove Tests, will provide data that are directly relevant to the regulations, DOE and EPA evade defining "directly relevant". The DOE defines information that is "relevant" and information that is "necessary":

"Information is relevant if it is pertinent to developing an understanding of or to predicting effects of parameters, processes, and events important to the assessment of and determination of compliance with the regulatory requirements. Parameters, processes, and events include the design basis performance of the facility and disposal system, waste characterization, waste interactions, and human intrusion or predictable future events."

"Information is relevant if it improves the confidence in technical description (conceptual model) of a parameter, process or event and its representation in compliance assessments."

"Information is necessary if it is specifically required by a regulation or statute, or if it is required by the regulator or the regulatory process to demonstrate, evaluate, or maintain compliance."

Assessments: Under the Land Withdrawal Act, one of the principal criteria for in-situ, radioactive tests is that they be "directly relevant" to compliance and supportive of demonstrating compliance with post-closure PA analyses. No justification exists for either the Bin or Alcove Tests demonstrating their utility or necessity based on proving compliance with any regulation or standard.

There is no obvious connection between the relevance of the proposed Bin and Alcove Tests, and demonstrating compliance with 40 CFR 191. This regulation specifies release limits for the radioactive constituents, none of which are gases. Conceivably, pressure created by gas generated from metal corrosion and from organic biodegradation could fracture the geologic formation, but there is inadequate evidence to support the movement of radionuclides along the fractures until they reach the "accessible environment" (40 CFR 191.12). Considerations about evaluating the potential for human intrusion scenarios are provided in Appendix A.3.

The proposed Bin or Alcove Tests are not "directly relevant", "relevant" or "necessary" to demonstrating compliance with 40 CFR 264, Subpart X and 40

CFR 268. The Bin Tests could provide marginal confirmation of gas-generation models, but the test design and hardware are inadequate. Similarly, the Alcove Test cannot provide defensible or cost-effective data because it will not provide a source term for VOCs, it will not determine gas loss into the rock or around the seals, and the results cannot be readily scaled.

Recommendations: The WIPP Project should abandon the Bin and Alcove Tests and turn its efforts to completing a regulatory compliance package. Without these tests, many of the time consuming requirements of the LWA would not apply, such as the testing approvals from the EPA and New Mexico, along with a test phase plan and a retrieval plan. Certain test phase activities and requirements in the LWA might be deferred until waste disposal operations began after compliance certification. In short, the time and money needed to test waste at WIPP would be better spent securing certifications and permits needed to permanently dispose of waste at WIPP.

III.2.5. Regulatory Barriers to Bin and Alcove Tests.

Observations: The LWA establishes requirements, procedures and schedules whereby actual TRU waste could be emplaced at WIPP. According to the LWA, the Test Phase begins upon the initial receipt of TRU waste at WIPP. Although nonradioactive waste tests have been on-going at WIPP, these tests are not considered to be part of the Test Phase as defined by the LWA.

Several other requirements appear to impose limitations on the tests that would severely restrict the utility of the resulting data, although the various program participants do not agree on the details of these restrictions. For example, EPA states in its NMD that "no waste container should be emplaced in the underground repository if it contains flammable mixtures of gases in any layer of confinement, or mixtures of gases that could become flammable when mixed with air." The EPA further defines any flammable mixture as potentially flammable if it "exceeds 50 percent of the lower explosive limit (LEL) of the mixture in air." Such constraints may require bin purging, and potentially alter test results. The WIPP Safety Analysis Report also limits the generation of potentially flammable gas mixtures within Type 1 Bins to 50 percent of the LEL for the entire duration of the tests. In addition to flammability restrictions, DOE safety requirements restrict the opening of bins after testing. Because there are no double containment capabilities per DOE Order 6430.1A currently at the facility, the bins cannot be opened after testing to examine the wastes and determine the corrosion and other reaction products and processes.

Assessments: As interpreted by the ITR Team, the Test Phase requirements outlined in the LWA will not apply if DOE does not proceed with radioactive testing at WIPP. Specifically, requirements associated with submitting a Test Phase Plan to EPA for approval should not be necessary if no radioactive testing is performed at WIPP before certification.

III.3. Technical Performance Assessment

PA analyses performed to date have been directed at satisfying regulatory requirements of 40 CFR 191. However, the PA analyses have not been directly linked to a clearly defined compliance strategy. This has resulted in the PA analyses being based on a series of assumptions and approaches that are not clearly linked with other elements of the WIPP program. A PA analysis using the most recent conceptual and mathematical models available and a well-documented and reviewed set of parameter ranges would determine the real weaknesses in the data base. The PA analysis is important in assessing the ramifications of gas pressure build-up, particularly for brine flow and room closure, with and without future human intrusion events.

III.3.1. PA Modeling

Observations: The RCRA regulations, 40 CFR 268, and the Radioactive Waste Disposal Standard, 40 CFR 191, call for somewhat different PA approaches. 40 CFR 191 clearly calls for a probabilistic approach to PA, using Complementary Cumulative Distribution Functions (CCDF) methods to show compliance. On the other hand, the RCRA post-closure regulation calls for a deterministic single-value calculation methodology in demonstrating compliance.

Assessments: Many significant uncertainties in conceptual models and parameters cannot be reduced in the deterministic evaluation specified in 40 CFR 268; therefore a probabilistic approach may be the only defensible way of showing compliance in the regulatory/legal environment.

Recommendations: The WIPP program should propose a consistent approach for all regulatory compliance analyses, using the same conceptual model basis and set of computer codes. A database consisting of all available data from all credible sources, including experimental and field data, data from literature surveys, and professional judgment input, must be formalized as a basis for all PA calculations. Specific parameter selection may vary depending on the performance measure selected, as determined by the requirements specific to each regulation.

The use of probabilistic risk assessment based on the intent of a given regulation could be proposed to supplement compliance demonstration.

III.3.2. Model and Parameter Consistency

Observations: Many parameter ranges have been selected primarily on expert judgment or broad literature surveys. It is uncertain how consistent the parameter ranges selected for PA calculations are with the geologic/hydrologic setting. In addition, little effort has been made to autocorrelate the parameters to account for covariance, which would serve to reduce the uncertainties in the resulting performance measures.

Assessments: Models and selected parameter ranges are not internally consistent, or in many areas, consistent with experimental studies. The process models appear inadequately linked to the hydrogeologic setting, and design and operational conditions.

Parameter distributions are at least as important as parameter ranges, especially when Monte Carlo PA analyses are being performed. The simplest approach is a straight-line distribution between the extreme values of the range, and is necessary when little is known about the natural distribution of parameter values. Selection of a most-likely value, or an average or median value with a Gaussian or log-normal distribution about that value would greatly reduce the probability of extreme values of performance measures, if those values and distributions can be at all justified. Expert judgment can often be used to provide this information if site-specific data are not available.

Recommendations: A critical evaluation of critical parameter ranges and "best values" should be completed before performing the PA analyses used to support the regulatory compliance package. Parameter ranges should be evaluated for consistency with the geology and hydrology of the repository environment. Parameters critical to performance measures of regulatory concern should be identified with multivariate sensitivity and uncertainty analyses, using the models for the performance calculations.

III.3.3. Simple Model for Evaluating Coupled Processes

Observations: Currently the WIPP Program uses detailed process models which are linked serially to perform total system analyses, including sensitivity and uncertainty analyses and bounding calculations. This approach does not readily allow the assessment of interactions between various parameters and processes. Assessment of these coupled processes requires a complex set of interactions among component models and codes, and a careful review of parameter selection rules to assure consistency among interdependent variables.

Assessments: The lack of ability to effectively model interactions among physical processes can result in a misleading, overly-conservative PA analysis. For example, the system of waste-brine-gas-rock is an inter-related process, such that the amount of brine available controls the amount of gas produced as the waste decomposes, the gas pressure build-up controls the rate at which brine can enter the repository volume, and the opening of fractures in the repository wall increases the volume available for the gas to expand into, thus releasing the pressure (but possibly allowing more brine to enter). This coupled inter-relationship is currently modeled using simplistic step functions in a few cases, but complete interactions among the various mechanisms are not allowed.

More detailed coupling mechanisms could better assess the probable course of physical-chemical processes that are likely to operate in the repository and vicinity after closure. Similarly, several sets of parameters are covariant; that is, changes in one parameter require related changes in other related parameters, such as the relation between permeability and porosity in a rock mass under stress. Many other examples exist.

Treating physical processes as independent or as operating in a serial manner leads to weaknesses in the PA analysis that may be questioned by regulators and others. Some treatment of coupled processes and parameters will probably be needed to build confidence in modeling results, or to demonstrate that the TRU disposal system meets regulatory requirements.

Recommendations: System codes and models should be developed or modified to allow analyses of coupled phenomena, if PA analyses do not adequately demonstrate compliance with the various regulations and regulatory standards, using current models, assumptions and data. Such a system code would aid in total system bounding calculations; parameter and process sensitivity and uncertainty analyses; developing DQOs for the test programs; and identifying specific analyses needed using the detailed process models. These developments should be completed as soon as possible after the need is recognized in order to provide guidance for future experimental efforts.

Monte Carlo and other parameter selection techniques should be examined to assure that all correlated parameters are being dealt with properly.

III.3.4. Use of Detailed (First Principle) Models

Observations: The WIPP PA process depends on developing detailed process models and computer codes that are based on a 'first-principles' approach to the processes. Such models require that the chemistry and physics of the subject process be understood in detail, and that critical attributes of the physical system in which the process operates be described in great detail.

Data collected from the site and the laboratory, together with studies of similar processes at other locations, are often the only information available to describe and predict how a process will operate within the WIPP system. This is especially true in describing how physical or chemical processes interact with the heterogeneous geologic, geochemical and hydrogeologic environment.

Assessments: First-Principle models are being developed for all processes instead of using analytical models based on experimental and other empirical information. Because the WIPP repository environment is heterogeneous, many of the complex processes that are expected to operate cannot be described completely in terms of their underlying physical and chemical principles. Moreover, the WIPP program has not made a thorough examination of models available from sources outside of SNL and other National Laboratories.

Recommendations: First-Principle models should be supplemented with empirical information and empirical models developed, as appropriate, to help bound the limits and effects of processes. Such an approach may not provide a detailed understanding of a process, but empirical models are more amenable to understanding the limits of the process. It is important to ensure that empirical models do not violate basic physical and chemical principles.

The WIPP PA organization should use more of the available data collected at WIPP and data from the technical and scientific literature to build process models that can approximate processes operating under real repository conditions.

Models available from sources outside the National Laboratories should also be investigated rather than relying on building new models from first principles for all processes. Existing models often have the advantage of being more cost-effective, are recognized by the scientific community at large, and have been verified and validated in several applications, thus adding to the credibility of the WIPP PA analyses. Models describing coupled processes and complex processes such as rock mechanics, have been developed, tested and applied to real problems, and are available from other government agencies, universities and specialized consulting firms.

III.3.5. Confidence in PA Verification/Validation

Observations: A systematic traceable path from data collection through model parameter selection to establish a 'pedigree' for all PA compliance calculations does not appear to exist at the present time. Peer review of parameter ranges and distributions, conceptual models, assumptions, and computer codes has not been systematically performed and documented. Peer review is often the only method for building confidence in PA analyses when many of the models and codes used for simulating complex processes may not be validated by observation because of the long time frames or complex nature of the processes.

Assessments: No formal program for building confidence in PA modeling has been developed, including verification, validation, and confirmation experiments. Confidence in the PA calculations required for compliance demonstration is as important as the content of those calculations. Important components of model confidence include documentation of models, codes, data, and model and code verification and validation.

Recommendations: The WIPP program should establish a formal program to build confidence in PA analyses. A set of procedures should be implemented that requires complete documentation of all PA activities and establishes the mechanisms to be used for verification and validation of all codes that will be used for compliance calculations. The peer review process should also be formally established, particularly as part of, or in lieu of, model validation. The review should evaluate assumptions underlying conceptual models, parameter ranges and distributions, and calculational approaches. To the extent possible, the review should be performed by technical specialists outside of the organization to assure the review's independence.

III.4. Gas Generation and VOCs

Gas generation and VOC data are fundamental to WIPP's ability to assess the future performance of the site and to demonstrate compliance with regulatory standards (See Appendix C). Gases escaping from the repository unit boundary could carry contaminants exceeding regulatory release limits. The most likely path for gas migration away from the repository is the laterally extensive anhydrite layer above and below the repository horizon. A key component of assessing the gas-generation problem is being able to reliably predict the consequences of high gas pressures within the repository, including the potential for gas pressure to exceed the pore-brine pressure and drive the brine towards the regulatory boundaries.

The issues associated with gas generation and VOCs must be resolved to demonstrate regulatory compliance. Indeed, gas generation and VOCs are perceived important at each of the three operational lifetime stages of WIPP: ventilated, transitional, and long term. During the ventilated and transitional stages, the gas and VOC information required by 40 CFR 191 Subpts. A &B, 40 CFR 268.6, and 40 CFR 264 Subpt. X include the gaseous species that may be generated by the wastes, and rates of production under different combinations of repository-environmental conditions. During the long-term stage, 40 CFR 191 Subpt. B, and 40 CFR 268.6 require the above data and information on gas-generation potential and concentrations of hazardous species in brines. Evaluating the concentration of hazardous constituents in the brine is based primarily on estimating brine inflow rates into the repository space, the dissolution of waste forms in brine, leaching of the soluble hazardous constituents, and dissolution of at least some VOCs in the brine.

III.4.1. Gas-generation Model

Observations: In WIPP's terminology, gas-generation models are distinct from the models that deal with VOCs in waste drums, containers, or in the repository rooms and panels. The term gas-generation model designates models dealing with the major gases, such as carbon dioxide, hydrogen, nitrogen, various nitrogen oxides, methane, and hydrogen sulfide.

The latest version of the gas-generation model, developed at SNL for WIPP, treats gas generation, under oxidizing and anoxic conditions, by reactions of water and other gases with metals and by bacterial degradation of organic matter. A summary of the capabilities of the gas-generation model is as follows:

- The gas-generation model is a reaction model based on chemical thermodynamic equilibria in reacting systems and chemical kinetic (reaction rate) data for gas generation by metal corrosion and bacterial degradation of organic compounds.

- The model computes concentrations of reactive gases at an equilibrium with pure iron-containing phases. Depending on the reactive gases used in the model (such as water, carbon dioxide, hydrogen, and hydrogen sulfide), it computes thermodynamic stability fields, at certain temperatures and pressures, of iron oxide, carbonate, or sulfide phases as functions of the partial pressures (or fugacities) of the reactive gases.

- The model computes the masses of gaseous species that can be consumed or produced when chemical equilibria are "instantaneously attained" in systems of gases and iron-containing solid phases.

- The model calculates reaction progress in terms of the masses of gaseous species consumed or produced as a function of time. For this calculation, the model uses data from the literature and laboratory studies on the rates of bacterial degradation of organic materials and the rates of gas generation or consumption in metal-corrosion reactions.

- To account for large uncertainties in the rates of different reactions and other parameters, the model assigns probability distribution functions to individual parameters, and it takes parameter values within their ranges by means of a statistical technique known as "the Latin hypercube." In a calculation of gas pressure as a function of time in a certain chemical reaction (or a set of reactions), the statistical sampling technique produces an envelope of curves for pressure as a function of time. Such an envelope is considered to represent the expected results more reliably.

The development of the gas-generation model during the past several years has been primarily a one-person effort. More recent work on the gas-generation model has been done by approximately 1.5 FTEs: one principal investigator and one part-time computer programmer.

Assessments: The gas generation model is an essential element in the PA process. However, the model contains several inadequacies that limit its value to overall PA evaluations, and there appears to be a considerable time lag in integrating the state-of-the-art gas generation submodel and information into the overall PA model. This restricts the ability of the PA to reflect the most current understanding of gas generation in the initial compliance assessment and in bi-annual PA updates required by the LWA.

The current version of the gas model is inadequate for the following reasons:

- The model does not account for realistic brine or solid compositions in the solid-brine-gas systems that approximate reactions in the stored wastes. More specifically, the component model for corrosion uses phase stability diagrams for gas-solid interfaces to predict the behavior (passivity) of brine-solid interfaces, and the effects of important aqueous species, such as magnesium and chloride ions, are ignored. Laboratory studies of metal corrosion have demonstrated that significant quantities of gases evolve only when metals react with brines. On a time scale of two-year-long tests, gas generation is insignificant when metals are in contact with water vapor only.

- The gas-generation model stops at "the edge of the waste" without looking at the gas-brine-solid system in the rock. In microbial gas production, brine is a necessary medium for halophilic bacteria and, generally, water is one product of oxidation or respiration of organic matter. A brine, containing high concentrations of magnesium, sodium, calcium, and chloride ions, may react with pure metals, metal oxides, or sulfides, making solid phases that are not accounted for in the model. To determine whether the brines react with the metallic or other solid phases in the waste, the model must eventually reflect the complex chemical speciation needed to describe three-phase multicomponent systems. The model will then be able to identify the potential role of biogeochemical processes in PA of the geologic setting.

- The gas-generation and fluid-flow models cannot take into account the physical heterogeneity of the waste sources in larger-scale tests, such as the proposed Bin Tests, or of the real waste destined for WIPP.

- The gas-generation model does not analyze any of the mechanisms that may limit or reduce the gas pressure within the repository. A "worst possible case" of gas generation dictates an unrealistic scenario where a rise in gas pressure and its mass in the repository is not countered by any physical or chemical processes, such as sorption, liquefaction, dissolution in brines or mineral-forming reactions.

- The analysis of the brine and gas-flow models is focused on the physical aspects of gas behavior within and outside the repository space, but it does not sufficiently address the chemical interactions and their potential consequences. Indeed, no activities were identified during the review that dealt with the geochemical behavior of gases downstream from their sources in the waste, within the geological environment beyond the boundaries of the waste storage rooms.

The model is perceived by program managers at DOE/WPIO and SNL as very important to providing inputs to gas and brine-flow modeling and to PA. However, except for the principal investigator for gas-generation modeling, it is not apparent that a single individual in the DOE-SNL-WIPP complex has any sufficiently thorough, hands-on understanding of the fundamentals, working functions, and limitations of the model. There has been only limited exposure of the model to the technical community, there have been no in-depth peer reviews, and insufficient documentation is available to enable outsiders to exercise the model and judge its merits.

Recommendations: A peer review of the gas-generation model should be conducted at the earliest possible time to develop a working understanding of the model, evaluate the technical data needed, and assess the level of future model refinement needed for performance assessment.

The entire gas modeling effort should be expanded to address solid-brine-gas interactions, and which gases should be considered, under the expected range of environmental conditions in the repository and geological setting. Consideration should also be given to incorporating such effects as:

- passivation of carbon steel by $FeCO_3$, FeS, FeS_2, or oxides that may prevent gas generation should be predicted with potential-pH (Pourbaix) diagrams calculated specifically for carbon steel (or iron) in contact with brine solutions
- gas-interaction or gas-behavior models in the geological surroundings of the repository
- sorption of gases on solids
- mineral-gas and brine-gas reactions
- important aqueous species, such as magnesium and chloride ions, to predict the formation of known corrosion products

Expertise should be more thoroughly integrated with the modeling program in related fields such as metal corrosion, radiolysis, microbiological corrosion, chemical/ionic speciation in brines and gases, solid-brine-gas reactions, and organic compounds in gaseous phases and solutions.

Interactions with and inputs to the gas-generation modeling activity should be increased with the PA Program, the WPIO Technical Support Group, and other relevant scientific/performance assessment groups.

A literature review and a search for analogs, natural or engineered, should be conducted of those gas-generating processes that are of concern to WIPP's mission. If there are analogs, then they should be analyzed and results integrated relative to their importance.

The credibility of the gas-generation model and other activities that receive its input should be strengthened by accelerating their development and directing them toward the goals of demonstrating compliance with the regulations, the geological environment of the repository, and larger-scale tests as appropriate.

III.4.2. Laboratory Evaluations of Gas Generation

Observations: Laboratory studies of gas generation deal primarily with the major gases generated by metal corrosion, microbial processes and radiolysis: hydrogen, carbon dioxide, nitrogen and its oxides (N_2O, NO_x), methane, and hydrogen sulfide. A detailed description of gas-generation phenomena is presented in Appendix B. Plans exist to study VOCs, as gaseous and dissolved species, that may form from organic species in alpha-radiation fields.

The current phase of laboratory studies of gas generation (See Appendix D) is managed and coordinated by SNL through subcontracts with PNL (metal corrosion), ANL (radiolysis of brines and plastic materials), and BNL (bacterial degradation of cellulose, irradiated plastics and rubber materials). Studies of gas generation by metal corrosion, alpha-particle radiolysis of brines, and bacterial degradation of cellulose-containing materials are in various stages of completion.

Assessments: The laboratory studies of gas generation are, as a whole, consistent with the current state of knowledge of the field and with the results of other investigators reported in the literature. Many results emerging from gas-generation studies are empirical in nature, such as the dependence of steel passivation on carbon dioxide pressure, or the dependence of gas-generation rates on the pressure of hydrogen-gas in the experimental system. Similarly, the results of bacterial gas-production experiments are within the bounds of carefully obtained empirical data.

The SNL reports strongly emphasize careful documentation of the laboratory procedures, description of the experiments, and discussion of the results. This emphasis on the experimental data and time constraints of the program probably explain a certain lack of theoretical depth in the released reports. However, a theoretical understanding of phenomena can support certain laboratory results, can influence the development of gas-generation models, and may help reduce uncertainties that are inherent in the current version of the gas-generation model.

The results of gas-generation studies in the National Laboratories are consistently used in the Gas-Generation Model Program. However, it is far from clear, to what extent (if at all) laboratory and model studies are driven by any data needs for the higher-level PA models.

III.4.2.1. Corrosion Induced Gas Generation

Observations: Bench-scale corrosion experiments for the WIPP program were started at PNL in November, 1989 with the objective of measuring rates of gas evolution caused by corrosion. The corrosion laboratory is very well equipped and more specific information on PNL activities can be found in Appendix D.2.

It is believed that waste inside WIPP will eventually be inundated with brine, with an overpressure of hydrogen, carbon dioxide, and other gases. Therefore, experiments are being done with both humid and inundated wastes, using Type A brine which simulates the brine expected in WIPP. In the case of inundated wastes, the composition of the brine is known at the beginning of experiments, and the composition of the brine at the end of the experiment is measured. Brine samples could be taken during the course of experiments, but are not. Corrosion coupons (carbon steel samples) are removed from pressure vessels at the end of experiments for evaluation.

Most of the oxic corrosion is believed to occur while drums are stored at generator sites and that this mode of corrosion will not be important inside WIPP, unless air inside the repository is continuously replenished during the life of the repository. Likewise, anoxic corrosion is anticipated to be responsible for most of the gas generation inside the repository. Based upon laboratory experiments, tit has been concluded that low concentrations of oxygen can accelerate the rate of anoxic corrosion. This acceleration is attributed to the reduction of oxygen on the corroding metal surface. Rates of anoxic corrosion and associated gas generation will accelerate if the brine becomes oxygenated.

Molar gas-generation rates are calculated from the plenum volume and the measured gas pressure with the initial pressure subtracted. The ideal gas law cannot be used for evaluating hydrogen and carbon dioxide; an equation of state based upon the Van der Waals theory is used for these gases. Gas dissolved in the brine is accounted for with Henry's Law. Some hydrogen can be lost by the reduction of metal oxide, but the loss is not accounted for. Rates of gas generation are verified by comparing data to weight loss measurements of metal samples. Before weighing samples, inhibited hydrochloric acid is used to remove all corrosion. Typically, gas-generation data and weight loss measurements agree within 5%, which is exceptional. Results of all experiments are thoroughly documented in reports that are sent to the contract manager at SNL.

Passivation. Passivation of active metal surfaces by gases in the repository may significantly reduce the rates of corrosion and hydrogen generation. PNL has observed passivation of carbon steel surfaces by hydrogen sulfide at a threshold partial pressure of about 5 atm. These results are slightly different from those published by other research groups in that they think surfaces are passivated by protective films of FeS. Other groups claim that the formation of FeS_2, not FeS, is required for passivation.

PNL has also observed the passivation of carbon steel surfaces by carbon dioxide. They conducted experiments at various ratios of carbon dioxide to metal surface area and found that passivation can be limited by carbon dioxide availability. No passivation was observed without carbon dioxide. At a carbon dioxide level of 0.32 mol/m^2 of metal surface, surfaces were completely passivated by siderite, $FeCO_3$. The threshold carbon dioxide level for passivation was about 0.16 mol/m^2 of metal surface. Before passivation, rates of corrosion and gas generation are enhanced by acidification of the brine, which is due to dissolved carbon dioxide in the form of carbonic acid. Though no actual pH measurement has been made at high pressure to confirm this conclusion, theoretical calculations indicate that significant pH suppression is possible ($3.3 < pH < 3.4$).

Nonadhering Corrosion Products. Gas generation can also be inhibited by the accumulation of nonadherent solid corrosion products on the surface of corroding metal. After compressing the waste, rock will hold such corrosion products on metal surfaces, thereby preventing corrosion. Such effects were observed by PNL during experiments with moist salt and in the absence of brine at a temperature of 150°C and pressures of a few atmospheres. Clay-like deposits formed on corroding metal surfaces in high-magnesium brines (similar to Type A brine), and were identified as amakinite ($Fe_xMg_{1-x}(OH)_2$), a bluish gray, non-adherent, non-protective deposit. The corrosion rate was greatly reduced because mass transport limitations were imposed by this layer.

PNL has observed the formation of a blue-green-gray corrosion product that looks like amakinite on samples from experiments with simulated WIPP brine. X-ray diffraction indicated, however, that this product was not amakinite; it could not be identified with data in the PNL x-ray-diffraction library. However, no effort has been made to identify this corrosion product when sent to SNL for identification. In general, this product does not adhere to the surface of corroding metal and is non-protective. It usually forms a colloidal suspension that coats the walls of pressure vessels.

Brine/Salt Interactions. Researchers at PNL are conducting a wide range of experiments that account for both inundated and humid conditions. For all practical purposes, metallic samples in the vapor phase remain unreacted, except for a slight tarnish. No (significant) corrosion has been observed in the vapor phase.

Brines have not reacted with Hastelloy C-22, Hastelloy C-276, Inconel 625, or Titanium Grade 12 pressure vessels. Not one of the 316 stainless steel tubes in the Bourdon pressure gauges has failed.

Metallic corrosion specimens have been contacted with salt (halite) from the floor of WIPP in experiments at PNL. The current test plan proposes to use a simulated backfill that consists of 30% bentonite and 70% salt. In the past, the use of an alkaline backfill has been proposed.

Assessments: In general, the PNL studies currently being performed provide data pertinent to evaluating corrosion-induced gas generation. However, data needs should be defined more precisely before additional money is invested in costly experimental work.

An alkaline backfill ($12 < pH < 13$) could reduce corrosion and associated gas-generation rates by orders of magnitude, provided that there is relatively little aluminum, which corrodes very quickly in an alkaline environment.

Recommendations: Bench-scale corrosion experiments should be conducted with alkaline backfill, however, to assess the potential for reducing corrosion induced gas generation. Bench-scale corrosion tests could be conducted with actual TRU wastes, and wastes could be subjected to expected repository conditions (lithostatic pressure).

If large-scale corrosion experiments are required based on an assessment of data needs, then they should use (a) well-characterized simulated wastes; (b) a more realistic test environment; (c) a corrosion-resistant vessel with a hermetic seal; and (d) in situ corrosion sensors. Simulated wastes can be more fully characterized than TRU wastes, and large-scale laboratory tests with simulated wastes would allow complete characterization of wastes and products after completing the experiments using mass balance determinations. Vessels could be used that would allow experimentation at lithostatic pressure. Personnel with extensive experience in designing and performing large-scale corrosion experiments need to be directly involved in planning any large-scale laboratory tests.

More elaborate in situ corrosion monitoring should be considered. For example, corrosion rates could be measured with electrical-resistance probes. The corrosion potential could be determined by monitoring the voltage differences between a carbon steel sample and a saturated calomel electrode. The pH, which is sensitive to dissolved carbon dioxide, could also be measured in situ.

III.4.2.2. Microbiologically Induced Gas Generation

Observations: Excellent bench-scale, microbial gas-generation studies have been conducted and have confirmed earlier studies[3] (summarized in Appendix B.2.3) and gas-generation model estimates. Most studies have been completed or are nearing completion, enabling data input into the anticipated 1994 PA. Other bench-scale, microbial tests underway or planned include:

- confirming radiolysis effects on the biodegradability of plastic and rubber waste materials,
- characterizing synergism/antagonism between biodegradation and corrosion of wastes,
- quantifying effects of pressure on waste biodegradation,
- characterizing waste biodegradation products, and
- demonstrating realistic limitations to microbial gas generation.

The focused and aggressive bench-scale, laboratory-test program at BNL:

- has provided microbial gas-generation data to support estimates predicted to date by theoretical calculations;
- has elucidated the effects on microbial gas generation of (a) humid and brine-inundated conditions, (b) limited nutrient availability (e.g. nitrate as an electron acceptor), and (c) backfill (bentonite) addition, which catalyzes gas generation;
- is addressing and quantifying synergistic/antagonism effects between microbial gas generation and corrosion through a cooperative program with PNL;
- is examining the vulnerability of irradiated plastic and rubber materials to biodegradation and gas generation in a cooperative study with ANL;
- has isolated and characterized halophilic (salt-loving) microorganisms from within the WIPP facility and surrounding environs, demonstrating their ability to degrade cellulose[4];

- is producing results representative of long-term repository conditions in reasonably short periods of time, because test conditions can be closely controlled and designed to obtain rapid results;
- is examining and quantifying degradation products (e.g. organic acids, alcohols) from cellulose biodegradation; and
- will evaluate the effect of pressure on the cellulose degrading activity of the halophilic enrichment cultures and isolates from the WIPP site. The current plan specifies a pressure test at 150 psia, which is the design criterion for the Type 2 bin.

Researchers at PNL and BNL are now collaborating on microbial-induced corrosion, a collaboration which was initiated by SNL.

Plutonium-microbe interactions may also be important because low concentrations of plutonium may be toxic to microbes and alpha radiolysis may convert non-biodegradable material into biodegradable material. In collaboration with BNL, ANL is initiating studies of plutonium-microbe interactions, an interaction which was also initiated by SNL.

Assessments: There is a great deal of uncertainty regarding the potential activities of microorganisms in the underground environment at WIPP during the ventilated, transitional and long-term timeframes. This uncertainty means that the amounts, types and production rates of gases from microbial degradation of organic wastes can not be predicted with much confidence. The most critical factor concerning microbial gas generation is brine inflow. If the repository environment remains dry, microbial activity will be limited by moisture in the waste, and gas generation should be minimal. If, however, the wastes become inundated with brine, microorganisms could flourish until nutrients, most likely phosphate, become limiting. Under brine inundation, microbial populations would likely degrade organic wastes using a sequence of electron acceptors and produce a variety of gases (CO_2, H_2S, N gases and CH_4). The production rates and amounts of these gases are highly speculative and are dependent on how rapidly oxygen is consumed, the breaching of drums and intermixing of drum contents and other highly indeterminate events. The gas generation model assumes complete biodegradation of wastes with attendant gas production. This is highly unlikely, because in the natural environment such efficiency does not occur. One notable example is the burial of organic matter over geologic time which underwent partial microbial degradation over time, producing today's principal energy resources -- coal, petroleum and natural gas.

Recommendations: Bench-scale, laboratory tests to evaluate microbiological effects on gas generation should be conducted at WIPP lithostatic pressure to be representative of anticipated long-term, repository conditions.

III.4.2.3. Radiolysis Induced Gas Generation

Observations: Radiolysis experiments for WIPP have been conducted by researchers at ANL since June, 1989 to investigate the effects of radiolysis on WIPP brines and various organic wastes. The alpha radiolysis of brine produces both hydrogen and oxygen due to the decomposition of water, whereas radiolysis of organic wastes produces VOCs. Radiolysis may also alter the susceptibility of organic wastes to other types of degradation.

Radiolysis effects in WIPP will be primarily due to alpha particles emitted during the decay of dissolved or suspended ^{238}Pu and ^{239}Pu. Both the alpha dose and hydrogen generation depend on plutonium concentration. Experiments conducted with plutonium concentrations of 10^{-4}, 10^{-6}, and 10^{-8} molar have indicated that the contribution of radiolysis to net gas buildup is negligible at plutonium concentrations less than 10^{-3} molar, although lower concentrations can affect the gas composition because carbon dioxide can be produced at the expense of oxygen.

The yield (G value) for the radiolysis reaction has been measured for four different brine compositions and ranges from 0.6 to 1.4 molecules of hydrogen produced per 100 eV of energy absorbed. The average yield (G value) for all brines evaluated is approximately 1.2 ± 0.2 molecules of hydrogen produced per 100 eV of energy absorbed.

ANL has found that a large number of VOCs are generated by the dry radiolysis of dry plastics by alpha particles. Thus far, thirty or forty radiolysis-generated VOC products have been identified. The yield values are anticipated to be small, but have not yet been quantified.

Radiolysis effects in the proposed repository at Yucca Mountain will be due primarily to gamma radiation emitted from solid waste forms. Based on gamma radiolysis evaluations, there is little evidence to support the hypothesis that alpha radiolysis can significantly impact rates of corrosion in WIPP. In the past, the effect of gamma radiation on corrosion rates in salt was evaluated, and corrosion rates were found to increase by a factor of two (2X) at radiation levels above 10^5 rad/hr. The effects of radiation on corrosion were unimportant at levels below 10^3 rad/hr, which is greater than the radiation levels anticipated for contact handled TRU waste proposed for WIPP disposal.

Assessments: Radiolysis is not perceived to be a major contributor to gas generation. Bench-scale laboratory test currently underway should confirm whether radiolysis of plastics and rubber materials makes these materials amenable to biodegradation, hence gas generation.

III.4.3. Volatile Organic Compounds

Observations: Volatile Organic Compounds (VOCs) to be evaluated under 40 CFR ˜ 3 can be generated by radiolysis of the waste, microbial waste degradation, or can be from solvents contaminating the waste. Radiolysis is not considered an important gas generation mechanism, and the contribution of radiolytically-produced VOCs to the increase in gas pressure should be negligible. Volatile organics generated by microbial degradation would probably not be regulated VOCs.

The degradation of VOCs in brine by either hydrolysis or biological reactions has not been investigated.

The migration of VOCs is thought to be driven by increasing gas pressure caused by gas generation, and the VOCs could be transported to regulatory boundaries by other gases.

Assessments: As important as the VOCs are for demonstrating WIPP's ability to comply with the environmental safety regulations, the studies of these compounds seem to lag behind the studies of other gases. There is insufficient evidence that either radiolysis or microbial actions generates a large enough volume of VOCs to affect the results of, or be included in, the gas generation model.

Solubility of VOCs in brine, the adsorption of VOCs to geological materials, and biodegradation of VOCs, or all of these considerations have not been adequately examined. Any of these effects would likely minimize the possibility of VOC migration to regulatory boundaries.

III.4.4. Gas Effects on Repository Performance

Observations: Currently, rock mechanics models predict gas pressures in the disposal room at various times and at different assumed gas-generation rates by coupling room closure with gas generation from waste. Modeling results reported during the review did not substantiate the thesis that extensive fracture propagation will take place along horizontal discontinuities. However, the continuum model which analyzes simulated gas pressure effects operates in a relatively simplistic manner. Neither two-phase fluid flow nor fracture propagation behavior is explicitly coupled to the mechanical model to allow prediction of the consequences of high gas pressures. The assumption that fractures will propagate or that existing fractures in anhydrite marker beds will dilate appears to be largely subjective, rather than being based upon any specific modeling results; WIPP scientists disagree about the validity of this assumption.

Model development aimed at more accurate characterization of the Disturbed Rock Zone that surrounds all excavations is underway (primarily to support seal design activities), but it is not clear that the more significant need for coupling of a fracture propagation/flow model will be addressed within a sufficient time frame to support gas generation aspects of PA.

Repository design concepts employed for WIPP currently aim at a final post-closure state having minimum achievable void space. This strategy includes optimum space utilization for waste storage (all rooms and entries will be filled to the maximum possible extent) and emplacement of salt or salt/bentonite backfill that will compact to minimal (less than 5%) void space in the transitional to long-term time frame. Despite minimizing gas volume at a given gas pressure, and thus minimizing stored energy, the strategy maximizes the likelihood of achieving fracture pressures, and does not appear to reduce the assumed gas generating potential of the waste inventory.

Assessments: Knowledge of the future environment inside the repository is the greatest source of uncertainty in modeling gas generation because of corrosion, microbial growth, and radiolysis. The rates of gas generation from both anoxic corrosion and microbial growth will probably be high if the waste is inundated with brine, but otherwise, gas generation will be relatively insignificant.

Recommendations: It is recommended that external sources of such programs be explored and representative analyses be performed to increase confidence in predictions of the consequences of high gas pressure on the repository environment. Computer programs capable of more realistic modeling of the coupled stress/flow problem exist and should be used to confirm present assumptions about the effects of high gas pressures. In recent years, considerable advances have been made in the capabilities of both geotechnical and reservoir engineering simulation programs, and there are examples of both that can model problems of this type.

Existing geohydrology codes should be used to determine if the repository environment is most likely to be dry, humid, inundated, or have mixed conditions during the 10,000 year life of the repository.

Engineered alternatives to the present design concept should be further explored to determine if aiming for minimum achievable void space results in optimum repository performance over the long term. The use of alternative backfills (such as coarse rock fill or pelletized gas getters) or increased repository volume are examples of strategies for obtaining similar waste containment with increased void space. Useful work in this general area was begun by the Engineered Alternatives Task Force, and the ITR Team recommends that further studies of repository design, storage configuration, and backfill methods be undertaken as part of future PA activities.

III.5. Testing with Radioactive Waste

The Bin and Alcove Tests are only a small part of all the tests or studies addressing gas behavior in the wastes, repository, and geological medium. The studies in the gas group, as well as most of the other studies in the Test Phase Plan, are written with a clear understanding of the technical issues involved, programmatic goals, and many constraints and uncertainties that lie on the paths to obtaining the necessary answers from the studies. Some studies are in various stages of progress, but many are thought of as being done at some future date.

III.5.1. Bin-Scale Testing

Observations: The Technical Needs Assessment Document (TNAD)[5], describes the Bin Test program as providing confirmatory information relative to the gas-generation model that feeds PA. A direct data input between the Bin Tests to the model or to PA does not exist. Consequently, it would be difficult to use the Bin Test data in verifying or directly confirming the models used for gas generation or PA.

The primary data to be obtained from the Bin Tests would be the time history of the gas-generation rates, gaseous species, and gas pressures within individual bins. In addition, the species in the brines in Type 2 bins would possibly be chemically analyzed at the end of the test period (1-5 years). However, the test data are stated as only indirectly linked to 40 CFR 191 and 40 CFR 268 because gas generation is not directly regulated by these two regulations. Rather, gas generation data is used to evaluate the potential for providing pathways for the loss of regulated contaminants (radionuclides or VOCs) from the repository if gas pressures approached or exceeded lithostatic pressure.

The latest test plan for the bin program was the "Test Plan: WIPP Bin-Scale CH TRU Waste Tests (Type 2 bin)"[6] and was specific to the Type 2 bins. An earlier test plan, which was published in 1990[7], suggested experiments with 144 bins (Type I), each holding about six drum-volume equivalents of contact-handled (CH) TRU wastes. These wastes were to be selected based on being representative of the national TRU waste inventory. The bin-scale test program was subsequently decreased in scope to include TRU wastes in only seven Type 1 bins and 12 Type 2 bins.

According to the Bin-Test Addendum #1, about six drum-volume equivalents of TRU wastes were to be loaded into a Type 1 bin; however, only five drum-volume equivalents were actually loaded into each of the seven Type 1 bins. Five drum-volume equivalents are intended to be loaded into a Type 2 container after they are characterized for their radionuclide content and waste matrix type. Other materials (metals, brine, salt, etc.) might be added to the bin depending upon the individual test to be monitored. The instrumented bin would be overpacked within another container. The rates and quantities of evolved gases would then be determined. While the Type 2 bins would have a design capability of 700 psia, they would be operated at a pressure of 150 psia.

Assessments: Bin Tests should not be conducted underground at WIPP. Comparable data can be acquired in scientifically-defensible tests at a location that imposes minimal constraints on the test conditions. Lessons learned from the design of the Type 1 bin and its associated instrumentation and control systems should be applied to any proposed alternate test design.

III.5.1.1. Type 1 Bin Testing

Observations: Type 1 Bin Tests would be conducted under nearly dry conditions, and the amounts of gas that may be generated in the one to two years of testing are expected to be very small. Increases in the gas pressure within the bins are expected to be of an order of 0.03 atm (about 0.4 psi). The head space of a Type 1 bin measures 500 liters. At the initial atmospheric pressure, it contains approximately 20 moles of gas. An increase in the pressure by a small magnitude of 0.03 atm corresponds to an addition of about 0.55 moles of gas to the head space.

Type 1 bin design is severely constrained by the bin's similarity to a Standard Waste Box. This has resulted in an extremely large lid gasket area which adds to the uncertainties in achieving the design criteria for leakage for each of the bins in the test matrix. Although the criterion for a helium leak rate of 10^{-7} cc/s was achieved in conformance testing, leakage of the bins and associated test systems is still expected to be a significant factor limiting the quality of the test data. It is probable that test data will be purely qualitative, at best confirming the general hypotheses of oxygen reduction and hydrogen generation, rather than providing data adequate to confirm or add confidence in the gas-generation model.

Instrumentation, control and sampling systems on the Type 1 bins have undergone extensive development and testing. They are believed to be reliable and it is unlikely that they will place significant constraints on data quality. Primary data will actually be derived from laboratory analyses of gas samples rather than the instrumentation system.

System designers have learned useful lessons from their work on the Type 1 bins that will be applicable to the design of any future large-scale laboratory test. In particular, the Westinghouse Model Shop at WIPP, in which recent control system work for the Type 1 bin has been undertaken, provides an effective engineering development facility for rapid solution of design problems.

Assessments: There are no apparent reasons for conducting Type 1 Bin Tests underground at WIPP. Type 1 Bin Tests fall far short of any reasonable expectations, and they would add nothing substantive to the demonstration of WIPP's ability to meet regulatory requirements. Any future comparison between the results of the Type 1 Bin Tests and of the gas-generation model may be disappointing and not worth the great costs and regulatory constraints placed on the execution of the tests.

Type 1 Bin Tests will be conducted with both dry and humid conditions. Since little or no gas was generated during bench-scale corrosion experiments conducted under dry and humid conditions, the results of Type 1 Bin Tests will be of limited value to PA.

The Type 1 Bin Tests, as currently designed[8], will not provide technically defensible nor sufficient data on microbial gas generation for use in the gas-generation and PA models. Some Type 1 bins, containing organic matter under humid conditions, may produce some carbon dioxide from biodegradation of the organic matter under oxic conditions. This gas generation, however, will occur very slowly, because the only microorganisms present to consume the waste are those resident on the waste when it was placed in the bins (Type 1 bins will not be inoculated). Insufficient gas will be generated during the time frame of the test to confirm the models before submittal of compliance documents. Carbon dioxide generation from microbial activity during the oxic phase would not be distinguishable from carbon dioxide generated from radiolysis. Because no post-test analysis of the contents of the bins is planned, no microbial growth or microbial bioproduct determinations can be made to confirm biological activity and gas generation. The method of analyzing the waste before filling of the bins does not allow for quantifying the amounts of cellulose and other organic matter present. Therefore, it is not possible to theoretically calculate possible gas generation from the microbial degradation of organic matter.

It is unlikely that anoxic conditions will be achieved in the Type 1 bins because of (1) the ingress of oxygen around the bin seals, (2) possible slow aerobic, microbial reaction rates during the time frame of the test, (3) possible lack of a resident, anaerobic, microbial population on the wastes (the Type 1 bins will not be inoculated), and (4) the possibility that no suitable electron acceptor (e.g. NO_3^-, SO_4^{2+}) will be available in the bin environment. Therefore, transitional and long-term time frames will not be represented in the Type 1 bin study.

The initial characterization of the wastes placed in the first six Type 1 bins is insufficient for any substantive analysis of gas generation that may be detected by the tests. The procedures of waste characterization for Type 1 Bin Tests include broad categories of different materials and their weights, but they do not include the necessary and more detailed data on the chemical and physical characteristics, or the data on the physical configuration of the waste in the bins. The bin-test procedures do not allow the bins to be opened and the waste examined at the end of the tests.

III.5.1.2. Type 2 Bin Tests

Observations: Type 2 Bin Tests include combinations of nonradioactive and TRU waste materials under humid or brine-saturated conditions, and in the presence of the backfill material, presently thought of as a mixture of rock salt (70%) and bentonite (30%)[9]. The bins will be operated at a total pressure of up to 10 atm (150 psi), for a period of two to five years. A stringent oxygen-exclusion criterion specifies and oxygen penetration rate of no more than 2 ppm per year.

The gas-generation results of Type 2 Bin Tests will be compared against the predictions of the gas-generation model. If the bin-test results fall within an acceptable band of the model predictions, the tests will be considered to add confidence to the gas-generation model. If not, experts will be convened to analyze the discrepancies. Interpretation of the Type 2 test results will also be constrained because there is no planned examination of the bin waste at the end of the tests, and the brines will be sampled only once at the end of the tests.

Instrumentation and control systems for the Type 2 bin have not been designed, although much of the same equipment developed and tested for the Type 1 bin is likely to be directly applicable. This applies particularly to the Data Acquisition Package. Pressure and temperature are the primary data required from the Type 2 bin instrumentation; other instrumentation such as oxygen sensors and humidity gauges are considered to be of secondary importance because primary data would be obtained from head space gas sample analysis. Primary instrumentation is expected to perform within the specified DQO limits, although difficulty in locating secondary instrumentation capable of functioning at high pressure was identified as a problem by project personnel.

A detailed design of the hardware for Type 2 Bin Tests does not exist. The shape of the pressure vessel is unknown (spherical vessels, cylindrical vessels with elliptical ends, and cylindrical vessels with flat ends are all under consideration). Adequate materials for construction of pressure vessels and related hardware have not been identified. PNL's knowledge and experience in the design of pressure vessels for corrosion testing has not been made directly accessible to Westinghouse engineers.

Westinghouse has investigated commercially available pressure vessels for Type 2 bins. However, there are a number of constraints on the Type 2 bins that may preclude using such commercial hardware for the proposed in-situ tests. For example, these pressure vessels must be shippable in a TRUPACT-II container. Furthermore, each vessel must be able to hold the contents of 5 waste drums at elevated pressure. These constraints are summarized in DOE/WIPP 93-037[10] and are based on SNL specifications.

Several commercially available pressure vessels have been proposed for Type 2 Bin Testing, including a spherical pressure vessel. The estimated cost of a commercial vessel, capable of meeting all SNL specifications, is approximately $90K, assuming 304L or 316L stainless steel is the material of construction. The pressure vessels would have a maximum operating pressure of approximately 300 psi (psig).

It is very difficult to seal pressure vessels for high pressure corrosion and gas-generation experiments, but no detailed seal design beyond the conceptual stage has been prepared for Type 2 bins. A vacuum-flange seal design has been proposed, as well as a design that is based on two concentric, soft-annealed, solid-nickel O-rings. According to SNL, such metal-metal seals should be able to handle the nominal operating pressure of 150 psi (psig) very easily. SNL also noted that such a seal should be compatible with the materials used to fabricate pressure vessels.

Assessments: The Type 2 Bin Tests, as currently designed[11] will not distinguish between differing gas-generation mechanisms (corrosion, microbial degradation, radiolysis), and are inadequate for characterizing microbial gas generation for the WIPP facility during the ventilated, transitional and long-term time frames.

The practical experience with pressure vessels and results of corrosion testing gained at PNL have not been adequately communicated to those responsible for the design of the Type 2 bins. Though pressure vessels for Type 2 Bin Tests will contain a relatively corrosive brine, with both magnesium and chloride ions, little thought has yet been given to the possibility of stress corrosion cracking. During extended testing under these conditions, both 304 and 316 stainless steels, which are the materials proposed in the conceptual design of Type 2 bins, are prone to stress corrosion cracking in magnesium-containing brines. Hastelloy C-22, Hastelloy C-276, and Inconel 625 are less susceptible to such failure, will not contribute to gas generation and should be investigated as a material of construction.

There appeared to be considerable uncertainty that the Type 2 bins can achieve their required leak tightness. In addition, some Project personnel expressed concern that the contained waste matrices in the bins would outgas oxygen for a very long time, thus preventing anoxic conditions from being achieved.

The difficulties and uncertainties in waste characterization that were mentioned in the assessment of Type 1 Bin Tests carry to Type 2 tests as well. In Type 2 tests, the pressure limit of 10 atm is not justified by any known behavior of the solid-brine-gas systems under the expected repository conditions, where the pressures may go much higher, into the hydrostatic or lithostatic range of about 65 to 150 atm.

Since wastes will be inundated with brine in Type 2 Bin Tests, the rate of gas generation is expected to be significant.

Some Type 2 bins will be inundated with a brine containing a microbial inoculum derived from WIPP brine, muck and other sources (surface lakes and sediments). Microbial gas generation from these bins is expected. However, the design of the Type 2 Bin Tests precludes obtaining technically defensible data because:

- Other gas-generation mechanisms can potentially produce the same gases as microbial degradation. An exception is N_2O, a distinctive microbial gas product. Therefore, gas-generation mechanisms can't be assigned.

- The pressure limit on the Type 2 bins is well below the lithostatic pressure that could potentially be developed after repository closure and gas generation. Therefore, the effects of gas pressure on microbial activity will not be evaluated in this test program.

- The characterization of the waste being placed in the bins is not sufficient to theoretically calculate gas generation with sufficient accuracy to correlate the results with actual gas generation.

- After the tests are completed, the bin waste contents will not be analyzed; therefore products of microbial degradation, corrosion and radiolysis will not be determined. This will not allow for determining mass balance, quantifying gas generation based on mechanisms, or assessing synergistic/antagonistic mechanisms controlling gas generation (e.g. the passivation of metal due to microbial carbon dioxide generation).

- The proposed brine analysis is inadequate to analyze microbial activity for correlation of microbial gas generation. Microorganisms generally attach to solid products (in this case, the cellulosic materials in the TRU waste) making it impossible to adequately correlate microbial populations in the brine with actual conditions in the solid materials and gas production.

The design of experiments and hardware for the Bin Tests are inadequate. Specific problems include: poor waste characterization; an unrealistic test environment; incomplete design for the pressure vessel and seal; and limited use of instrumentation. Ideally, a bin should be able to contain waste from six drums, operate at lithostatic pressure, and fit inside a TRUPACT II container. However, such vessels could be too large and too heavy to fit inside a TRUPACT II container, under current container constraints.

Originally, Type 2 Bin Tests were to be conducted at elevated (lithostatic) pressure. However, SNL/WPIO have decided to limit the operating pressure to 150 psi (approximately 10 atm). This pressure is not based on scientific reasoning or the needs of PA.

The current experimental plan calls for only one brine sample at the end of the experiment. More frequent brine sampling would require periodic circulation of the brine so representative samples could be obtained. Such circulation would perturb rates of mass-transfer conditions and gas generation in the bin, making results difficult or impossible to interpret.

The duration of Type 2 Bin Tests will be relatively short compared to the life of the repository and cannot be used as justification for doing the tests. The duration of these tests is comparable to the duration of bench-scale experiments that are better controlled and characterized.

III.5.1.3. Waste Characterization

Observations: The Type 1 Bins were filled at the Argonne West facility at Idaho with "real" TRU waste that originated at Rocky Flats, and was stored in the Air-Support Building at Idaho National Engineering Laboratory (INEL). There are approximately 33,000 drums of waste stored in the INEL Air-Support Building, of which approximately 9,000 were identified as being certifiable for shipment to WIPP under the existing WIPP Waste Acceptance Criteria (WAC). A summarized version of the existing WIPP WAC and relevant transport regulations is attached as Table III.5-1. A statistical sampling program was recommended by SNL to randomly select the required number of drums from this population, for the Bin filling. It should be noted that only whole drum contents can be taken and placed into the Bins, to avoid the situation of generating new waste if drum contents were allowed to be split and segregated.

In total, over a period of almost 2 1/2 years, seven Type 1 Bins have been filled with TRU waste. Each bin contains the waste from 4 or 5 TRU waste drums. Table III.5-2 summarizes the contents of the first six Bins filled. Bin 7 was still undergoing data QA checking at the time of the review. The drum contents were originally selected from their TRU Contents Codes (TRUCON Codes), and at the time of commencement of the filling operation, it was intended to fill some 144 Bins. Hence, although it now does not seem appropriate that three Bins contain mainly glass waste, at the time of filling, these Bins were only to be a small proportion of the overall number. Glass waste is fairly innocuous, in that it is not expected to generate significant quantities of gas but it is also relatively easy to identify and to certify as compliant with Transportation and WIPP WAC requirements.

The filling of the bins at Argonne West was carried out within a hot-cell facility, using remote manipulators to handle the waste. Before entering the hot-cell, drums were examined using Real-Time Radiography and NDA (Non-Destructive Analyses), and were headspace gas sampled, to analyze for the presence of VOCs. Real-Time Radiography is basically x-ray examination of the drum, to look for the presence of noncompliant materials (e.g. free liquids), and NDA is used to give an estimation of the plutonium content, by assessing neutron and gamma energy emissions from the drum. The Real-Time Radiography operators also estimated the weights of the individual items, by type, within the waste (e.g. weight of

Table III.5-1. **Summary of Radioactive Waste Acceptance Criteria**[12,13]

Criteria	TRU Waste
General	Heavy and bulky objects must be blocked or padded so as to not damage container during shifting
Containers	55-gallon drums or Standard Waste Boxes (assay only). All containers must be fitted with a filtered vent.
Package Weight	1,000 lb. gross for 55-gal drums 4,000 lb. gross for Standard Waste Boxes
Free Liquids	Less than 1 vol% in internal containers, aggregate amount < vol% of external containers
Explosives & Compressed Gases	No explosives permitted, gas cylinders must be permanently vented and drained.
Particulates	Immobilization of Particulates required if over 1 wt% is below 10 micron diameter or if over 15 wt% is below 200 microns in diameter
Mixed Waste	Must be characterized and exist as co-contaminants
Thermal Power	Maximum of 20 watts per Standard Waste Box, 2.85 watts per 55-gallon drum, or 40 watts per TRUPACT; further restricted by content code and number of packaging layers.
Fissile Material	Including two times the measurement error, shall be less than 200 grams ^{239}Pu FGE per Drum, 325 grams per Standard Waste Boxes, or 325 grams per TRUPACT; further restricted by content code and number of packaging layers
Plutonium Equivalent Activity	No more than 1,000 Plutonium equivalent Curies (PE-Ci) per container.
Dose Rate	Maximum 200 mrem/hr Total at surface and max of 10 mrem/hr at 2 meters. Neutron contributions of >20 mrem/hr must be documented.
Surface Contamination	Maximum 50 pCi/100cm^2 alpha; 450 pCi/100cm^2 beta-gamma (as matter of practicality, no detectable removable surface contamination will be acceptable).
Labeling	DOT Labels, RCRA Labels, Bar Code ID Number. Labels must have 10 Year life expectancy
Data Package	Data Package required for each container with certification statement and all data identified in WIPP/DOE-69.

Table III.5-2. Type-1 Bin Contents Summary

Waste Cat.	No. Drums	Pu (g)	Comments
Glass	4	73.67	Mainly glassware plus Raschig rings some plastic (bags and polybottles) some cellulosics (fiber- board) some metal plus vermiculite/oil-dry.
Glass	4	9.98	Glassware/Raschig rings 132 kg steel 11 kg plastics 18 kg cellulosics 6 kg plus vermiculite/oil-dry.
Metal	5	9.56	Cellulosics 1 kg plastics 21 kg rubber 4 kg steel 100 kg Al 36 kg other non-corroding metal 7 kg vermiculite/oil-dry 8 kg.
Metal	5	14.10	Cellulosics 6 kg plastics 22 kg rubber 3 kg steel 175 kg Al 16 kg other non-corroding metal 39 kg vermiculite/oil-dry 7 kg.
Combustibles	5	9.11	Cellulosics 16 kg plastics 65 kg rubber 41 kg steel 6 kg non-corroding metal 33 kg vermiculite/oil-dry 45 kg.

plastics or cellulosics),utilizing both the TRUCON Code data and the Real-Time Radiography data. The drums of waste were then posted into the hot-cell, and were opened and their contents removed. Individual packets in the drum were opened, and contents were classified by type, weighed, and loaded into the bin. Samples of the atmospheres within packets were taken for analysis for VOCs. The whole process was recorded on video tape, and was well documented and QA checked.

Assessments: INEL had little operational experience using Real-Time Radiography when the bins were filled, and a great deal of valuable hands-on experience was gained from this process.

In the future, certification for WIPP-bound waste will be primarily based on a combination of process knowledge, Real-Time Radiography (or an equivalent non-destructive examination) and NDA. Because access to the waste is limited by radioactivity, and because there is no desire to set unnecessary precedents adversely affecting future generators, the level of waste characterization carried out for the Type 1 Bin Tests was considered acceptable.

Recommendations: Even though the waste characterization for the Type 1 Bin Test was probably as good as it could be, better characterization and understanding of the waste source term should rely on laboratory testing. Laboratory testing can utilize real wastes, can be undertaken at different scales, and above all else, offer the capability of carefully controlling the input materials. Laboratory testing could evaluate the complete segregation of controlled amounts of waste materials, then assess controlled combinations of materials to look for synergistic effects.

III.5.1.4. Bin Tests and the Repository

Observations: Room 1, Panel 1 provides a stable environment for the proposed bin scale tests. Roof support has been proven adequate in the short term and it is highly probable that safe conditions will be maintained for the duration of the planned test phase. Temperatures remain reasonably stable (varying annually by about 7° C) and the room is clean and reasonably dust free. No detrimental effects on test instrumentation or test data quality assurance are expected to result from their being conducted underground. However, interdependencies between the test objectives and the proposed test location present some constraints that may limit the value of the tests and that detract from the WIPP mission of demonstrating safe disposal of TRU waste.

With regard to the test objectives, requirements for purging flammable gases from the Type 1 bins, and possible difficulties in maintaining absolute humidity in Type 1 and Type 2 bins at a value equivalent to closed repository conditions, have the potential for limiting the data value.

Assessments: Room 1, Panel 1 contains roof support far in excess of requirements for roof support in an operational repository. There have been some benefits derived from the design, installation and monitoring of the support system, particularly with regard to developing an understanding of roof deterioration. It is noted, for instance, that analysis of load cell results has caused a change in assumptions regarding mechanisms of roof deformation. Nonetheless, it is felt that using a disposal panel room as a long term test site is a departure from the WIPP mission unless waste-repository interactions are being studied specifically. Using a room merely as a surrogate for a surface laboratory imposes constraints that may later be viewed as precedents for other tests or for repository development.

III.5.1.5. Post-Test Brine Sampling

Observations: Sampling will be performed at the end of Type 2 Bin Tests, but periodic brine sampling during the testing would require agitating the liquid in the brine, thereby disturbing the gas-generation mechanisms. Active (periodic) brine sampling could be done during the experiment, but it would be more difficult, and must be done in accordance with DOE Order 6430.1A. A conceptual design for brine sampling was shown using a simple siphon[14]. Westinghouse has visited nuclear reactor sites to investigate radioactive liquid sampling techniques with glove boxes.

Westinghouse WID has a requirement that before receiving waste (for Tests, or any other reasons) there must be a means in place to return, to the point of origin, waste and potential waste arising from abnormal occurrences. In the case of the Type 2 Bin Tests, the capability to remove all liquid (brine) from the Bins following test completion must be provided, and such liquid must be immobilized for return. The pre-conceptual design of the proposed immobilization process would circulate hot gas through the Bin, followed by the application of a light vacuum to condense the liquid as "clean" water. WID also proposes to use computer tomography to certify that the bins are effectively free of liquids.

Assessments: Useful chemical information could potentially be obtained from brine analyses. However, specific information on how the brine would be removed from the Type 2 bins and stabilized, or the costs associated with the process, were not available. A very rough ITR estimate of the cost for an immobilization facility would be in the tens of millions of dollars, yet WID's cost estimate for this facility was reported to be in the range of a few million dollars.

The process for liquid immobilization is unproved, and will probably require significant design and development activities.

III.5.2. <u>Alcove Test Program</u>

III.5.2.1. Test program scope

Observations: The TNAD[5] described the Alcove Test program as being relevant to compliance with 40 CFR 264, Subpart X, 40 CFR 268, and 40 CFR 191. The Test Phase Plan[15] provided a brief narrative on the design of the Alcove Test. The new Alcove Test plan[16] was refocused to provide data to address 40 CFR 264 and 40 CFR 268. As currently proposed, the primary data to be obtained is the VOC concentration in the alcove atmosphere. The Alcove Test plan stated other potential test objectives, but provided qualifiers that many of them might be unobtainable.

In addition to the VOCs, the Alcove Test plan requires measuring other gaseous co: ponents in the alcoves. However, no measurement of the total VOC inventory in the tested drums was proposed (nor is it feasible). Consequently, the source term for the VOCs would be unknown.

III.5.2.2. Test Plan definition

Observations: The Final Draft Alcove Test Plan[17] provides background information on the development of the Alcove Test program. Portions of this section of the ITR report are taken from that test plan.

The original Alcove Test plan [18], published in 1990, proposed a test matrix of up to six alcoves with up to 3850 drums (total) of TRU waste selected to be representative of the major categories of the national TRU waste inventory. Based on certain NAS concerns, the Alcove Test was decreased in scope to one alcove with 1050 drums of TRU wastes and another alcove as a control, i.e., no TRU wastes in it.

For the tet, the 1050 TRU drums would be emplaced in an alcove and allowed to emit gases into the alcove atmosphere. The proposed alcove would have one quarter the volume of a full size disposal room. It is expected that it would be somewhat more geologically stable than a full size room because of its smaller width (25 ft versus 33 ft). The number of drums to be emplaced (1050) is approximately one sixth that for a full size disposal room. Consequently, the VOC releases into an alcove would be expected to produce a lower concentration than in the full room.

A conceptual seal barrier is proposed to contain the evolved gases, yet allow sampling of them for chemical analysis. This seal will be specifically designed for the alcove and will not provide useful data for design of seals used in the disposal phase.

The alcove gas seal barrier seal has very stringent leakage requirements (~1% alcove volume per day). These requirements can probably only be satisfied if a very stiff liner is installed as soon as possible after excavation. However, the proposed alcove gas barrier design is only conceptual. Thus, it has not been possible to review it critically. Room or panel seals will be of different construction from the conceptual (and most likely) alcove gas barrier and will not be installed under similar circumstances. Therefore, little of the experience gained in constructing and monitoring the alcove gas barrier can be directly applied to disposal room seals.

Some gas losses into the Disturbed Rock Zone around the alcove will occur. These losses will be difficult to quantify. The Final Draft Alcove Test Plan notes that there is considerable uncertainty in the estimates of total leakage and that the upper limits of those estimates would lead to an unacceptable test. Using the upper leakage limit stated in the test plan, as much as 50,000 liters/day could leak into the Disturbed Rock Zone. This level of leakage represents about 80% of the void volume of the alcove.

Geometrical and age differences between the alcove and disposal rooms are likely to result in considerably different loss rates. These uncertainties make it both difficult to plan a valid test and to extrapolate the test data to a meaningful analysis of disposal phase operating conditions.

Assessments: The Alcove Test plan is insufficiently developed and has no technical basis for compliance demonstration. The latest version of the test plan (1) showed large improvements from the first test plan However, many details were still at a conceptual rather than a specific and concrete stage. Frequent comments required cross referencing between the test plan documents; this caused additional confusion in the ITR Team's review of the test plans. This lack of a unified test plan document was viewed as an additional weakness of the test program.

Because the total amount of VOCs in the test drums would not be measured, the source term for the gases cannot be estimated. Measurements of VOCs in the wastes will have to be made at the waste generating sites, e.g.. INEL, WHC, LANL, SRS, etc. if these data are required. Data of this type is currently being generated at INEL where some capability for modeling VOC emission rates is being developed[19]. Drum headspace analyses will allow defensible statistical VOC concentrations to be determined from large drum populations and enable reasonable predictions of emission rates to be made. Storage buildings at the generator sites allow VOC concentrations in ventilation air to be quantified in an environment without large uncertainties introduced by losses that bypass the collection system. Continued support for this work is encouraged. The data will be of significant value in designing disposal room ventilation systems that can provide air quality within regulatory limits.

An additional concern was that corrosion of test drums could occur if there were puddling of brine and subsequent contact of the brine with the drums. Such corrosion could lead to radionuclide releases during retrieval with a subsequent increase in the volume of TRU waste because of contamination of the salt and brine. This could pose a significant, but not insurmountable, decontamination problem.

The alcove will not be backfilled, therefore any absorption of VOCs that might occur in the backfill, and any effects of the backfill on gas diffusion rates will not be addressed.

Requirements for waste retrievability during the test phase (mandated by the LWA and No Migration Determination) place additional constraints on the Alcove Test that limit the test's value. For instance, backfill cannot be used, as noted above, and roof support must be installed to ensure safe conditions for the duration of the test. The effect of potential roof collapse on drum integrity cannot be assessed. Sudden VOC or radionuclide releases associated with the breaching of drums by a large roof fall are a potentially significant operational problem, but one that cannot be addressed by the proposed test phase. In general, the limitations of maintaining retrievability (if only in theory) minimize the interactions between the waste and the repository that would be the strongest justification for underground testing.

Retrieval of waste from any underground test that approaches operational conditions would be extremely expensive. Even minor problems, such as leakage of just a few drums because of corrosion at the floor level or drum penetration from a failed rock bolt could cause major difficulties. Seepage of contaminated brine into fractures in the floor could occur. Recovery of this material would require mining equipment that would in turn be contaminated. Rehabilitation of roof support in the event that roof instability was detected would probably require working above stacked drums with limited headroom. It would be difficult to demonstrate sufficient confidence in predictions of roof falls to allow work crews to access the room for drum retrieval without some remedial rock bolting. The risk of these difficulties, while small, is not warranted for obtaining the type and quality of data expected from the Alcove Test program.

Failure of either the roof rock or elements of the roof support system may result in breaching waste drums, and would considerably increase the cost and difficulty of waste retrieval during a disposal phase. Furthermore, roof support designs which ensure at least 5 years of maintenance-free life without failure of either part of the salt roof or some of the rock bolts has not been demonstrated at WIPP. Mechanically anchored rock bolts, used in the conventional drift roof support at WIPP, can fail under high loads, and are susceptible to an increased likelihood of failure in the more humid and corrosive environment of a sealed alcove[20]. The roof support in Room 1 Panel 1, which is the most thoroughly researched support system at WIPP, is expected to provide reliable support for considerably longer than 5 years, but it requires regular maintenance. If the tension in the bolts is not relieved regularly, they would probably fail. In fact, the precedent set by this overly-engineered roof system is believed to be an impediment to future, more rational roof support design. A different, still conceptual, roof support system being considered by project personnel uses new rock bolt technology with sliding nuts, but the concept has not been tested with corrosion protection needed in the humid repository atmosphere. The roof support system for the alcove has not yet been chosen and was not reviewed.

Recommendations: The Alcove Test program should be abandoned. Data on VOC emissions from large populations of drums can be obtained more cost effectively and accurately from measurements taken at generator sites. VOC emissions from sealed panels via the Disturbed Rock Zone and open fractures within marker beds may be a concern during disposal operations if they occur in areas with low ventilation rates, or if the leakage rates are sufficiently high to impact the overall repository air quality. However, leakage effects can best be estimated from the previously mentioned VOC data and gas leak tests using representative panel seals. The Alcove Test is unlikely to reduce significantly the uncertainty in the results of these calculations because of differences in seal design, drift age and geometry, as noted above.

A test similar in concept to the Alcove Test may be more appropriately incorporated into the disposal phase, when it could provide data on gas and VOC emission from TRU waste under realistic repository conditions. The ITR Team has made no assessment of the operational or regulatory need for these data. A large-scale test replicating repository conditions to assess disposal phase health hazards related to VOC emissions could also be considered during the disposal phase.

Seal tests proposed by SNL to support disposal phase seal design should be completed independently of the Alcove Test.

III.5.2.3. Alcove Test Contribution to Technical Information Needs

Observations: Based on interviews, data to be generated by the Alcove Test program would not have any linkage to either the gas-generation model or PA. The program was generally described as ". . . having the potential for showing scaling and synergistic effects of the waste within the repository." No details on the specific effects were provided by Project personnel. No suggestions were provided for how data could be extrapolated to the national TRU inventory.

The TNAD suggested that potential decreases in radiolytically generated gases might be observed in the TRU alcove. However, Attachment B to the test plan provided calculations that showed that only very small amounts of radiolytically-evolved gases would be generated. It will be difficult (or impossible) to measure small changes in gas generation if the total gas produced by radiolysis is small to begin with.

Absorption of VOCs onto the alcove walls as well as migration into the Disturbed Rock Zone cannot be accounted for from the test data to be measured.

Assessments: There is no connection between the Alcove Test data and PA. Although VOC data will be required to support a disposal phase NMD, the Alcove Test program will not provide that data in a cost-effective manner.

Project personnel provided the ITR Team with documentation that estimated costs of 20M$ for the alcove program, yet waste characterization efforts were estimated at 19.4M$ in the WIPP Desk Reference Manual. Other, more cost effective methods for obtaining the VOC data appear to be available as noted previously.

The Alcove Test Program, as proposed[21], will not provide data on microbiological gas generation or any information on microbial degradation of VOCs. No significant biodegradation of TRU waste constituents is expected to occur in the Alcove Test[22], because of the low moisture content of the wastes deposited in WIPP and the short duration of the tests.

Microbial degradation of VOCs adsorbed to rock matrices potentially could occur, diminishing the likelihood of VOCs reaching the WIPP regulatory boundaries through fractures. Subsurface biodegradation of some VOCs is used effectively in a bioventing process for soil remediation. This entails using microorganisms attached to mineral particles (a biofilter) for in situ degradation of VOCs transported in air[23,24]. Conceivably, microorganisms that have already been enriched and isolated from brine and solid samples collected underground at WIPP[25] could colonize rock surfaces and degrade VOCs adsorbed to rock materials. Adsorbed VOC biodegradation testing could be completed inexpensively and expeditiously by coupling SNL's bench-scale VOC adsorption test plan with a microbial degradation study.

To provide stability of the Alcove Test room for the duration of the test and to ensure retrievability of the emplaced TRU test wastes, very stringent roof support would be required. The use of such an extensive support system might establish an unnecessary precedent for the repository during disposal operations with attendant increased disposal costs.

III.5.3. Bin and Alcove Test Integration with Laboratory Tests

Observations: There is no connection between the VOC data being obtained at INEL and the Alcove Test program. From preliminary information provided to the ITR Team by INEL personnel, the VOC data obtained there appear to correlate reasonably well with a VOC model that the INEL personnel have produced. Enhancement of their model and measurements appears to be more cost effective and timely than pursuit of the Alcove Test.

The integration of gas-generation modeling with bench-scale laboratory studies of corrosion, radiolysis, and microbial gas production is very good. Information is exchanged both ways. Unfortunately, Bin Tests don't adequately complement the bench-scale laboratory test program because the Bin tests provide only partial confirmation of the gas generation model.

Assessments: The Alcove Test program is not integrated into the lab-scale or bin-scale test programs. No data feeds exist between them. The Alcove Test program will not provide data to support long term waste isolation in the repository.

III.5.4. <u>Repository Conditions and Operations</u>

Assessments: The WIPP underground should be used for tests related specifically to advancing the knowledge of waste containment and repository performance. Long term maintenance-free stability of rooms is not a reasonable expectation in bedded salt at a depth of over 2000 feet; in fact the reason for choosing WIPP as a repository site was in part the ability of salt to deform rapidly to encapsulate and immobilize the waste. Tests having this requirement of long term stable environments should be conducted at other locations.

Further lessons can probably be learned from continued monitoring and adjustment of the Room 1 support system and it is recommended that this work be continued until detachment of the roof slab from the main roof has occurred. This is likely to provide information on the development of shear fractures and bed separations that will have value when designing room monitoring systems during the disposal phase. This is particularly relevant since Room 1 is likely to be the least stable room of each panel.

The WIPP can justifiably be regarded as a state-of-the-art facility, containing excellent equipment that is extremely well maintained. It has served as the site for some first class research that has benefited both the goal of waste disposal and more generally, the technical community involved in underground mining and disposal. However, once waste is emplaced in WIPP, there will be little flexibility for large-scale experimentation with mining methods like those occurring at most mines. As a result, the operator must make the most of every opportunity to learn about the behavior of the rooms and repository, and to develop mining skills prior to waste disposal. It is important to note that there is presently a very small area of 'open ground' at WIPP, and that ground conditions may be very different by the time Panel 8 is mined.

Panel 1 offers opportunities to test various room profiles to determine their stability and closure rate and to develop the monitoring procedures that will be used in disposal rooms. Some work along these lines is underway and should be continued. Room profile tests can be undertaken relatively cheaply and will be helpful in maintaining operator skill in the pre-certification/permitting period. The aim of room profile testing should be to develop roof shapes that can be maintained safely with a minimum degree of artificial support. This will result in reduced likelihood of drum breaching from large rockfalls during the disposal phase and will minimize bed separations in the roof, thereby enhancing waste containment.

Engineering staff from the M&O have visited a few evaporite mining operations to widen their experience of design and ground control techniques. Roof and floor stability in bedded salt is highly dependent upon relative room and pillar widths and roof/floor beam thickness. Gas emissions from disposal rooms, in which only minimal seals are expected to be placed, may be sensitive to roof and floor bed separations. Lessons regarding mitigation of these problems can be learned by a wider review of North American mining methods and close contact with mining companies.

Engineering staff should be encouraged to share operational experience with the technical community, in addition to the primarily theoretical developments that are shared today. The mining industry comprises many individuals and companies with extensive practical experience who can critically review operational information, but relatively few who can offer useful opinion on salt mechanics theory.

Backfill systems: Backfilling is practiced in several evaporite mining operations around the world, but experience with placing fill in the confined geometry anticipated in disposal rooms is limited, and has in general not been very encouraging. The operational difficulties of placing fill close to the roof, above and around waste drums should not be overlooked. In particular, there is a big difference between placing small amounts of fill for a single test and running a system on a continuous or regular basis. Dust, corrosion, and spill clean up are typical problems that may severely limit room or equipment availability. Low in-place densities are typical with dry placement systems unless very coarse backfill is used with a high speed pneumatic or mechanical flinger system. Although some problems may have been studied already, the time needed to implement and prove an effective operational backfill system should not be underestimated.

Instrumentation: The instrumentation that is being used and will be used in the disposal phase is standard "off the shelf" equipment, and there are no apparent instrument issues. The operational tests and commissioning phase will provide DOE with the opportunity to test the instrumentation under real repository conditions. The repository environment will be a harsh environment compared to laboratory conditions. Dust and possibly humidity will have to be dealt with on a normal routine basis. Instruments will have to be located and protected from unanticipated rock movement (i.e.. roof fall or rock slip) and from operators and machinery working in the tight and somewhat darker areas of the underground repository openings.

Operational scale-up: Any mine, repository or plant in which several processes must work together to facilitate safe and efficient completion of an overall objective must be commissioned according to a carefully controlled plan.

M

WIPP is an unusual facility in that it has functioned for a number of years as a scientific test site and many of its components have been used to support those tests rather than the longer term mission of safe TRU disposal. As a result of this long period of activity, there may be a temptation to view it as an operationally ready facility, rather than one that only is in the first stage of the Engineering project plan described above. Reliance on in situ tests such as the proposed Bin Tests tends to enhance the image of operational readiness while actually deflecting resources from the real tasks required for commissioning. As an example, waste handling and health physics personnel have concentrated for several years on procedures for the receiving, purging, and transferring underground of seven Type 1 bins. The real goal of being able to handle tens of thousands of drums and Standard Waste Boxes each year has become subsidiary. This is believed to be a serious shortcoming in medium and long term planning.

Engineering Operations Testing. The main objective of the testing phase of a project is to demonstrate that all engineering systems are installed and function correctly. Simplistically, this could be thought of as checking that everything functions once. The main stages of the testing phase can be summarized (in generic terminology) as:

Performance Acceptance Tests (PATs): These tests check that equipment has been constructed and installed in accordance with Engineering Drawings. PATs may be carried out at an equipment manufacturer's facility, but may also need to be repeated on installation at Site, to confirm that no damage has occurred during transportation. At this stage of testing, no sources of external power (e.g. electrical, hydraulic, etc.) are connected to machinery. Dimensions and material of construction are checked, moving components may be moved by hand to check freedom from interferences.

Loop Acceptance Tests (LATs): These tests check that control loops function appropriately (e.g., if a level detection switch is reached, then the signal to switch a pump is sent).

Facility Acceptance Tests (FATs): These check that engineering sub-system function correctly, and allow sub-systems to be combined to correct facility operation. At this stage of testing, power is applied to moving components, control loops are integrated into testing, and whole sections of the facility are operated.

Following completion of the above three stages of testing, it will have been demonstrated that the facility has operated at least once. At this stage, where appropriate, a facility can be handed over from an Engineering (Construction and Installation) Contractor to the Operating Contractor. In the case of WIPP, the M&O Contractor has responsibility for both these functions.

III.6. Associated Test Issues

III.6.1. Management

Observations: During this review, changes in the WIPP project management structure were being made by the DOE, consistent with the views and management policies of DOE/HQ, and the WIPP mission statement.

III.6.1.1. Management Path Forward

Assessments: Increased regulatory and stakeholder oversight, changing regulatory requirements and uncertain compliance criteria have produced an attitude of risk aversion which impedes changes in programmatic direction and organizational culture, though the benefits may be clear.

Although the Bin and Alcove Test Program may originally have been based on scientific merit, it appears to the ITR Team that the Bin and Alcove Tests have evolved in response to a perceived need to introduce radioactive waste into the repository.

Recommendations: The WIPP mission statement should be used as the basis of a clear vision of the path forward. WIPP management should use this vision to create an organization committed to successfully obtaining certification and permits within a defined period contingent on EPA and NMED actions.

The WIPP management structure should be based on strong, focused leadership that develops clear lines of authority, responsibility and accountability. To support this, management changes should be directly tied to the future state of the project, as proposed in the WIPP Near Term Path Forward, the Allocation of Mission, and the WIPP Work Flow (Chapter II). These should be presented, with other basic management information, in the WIPP Project Management Plan.

Management decisions about WIPP activities and testing should be clearly based on scientific merit and linked to technical data needs derived from PA and compliance demonstration. The Bin and Alcove Tests could fill that need, however, regulations governing activities underground at WIPP limit the scientific justification and value of the tests. Future non-technical WIPP decisions should be preceded and supported by a firm technical and scientific foundation.

The conflicting and changing desires of multiple oversight and stakeholder groups contribute to a lack of project focus. This should be managed by assuring availability of information and an increase in the level of interaction with regulators, stakeholders, and oversight groups. Before decision points are reached, WIPP should discern the values of oversight and stakeholder

M

organizations, and create oversight and stakeholder understanding of the WIPP path forward. With proper preparation, decisions should become pro forma.

III.6.1.2. Programmatic Document Hierarchy

Assessments: The hierarchy of project documentation was unclear. Many documents normally associated with a project of the magnitude and complexity of WIPP were not found. The WIPP Project Management Plan, for example, was still in draft form, and was not used to manage the project. The apparent lack of system engineering plans, operating program plans, and a DQO process are other examples.

Recommendations: Decisions at upper management levels are generally based upon summarized information. Concise overview documents discussing key project issues are an important element of effective management and decision making. For complex projects like WIPP, the executive summaries of a series of large reports are an inadequate substitute for short, clear, overview documents explaining key issues in non-scientific terms. The WIPP project management plan should be completed consistent with the near term path forward and serve as the cornerstone document defining key project issues in concise and understandable terms.

III.6.1.3. Tenure of Personnel

Observations: The tenure of many WIPP Project personnel (DOE, SNL, WID) in their present positions is short. Personnel turnover appeared to be high. For example, over a period of three years, there were three SNL bin-scale test project managers, and the SNL principal investigator was changed. Similar personnel turnover has occurred within DOE/WPIO. Often, project personnel lacked the general knowledge necessary to answer questions beyond their areas of job specialization or tenure. Perturbations in management and test plans, coupled with regulatory changes make it difficult for project personnel to understand their roles in the path toward certification and permitting. Loss of knowledgeable personnel impedes progress by reducing the understanding of the historical context of the project (i.e., corporate memory) and increasing the potential to revisit past problems and decisions.

Recommendations: The WIPP project should view the retention of capable, knowledgeable personnel as important to program success. Communication should be maintained with knowledgeable people no longer active in the project so that historical perspective is maintained during changes in staff and direction.

III.6.1.4. Intra-Project Communication

Observations: A significant number of organizations are involved within the WIPP project. It was unclear that communication among these organizations is structured and focused on the achievement of the common WIPP Mission. For example, key issues identified by performance assessment as critical to regulatory compliance were not communicated to many program participants.

Each organization (DOE, SNL, WID) has its own Quality Assurance plan. It appears that these Quality Assurance plans are not connected through a normal flow from DOE to Westinghouse and/or DOE to SNL.

The Westinghouse Quality Assurance plan is being transformed into a less prescriptive graded NQA-1 program. A program that is not prescriptive is more readily accepted by project participants, and can enhance progress. A graded NQA-1 program allows quick QA plan changes and can accommodate unanticipated conditions or eliminate unnecessary steps, while assuring the health and safety of the work force. This can form the basis for a uniform project wide QA plan.

Recommendations: Communication between the scientific advisor and the M&O contractor, should be continuous rather than on an "as-needed" basis.

All quality assurance plans and programs for this project should be reviewed for consistency and changed to reflect the proper flow from organization to organization.

The quality assurance plan should be tested during the Engineering and Operations Testing, Cold Commissioning, and Hot Commissioning Phases proposed in the near term path forward. This will provide WID with the opportunity to train people to the QA plan and procedures under actual field conditions.

III.6.1.5. Inter-Program Communication

Observations: Based on experience from past Independent Technical Reviews, and the working knowledge of members of the WIPP ITR Team, it appears that TRU-waste disposal within the overall defense complex is not uniformly treated as an integrated system problem. Waste characterization and modification, waste acceptance criteria, generator utilization, and repository disposal are often dealt with in a piecemeal, locale-specific fashion. Some waste generators believe that they will not be involved in the proposal and development of treatment processes for TRU waste at WIPP.

Recommendations: A fundamental statement of the national TRU waste disposal strategy should be promulgated by DOE. Waste generator experiences with characterization, treatment, and interim storage should be utilized in preparation of a national strategy.

TRU waste generator disposal near-term needs should support certification and permitting of the WIPP project. Information on characteristics and properties of TRU waste relevant to disposal at WIPP is available at waste generator sites. Together, WIPP and the generator sites should determine the scope and value of this information before alternative tests are planned.

Actual VOC generation rates and species could be measured at the generators' sites. A large, random population of drums can be selected and measurement of gas-generation rates can possibly be made with a gas monitoring system. TRUCON Code (waste type), fissile content, age of waste, and external temperature can be taken into account. Results could determine which drums produce an unusually high gas output and they could be opened and investigated in a facility such as that at Argonne West. This will give more information of better quality at lower cost than the proposed Bin and Alcove tests.

III.6.2. Cost & Schedule

Observations: Based on this review, it appears that WIPP expended significant effort in FY1993 toward development of realistic cost and schedule baselines. Determination of the cost of proposed tests remains difficult because estimates are simplistic and performed by many participants. Consistent work breakdown structures or costing systems did not appear to be used by the principal WIPP organizations.

It is unclear whether waste characterization is included in the Alcove Test program cost estimate. The table entitled "FY 1993 WIPP Total Participant Funding" in the WIPP Desk Reference Manual cites a projected FY1993 waste characterization expense of $19M, but the estimated total cost of the Alcove Test program is $20M. These estimates cannot be consistent.

Recommendations: Evaluation of the cost effectiveness of proposed tests is enhanced when cost estimates are available and realistic. The rationale for setting resource allocation priorities should be clearly delineated. Realistic cost and schedule baselines for anticipated testing, regulatory or disposal decisions should be created. A consistent accounting system and work breakdown structure, shared by the primary program participants, should be considered.

III.6.3. Contingency Tests

Observations: The Contingency Test Task Force (CTTF) provided a thorough and well organized review of alternatives to the Bin and Alcove Tests, and a basis for considering alternative large-scale tests. Assumption A in Section 3.4 of the CTTF report[26] specified, "CTs (contingency tests) should provide the same type and quality of information as baseline tests." This limited the range of options considered. The CTTF review found that alternative sources of information on VOCs can be used to meet WIPP project needs.

Recommendations: Alternatives beyond those reviewed by the CTTF should be considered when developing large scale laboratory tests. Other sources of information on VOCs generated by TRU waste (INEL data for example) should be used by the WIPP project.

---

[1] Land Withdrawal Act, 1992

[2] DOE, 1993a

[3] D. E. Caldwell, R. C. Hallet, M. A. Molecke, E. Martinez, and B. J. Barnhart, "Rate of CO_2 Production from the Microbial Degradation of Transuranic Wastes under Simulated Geologic Isolation conditions," SAND87-7170 (January 1988).

[4] R. I. Vreeland, Personal Communication, West Chester University, West Chester, PA (August 31, 1993).

[5] Gas-Generation and Source-Term Programs: Technical Needs Assessment for the Waste Isolation Pilot Plant Test Phase, Revision 0, DOE/WIPP 92-062

[6] "Test Plan: WIPP Bin-Scale CH TRU Waste Tests (Type 2 bin), July 9, 1993" (SAND93-1559)

[7] Molecke, SNL, Test Plan: WIPP Bin-Scale CH TRU Waste Tests, SAND90-1974

[8] Pickering and Orrell, 1993

[9] A. C. Peterson, S. A. Orrell, J. T. Holmes/SNL, Test Plan: Waste Isolation Pilot Plant Bin-Scale CH TRU Waste Tests (Type 2 Bin), SAND93-1550

[10] DOE/WIPP 93-037, August, 1993, p. 11

[11] Peterson et al. 1993

[12] WIPP-DOE-069, Rev 4

M

[13]TRUPACT SARP

[14]WIPP 93-037, August, 1993, Figs. 4b, p. 15

[15]Test Phase Plan for the Waste Isolation Pilot Plant, Revision 1, DOE/WIPP 89-011

[16]Alcove Test plan

[17]The Final Draft Alcove Test Plan

[18]Original Alcove Test Plan (

[19] Connolly, M.J. to P.J. Higgins, "Transmittal of Requested Information--MJC-45-93," Idaho National Engineering Laboratory Letter, 8/23/93.

[20]Lucas, 1984

[21] Alcove Test Program, DOE/WIPP 93-035

[22] DOE/WIPP, August 1993

[23]Brown and Jasiulewicz 1992

[24]Davis and Madsen, 1991

[25]Vreeland et al. 1993

[26]Contingency Test Task Force Report Evaluation of Alternate Tests as Contingencies to Replace the Currently Planned Bin and Alcove Tests at WIPP

THIS PAGE

LEFT BLANK

INTENTIONALLY

APPENDIX A

REGULATORY REFERENCE

A.1. Major Laws and Regulations Affecting WIPP

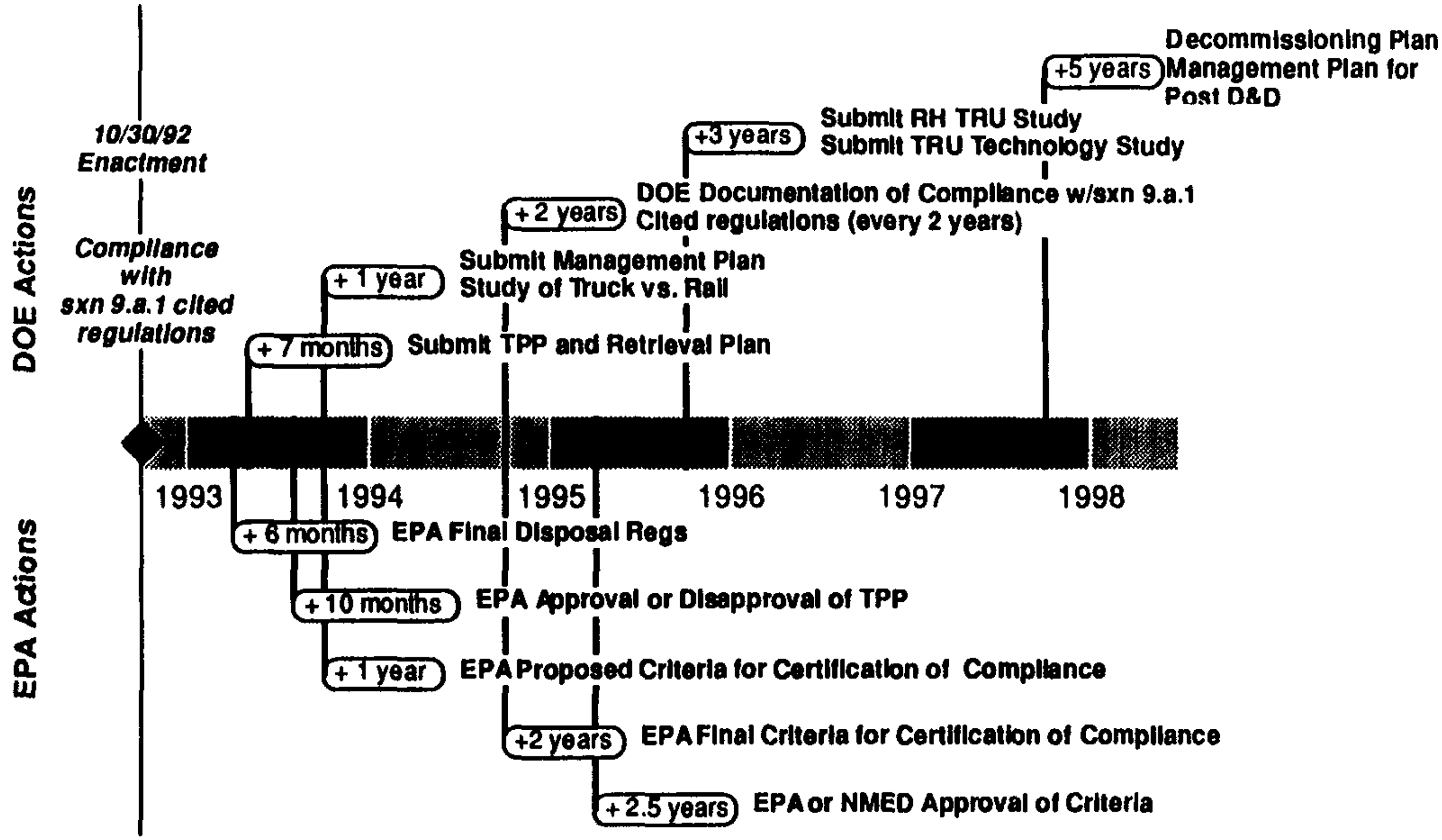
Certain laws and regulations form the mission and basis for WIPP, and significantly influence compliance demonstration activities.

A.1.1. Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980, Public Law 96-164.

Section 213 of this law authorized the construction of WIPP for the "purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission."

A.1.2. Waste Isolation Pilot Plant Land Withdrawal Act of 1992, Public Law 102-579.

The WIPP Land Withdrawal Act (LWA) was enacted on October 30, 1992. In addition to withdrawing public lands surrounding the WIPP site, the LWA established about 140 separate requirements, of which about 80% are new requirements for DOE and other Federal agencies. Key among the new requirements is a new regulatory framework in which EPA must certify WIPP's compliance with the radioactive waste disposal standards (40 CFR 191) prior to establishing WIPP as a disposal site. The LWA also established numerous requirements involving close and extensive interactions with other agencies, other agency reviews and certifications, and intensive DOE documentation of compliance with applicable regulations. The key actions required by the LWA are represented in Figures A.1 and A.2. In these figures, actions required of DOE are above the horizontal timeline, while actions required of EPA are below it. The LWA includes a number of new prerequisites to starting the Test and Disposal Phase with TRU waste.



If no TRU Waste Tests at WIPP, then no requirement for:

- *Test Phase Plan*
- *Retrieval Plan*
- *Certification of Safety*
- *Stability of Test Rooms*
- *Final Disposal Regulations to Start Tests*
- *Compliance with NMD*
- *Payment of $20M/Year to N.M.*
- *Transportation Training*

Fig. A.1. LWA Mandated Activities by DOE and EPA

Key prerequisites that must be met before the first Test Phase shipments can begin include the following:

- EPA must promulgate final 40 CFR 191, Subpart B, disposal regulations within 6 months of the date of enactment.
- DOE must submit for EPA's formal review and approval its Test Phase Plan and Waste Retrieval Plan within 7 months. EPA must approve the plans (or portions of the Test Phase Plan) within 10 months of enactment.
- EPA must determine WIPP's compliance with the terms and conditions of the No-Migration Determination issued by EPA under RCRA.
- The Mine Safety and Health Administration (MSHA) must concur in the adequacy of DOE's plan for assuring room stability in the underground test rooms.
- The Occupational, Safety and Health Administration (OSHA) must certify DOE's accident prevention and emergency response training.

Key Disposal Phase prerequisites include the following:

- EPA must certify, by rulemaking, that DOE will comply with the disposal regulations (40 CFR 191, Subpart B).
- DOE must notify Congress of compliance with all applicable environmental laws and regulations.
- DOE must submit to Congress recommendations for the disposal of all TRU waste under DOE control, including a timetable for disposal of such waste.
- DOE must complete a survey identifying all TRU waste types at all sites from which wastes are to be shipped to WIPP, with notice and opportunity for public comment, and provide results to EPA.
- DOE must submit to Congress decommissioning and post-decommissioning plans.
- DOE must wait 180 days after notifying Congress that DOE is in compliance with all applicable environmental laws and regulations.
- DOE must acquire 2 existing oil/gas leases, if EPA determines such acquisition is required to comply with the final disposal regulations or with the Solid Waste Disposal Act.

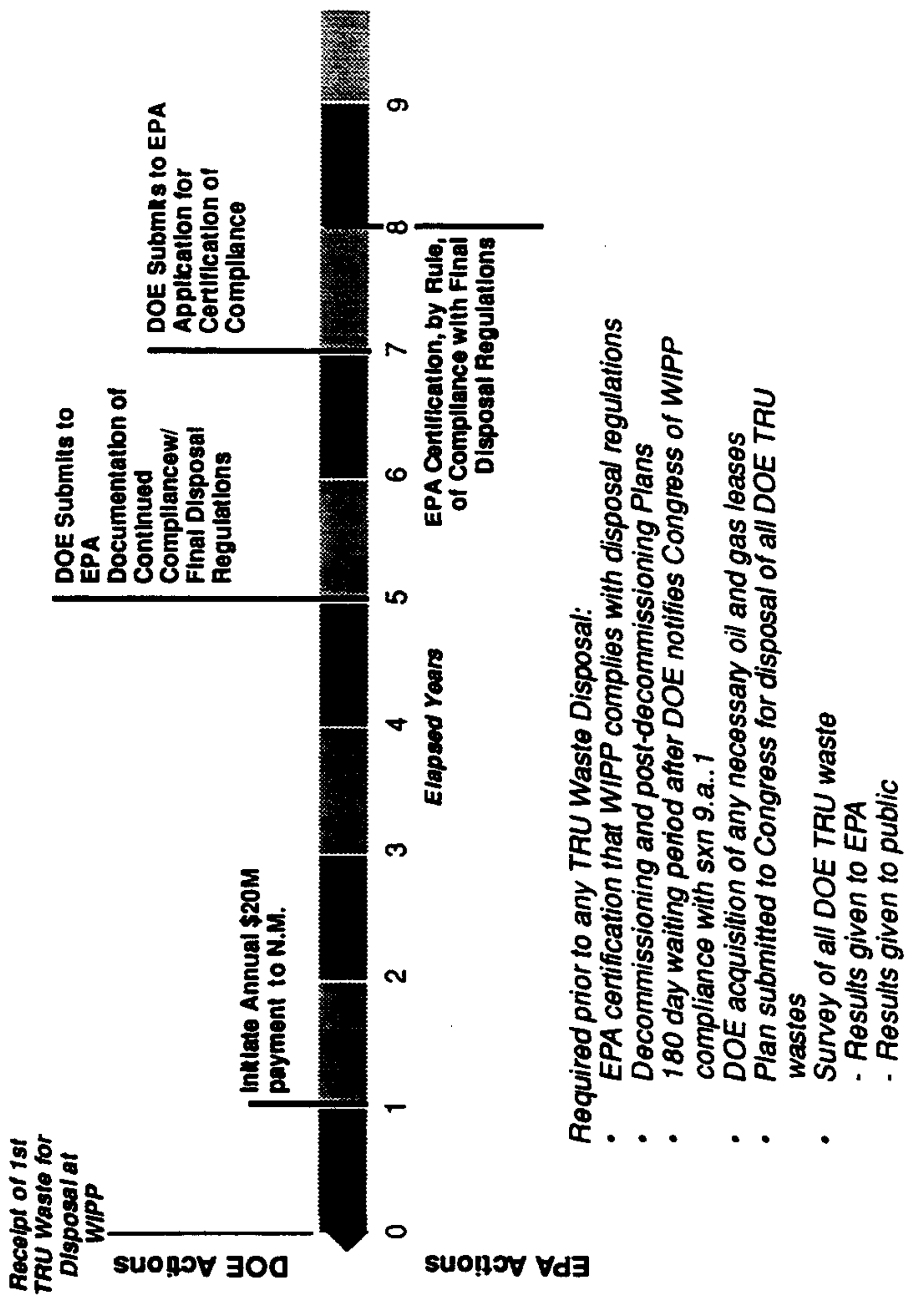


Fig. A.2. LWA Mandated Disposal Actions by DOE and EPA

A.1.3. Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes, 40 CFR 191.

Subpart A of the regulation applies to radiation doses received of the public as a result of the management and storage of spent nuclear fuel or high-level or transuranic radioactive wastes. Subpart B applies to radioactive materials released into the accessible environment as a result of the disposal of spent nuclear fuel of high-level or transuranic wastes; radiation doses received by members of the public as a result of such disposal; and radioactive contamination of certain sources of ground water in the vicinity of disposal systems for such wastes.

A.1.4. Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities, 40 CFR 264.

These standards apply to owners and operators of facilities, including WIPP, which treat, store, or dispose of hazardous waste. Subpart X of this regulation pertains to "miscellaneous units," as defined by RCRA regulation. WIPP has been identified as a miscellaneous unit.

A.1.5. Land Disposal Restrictions, 40 CFR 268.

This regulation identifies hazardous wastes that are restricted from land disposal and defines those circumstances under which an otherwise prohibited waste may continue to be land disposed. A petition process is identified in 40 CFR 268.6, which outlines the process of seeking an exemption from a prohibition. Since DOE intends to dispose of untreated wastes at WIPP, it must petition the EPA for a variance under 40 CFR 268.6.

A.1.6. Conditional No-Migration Determination for the Department of Energy Waste Isolation Pilot Plant, 55 FR 47700, November 14, 1990.

In response to a petition from the DOE under 40 CFR 268.6, EPA made a determination of no migration for the placement of hazardous waste at WIPP during the Test Phase. This determination imposes several conditions on such placement and is for a maximum of 10 years. As a result of this determination, DOE may place a limited amount of untreated waste subject to the land disposal restrictions in WIPP for the purposes of testing and experimentation.

A.2. Regulatory Instability

Since WIPP was authorized by the Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980, the WIPP project has been subjected to a constantly changing regulatory framework. Most significant was the DOE's acknowledgment in 1987 that its facilities were subject to the RCRA. Until then, the DOE had not been involved in rulemaking activities that related to RCRA. Subsequently, the DOE became subject to RCRA regulations, and the WIPP project was forced to react to a new set of regulatory requirements. The Land Disposal Restrictions in 40 CFR 268 are of particular concern, because they require that all hazardous wastes be treated before disposal to the land. Since the DOE had planned to dispose of untreated wastes at WIPP, its basic strategy was to apply for a variance under 40 CFR 268 rather than to treat TRU mixed wastes.

After the DOE acknowledged that its facilities were subject to RCRA regulations, DOE facilities that were storing, treating, and/or disposing of hazardous wastes were required to submit Part A permit applications to the appropriate regulatory authorities. By so doing, these facilities would qualify as "interim status" facilities until their final (Part B) permits were prepared and approved. Not knowing which regulatory body was responsible for the WIPP site, the DOE submitted applications to both the EPA Region 6 and the State of New Mexico Environmental Improvement Division (NMEID). Because the EPA had delegated its basic program to the NMEID, EPA would not accept DOE's application. Because the NMEID had not yet been authorized to regulate mixed waste, it would not take action on DOE's application either. The WIPP site was thus caught in a "regulatory limbo."

The NMEID [now called the New Mexico Environment Department (NMED)] was not authorized to regulate mixed waste until 1990. Shortly after being authorized to regulate mixed waste, the NMEID required that DOE submit both the Part A and Part B RCRA applications. The DOE maintains that it followed all procedural requirements, thereby qualifying for interim status. As an interim status facility, the DOE would be authorized to treat, store, and/or dispose of hazardous waste before receiving approval of its Part B application. The Attorney General of New Mexico challenged the Department of Interior's Administrative Withdrawal of WIPP lands and the DOE's assertion that WIPP qualified as an interim status facility and filed suit in U.S. District Court. This lawsuit resulted in a court-ordered permanent injunction in January 1992 prohibiting shipments of waste to WIPP. In July 1992, the U.S. Court of Appeals reversed the U.S. District Court's ruling; however, the permanent injunction is still in effect and must be lifted by the U.S. District Court before shipments can begin.

In 1985, the EPA promulgated its environmental radiation protection standards for the management and disposal of spent nuclear fuel, high-level and transuranic radioactive wastes. In 1987, following a legal challenge by the Natural Resources Defense Council, the U.S. Court of Appeals remanded subpart B of the 1985 standards to the EPA for further consideration. Due to a lack of binding standards, the DOE agreed that it would comply with the 1985 standard until a new standard was promulgated. The WIPP LWA of 1992, however, reinstated the 1985 disposal standards except three aspects of sections 40 CFR 191.15 and 191.16 that were subject to the remand ordered by the Court. EPA has yet to repromulgate its final disposal standards. The WIPP LWA also established EPA as the regulator under 40 CFR 191. Until that time, the EPA was responsible only for establishing the standard and it was the DOE's responsibility to certify that the standard was satisfied.

In addition to the final disposal standard, EPA has yet to issue its certification criteria (40 CFR 194). The certification criteria are intended to establish requirements that will support a "reasonable expectation" of compliance and to identify the required format and content of WIPP's certification application. The LWA requires that EPA issue proposed criteria by October 1993 and its final criteria by October 1994. However, the EPA has indicated that the draft rule will not be available for public comment until early 1994 and does not expect to issue the final rule until early 1995.

The EPA is currently soliciting advice and counsel from the National Advisory Council for Environmental Policy and Technology (NACEPT) regarding WIPP activities. The WIPP Review Committee was formed as a NACEPT Subcommittee to provide independent advice and counsel on specific EPA activities, issues, and needs as they relate to the EPA's implementation of the Land Withdrawal Act. This committee will advise the EPA Administrator on policy and technical matters including:

- EPA's decision to approve/disapprove DOE's Test and Retrieval Plans for the WIPP;
- EPA's development of compliance criteria for implementing 40 CFR 191 disposal standards; and
- EPA's decision whether or not the WIPP complies with 40 CFR 191.

After this review, the public provided comment on three compliance questions:

- To reduce uncertainty in compliance assessment, should the EPA specify certain "future states" assumptions? If so, what aspects of the future should the EPA address and how?
- To reduce uncertainty in compliance assessment, should the EPA specify certain assumptions related to human intrusion? If so, what aspects of human intrusion should the EPA address and how?
- Should the EPA address the use of engineered barriers at the WIPP? If so, why and how?

Each issue is significant and the answers to these questions will significantly impact the DOE's compliance strategy.

A.3. <u>Regulatory Conflicts Between 40 CFR 191 and 40 CFR 268.</u>

The RCRA discourages land disposal of hazardous wastes. RCRA states, "... reliance on land disposal should be minimized or eliminated, and land disposal, particularly landfills and impoundments, should be the least favored for managing hazardous wastes." (RCRA, Section 1002(b)(7)). This law motivated the EPA to issue regulations, i.e. 40 CFR 268, that encourage treatment of hazardous wastes rather than land disposal. On the other hand, the NWPA and the LWA are supportive of disposal of radioactive wastes in deep geologic repositories. These laws motivated the EPA to issue and recently re-issue regulations, i.e., 40 CFR 191 that are stringent but do not require that the waste be treated. Since the WIPP must also comply with 40 CFR 268, however, the DOE is evaluating compliance options and to what extent TRU wastes need to be treated before being disposed of at WIPP.

Currently, the DOE plans to dispose of untreated TRU wastes at WIPP. In order to comply with EPA's Land Disposal Restrictions (40 CFR 268), the DOE must either treat its waste using EPA's performance standards/technologies or it can petition for a variance under 40 CFR 268.6. This variance, if granted, would allow untreated waste to be emplaced at WIPP. This variance petition would require a performance assessment to be performed, similar to that required under 40 CFR 191, that would demonstrate that the waste "will not migrate for as long as the waste remains hazardous."

The regulations specify different points of compliance: a "unit boundary" per 40 CFR 268 and the "accessible environment" which lies beyond a "controlled area" per 40 CFR 191, as schematically shown in Figure A.3. For surface impoundments, landfills, and waste piles (none of which compare to the WIPP), the unit boundary is defined as the outermost extent of the engineered barrier(s), such as a liner, ditches or berms, that contain the waste. Hazardous wastes that cross this boundary cannot exceed the EPA's soil contamination limits. If the wastes are not enclosed, the unit boundary includes the downwind edge of the disposal unit at a height of 1.5 meters, the typical height at which humans could inhale hazardous material. Hazardous gases and suspended particulates that cross this boundary cannot exceed the EPA-established limits.

The concept of a unit boundary was developed for disposal facilities that lie at or just below the ground surface. The WIPP, however, lies 2100 feet below the surface of the ground. Consequently, the EPA moved the unit boundary from the surface to the portion of the Salado Formation that falls within the WIPP land withdrawal area[1]. The top of the Salado lies 1000 feet beneath the surface and its lower member extends down to 3000 feet. Hazardous gases that cross the top of the Salado Formation cannot exceed the EPA's air contamination limits, even though there is essentially no air 1000 feet below the ground for humans to inhale.

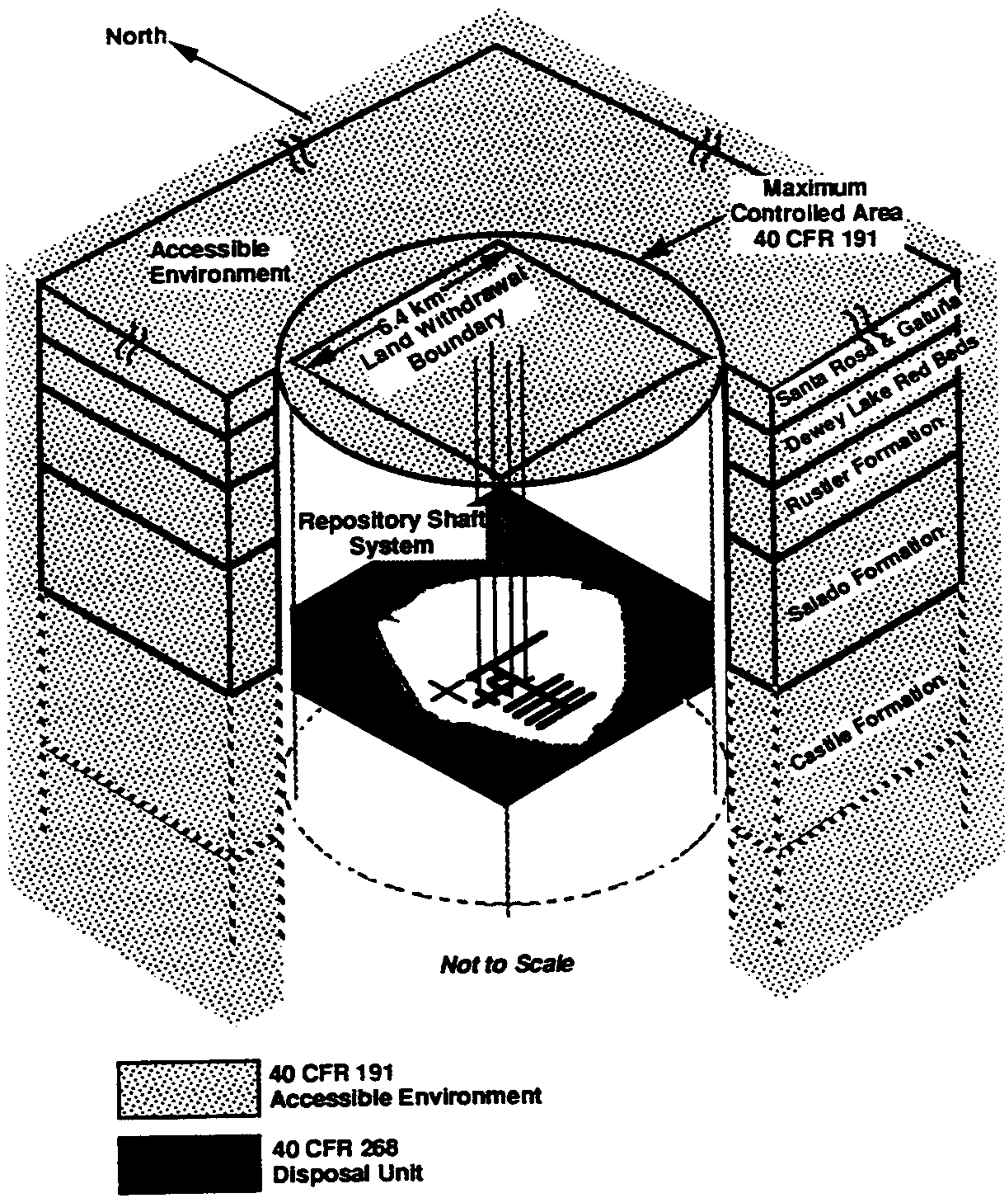


Fig. A.3. WIPP Regulatory Boundaries

As defined in 40 CFR 191, the controlled area would allow the WIPP to take more credit for the surrounding geology. However, DOE restricted the controlled area so that it coincides with the land withdrawal area. Still, the controlled area encompasses more geology than the unit boundary. The top of the controlled area lies at the land surface, but the top of the unit boundary lies 1000 feet below the surface.

Finally, the regulations dictate different approaches to performance assessments. The RCRA regulations, including 40 CFR 268, are deterministic i.e., they call for a single value calculation while 40 CFR 191 is probabilistic i.e., a complementary cumulative distribution function plots the probability of exceeding multiples of the EPA's release limits. In addition to those already stated, other differences can be found between these regulations, such as different monitoring requirements.

A.4. Human Intrusion Scenarios.

Appendix B, Subpart B, 40 CFR 191, provides guidance regarding how human intrusion should be addressed in Performance Assessments. Although this guidance is not mandated by regulation, the applicant must demonstrate that any alternative approach will provide adequate protection of the general environment from radioactive material. According to Appendix B, performance assessments can assume that "... the likelihood of such inadvertent and intermittent drilling need not be taken to be greater than 30 boreholes per square kilometer of repository area per 10,000 years for geologic repositories in proximity to sedimentary rock formations..." (40 CFR 191, Subpart B, Appendix B). When applied to the Delaware Basin, this assumption yields 900,000 boreholes per 10,000 years of which 15 would penetrate the WIPP facility[2].

The New Mexico Attorney General[3] claims that the drilling frequency at the WIPP would be at least ten times higher than the EPA's worst case, and the New Mexico Environmental Evaluation Group[4] claims that the frequency would be almost 18 times higher. The Attorney General reports that in the two-mile band surrounding the WIPP site, 63 boreholes have been drilled since 1977, making the actual drilling rate in that area 340 holes per square kilometer per 10,000 years. The EEG reports that within the same area, 99 wells have been drilled since 1978, making the actual drilling rate 530 holes per square kilometer per 10,000 years. Thus, depending upon how the data are manipulated, the "worst case" for human intrusion could be 15 to 255 hits per 10,000 years.

The "hits" generally fall into three categories or scenarios[5]:

(1) boreholes penetrate a waste-filled room or drift and into a pressurized brine reservoir in the underlying Castile Formation;

(2) boreholes penetrate only a waste-filled room or drift; and

(3) while (1) and/or (2) occurs, water within the Culebra formation, which lies above the repository, is pumped from a well located downstream from the repository.

Human intrusion is the most likely scenario whereby the WIPP repository could release radionuclides. Assessment of such scenarios indicates that most of the radioactive release would be pumped out of the borehole with the drill cuttings. The concentration of the radionuclides depends upon two highly uncertain parameters: the size of the hole and the duration of the drilling. Because the DOE's compliance argument hinges on these parameters, models are being developed to determine the amount of waste that would be removed by the drill cuttings and by erosion of the borehole caused by the circulating drilling fluid.

Assessments of scenarios (2) and (3) indicate that radionuclides could contaminate the Culebra groundwater[5]. Without human intrusion, however, radionuclides are not predicted to reach the Culebra formation. Regional and local groundwater flow within the Culebra formation are also being modeled to determine radionuclide concentrations and transport time. In addition to the model, 21 studies are currently in progress or will be undertaken "... to evaluate the ability of the Culebra and surrounding units to adequately confine the waste disposed of in the repository after inadvertent human intrusion."[6].

Besides modeling, laboratory, and field studies, DOE has utilized "expert opinion" to estimate the probability of future human intrusion. The DOE convened four panels of independent experts to determine the probability that humans would disturb WIPP. The estimates ranged from 0.01 to nearly 1[7]. Other experts[8], working for the former Basalt Waste Isolation Project, could not agree on a probability that humans may disturb a potential repository in Hanford, Washington. Recently, protective barriers were surveyed[9] that could deter human intrusion. Among others, he suggests that warnings be inscribed on a large number of small (several centimeters) markers. The markers would be buried with the waste and when a drill hits them, they would be brought to the surface and frighten the drillers away. According to the EPA, monument could be used to reduce the probability of human intrusion. However, none of the experts would say by how much.

Recognizing the potential impacts of human intrusion, the EPA is considering the benefits of promulgating criteria for engineered barriers[10]. According to the EPA, such barriers could mitigate releases, provide defense- in-depth and compensate for uncertainty[11]. Because natural disturbances do not affect the WIPP repository, we assume that engineered barriers would lessen the impact of human intrusion.

In summary, human intrusion is the most likely scenario whereby radionuclides could be released into the accessible environment. Although 40 CFR 191, Subpart B, Appendix B offers guidance on acceptable methods for handling human intrusion, it is not the only allowable approach. Some effort has been made to examine alternative human intrusion scenarios and resulting conceptual models. Currently, the EPA is soliciting input from the public on how it should proceed in developing its compliance criteria related to human intrusion. Therefore, the DOE needs to formalize and document its alternative approach quickly, based upon declining oil dependency, creep closure of boreholes, and effectiveness of passive institutional controls, and include the approach for earliest submission to the regulator.

---

[1] EPA, 1990

[2] Guzowski, 1991

[3] Udall, 1993

[4] EEG, 1993

[5] Bertram-Howery, et al., 1990

[6] DOE, 1993b, page 5-1

[7] Hora et al., 1991

[8] Davis and Runchal, 1984

[9] Tolan, 1993

[10] EPA, 1993

[11] Petti, 1993

APPENDIX B

GAS GENERATION PHENOMENA

TECHNICAL REFERENCE

Appendix B provides a background discussion of the anticipated principal WIPP TRU waste gas generation mechanisms. Section B.1. discusses corrosion, and B.2. microbial processes, which are considered to be the principal gas generation mechanisms. Radiolysis, a minor generator of gas, is discussed in Section B.3. Section B.4. comments on volatile organic compounds. These discussions are topical and not meant to be complete or exhaustive. Other sources such as books, technical journals and WIPP reports, should be consulted for detailed information.

B.1. Corrosion Gas Generation Mechanisms

B.1.1. Corrosion of Carbon Steel in Air.

The corrosion of iron or carbon steel that is in contact with a gas phase is due to oxidation by water vapor or oxygen.

$$2Fe + 3H_2O \longrightarrow Fe_2O_3 + 3H_2$$

$$4Fe + 3O_2 \longrightarrow 2Fe_2O_3$$

If the partial pressure of hydrogen becomes sufficiently high, the hydrogen will back react to water.

B.1.2. Corrosion of Carbon Steel in Brine.

The corrosion of iron or carbon steel in contact with brine involves two simultaneous electrochemical reactions, one anodic and the other cathodic. The anodic reaction results in "active" corrosion (or dissolution) that liberates electrons.

$$Fe \xrightarrow{\text{brine}} Fe^{2+} + 2e^-$$

The cathodic reaction involves the dissociation of water, followed by the cathodic evolution of hydrogen from the metal surface.

$$H_2O \xleftrightarrow{\text{brine}} H^+ + OH^-$$

$$2H^+ + 2e^- \xrightarrow{\text{brine}} H_2 \uparrow$$

Electrons liberated by the anodic dissolution of iron are consumed by cathodic evolution of hydrogen. Increasing temperature, increasing ionic strength of the brine, and decreasing pH all increase the reaction rates. Under certain conditions, the reaction rates at the bare metal surface become negligible and the surface is said to be *immune* to corrosion. Under other conditions, protective films of oxides or other compounds form on surfaces, thereby preventing corrosion and gas generation. If they are adherent, such films can prevent the sustained oxidation of the underlying metal substrate. Metal surfaces protected by such films are called "passive."

Passivation prevents gas generation. Carbon steel can be passivated by an oxide formed by the reaction of water and iron. It can also be passivated by any one of several gases that are anticipated in the WIPP environment, including carbon dioxide and hydrogen sulfide. The first step in forming a passive film of siderite, $FeCO_3$, involves the production of carbonic acid during the dissolution of gaseous carbon dioxide, and its dissociation into hydrogen, bicarbonate and carbonate ions:

$$CO_2 + H_2O \xrightarrow{\text{brine}} H_2CO_3$$

$$Fe^{2+} + CO_3^{2-} \xrightarrow{\text{interface}} FeCO_3 \downarrow$$

Similarly, the first step in forming a passive film of iron sulfide involves the dissolution of gaseous hydrogen sulfide, H_2S, producing sulfide anions.

$$H_2S \xrightarrow{\text{brine}} HS^- + H^+$$

$$HS^- \xrightarrow{\text{brine}} S^{2-} + H^+$$

Dissolved hydrogen sulfide (sulfide anions) can react with dissolved iron cations to form passive films of troilite (FeS).

$$Fe^{2+} + H_2S \xrightarrow{\text{interface}} FeS \downarrow + 2H^+$$

$$Fe^{2+} + HS^- \xrightarrow{\text{interface}} FeS \downarrow + H^+$$

$$Fe^{2+} + S^{2-} \xrightarrow{\text{interface}} FeS \downarrow$$

If the reduction of hydrogen is included, the overall reaction becomes

$$Fe + H_2S \xrightarrow{\text{interface}} FeS + H_2 \uparrow$$

Polysulfide can react with dissolved iron to form passive films of pyrite, FeS_2. If the reduction of hydrogen is included, the overall reaction becomes

$$Fe + H_2S_2 \xrightarrow{\text{interface}} FeS_2 + H_2 \uparrow$$

In some cases, nonadherent corrosion products are formed. For example, consider the formation of anakinite on carbon steel submersed in a magnesium-containing WIPP brine.

$$xFe^{2+} + (1-x)Mg^{2+} + 2OH^- \xrightarrow{\text{interface}} Fe_xMg_{1-x}(OH)_2 \downarrow$$

Although this corrosion product does not form an adherent passive film, it can inhibit corrosion if it is held at the metal surface by gravity or compression. Note that other corrosion phenomena, such as pitting, may become important even if surfaces are passivated. Halide ions, such as chloride ion, can result in localized breakdown of passive oxide films.

B.1.3. Maximum Possible Gas Evolution.

The complete corrosion of one mole of iron in brine generates from $^{2}/_{3}$ to $1^{1}/_{2}$ moles of hydrogen gas. If the weight of an empty 55-gal carbon steel drum [about 60 lb (27 kg)] is equivalent to 488 moles of iron, about 488 moles of corrosion-generated hydrogen per drum would be expected if all the iron is reacted. About 110 lb (50 kg) of carbon steel per drum would be required to produce the 900 moles of hydrogen per drum that has been quoted in various WIPP documents. But, this amount of gas can only be produced if there is adequate brine available to support the corrosion. It is important, consequently, for the WIPP Project to obtain realistic bounds on the amount of brine that might contact metals in the repository.

B.1.4. Brine Availability.

Brine availability is one of the most important sources of uncertainty in the PA component model for corrosion. The rates of gas generation by both anoxic corrosion and microbial growth will probably be high if the waste is inundated with brine. Otherwise, gas generation will be insignificant.

As a first-order approximation, we can assume that gas is generated only when waste comes in contact with brine (inundated condition) and that these reactions are fast (essentially instantaneous). Gas generation by waste under humid conditions is relatively insignificant. In the latter case, it is unlikely that lithostatic pressure will be exceeded. Thus, gas generation will be of very little concern.

B.2. Microbial Gas Generation

B.2.1. Interactions Between Microorganisms and TRU-Wastes in the WIPP Repository

The purpose of Section B.2. is to review what is known about microorganisms inhabiting the WIPP environment, and the significance of microorganism-waste interactions on long-term disposal of TRU wastes in the repository. Section B.2. also highlights the uncertainties relative to microbe-waste interactions and estimates their magnitude.

B.2.2. Microbial Ecology Background.

Because microorganisms are ubiquitous, TRU wastes will be contaminated with microorganisms indigenous to the generator sites. Most waste will be dry except sludges to which cement is added to reduce free water in the waste containers. Microorganisms will survive in the waste container environment and sustain themselves by slowly degrading organic materials (readily oxidizable organic matter entrained in the paper tissues, cellulosic materials, and possible organic solvents). Limited entrapped moisture will probably restrict biodegradation of waste in intact containers.

After the waste containers are emplaced underground at WIPP, microorganisms brought in by the ventilation system (predominantly organisms from the above-ground vicinity at WIPP) and organisms present in the brine seeps, muck, backfill material and salt crystals can be expected to contaminate the waste through drum seals and most certainly when the drums are breached. Microorganisms from the WIPP environs will probably be halobacteria [halophilic (salt-loving) or halotolerant (tolerant of salt) organisms], because the highly saline environment in and around the WIPP site selects such organisms. The humid conditions of the repository and possible brine intrusion could potentially create conditions that would allow the halophilic/halotolerant organisms to reproduce and to degrade the wastes. If brine inundation of the waste occurs, those organisms that were resident on the waste at the time of generation would probably not survive, because of salt intolerance. The predominant population on the waste would become the halophilic bacteria inhabiting the WIPP site.

The study of bacteria in hypersaline environments is in its infancy. Halobacteria require salt concentrations between 1.5 M (9%) NaCl and 3.5 to 4.5 M (21 to 27%) NaCl. Their briny habitat may also be rich in other ions, including potassium, magnesium, sulfate, carbonate, and hydroxide. Many halobacteria exhibit active growth and motility (motion) in saturated salt solutions and are only mildly inconvenienced by the salt crystals they encounter[1]. The most halophilic, Archaea, often become trapped in fluid inclusions and survive extremely well within the salt crystals. The organisms' ability to be captured and survive in brine inclusions is perhaps their most critical survival skill. The metabolic diversity of these organisms and their long-term survival in fluid inclusions inside salt crystals are only two of the many questions regarding these bacteria[1]. Little is known about the survivability and metabolism of the halobacteria. SNL studies have emphasized isolating the bacteria from surface and subsurface locations at WIPP and enriching the cultures to study their waste-degrading characteristics.

B.2.2.1. Caldwell Study on Microbial Populations Above Ground at WIPP. In 1978 a preliminary biogeochemical investigation[2] was undertaken to identify and quantify some of the key microbial agents and processes occurring in the surface soils and waters of the WIPP site and vicinity. Halophilic and thermophilic (heat-loving) microorganisms were identified in this population study. Microorganisms were abundant in all surface environments that were sampled, but the data did not quantify any potential biogeochemical cycle that could affect the transport and fate of radionuclides.

B.2.2.2. West Chester University Study of the WIPP Environs. A more substantive investigation of the microflora above-ground and below-ground at the WIPP site was undertaken in 1990 by West Chester University[3]. The cultures were obtained by creating culture conditions that select microorganisms with a specific type of metabolism (for example, microorganisms that can oxidize cellulose using sulfate as an electron acceptor). The goals of this study were: (1) to assess bacterial population sizes and distributions in Nash Draw (a surface region characterized by brine lakes near the WIPP) and in the underground WIPP facility and (2) to examine and compare the degradation rates of different types of papers (cellulosics) by organisms isolated from the WIPP environs. Results of this study were reported to SNL in monthly and annual reports but have not been published.

The West Chester University study isolated large numbers [106 CFU/ml (colony-forming-units)] of halobacteria from mud and lake samples from Nash Draw. Brine samples from underground at WIPP contained 104 CFU/ml. Solid, dry salt crystals from the WIPP underground contained from 0 to 104 CFU/gram of salt. Viable halobacteria from salt crystals presumably come from fluid inclusions. The results of a taxonomic study indicate that a biochemically diverse population of extremely halophilic and halotolerant bacteria exists at and within the WIPP site. These studies suggest that gas may be generated under a variety of environmental conditions. Preliminary studies on bacterial cellulose degradation showed that after halobacteria and cellulose fibers were exposed to brine, the organisms attached to the fibers within two hours, and then visible biofilms with red or pink pigmentation developed. Many halobacteria are facultative anaerobes (grow under either aerobic or anaerobic conditions). Under anaerobic conditions, the halophilic facultative anaerobes degrade carbohydrates, cellulose, or amino acids and produce gas. Preliminary studies have also demonstrated that microbial degradation of cellulosics produces various organic acids.

B.2.3. Biogeochemical Processes that could Affect TRU Waste Disposal.

Microbial degradation of organic matter produces gases, by-products, and conditions that can transform the types of metals and radionuclides that are present in the TRU-waste inventory. Such processes include (1) aerobic respiration, (2) anaerobic respiration using various electron acceptors, (3) fermentation and methanogenesis, and (4) metal/radionuclide bioaccumulation or biotransformation or both. The following subsections briefly describe the bioprocesses and their implications for the disposal of TRU wastes at WIPP. They also summarize the results and conclusions of ongoing BNL studies[4] on biodegradation of organic-matrix, simulated TRU wastes using halobacterial isolates/enrichments under anticipated repository conditions.

B.2.3.1 Aerobic Respiration. Cellulose is composed of glucose units bound together in a long, linear chain. Many microorganisms must decompose cellulose since the microbial cell is impermeable to the large cellulose polymer. Such microorganisms excrete enzymes that hydrolyze the insoluble cellulose, converting it into soluble sugars that penetrate the cell membrane:

$$\underset{\text{cellulose}}{(C_6H_{10}O_5)_n} + n\,H_2O \longrightarrow \underset{\text{glucose}}{nC_6H_{12}O_6}$$

The hydrolysis of cellulose consumes water. In the presence of oxygen, the glucose molecule, $C_6H_{12}O_6$ (or more simply $[CH_2O]_6$) is oxidized by aerobic microorganisms producing carbon dioxide and water:

$$CH_2O + O_2 \longrightarrow CO_2 + H_2O$$

The microorganisms derive energy for cellular activities and reproduction from this reaction. Some of the glucose is converted to biomass ($C_5H_7O_2N$). Nitrogen compounds are required for biomass production.

$$CH_2O + 0.11\,H^+ + 0.11\,NO_3^- + 0.21\,0_2^- \longrightarrow$$

$$0.11\,C_5H_7O_2N + 0.67\,H_2O + 0.44\,CO_2$$

The biological oxidation of glucose produces water. The water budget is difficult to calculate for TRU-waste. The amount of water consumed in cellulose hydrolysis is equivalent to the number of glucose units making up the cellulose polymer. The water produced from oxidation of glucose is dependent on how much glucose is converted to biomass versus how much is oxidized directly to carbon dioxide and water.

Aerobic microbial degradation of cellulose is anticipated to occur[5] until the oxygen entrained in the TRU-waste, or produced from radiolysis of brine or sludges, is consumed. Limitations to bio-oxidation of cellulose are lack of water for cellulose hydrolysis and/or the availability of nitrogen compounds for biomass production. Brush[5] estimated that only about 1% to 2% of the estimated 10 kg of cellulosic material per drum can be oxidized because of limited oxygen availability.

BNL studies[4] have shown that when halobacteria isolated from the WIPP site oxidized cellulose, the amount of CO_2 generated compared well with theoretical estimates used for models (Brush, December 1991).

Estimated Gas Production Rate[6]
from Inundated Waste (moles gas/drum/year)

Minimum = 0
Best = 1
Maximum = 5

Laboratory Gas Production Rates[4]
from Inundated Waste (moles gas/drum/year)

Environment	No additions	Inoculated	Inoculated + Nutrients	Inoculated + Nutrients + NO_3^-
Aerobic	0.16	0.0	1.28	3.68
Aerobic with bentonite	0.48	0.16	4.48	5.44

Barnhart[7] and Caldwell[8] reported carbon dioxide production from aerobic and anaerobic biodegradation of simulated, organic-matrix, TRU wastes. The inoculum for these studies, derived from a shallow, TRU-waste, burial site at Los Alamos National Laboratory, was not representative of the microflora from the WIPP site. Therefore, gas generation data from this study are not comparable to present data of BNL investigators[4] who are using a halobacteria inoculum from the WIPP site.

Carbon dioxide produced by aerobic bacterial oxidation of glucose could passivate metals minimizing chemical corrosion. This potential synergistic effect is being evaluated by collaborative investigations between BNL and PNL.

B.2.3.2. Anaerobic Respiration of Cellulosics. In the absence of oxygen as an electron acceptor, microorganisms resort to anaerobic respiration in which the final electron acceptors are such compounds as nitrate, manganese oxides or hydroxides, iron oxides or hydroxides, and sulfate. The use of these electron acceptors is dependent on their availability, the capability of the microbial population to use these electron acceptors, and the oxidation-reduction potential of the system. As the system becomes less oxidizing (more reducing), the electron acceptors will be used in the order presented. That is, after oxygen depletion, nitrate would be used first, if available. After the most easily oxidized materials are consumed, sulfate will be used as an electron acceptor by the appropriate microbial population. Anaerobic respiration reactions and laboratory results on the biodegradation of cellulosics by halobacteria from WIPP are summarized below.

- **Nitrate Reduction/Denitrification.** Nitrate is the first electron acceptor to be used by microorganisms after the depletion of oxygen:

$$CH_2O + 0.8\,NO_3^- \longrightarrow 0.6\,H_2O + 0.8\,HCO_3^- + 0.2\,CO_2 + 0.4\,N_2$$

$$CH_2O + 0.46\,H^+ + 0.46\,NO_3^- \longrightarrow$$

$$0.076\,C_5H_7O_2N + 0.96\,H_2O + 0.624\,CO_2 + 0.192\,N_2$$

While some bacteria convert nitrate into nitrite and ammonia, other microorganisms are capable of reducing nitrate all the way to nitrogen. This latter process is called denitrification. In some instances, certain gaseous intermediates, such as nitrous oxide, will be produced. Note that this process produces not only gaseous nitrogen products, but carbon dioxide as well.

Nitrate reduction/denitrification is expected to occur in the WIPP repository, because the WIPP waste inventory contains copious amounts of nitrate[5]. Nitrate-containing wastes and the cellulosic wastes will be in separate containers. Therefore, the waste containers must be breached and brine inflow into the repository must occur to mix the two wastes before microbial nitrate reduction/denitrification takes place.

Studies at BNL[4] have shown that in an inundated brine environment, halobacteria from the WIPP site can produce gas during cellulose degradation.

using nitrate as an electron acceptor. Table B-1 summarizes this laboratory produced information.

TABLE B-1

Gas Production rates under Anaerobic conditions with Nitrate as an Electron Acceptor (moles gas/drum/year)

Environment	No Additions	Inoculated	Inoculated + Nutrients	Inoculated + Nutrient + NO_3^-
Anaerobic	0	0.48	3.36	6.24
Anaerobic + Bentonite	0	1.12	2.08	4.0

- **Manganese Reduction.** After all nitrate is consumed, some microorganisms can use manganese (IV) oxides and hydroxides as electron acceptors:

$$CH_2O + MnO_2 \longrightarrow Mn^{2+} + CO_2 + H_2O$$

Manganese reduction is not believed to be important in the WIPP repository because manganese is not present in the waste inventory nor in the geologic matrix of the mine. Hence, no laboratory studies using manganese as an electron acceptor have been performed or proposed.

- **Iron Reduction.** As conditions become still more reducing in the environment, some microorganisms will use Fe(III) as an electron acceptor:

$$HCOOH + 2Fe^{3+} \longrightarrow 2Fe^{2+} + 2H^+ + CO_2$$

A considerable amount of iron is present in the WIPP inventory from drums and metal parts. It is unclear, however, how much iron will be in a form available for microbial reduction because some of it will be combined as various corrosion products[5]. If magnetite (Fe_3O_4) forms, however, microbial iron reduction could be a significant process. At this time, no laboratory studies are underway to evaluate this possibility.

- **Sulfate Reduction.** Under highly reducing conditions and in the absence of other electron acceptors, some microorganisms will use sulfate as an electron acceptor and produce hydrogen sulfide:

M

$$CH_2O + 0.5\,SO_4^{2-} \longrightarrow 0.5\,H_2S + HCO_3^-$$

Bacterial sulfate reduction could be a significant gas generation process in the WIPP environment. Sulfate is abundant in the brines, and sulfate from evaporite minerals may also become available to the bacteria under inundated conditions. Laboratory studies[4] have demonstrated that halophilic, sulfate-reducing bacteria from the WIPP environs are capable of using cellulosics inundated in brine as an energy source. Gas generation is still being evaluated. If hydrogen sulfide is generated in the WIPP repository, it would be expected to react with iron, producing several corrosion products (FeS_2 and H_2). The formation of FeS_2 could produce passive films which further decrease corrosion (Section B.2.).

B.2.3.3. Fermentation and Methanogenesis. Fermentation is carried out by anaerobic bacteria that use organic compounds as electron donors and acceptors. Many reactions can lead to the evolution of methane in oxygen-depleted environments. A very common mechanism for methane formation is the reduction of carbon dioxide. Methanogenic bacteria can ferment simple organic molecules using carbon dioxide as an electron acceptor:

$$CH_3COOH + 2\,H_2O \longrightarrow 2\,CO_2 + 8\,(H)$$

$$\underline{8\,(H) + CO_2 \longrightarrow CH_4 + 2\,H_2O}$$

$$\text{Net: } CH_3COOH \longrightarrow CH_4 + CO_2$$

They can also use hydrogen as an energy source with carbon dioxide as the electron acceptor:

$$4\,H_2 + CO_2 \longrightarrow CH_4 + 2\,H_2O$$

Cellulosic degradation by halobacteria from the WIPP environment has produced several fermentation products. Methane production, however, has not yet been noted in the experiments underway at BNL[4]. Methane has been shown to be produced, however, from low-level radioactive wastes disposed of in shallow-land trenches and pits[9] and is expected to be produced eventually in certain tests now in progress at BNL. Brush[5] believes that fermentation and methanogenic reactions could be important gas-generating mechanisms in the WIPP environment because they could occur in unbreached drums/waste boxes without electron acceptors from sludges or brines.

• **Organic Acid Formation.** Byproducts of cellulose biodegradation and fermentation can be organic acids. Organic acids are important for mobilizing radionuclides and heavy metals[10] by changing the pH and Eh of the environment and because of chelation properties[7]. Organic acids have been detected as a product of biodegradation of cellulosics by halobacteria from the WIPP site[3 4].

B.2.3.4. Toxicity, Irradiation and Pressure Effects. Environmental factors, including metal toxicity, irradiation and pressure, can affect the microbial degradation of the cellulosics in the WIPP waste inventory. Metals from the waste and from the containers can be expected to corrode, releasing soluble metals into the brine. In addition, radionuclides (americium, plutonium, thorium, and uranium) may be solubilized. Soluble metals/radionuclides can potentially diminish or inhibit biological activity because of toxicity[11]. Microorganisms can readily adapt to soluble heavy metals, particularly if the release of soluble metals into the brine is slow. The toxic effects of plutonium will be evaluated at BNL in conjunction with ANL in studies that examine synergism between radiolysis and microbial gas generation[4].

Irradiation has the potential to influence microbial degradation of organic wastes in two ways: (1) irradiation can potentially inactivate microorganisms, and (2) irradiation can alter plastic and rubber materials making them either more resistant or less resistant to microbial attack.

Barnhart[7] reported on bacteria isolated from a shallow, TRU-waste burial site at Los Alamos National Laboratory, that are resistant to total doses of 54 krads of x-irradiation. Caldwell[8] found that a microbial inoculum taken from the same LANL burial site demonstrated a 70% reduction in CO_2 generation from cellulose degradation when 300 mg (20 mCi) of PuO_2 was added to the culture. The two studies cannot be compared directly. The Barnhart[7] study involved irradiating the organisms and then cultivating them on an organic energy source. In the Caldwell[8] study, the irradiation source was incorporated into the growth substrate, more closely simulating the environmental situation at the WIPP. Because neither study used halobacteria from the WIPP, the results cannot be considered definitive for the WIPP environment. BNL and ANL will collaborate to evaluate radiolysis effects on microbial degradation of wastes. The study will examine irradiation effects as well because a plutonium source will be used[4] with the culture.

Ionizing radiation alters some plastics by fragmenting the main polymer chains, creating C-C double bonds and altering the chemical composition of the material[5]. The effects of ionizing radiation on rubber materials are less well known. Radiolysis effects on plastic and rubber materials may enhance the biodegradation of these materials. If so, gas generation estimates should be increased to accommodate the presence of these altered materials in the waste inventory. BNL has initiated a bench-scale program to evaluate radiolysis on the biodegradation and gas generation potential of plastic and rubber materials[4]. Results of accelerated testing are expected soon.

Studies have not yet been carried out on the effect of pore-brine or lithostatic pressure on microbial degradation of organic wastes in the WIPP repository. BNL experiments at 150 psia[4] were designed to support the proposed Type #2 Bin Test Program and did not simulate possible repository conditions. The effect of lithostatic pressure on biodegradation should be the objective of laboratory studies. Studies conducted on microorganisms in deep ocean trenches[12] revealed that microorganisms can withstand high pressures.

B.2.3. Biotransformation of Radionuclides in the WIPP Repository.

Microorganisms can transform metals and radionuclides through the following mechanisms: (a) solubilization, (b) precipitation, (c) accumulation, and (d) volatilization[13, 14, 15, 16, 17, 18]. Changes in redox potential, pH, and the biodegradation of chelating agents have been shown to mobilize or precipitate metals and radionuclides. Organic acids, such as those found in WIPP brines, can alter brine pH and can act as chelating agents for radionuclides. Microorganisms readily accumulate metals (including radionuclides) within their cells or on their surfaces[13 16]. This immobilizes the radionuclides, which can mitigate dispersion. Microbial methylation of several metals (such as mercury, tin, arsenic) and metalloids (selenium, tellurium) occurs readily , sometimes rendering the metals volatile. Barnhart[7] examined the potential methylation of TRU elements, but results were inconclusive.

B.2.4. Biodegradation of Volatile Organic Compounds

After TRU-wastes are emplaced at WIPP, release of hazardous VOCs into the repository is expected. Migration of VOCs is currently assumed by SNL and DOE to occur if gas generation induces fractures in the geologic formations, creating a migration path to the regulatory boundaries. Current transport models do not consider the solubility of VOCs in the brine, hydrolysis of the VOCs in brine, adsorption of the VOCs on rock matrices, or in-situ biodegradation of VOCs. These processes can significantly reduce the transport of VOCs in the subsurface environment. Biodegradation of chlorinated aliphatic solvents, such as trichloroethylene, carbon tetrachloride and others, has been shown to occur in anaerobic environments by methane-utilizing microorganisms[19 20]. In-situ biodegradation of the VOCs at the WIPP site could totally eliminate the possibility of these hazardous compounds migrating to the regulatory boundaries in concentrations exceeding regulatory limits. Results from studies of mechanisms which decompose VOCs before they reach the site boundary will be important to the certification and permitting processes, and their inclusion in the test program should be considered.

B.3. Radiolytically Generated Gas—An Alpha Radiolysis Primer

The intent of Section B.3. is to provide a basic overview of alpha radiolysis of materials, focusing on the potential for gas production. Portions of this section are taken from Spinks and Woods[21] and the TRUPACT II SAR[22] Appendix on "Radiolytic G Values For Materials -- Application to Transportation of CH-TRU Wastes," written by Dr. Marilyn M. Warrant (SNL). For more information, the reader is referred to that section of the TRUPACT II SAR because it represents the most extensive review on alpha radiolysis performed to date.

B.3.1. Basic Mechanism

Ionizing radiation interacts with matter as it passes through it. Most of the radiation from contact-handled TRU wastes consists of alpha particles. Alpha particles are a form of ionizing radiation consisting of helium atoms stripped of their electrons; hence, they have a double positive charge. An alpha particle interacts with matter primarily by losing energy through inelastic collisions with electrons. The collision leads to excitation and ionization of the atoms or molecules to which those electrons belong. Free radicals may also be formed. The number of ion pairs formed is approximately linear with distance until the alpha particle nears the end of its path in a given material. At that point, it will produce a much larger number of ion pairs.

The rate of energy loss by ionizing radiation is expressed in terms of linear energy transfer (LET). Alpha particles have very high LET. The tracks formed by the passage of an alpha particle contain ions, free radicals, and atoms. The free radicals are extremely reactive; gases may be produced by their recombination. For example, if the concentrations of hydrogen free radicals in a track or spur are high enough, they will recombine to form a hydrogen molecule. Other reactions may compete for the hydrogen free radicals through scavenging processes. Consequently, not all hydrogen free radicals produce hydrogen molecules (gas).

B.3.2. Distance Traveled

An alpha particle will traverse a distance of approximately one centimeter in dry air. A single sheet of paper will stop it as will the layer of dead skin on a person's body. It will travel about 50 microns in a particle of plutonium dioxide. Most likely, the plutonium in contact-handled TRU material will be in the oxide form.

B.3.3. Alpha Radiolysis of Organic Materials

As stated in the SAR, alpha radiolysis of organic materials will generate gases. Depending on the organic matrix, the evolved gases may be hydrogen, carbon dioxide, carbon monoxide, methane, etc. Radiolysis of cements, sludges, water, and brine will also generate gases. A measure of the gas production potential of a material is the G(value). It is defined as the number of molecules of gas produced per 100 electron volts (eV) of energy deposited in the matrix.

Kosiewicz[23] reported the G(values) for rubber materials to be about 0.04 to 0.15, plastics at 2.0 to 6.3, bitumen at 1.1, and cellulose at 1.4. With increasing dose deposited in a waste matrix, the values decreased. This decrease was attributed to depletion of the waste matrix within the limited range of penetration of the alpha particles. Reed[24] has reported G(values) for hydrogen to be 1.1 to 1.4 for alpha radiolysis of WIPP brine A. In a sludge or brine, depletion might not occur if more molecules of water were bought within the range of the alpha particles.

The following very simple equation can be used to estimate the amount of gas produced by alpha radiolysis:

$$\text{Moles gas/(year-drum)} = (0.1 \text{ mol})(\text{\# alpha Curies})(G(\text{gas}))$$

This equation does not correct for the decrease in gas evolution caused by matrix depletion. Confusion may occur when trying to make comparisons with calculations done in the TRUPACT II SAR because the SAR converts the radionuclide decay energy into wattage. It is not the intent of the SAR to suggest that thermal heat is the cause of gas production, but rather wattages are a way to use the dose deposited in the waste matrix for calculations.

B.4. VOCs

A VOC is a compound whose normal boiling point is less than 200°C. Examples of some VOCs are trichloroethane, acetone, carbon tetrachloride, and methylene chloride. VOCs are present in some TRU wastes as residues from the processes which produced the wastes. Some of these processes include liquid-liquid extractions, degreasing of machining parts, and clean up of equipment or gloveboxes. Because the VOCs are volatile, they evaporate off the waste matrices on which they were originally absorbed.

B.4.1. Liquefaction of VOCs.

Repository pressure can range from surface ambient (1 atm) to the hydrostatic pressure of the salt-pore brine in the Salado formation (about 65 atm) or the lithostatic pressure at the repository depth (about 150 atm). At the higher pressures volatile organic compounds, if present at high enough partial pressures, may liquefy.

Conditions for existence of a VOC liquid phase are: local temperature between triple point and critical point temperatures, and VOC partial pressure at or above the saturation pressure corresponding to the local temperature. The triple and critical point temperatures, and saturation pressure are thermodynamic properties. For volatile organic compounds, the triple point temperatures are too low to be of concern, critical temperatures are higher than 30°C and saturation pressures at 30°C are below one atmosphere. WIPP conditions may allow a VOC condensate phase to form.

B.4.2. Solubility in Brine:

An increase in pressure within the repository can also increase the solubilities of gases and liquids in the brine. The likelihood of degradation of VOCs is enhanced because they may degrade through hydrolysis or biodegradation when they are dissolved in brine.

B.4.2. VOC Quantities:

A sensitivity calculation was performed to determine what quantity of a VOC would have to be present in an alcove to be analytically detectable. The calculation assumed that the volume of the alcove minus the volume of drums in it produced a void volume of 664 M^3 as was suggested in the Alcove test plan. Only 4.5 grams of carbon tetrachloride are required in the alcove to meet the analytical DQO of 1 ppm (vol).

Similarly:

trichloroethylene	≈4.0 gm
trichloroethane	≈ 4.0 gm
dichloromethane	≈ 2.6 gm

The calculation suggests that it takes only a small amount of a compound to reach the 1 ppm (vol) level. This corresponds roughly to 1 drop of liquid carbon tetrachloride per every ten 55-gallon drums in the alcove.

---

[1] C. F. Norton, "Rediscovering the Ecology of Halobacteria," *American Society of Microbiology (ASM) News* 58, 363-367 (1992).5

[2] D. E. Caldwell, "Microbial Biogeochemistry," in *A Report of Biological Investigations at the Los Medanos Waste Isolation Pilot Plant (WIPP) Area of New Mexico during FY1978* (T. L. Best and S. Neuhauser, Eds.), SAND79-0368 (March 1980).

[3] R. I. Vreeland, Personal Communication, West Chester University, West Chester, PA (August 31, 1993).

[4] Francis, A. J., J. B. Gillow and M. R. Giles, Personal communication, Brookhaven National Laboratory, Uptown, NY (August 31, 1993).

[5] L. H. Brush, "Test Plan for Laboratory and Modeling Studies of Repository and Radionuclide Chemistry for the Waste Isolation Pilot Plant," SAND90-0266 (January 1990).

M

M

[6] L. H. Brush, "Current Estimates of Gas Production Rates, Gas Production Potentials, and Expected Chemical conditions Relevant to Radionuclide Chemistry for the Long-Term WIPP Performance Assessment," in *WIPP Performance Assessment Division, Preliminary comparison with 40 CFR Part 191, Subpart B for the Waste Isolation Pilot Plant,* SAND91-0893/3, (December 1991) pp. A-27 to A-36.

[7] B. J. Barnhart, E. W. Campbell, E. Martinez, D. E. Caldwell and R. Hallett, "Potential Microbial Impact on Transuranic Wastes under Conditions Expected in the Waste Isolation Pilot Plant (WIPP), October 1, 1978 - September 30, 1979," Los Alamos National Laboratory, NM, Report No. LA-8297-PR. (July 1980).

[8] D. E. Caldwell, R. C. Hallet, M. A. Molecke, E. Martinez, and B. J. Barnhart, "Rate of CO_2 Production from the Microbial Degradation of Transuranic Wastes under Simulated Geologic Isolation conditions," SAND87-7170 (January 1988).

[9] A. J. Francis, S. Dobbs and R. F. Doering, "Biogenesis of Tritiated and Carbon-14 Methane from Low-Level Radioactive Waste," *Nuclear & Chemical Waste Management* **1**, 153-159 (1980).

[10] A. J. Francis, "Microbial Transformation of Low-Level Radioactive Waste," in *Proceedings of a Workshop of the International Union of Radio Ecologists* (E. Bonnyns-Van Gelder and R. Kirchmann, Eds.) Brussels (April 25-27, 1984) pp. 229 - 238.

[11] M. R. Tolley, P. Smyth and L. E. Macaskie, "Metal Toxicity Effects on the Biological Treatment of Aqueous Metals Wastes: Is a Biocatalytic System Feasible for the Treatment of Wastes Containing Actinides?" *Journal of Environmental Science and Health* **A27**, 515-532 (1992).

[12] H. W. Jannash and C. O. Wirsen, "Microbial Life in the Deep Sea," *Scientific American* **236**, 42-52 (1977).

[13] C. L. Brierley, "Metal Immobilization Using Bacteria," in *Microbial Mineral Recovery* (H. L. Ehrlich and C. L. Brierley, Eds.), McGraw-Hill, New York (1990) pp. 303-323.

[14] A. J. Francis, "Characteristics of Nuclear and Fossil Energy Wastes," *Experientia* **46**, 794-796 (1990a).

[15] A. J. Francis, "Microbial Dissolution and Stabilization of Toxic Metals and Radionuclides in Mixed Wastes," *Experientia* **46**, 840 - 851 (1990b).

[16] L. E. Macaskie, The Application of Biotechnology to the Treatment of Wastes Produced from the Nuclear Fuel Cycle: Biodegradation and Bioaccumulation as a Means of Treating Radionuclide-Containing Streams. *Critical Reviews in Biotechnology* **11**, 41-112 (1991).

[17] A. J. Francis, C. J. Dodge and J. B. Gillow, "Biodegradation of Metal Citrate Complexes and Implications for Toxic-Metal Mobility," *Nature* **356**, 140-142 (1992).

[18] Francis et al., 1990

[19] J. M. Thomas and C. I. Ward, "In Situ Biorestoration of Organic Contaminants in the Subsurface," *Environmental Science and Technology* 23, 760-766 (1989).

[20] P. Howard II, et al., *Handbook of Environmental Degradation Rates,*, Lewis Publishers, Inc. (1991) Vol. 1.

[21] J. W. Spinks and R. J. Woods, *An Introduction to Radiation Chemistry,* John Wiley & Sons, New York (1976).

[22] NuPac TRUPACT II SAR, Rev.1, July 1989.

[23] S. T. Kosiewicz, "Comments on 'Gas Generation from Organic Transuranic Wastes. 1. Alpha Radiolysis at Atmospheric Pressure," *Nucl. Techn.* 92, 428 (1990).

[24] D. T. Reed, et al, "Radiolytically-Induced Gas Production in Plutonium-Spiked WIPP Brine," Boston Materials Research Society Meeting, Symposium V11.30, Boston, MA. (Nov. 30-Dec. 4, 1992).

THIS PAGE

LEFT BLANK

INTENTIONALLY

APPENDIX C

CONCEPTUAL RELATIONSHIP OF GAS STUDIES

C.1 Satisfying Regulatory Compliance

An aspect of compliance with the EPA environmental safety regulations is demonstrating that flows of regulated hazardous components (VOCs or radionuclides) at the compliance-control boundaries will not exceed the regulatory levels. There are two major and distinct parts of the compliance issue related to the generation, release, and flow of VOCs. These are

- generation of gaseous contaminants (including VOCs) in the repository and subsequent release to the geologic medium; and
- transport of VOCs to the regulatory boundaries of the site.

About 20 of the 95 studies listed in the 1993 Test Phase Plan address these two issues of gas generation and transport.

The regulatory levels for potential hazardous contaminants at site boundaries are presented in terms of the contaminant concentration value in such media as surface waters, ground waters, soils, soil gases, or air. This is true even if the regulations are written in a language requiring that certain upper-bound values will not be exceeded for health risk, ingestion of cumulative amounts of radioactivity, dose risk, or exposure to certain amounts of a contaminant over a specified period of time. The WIPP site boundaries are surfaces that envelope a specified volume of geologic formation. The lower boundary is deeper than the repository floor, the upper is above the repository but below the ground surface, and others bound the site laterally.

A concentration value of a VOC, (C_u), for which an upper limit has been set by EPA cannot be exceeded at the site boundary. The design of the repository and the engineered barriers of the site should minimize the expected concentration, C, that may reach the site boundaries. The attenuation of a VOC at the site boundary is the ratio C/C_u. To satisfy compliance requirements the attenuation value needed is

$$\frac{C}{C_u} < 1 \qquad \text{(C - 1)}$$

but lower attenuation values may be considered to be desirable performance targets.

C.2. Site-boundary Attenuation Ratio (N_b)

The concentration of a VOC, (C_u), at the site boundary is a function of the amount released from the repository, the rate of transport by gas or brine flow through the geological medium, and any process that may retain, decrease, or release the VOC in the geological medium. A simple combination of these processes defines the conservation of mass of the VOC to produce the attenuation ratio, N_b, as follows:

$$N_b = \frac{F_H \pm G}{QC_u} \bullet t \qquad \text{(C - 2)}$$

$$= \frac{C}{C_u} \qquad \text{(C - 3)}$$

where

F_H is the total mass flow of the VOC gas that migrates from the repository space into the geological medium (moles/year)

G is the total mass flow of the VOC that is either retained in (-), or added from (+), the geological medium (moles/year)

Q is the rate of total volume flow that transports the VOC to the site boundaries (liters/year)

C_u is the regulatory upper-limit concentration of the hazardous gas species at the site boundaries

C is the expected concentration of the VOC at the site boundaries

t time of the process (years)

The value of N_b that is needed to satisfy compliance requirements is:

$$N_b < 1 \qquad \text{(C - 4)}$$

To produce values for use in PA models for each parameter in Eq. (C - 3) a long list of technical data needs has to be developed. Each technical data need requires tests and modeling of the heterogeneous wastes in the repository, their gas-generation reactions, and travel paths in the geological environment. As stated earlier, among 95 studies listed in the 1993 Test Phase Plan, at least 20 address the issues of gas generation and transport. A list of activities and studies in the Test Phase Plan for WIPP that support the data needs of the individual parameters of N_b is presented in Table C.2-1.

Table C.2-1. Parameters for Gas Issues Hierarchy and their Supporting Tests.

Parameter		Activity or Study in Test Phase Plan	
Site-Boundary Attenuation Ratio	N_b	Regulatory requirements	2.1
		Compliance/long-term performance for §191	3.1
		Same for §268.6	4.1
Regulatory concentration at the site boundary	C_u	*Not identified explicitly*	2.1
Flux of gaseous contaminants out of the repository	F_H	?—Possibly included in G and F	—
		Gas-Generation Characteristics	5.3.1
		RCRA Constituents Source Term	5.3.4
Retention of gaseous contaminants by the geological medium	G	Regional Geochemical Studies	5.1.1.5
		Adsorption Studies/Non-Salado	5.1.2.1
		Radionuclide Solubility & Speciation/Non-Salado	5.1.2.2
		Gas Solubility in Salado Brines	5.1.4.1
		Retardation in the Salado	5.1.4.2
		RCRA Constituents Retardation in the Salado	5.1.4.4
Fluid volume flow to site boundaries	Q	Regional-Scale Transport/Non-Salado	5.1.1.2
		Model Development for the Non-Salado	5.1.1.3
		Field Testing/Non-Salado Hydrology	5.1.1.4
		Salado Hydrologic Properties	5.1.3
		Tracer and Transport Testing/Salado	5.1.4.3

One conclusion to be drawn from Table C.2-1 is that the Bin and Alcove Tests (activity 5.3.1. that supports parameter F_H) constitute only a small fraction of the many studies believed to be needed in the Test Phase of the repository. Table C.2-1 implies that the Test Phase Plan is not being driven by any explicit regulatory values of the concentrations of hazardous gas species at the site boundaries—parameter C_u has no value assigned to it for any individual gas species.

An analysis should be performed of conceptual relationships, such as that expressed in a mathematical form by the attenuation ratio N_b , to accelerate the resolution of all essential gas-related issues. The breadth of the parameters in Table C.2-1 and their related studies emphasizes the need to develop close working linkages among the individual tests.

THIS PAGE

LEFT BLANK

INTENTIONALLY

APPENDIX D

COMMENTS ON SOME LABORATORY STUDIES SUPPORTING WIPP

D.1. Historical Perspective on Gas Generation

Laboratory studies of gas generation on TRU wastes destined for WIPP were carried out for about four years, concluding in 1979. They were funded by DOE and coordinated by SNL, and were done primarily at LANL and SNL. Molecke summarized the data produced by the experimenters in 1979[1]. The program addressed four gas generation mechanisms:

- bacterial degradation of waste,
- thermal degradation,
- metal corrosion, and
- radiolysis of the organic waste matrices.

In the 1970s, thermal degradation of waste was considered a mechanism of potential importance because plans to dispose of high-level radioactive wastes in the salt repository would cause the repository temperature to rise substantially above the ambient rock temperature (about 25°C) Temperatures of 40°C or 70 °C were postulated depending on various heat loading scenarios.

Highlights of the 1970s laboratory studies included establishing the relative importance of the different gas-generation mechanisms and estimating the amounts of gas that could form in wastes of different composition and under different sets of environmental conditions. Bacterial degradation of organic wastes was identified as a very important gas-generating mechanism. Radiolytically evolved gases were not considered to be major contributors to the overall repository gas budget. While metal corrosion in a dry or nearly waterless environment was not considered to be significant, these early studies showed that corrosion under anoxic conditions in saline brines was the primary mechanism responsible for generating gas.

Estimates of both gas-generation rates and the upper bounds on the gas masses that may be produced by different kinds of waste have not changed drastically since the 1970s. About the same upper bounds for gas-generation rates (a few moles of gas per drum of waste per year) and total gas masses (up to about 5,600 moles per drum) continue to be cited in present reports.

The laboratory studies of gas generation by TRU wastes were terminated in 1979 as a consequence of permeability measurements of WIPP salt. When permeabilities were measured on salt core samples brought to the surface, they were found to be high enough that no overpressurization would occur in the repository. However, these cores had microfractures (due to relief of the overburden pressure) which provided erroneously high permeability values. In 1988, salt permeabilities measured in situ were three orders of magnitude lower than those obtained in the earlier laboratory determinations. Thus, the potential production of gases by the wastes in the repository and their accumulation in the repository became an issue of renewed concern.

The gas generation program was revived in 1988. In the mid 1980s, the main regulations bearing on the release and migration of radioactive wastes to the boundaries of the disposal site were those contained in 40 CFR 191. Gas generation in TRU wastes and its potential flow to the boundaries of the repository were at the time correctly judged to be of no importance to the transport of radionuclides. Since 1987, however, new regulations of the EPA (based on the RCRA and contained in 40 CFR 268.6) have required WIPP to demonstrate that certain hazardous components of the waste, including VOCs, would not exceed the regulatory concentration limits at the boundaries of the disposal site. Since VOCs are gases at the ambient operating conditions of the repository, they may be transported as minor components in mixtures of other gases that may form in the waste by various chemical or biological processes. Hence, the need to characterize and bracket gas-generation mechanisms in wastes resurfaced.

D.2 Summary of Current Laboratory Activities Evaluating Gas Generation

The current laboratory studies of gas generation are managed and coordinated by SNL (and funded by DOE) through subcontracts with PNL (metal corrosion), ANL (radiolysis of brines and plastic materials), and BNL (bacterial degradation of cellulose and irradiated plastics). Studies of gas generation by metal corrosion, alpha radiolysis of brines, and bacterial degradation of organic materials are in various stages of completion. Interactive studies of the following scope are planned for the near future:

- corrosion in the presence of byproducts of bacterial metabolism;
- corrosion in the presence of ^{239}Pu and ^{238}Pu in brines;
- bacterial degradation of irradiated plastics and rubber materials;

- bacterial degradation in the presence of ^{239}Pu in the growth medium.

The main gas-generating processes that are either under study or in planning for the near future, are:

- Production of hydrogen gas by corrosion of steel and other metals in saline brines.
- Corrosion and passivation of steel by reactions with carbon dioxide and hydrogen sulfide in gas and brine phases.
- Formation of gases and reactive radicals by alpha-particle radiolysis of brines and organic materials. Radiolysis is effected by plutonium in solids and brines.
- Effects of radiolysis on metal corrosion and, subsequently, gas generation.
- Bacterial metabolism utilizing organic materials, the products of which are such gases as carbon dioxide, hydrogen sulfide, nitrogen, nitrous oxide, other nitrogen oxides, and methane.
- Effects of radiolysis on bacterial gas generation, and on production of volatile and soluble organic compounds from metabolic byproducts.

Gas-generation studies focus primarily on the potential gas species and their rates of evolution from the main constituents of the TRU wastes or the materials that may be included in its packaging. At present, three major types of materials are used in gas-generation studies: metals in corrosion tests, organic materials in biodegradation experiments, and sodium-magnesium-chloride brines in alpha-radiolysis.

Components of these materials are:

Organics: biodegradable materials (cellulosics, sludges and other organic materials) and not-easily biodegradable components (plastics, including polyethylene, and leaded rubber).

Metals: low-carbon steels, other alloys and metals (aluminum, copper, titanium).

Brines: brine types A and B, magnesium-sodium-chloride type; dissolved radionuclide species included.

D.3 Laboratory-scale Corrosion Testing at PNL

Westerman at PNL found that sixty Hastelloy C-276 or Titanium Grade 12 autoclaves were capable of maintaining pressure-tight seals for more than one year. Most of these vessels have a 1 gal volume and can be operated at pressures as high as 3000 psig. Three vessels are unusually large (10 ft deep and 2 ft in diameter). Maximum operating temperature of 300 to 400°C can be maintained with proportional controllers.

Three autoclaves are being used for WIPP studies at pressures approaching lithostatic conditions, 900 psig carbon dioxide, 2000 psig hydrogen, or 2000 psig nitrogen at 30°C. These experiments were started in June 1993, and should be completed by December, 1993. Corrosion data are not yet available.

Some experiments must be conducted in pressure vessels constructed from Hastelloy C-22 pipes. These must be hermetically sealed with welds to maintain seal integrity. Because these vessels are not pressure coded, the maximum operating pressure is 300 psig. The vessels have a plenum volume of approximately 2 L. If a vessel passes a helium leak test, it has usually been found to be capable of holding pressure for at least two years. The biggest experimental problem encountered is sealing the high-pressure high-vacuum valves.

X-ray diffraction is used to identify corrosion products on the coupon samples removed from experiments. In some cases, x-ray fluorescence has been used to determine the elemental composition of the films (nickel, iron, zinc, etc.).

All laboratory WIPP work done at PNL is summarized in a report entitled *Hydrogen Generation by Metal Corrosion in Simulated Waste Isolation Pilot Plant Environments*, by M. R. Telander and R. E. Westerman[2]. This report will not be officially released until internal review is completed.

In addition to conducting corrosion research for WIPP, PNL has conducted corrosion research for the BWIP and Yucca Mountain Projects, as well as other large projects at Hanford. Their laboratory is staffed with several good electrochemists, and is equipped with several potentiostats.

Primary Data for Performance Assessment. Bin Tests, as now defined, will not provide primary data for the development of gas-generation models. The bench-scale laboratory program will provide more valuable data and is much more cost effective. These laboratory tests at Battelle PNL, ANL, and BNL are being conducted with well-characterized simulated wastes (substrates), and can be extended to include real wastes. Consequently, it should be possible to identify gas generation mechanisms and interactions (synergistic effects) from them. Furthermore, bench-scale experiments can potentially be conducted at lithostatic pressure in existing high-pressure autoclaves. Data from this laboratory program should provide high-quality data for incorporation into gas generation models.

Confirmatory Testing. SNL has predicted 35 pressure transients (pressure vs. time curves) that could be compared to experimental data from the proposed Bin Tests. Even though agreement of these predictions with such experimental data may help confirm gas generation models used by performance assessment, they will not provide complete confirmation because of inadequate waste characterization. Large-scale laboratory tests are needed to investigate waste interactions, as well as mechanistic synergisms.

D.4 Source Term Test Program (STTP)

Because SNL personnel stated that some type of VOC analyses would be done in the Source Term Test at LANL, one member of the ITR team interviewed the LANL STTP Project Leader to determine if the VOC analyses were related to TRU disposal. It was determined that these VOC analyses are not considered to be an alternate source of VOC information for WIPP disposal.

The Actinide Source Term Program (ASTP) has three major components: modeling; Los Alamos National Laboratory (LANL) measurements of leachates obtained from TRU-wastes; and laboratory experiments at other laboratories (SNL, LLNL, FSU, and LBL). The LANL Source Term Test Program(STTP) is described in the test plan provided to the ITR Team in July 1993[3]. The test plan states that concentrations of dissolved and suspended actinides in WIPP brines are a priority need for demonstrating compliance with 40 CFR 191, Subpart B.

The LANL actinide test program will include bench-scale tests using 1-5 liter containers and drum-scale tests using 65-gallon containers. Some of the bench-scale tests will be done at pressures up to 875 psig (60 bar). It is scheduled to start in April 1994. LANL personnel will not interpret the data, the first of which may be sent to SNL in August 1994.

There is an ambitious list of variables for potential measurement of properties of materials from brine leachate samples obtained during these tests.

Although, complexation and retardation are highly dependent on oxidation states, actinide oxidation state speciation is not definitely planned to be done. Oxidation state data could be combined with data on complexing and chelating agents to derive significant information on the potential for actinide mobility in WIPP.

Headspace gases in test containers will be analyzed for VOC's even though this is not required by the test plan. This will be done because the New Mexico Environment Department informally requested (not required) this information. No analysis will be performed of the headspace gases in the waste drums used to supply materials for the tests.

[1] Molecke, M. A., "Gas Generation from Transuranic Waste Degradation: Data Summary and Interpretation," SAND79-1245 (July 1979).

[2] Telander, M. R., Westerman, R. E., "Hydrogen Generation by Metal Corrosion in Simulated Waste Isolation Pilot Plant Environments," SAND92-7347, in press.

[3] LANL document CLS1-STP-SOP5-012/0, May 1993.

APPENDIX E

LIST OF ACRONYMS

Acronym	Definition
ALARA	As Low As Reasonably Achievable
ANL	Argonne National Laboratory
AOP	Annual Operating Plan
API	Applied Physics, Incorporated
ASTM	American Society for Testing Materials
ASTP	Actinide Source Term Program
BWIP	Basalt Waste Isolation Project
CCDF	Complementary Cumulative Distribution Functions
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
CH	Contact Handled
D&D	Decontamination and Decommissioning
D&E	Design and Engineering
DNFSB	Defense Nuclear Facility Safety Board
DOE	Department of Energy
DOE/EM	DOE Office of Environmental Restoration and Waste Mgt.
DOE/HQ	DOE Headquarters

DOT	Department of Transportation
DQO	Data Quality Objectives
DRZ	Disturbed Rock Zone
EEG	Environmental Evaluation Group
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ER	Environmental Restoration
FAT	Facility Acceptance Test
FGE	fission gram equivalent
FTIR	Fourier transform infrared
HVAC	Heating, Ventilation and Air Conditioning
ICP	inductively coupled plasma
INEL	Idaho National Engineering Laboratory
ITR	Independent Technical Review
LANL	Los Alamos National Laboratory
LAT	Loop Acceptance Test
LEL	Lower Explosive Limit
LWA	Land Withdrawal Act
M&O	Management and Operations
M&OC	Management and Operations Contractor
MIC	microbial-induced corrosion
MIIT	Materials Interface Interactions Test
NDA	Non-Destructive Assay
NDE	Non Destructive Examination

NEPA	National Environmental Policy Act
NESHAP	National Emission Standard for Hazardous Air Pollutants
NIST	National Institute of Science and Technology
NMD	No-Migration Determination
NMED	New Mexico Environment Department
NMV	No-Migration Variance
NQA	Nuclear Quality Assurance
OBES	DOE/Office of Basic Energy Sciences
ORIA	EPA Office of Radiation and Indoor Air
OSW	EPA Office of Solid Waste
PA	Performance Assessment
PAT	Performance Acceptance Test
PI	Principal Investigator
PNL	Pacific Northwest Laboratories
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RH	Remote Handled
RTR	Real-Time Radiography
SA	Science Advisor
SAR	Safety Analysis Report
SARP	Safety Analysis Report, per NRC convention
SCC	stress corrosion cracking

SDD	System Design Description
SIMS	secondary ion mass spectrometry
SNL	Sandia National Laboratories
SRS	Savannah River Site
STP	Source Term Program
STT	Source Term Test
STTP	Source Term Test Program
SWB	Standard Waste Box
TNAD	Technical Needs Assessment Document
TOB	Technical Oversight Board
TPP	Test Phase Plan
TRU	Transuranic
TRUPACT-II	Transuranic Package Transporter
TSG	Technical Support Group
U.S.C.	United States Code
VOC	Volatile Organic Compound
WAC	Waste Acceptance Criteria
WBS	Work Breakdown Structure
WHC	Westinghouse Hanford Co.
WID	Waste Isolation Division of Westinghouse
WIPP	Waste Isolation Pilot Plant
WM&ER	Waste Management and Environmental Restoration
WPIO	DOE/WIPP Project Integration Office
WPSO	DOE/WIPP Project Site Office

XRD	X-ray diffraction
XRF	X-ray fluorescence
YMP	Yucca Mountain Project

THIS PAGE

LEFT BLANK

INTENTIONALLY

APPENDIX F

SCOPE AND METHOD OF ASSESSMENT

F.1. Scope of Assessment

The scope of the Independent Technical Review of the proposed Bin and Alcove test programs at the WIPP site was limited in duration and focus. The review focused primarily on the regulatory approach used to show compliance with federal and state laws and regulations, the technical information needs required for performance assessment, and the ability of the proposed in-situ bin and Alcove test programs to provide the information. The review was further bounded by the situation at the time of the review, which included two periods of direct site interactions (July 26-30 and August 30-September 3, 1993). Modifications to the test phase plans, the tests programs or regulatory strategy after the review period were not considered in the assessment.

F.2. Method of Assessment

This ITR was based on the "Charter for the Independent Technical Review of Transuranic Waste Experiments at the Waste Isolation Pilot Plant" (Section F.3), developed and approved by DOE prior to the review.

Based on the Charter and previous ITR charters, the purpose of Independent Technical Reviews is to assess whether engineering practice is developed to a point that specific major projects/activities can be executed without significant technical problems. The objective of the ITR Team is to produce a documented, independent, engineering review of major projects funded by DOE-EM. Each review provides a factual understanding of the actual situation at the time of the review. The output of the review is a clear articulation of the strengths and weaknesses in the technology and engineering practice, the major uncertainties, and suggestions on beneficial courses of action.

Figure F.2-1 outlines the structure of the Independent Technical Review Organization which is subdivided into two groups, the ITR Team, and the Technical Oversight Board (TOB). The ITR Team is comprised of technical experts who examine the details of a given project, develop a thorough understanding of the Project and the factors and conditions that are important to its eventual success, and then use that input as the basis for developing a technical assessment of the project's status. The TOB is composed of senior level individuals who have extensive experience in the development, execution, management and evaluation of large and technically involved projects. They provide a solid reference point of experience and ideas against which the ITR Team can test its ideas regarding lines of inquiry, and the logic and validity of findings and conclusion.

The WIPP Independent Technical Review Team consisted of 9 technical personnel and associated support personnel. The members were employees of various organizations including: DOE, Los Alamos National Laboratory, Lawrence Livermore National Laboratory and private consultants. Resumes of the WIPP ITR members and a listing of the TOB membership are provided in Appendix J.

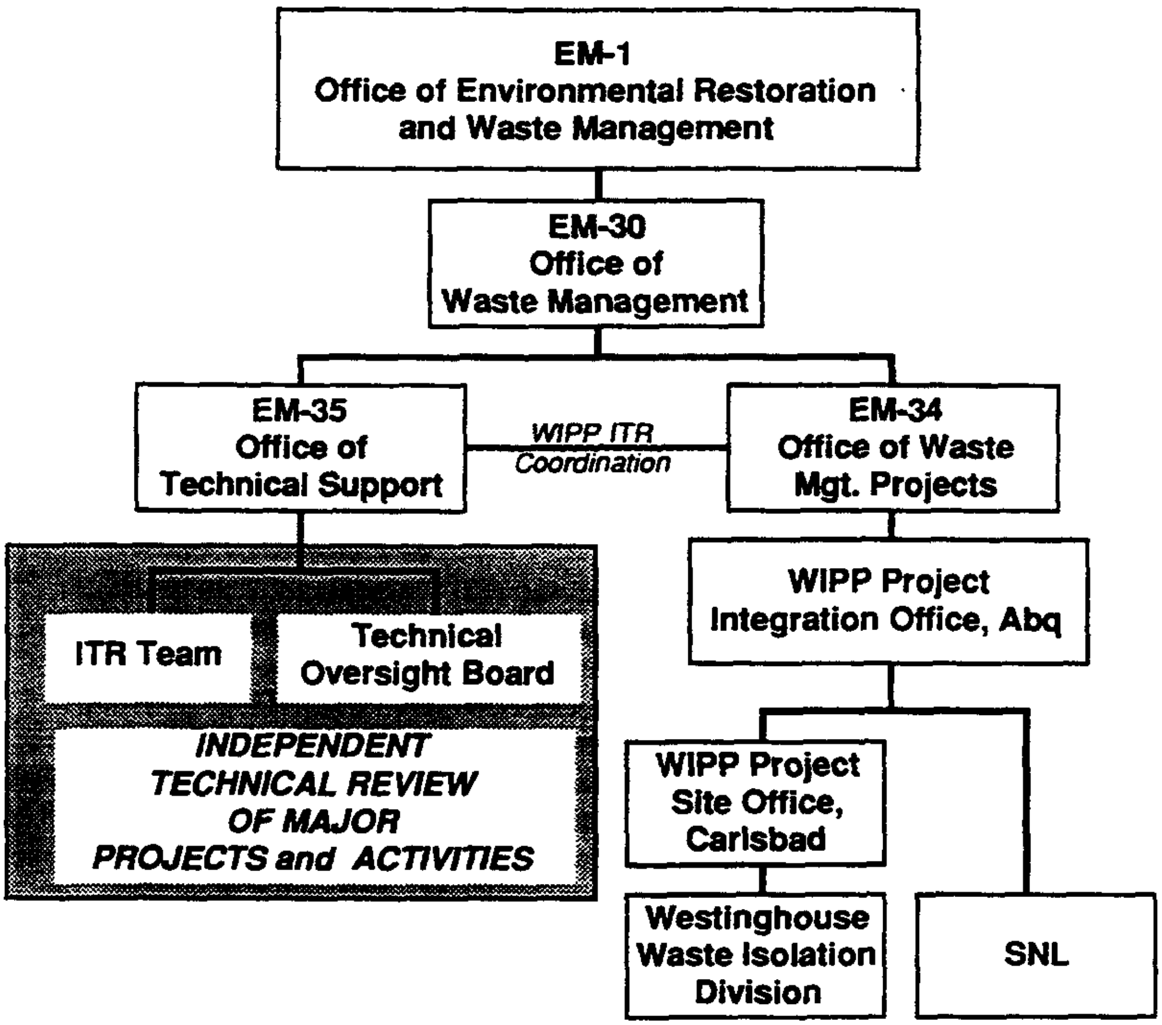


Fig. F.2-1 Independent Technical Review Organization

The review process consisted of document review, formal presentations by WPIO, WPSO, WID, SNL and other associated agencies.

During the first week of interactions with the project, July 26-30, 1993, the ITR Team listened to formal presentations given, toured the WIPP repository and associated facilities, reviewed documents, participated in informal group and individual discussions and interviews with WPIO, WPSO, WID and SNL personnel, and gathered information. During the week of August 16, 1993, the ITR Team met in Denver Colorado and reevaluated the review lines of inquiry for the second week site visit, and read documentation. During the second week of site interactions, August 30 September 3, 1993, the ITR Team interviewed personnel on specific topics and lines of inquiry. During the week of September 7, the ITR Team met at Los Alamos National Laboratory to develop consensus assessment issues and recommendations, and to initiate preparation of a draft Assessment Report.

F.3. Charter for the Independent Technical Review of Transuranic Waste Experiments at the Waste Isolation Pilot Plant

The following charter was used to direct the activities and evaluations of the WIPP ITR.

F.3.1. Mission

The mission of the Independent Technical Review (ITR) Team is to perform a review of the planned transuranic (TRU) waste experiments to be conducted at the Waste Isolation Pilot Plant (WIPP) for the U. S. Department of Energy (DOE-HQ). The purpose of the experiments is to provide information needed for models and calculations used in performance assessments, which are prepared to demonstrate regulatory compliance with disposal standards and provide safe management and disposal of radioactive and hazardous wastes.

The TRU-waste experiments include the bin test program and the Alcove test program. The proposed bin test program will provide data on gas generated by the degradation of TRU-waste in terms of generation rates, species and potential, which will then be used to confirm the predictive results of gas-generation models supporting performance assessment analyses. The Alcove test program will address the release of volatile organic compounds (VOC) for subsequent use in No-Migration calculations needed for compliance with RCRA (Resource Conservation and Recovery Act).

F.3.2. Objective

The objective of this ITR assessment is to review the need for, and technical validity of, the bin and Alcove test programs, as defined in the Test Phase Plan, the Technical Needs Assessment Document, and individual test plans. The test programs will be evaluated primarily with regard to providing data used for performance assessments, demonstrating WIPP regulatory compliance, and supporting the safe, timely disposal of waste. The ITR Team will document their independent review findings and recommendations in an unbiased, logical technical engineering report.

F.3.3. <u>ITR Interfaces</u>

The ITR Team will perform its activities under the general direction of DOE-HQ Office of Technical Support, EM-35. The DOE-HQ Waste Management Projects, EM-34, and the DOE-HQ WIPP Project Division, EM-342, will serve as advisors to EM-35, and will be informed of review activities.

The DOE WIPP Project Integration Office (WPIO) will coordinate the interface between the ITR Team, the WIPP Project Site Office (WPSO) and the two prime contractors: the Waste Isolation Division (WID) of Westinghouse, and Sandia National Laboratory (SNL). Direct discussions with WPSO, WID, and SNL staff will be required during performance of the review, and to the extent practical, WPIO shall participate in these discussions.

F.3.4. <u>ITR Task Descriptions</u>

The work to be performed under this charter is comprised of the following tasks:

<u>Task 1:</u> **Regulatory Interpretation and Compliance**

The ITR Team will review the WIPP approach to interpreting regulations and regulatory requirements (such as the 40 CFR 191 Disposal Standards, regulations implementing RCRA, and the WIPP Land Withdrawal Act [LWA]), formulating regulatory compliance strategies, developing compliance analysis processes and deriving informational needs, with regard to the currently defined bin and Alcove test programs. The ITR Team will compare the informational needs to the type of test results anticipated from the test programs to assess the scientific basis for, and the direct relevance, credibility and defensibility of, the data to be produced.

<u>Task 2:</u> **Technical Performance Assessment**

The ITR Team will review and assess the relationship of the bin and Alcove test programs to long-term performance assessment activities with respect to model verification, evaluation of synergistic effects, and uncertainty analyses.

The ITR Team will review and assess the association of the proposed bin test program with the scientific basis and technical understanding of TRU-waste gas generation (dominated by corrosion, radiolytic and microbiological mechanisms), and its affect on the long-term safe performance of WIPP.

Likewise, the ITR Team will review and assess the technical connection between the proposed Alcove test program, determining the release of volatile organic compounds and calculating gaseous source terms, and petitioning for a No Migration Determination under RCRA.

Task 3: **Test Implementation and Approach**

The ITR Team will review the approach to implementing the bin and Alcove test programs to assess: test scope adequacy; test plan definition; hardware design sufficiency; differences between testing and expected repository conditions; instrumentation and control system influences on data accuracy and reliability; and quality control/quality assurance practices.

Task 4: **Test Integration**

The ITR Team will evaluate the plans for integrating the bin and Alcove test programs with lab-scale programs, and with the total WIPP test program, to assess how experimental results will be incorporated into modeling verification tools for performance assessments. The utility of different test-scale and test-type results for use in WIPP performance assessment efforts will also be considered.

The ITR Team will also assess the integration of the bin and Alcove test programs into the function of WIPP as a geologic waste repository.

Task 5: **Associated Test Issues**

The ITR Team will review and assess the relationship of the proposed bin and Alcove test programs to such issues as: the adequacy of cost and schedule to support waste disposal decisions; the approach used to evaluate the need for, and adequacy of, contingency tests; the management approach to, and influence on, testing and operational status; the definition of acceptable waste forms; barriers to regulatory compliance; the technical preparedness of WIPP to transition from standby status to testing with TRU-waste.

Task 6: **Recommendations**

The ITR Team will provide suggestions, recommendations and/or alternate strategies, as appropriate, on the approach and implementation of the bin and Alcove test programs, their relationship with promoting the expeditious generation of information needed for performance assessments, and demonstrating WIPP regulatory compliance.

F.3.5. **ITR Team Qualifications**

The ITR Team will consist of a core group of knowledgeable, independent reviewers with expertise in one or more of the following areas:

- Defense TRU-waste knowledge with a broad understanding of the nuclear industry

- Generator Waste Processing, specifically in the areas of: TRU-waste generation and waste processing at DOE facilities; and the effect of various waste form alternatives on the basic waste generation processes.

- Geochemistry, with specific knowledge of WIPP and regional geology/geochemistry, and an understanding of geochemical interactions associated with hazardous and radioactive waste disposal.

- Metallurgy and Corrosion, specifically in the areas of: corrosion mechanisms; products of corrosion; corrosion inhibition; and the effects of near saturated brines on metal corrosion.

- Microbiology/Biogeochemistry, specifically in the areas of: bacterial degradation of hazardous, mixed waste, and nuclear waste forms; bacterial energetics; reactions of halotolerant and halophylic organisms, and the effect of salt environments on bacterial communities.

- Performance Assessment, specifically in the areas of: EPA Standards 40 CFR 191; requirements to conduct performance assessment of deep geologic repositories; and current performance assessment activities and challenges.

- Regulatory Compliance, specifically in the areas of: 40 CFR 191; RCRA 40 CFR 268; New Mexico state permitting requirements; the probability of permitting new technologies by state and federal governments.

- Test and Design Engineering, including instrumentation and data acquisition systems, design and test engineering

- Emanometry, including the physics and chemistry of gas generation and transport under deep geologic pressures and temperatures, with specific attention to the interpretation of time-dependent non-ideal behavior of generated gases, natural and waste related gas interactions, impacts of gas pressures on geologic medium (including salts) and brine migration.

- Repository Operations, including operation and/or engineering experience in repository operations including familiarity with mining, surface and underground facility design.

The team members shall be independent of WPIO, WPSO, WID and SNL, or any other group, agency or company presenting a potential conflict of interest. The team leader will be selected by DOE-HQ Office of Technical Support, EM-35, and will document that each team member's educational and experience background has been verified.

F.3.6. ITR Schedule

Team mobilization planning	start June 1, 1993
Initial pre-site visit	June 16-17
Document Request Memorandum	week of June 14
Team Member Orientation	July 20-22
Technical Oversight Board Evaluation of Review Plan	July 21
1st On-site Assessment	July 26-30
Review Plan Revision and Document Review	August 16-18
2nd On-site Assessment	August 30-September 3
Consensus Assessment Summary Preparation	September 7-10
TOB Review of Assessment Summary	week of September 20
Assessment Summary to WPIO	week of September 27
Draft Assessment Report Issued and Site Review	week of October 18
Final Assessment Report to DOE-HQ	week of November 1

F.4. Independent Technical Review Plan for Bin and Alcove test Programs for the Waste Isolation Pilot Plant (WIPP), Revision 1

NOTE: The Modifications to the Review Plan of 7/22/93 are highlighted by change bars in the right hand margins. The issues and lines of inquiry provided in this Review Plan, dated 8/24/93, can be modified at the discretion of the Independent Technical Review Team, as appropriate, based on information provided and evaluated during the review process.

F.4.1. **Introduction**

Independent Technical Review (ITR) of Major Projects, Major System Acquisitions, and programs was established as a Department of Energy, Office of Environmental Restoration and Waste Management (DOE-EM) activity in a memorandum from the Under Secretary of Energy, dated March 29, 1991, on the Status of the Hanford Waste Vitrification Plant. The DOE-EM ITR process was developed from this base.

F.4.2. **Structure of the Review Process**

This ITR will focus on understanding the need for, and technical validity of the WIPP *in-situ* bin and Alcove test programs, as defined in the Test Phase Plan and the Technical Needs Assessment Documents. The test programs will be evaluated primarily with regard to providing data to be used for performance assessments, demonstrating WIPP regulatory compliance, and supporting disposal of transuranic (TRU) waste. The ITR Team will document its review findings and recommendations in an unbiased, logical, technical, engineering report. The specific aspects are presented as six tasks in the charter and are summarized here:

1. The WIPP project approach to regulatory interpretation as well as compliance strategies to assess data needs required of the *in-situ* bin and Alcove test programs;

2. The relationship of the proposed bin and Alcove test programs to verification of the performance assessment model, the technical association of the bin test program to long-term repository performance, and the technical association of the Alcove test program to support a petition for a No Migration Determination for disposal of mixed TRU wastes;

3. The adequacy of the bin and Alcove test progr ms for implementation and experimental approach, including test plans, hardware, QA/QC, and extrapolation of test results to anticipated repository conditions;

4. Evaluation of the integration of the bin, alcove, and lab test programs with each other and with the total WIPP test program to provide model verification for performance assessment;

5. Associated bin and Alcove test issues, such as: programmatic costs and scheduling , project management and control, final waste form definition, barriers to regulatory compliance, the effect of public and oversight group interactions, and contingency tests;

6. If appropriate, the development of recommendations and/or alternate strategies for the bin and Alcove test programs to facilitate TRU waste disposal decisions / operations.

F.4.3. Approach to the Review

The review of the proposed WIPP *in-situ* transuranic experiments will follow the basic process developed for other ITR reviews, with modifications specific to this application. For example, this review will employ one team of approximately 10 individuals, which will subdivide to review specific topics, as necessary.

The review team will consist of a DOE Team Leader, an ITR Team Leader, team members and support personnel as required. Team members will have expertise in at least one of the following areas: (1) defense TRU waste, (2) generator waste processing, (3) geochemistry , (4) metallurgy and corrosion, (5) microbiology / biogeochemistry, (6) performance assessment, (7) regulatory compliance, (8) repository operations, and (9) emanometry. As required, the team will call upon expert consultants for highly specialized information and knowledge.

Prior to the review, the ITR Team will complete the development of the draft review plan with specific lines of inquiry. Following the review, the team leaders and team members will develop an overall consensus assessment report, with appropriate appendices to document supporting information and issues.

The WIPP *in-situ* transuranic bin and Alcove test program review plan and assessment report will be reviewed by the Technical Oversight Board (TOB). The TOB is composed of senior level individuals who have extensive experience in the development, execution, management, and evaluation of large and technically involved projects. They provide a solid reference point of experience and ideas against which the ITR Team can test its ideas regarding lines of inquiry, and the logic and validity of findings and conclusions. The TOB will function as a check to assure that the scope and depth of the science and engineering review are adequate to achieve the stated goal, and to assure the proper systematic evaluation of the project. The Board will also examine the results of the review, as appropriate to assure internal technical consistency and to confirm that findings are supported with sufficient information.

Initial preparation for the review was carried out by the ITR Team Leader. This will include: team mobilization, initial site visits, initial document requests, preparation of the draft review plan, and review plan presentation to the Technical Oversight Board. Subsequent activities will include team members.

The team members will be involved in three primary activities: (1) preparation for the review, (2) the review process, and (3) report writing. Preparation for the review will include three days during which team members will: review the ITR process, as described in the Independent Technical Review Team Handbook; complete the development of the review plan, with special focus on the lines of inquiry; discuss the application of the ITR process to review of the transuranic waste experiments to be conducted at WIPP; consult with independent, non-site individuals with specific technical and/or historical information about the WIPP tests and associated issues. Preparation may also involve other activities such as: revision of the review plan in the interval between the first and second weeks of the review at the WIPP site.

During the review, the team will have two primary site interactions: the first interaction will concentrate on a "horizontal" understanding of the project scope, underlying technical bases, and the site's perspective of the issues, through presentations, tours and document reviews; the second site interaction will use a "vertical slice" review approach to pursue lines of inquiry on points considered to be the potential bases for significant issues, via interviews, discussions and document evaluations. The second site interaction will also assure that initial information and understandings are correct and that potential implications related to issues are accurately perceived and understood. During both site interactions, the team will meet in private, as required, to consider the progress of the review, and to revise the review plan, as necessary, to successfully achieve its goals. Revisions to the review plan may require changes in the team's activities scheduled at the WIPP site.

Preliminary assessment report preparation can begin anytime during the review period. Immediately following the second week site review, the ITR team will convene at Los Alamos and prepare a consensus assessment summary as the first chapter of the report, which when completed, will be presented to the TOB and to DOE Headquarters. The assessment report will be compiled by the DOE and ITR Team Leaders, based on information compiled and written by team members. Additional visits, phone conversations or other communication may be required to address specific issues that arise during the assessment report preparation. The draft report will be reviewed by the WIPP site for factual errors, and the ITR Team will incorporate corrections as necessary. Upon completion, the assessment report will be submitted to DOE/HQ for disposition.

F.4.4. <u>Lines of Inquiry</u>

Lines of inquiry for the tasks will be developed during the Team Member Orientation meeting at Los Alamos National Laboratory (LANL), and revised based on information presented at the WIPP site following the first week of the review.

The following lines of inquiry were identified by ITR Team members as generally pertaining to more than one specific charter task:

- What is the regulatory and engineering justification for the Bin and Alcove test?

- What is the status of the test phase plan and the retrieval plan with respect to the Land Withdrawal Act (LWA)?
- How does performance assessment (PA) and data collection interact?
- How do Bin and Alcove tests integrate with other tests to define the repository environment or support PA?
- How are potential contaminant migration pathways being characterized?
- How will gas generation test results affect instrumentation and WIPP operations?
- What "off-site" issues affect the Bin and Alcove test programs?
- What procedural approvals are needed to initiate the Bin and Alcove tests?
- What are the personnel qualification criteria for the Bin and Alcove tests?

<u>Task 1</u>: Regulatory Interpretation and Compliance

Per the charter...

The ITR Team will review the WIPP approach to interpreting regulations and regulatory requirements (such as the 40 CFR 191 Disposal Standards, regulations implementing RCRA, and the WIPP Land Withdrawal Act [LWA]), formulating regulatory compliance strategies, developing compliance analysis processes and deriving informational needs, with regard to the currently defined bin and Alcove test programs. The ITR Team will compare the informational needs to the type of test results anticipated from the test programs to assess the scientific basis for, and the direct relevance, credibility and defensibility of, the data to be produced.

Examples of generic issues that can be addressed include:

- The laws, regulations, and DOE Orders that apply to Bin and Alcove tests
- The processes used to develop technical needs, including the issues hierarchy, analysis, and data quality objectives (DQO)

Potential lines of inquiry include:

- What is the definition of regulatory compliance?

- What laws, regulations, and DOE Orders apply to Bin and Alcove tests? What plans and procedures have been used to implement these laws, regulations and DOE Orders? What is the "flow-down" from the laws, regulations and DOE Orders to the Bin and Alcove tests? What is the connection between 40 CFR 191, RCRA 264, and 268 and the Bin and Alcove tests?

- What are the methods (e.g. performance assessment, expert opinion) that WIPP has used to demonstrate compliance with these requirements? Which of these methods require new experimental data?

- What is the anticipated influence on the Bin and Alcove test Programs of EPA's disposition of DOE's comments on 40 CFR 191?

- What process was used to develop technical needs? (including regulatory hierarchy, issues analysis, & data quality objectives [DQO])

- What regulations in CFR govern the masses and production rates of gases in the repository and their migration towards the accessible environment? What are the regulatory limits on gas migration?

- When will the data from the test programs be made available for performance assessment? What is the relationship between these two, the SAR, and other scheduled regulatory milestones?

- What are the specific test results that will be uniquely produced by the Bin and Alcove tests? What is the confidence level that these test results will be defensible?

- What is the basis for determining the time period needed to produce adequate test data?

- What industry experience has been evaluated to achieve no migration variances?

- What additional data are required to obtain the No Migration Determination to allow waste disposal?

- How does data derived from Bin and Alcove tests demonstrate retrievability? Will bin and alcove waste be retrievable as required by the Land Withdrawal Act? How long is the period of retrievability and how is retrievability defined? Are any of the containers allowed to deteriorate beyond retrievability?

- What have been the previous technical criticisms of these tests by oversight groups? What is the relevancy of these criticisms to the currently proposed test programs?
- What is the DOE's approach to ensuring compliance with requirements established in the Land Withdrawal Act?
- How is the Program intending to address NEPA issues associated with Type II Bin and Alcove tests?
- How can regulatory requirements be consolidated?
- What credit is given for emplacement of waste at repository horizon?

Task 2: Technical Performance Assessment

Per the charter...

The ITR Team will review and assess the relationship of the bin and Alcove test programs to long-term performance assessment activities with respect to model verification, evaluation of synergistic effects, and uncertainty analyses.

The ITR Team will review and assess the association of the proposed bin test program with the scientific basis and technical understanding of TRU-waste gas generation (dominated by corrosion, radiolytic and microbiological mechanisms), and the affect of gas generation on the long-term safe performance of WIPP.

Likewise, the ITR Team will review and assess the technical connection between the proposed Alcove test program, determining the release of volatile organic compounds and calculating gaseous source terms, and petitioning for a No Migration Determination under RCRA.

Examples of generic issues that can be addressed include:

- Room expansion will relieve pressure. Will the pressure relief be sufficient to prevent regulatory problems based on the PA model estimates?
- The performance assessment model and submodels to be used to demonstrate for regulatory compliance
- Identification of sensitive parameters and derived data needs for Performance Assessment requirements.

- Relationship of the bin and Alcove test programs to performance assessment
- Relationship of the lab test program to performance assessment
- Potential of the proposed bin test program to provide new scientific and technical understanding of the major gas generation mechanisms (corrosion, microbial, and radiolytic) of TRU waste
- Potential for gas generation to compromise long-term safe performance (via release of either the hazardous component or radionuclides) of the repository
- Potential for coupled processes to be impacted by gas releases

Potential lines of inquiry include:

- What is the performance assessment model? What (if any) independent verification of the model is available? What is the QA process for the performance assessment model? What is the minimum new information needed to meet PA requirements?
- What is the sensitivity of the performance assessment model to parameter variations? What parameters affect the model the most? How much and what types of additional work are required to minimally validate regulatory compliance? What is the role of gas generation in the additional work?
- What is the sensitivity of the model to variations in the gas source term? How does model uncertainty compare to the regulatory release limit? What is the maximum, credible amount of gas that can be derived from the TRU waste inventory? Which gas generation mechanisms are dominant at what time?
- An abundance of data exists from the German test at Asse where waste drums were exposed to brine. How long were these drums retrievable? How are these data being integrated into performance assessment models?
- Were the performance assessments to date based on a best case scenario, conservative (worst case) scenario, or something else? How was it chosen? Probabilistic or deterministic? How have data adequacy criteria been determined (DQO process)?

- What level of waste characterization data will be available, with appropriate QA/QC, to support the Performance Assessment and No-Migration Variance Petition?

- What is the process for incorporating results of tests into PA models? How are PA models evaluated and modified as a result of data incorporation? How will tests be evaluated and modified as a result of assessment of performance?

- What other mechanisms can be used to provide equivalent information to meet PA requirements?

- Are the performance assessment models driven by the results of the laboratory, Bin and Alcove tests, or are the models used to gauge the validity of the experimental results?

- How do the Yucca Mountain Project and WIPP Performance Assessment teams interact, i.e., how are lessons-learned and methodology advances transferred?

- What data are needed to "build confidence " in the gas generation and performance assessment models?

- What is planned to address performance assessment model validation, verification and confirmation?

- What is the maximum amount of brine that is estimated to be available for radiolytic, corrosive, or microbial gas generation? Of these mechanisms, which one can consume the brine to produce a maximum amount of gas? How much gas would that be? Would that quantity of gas compromise long-term performance of the repository? How does gas pressure buildup affect brine migration/availability?

- What analytical procedures are established for the analysis of trace contaminant levels in saturated brines?

- Which of the gas generation mechanisms is expected to dominate the gas production under maximum credible conditions in WIPP for the various time phases of the repository - ventilation, transitional, and long-term? How much gas can be formed under what (different) conditions? How will the Bin and Alcove tests define the microbiological gas evolution? How will gas contributed by the various mechanisms be differentiated?

- According to the TPP, gas generation will prevent room closure and consolidation of wastes, while promoting the outflow of radionuclides, VOCs, and other regulated sub stances. How sensitive are these effects to gas pressure?

- What gaseous species and gas masses are expected to be generated by different kinds of wastes? What are the waste form effects on gas generation?

- How is a complete mass balance done around the Alcove test? How much gas will corrosion of root bolts, beams, etc. contribute to the gas inventory of the Alcove?

- What are the physical and chemical bounds on the characteristics of the waste that will be used in the Bin and Alcove tests? What is the relationship between the waste inventory data (on hazardous constituents) and the proposed Alcove test program? How are the Source Term Test (STT) program and Alcove test program related to each other with respect to providing information on the potential for VOC migration in WIPP?

- What are the potential mechanisms for migration of gases in the repository? Does the geologic setting (rock minerals and brines) play any expected role in migration of different gaseous species out of the repository space?

- For the transition from oxic to anoxic corrosion, how is the transition time calculated? Most of the gas pressure of concern will come for anoxic corrosion after closure. How much unreacted metal will remain at the end of the period of oxic corrosion?

- Could galvanic coupling of dissimilar metals enhance rates of corrosion? If so, how are the effects of galvanic coupling being accounted for?

- The degradation of organic material and microbial action could generate a variety of chelating agents. How will these chelating agents effect the Pourbaix diagram, passivity, rates of corrosion, and the associated gas generation?

- How are mass balances determined around corroded surfaces? Where do corrosion products go? How is inventory kept? How were bounding conditions established for calculation of corrosion rates? How are bounding conditions confirmed to be conservative?

- What is the test plan for potentially significant microbial processes on radionuclide chemistry and microbial corrosion? How will information from these tests be incorporated into the PA model?

- What have been the previous technical criticisms of the microbiological test plan and what has been done to respond to these criticisms?

- In regard to retrievability, what are the anticipated rates of general and localized corrosion and how were these estimated?

- Some fraction of the waste containers will contact electrolyte. On the basis of statistics, how many?

- Radiolysis will generate NO_x and microbial growth will generate H_2S. Will such species be present at high enough concentrations to effect passivation, the rate of generalized corrosion, and related gas generation?

- How were literature data on oxic corrosion documented and used? Was documentation consistent with the QA plan?

- Have corrosion coupons already been placed inside the WIPP mine? If so, how many samples are emplaced and what metals do they represent? What are the rates of corrosion determined from these in situ test coupons?

- Though stress corrosion cracking is unimportant in direct gas generation, stress corrosion cracking will limit the life of roof bolts in the mine. In addition to affecting safety, bolt failure will affect the time to room closure by collapse and creep. How important is potential failure of the roof bolts?

- What is the potential for coupled-processes (synergisms) and how have they been considered?

- What analytical procedures are established for the analysis of waste sludges?

Task 3: Test Implementation and Approach

Per the charter...

The ITR Team will review the approach to implementing the bin and Alcove test programs to assess: test scope adequacy; test plan definition; hardware design sufficiency; differences between testing and expected repository conditions; instrumentation and control system influences on data accuracy and reliability; and quality control/quality assurance practices.

Examples of generic issues that can be addressed include:

- The QA program for the Bin and Alcove tests
- Engineering design of the bin hardware
- Engineering design of the alcove seals
- Relationship of test conditions to repository conditions, including the sensitivity of test data and data uncertainty
- Characterization of the test wastes
- Relationship of test wastes to DOE waste inventory
- Relationship of test wastes to major gas generators in DOE waste inventory
- Relationship of waste simulants to real wastes
- Proposed test hardware

Potential lines of inquiry include:

- What pressures are estimated in the bins or alcove by the end of the test programs? What hydrogen levels are anticipated in the bins or Alcove tests by their end? Based on leak test criteria, how much gas could be lost from the individual test bins during the five year test period? What are the specific effects on additional gas generation caused by purging of the gases (if necessary) in the test bins? Ditto for the alcove?
- How will the wastes to be generated differ from the wastes generated to date?
- To what extent are standard ASTM tests being used when possible?
- What documented/approved QA plan has been provided for all testing. (including test and objective descriptions, calibrations), and what is the trace of metallic samples.

- How has instrumentation reliability in the humid environment been validated?

- How was the limit of 2 psi determined for Type I bin and 80 psi for Type II bin? What is the influence of repository temperature fluctuations on these psi limits?

- What are the assurances that the bins will not release VOCs into the repository ventilation system?

- What is the conservative, worst case test schedule for alcove and Bin tests?

- Will the Alcove test room be backfilled, and if so, how?

- What are the reasons for conducting these tests at WIPP?

- What are the location-dependent factors?

- What is the timing of acquiring waste for the Bin Alcove tests? How were the number of test barrels/bins determined? How long to decide on "specific" tests and timing to initiate the full suite of bins (33)? Ditto for the conditionally planned bins. Ditto for Alcove tests.

- What is the waste characterization process? What sources of information are used to obtain data on the volatile organic chemical constituents of the waste inventory?

- Define "bounding" approach for waste characterization and waste acceptance criteria?

- What simulants are used for actual inventory waste matrices?

- What work from outside the WIPP program has been evaluated in order to develop Bin and Alcove tests, with specific attention to international programs?

- The LWA requires DOE to submit comprehensive recommendations for disposal of all TRU wastes. Because some of the TRU wastes are Pu-238, what are the plans for making these recommendations to include Pu-238?

- What is the relevance of alcove conditions to repository room conditions? (excavation, design, and support & seal performance)

- What new data on VOC constituents will be obtained in these tests?

- What are the various filter and drum seal configurations? How do the various filter and seal configurations influence VOC emission and data interpretation.

- What are the major issues in a repository operation? (repository ops = how they open the mine, how the waste interacts with the mine, what happens with the roof support, ventilation). Which tests apply to these issues? How do the tests apply to these issues? How is the data from these tests assured to be defensible to answer these issues? How do these tests adversely affect repository operations?

- What are the important factors of the repository environment which will affect the tests?

- How is test data extrapolated to long term repository conditions

- What defines seal performance?

- What are the changes of brine chemistry over time?

- What does geochemistry tell about past, present and future isolation?

- What do the tests tell about radiation, mechanical stress, and thermal fields on the geologic setting?

- How is the transmissivity of the marker bed characterized? How is the potential damage to the marker bed during mining operations evaluated?

- How was the requirement for 70% humidity determined?

- Assuming a corrosive environment, what impact will there be due to the metallic ground support system?

- How will Bin and Alcove tests define waste and fluid interactions? What is the time frame for data collection? What is the sensitivity of the tests? Is this sensitivity required for modeling? What is the uncertainty of the data collected?

- What is the composition of currently existing brine? What is the model for compositional changes with time?

<u>Task 4</u>: **Test Integration**

Per the charter...

The ITR Team will evaluate the plans for integrating the bin and Alcove test programs with lab-scale programs, and with the total WIPP test program, to assess how experimental results will be incorporated into modeling verification tools for performance assessments. The utility of different test-scale and test-type results for use in WIPP performance assessment efforts will also be considered.

The ITR Team will also assess the integration of the bin and Alcove test programs into the function of WIPP as a geologic waste repository.

Examples of generic issues that can be addressed include:

- Interconnections between the test programs
- Contributions of the bin, alcove, and lab test programs to the overall WIPP test program
- Relationship of the waste matrices used in the WIPP test programs to the overall DOE waste inventory
- The potential for WIPP to dispose of the TRU waste inventory from the entire DOE complex

Potential lines of inquiry include:

- How are the bin, alcove, and lab test programs integrated? Where is this integration specifically shown? What are the specific data outputs to be provided by the individual test programs? When are these data outputs obtained? How are the test programs complementary to each other? Where is there overlap between the programs as additional quality checks on the data?
- What are the mutual dependencies of the results of the lab, Bin and Alcove tests?
- How much additional time would be required to significantly decrease the data uncertainty? How would costs increase if the schedule is extended by the length of time?
- What are the most essential impacts of the lab, Bin and Alcove test results on the future development of the repository?

Task 5: **Associated Test Issues**

Per the charter...

The ITR Team will review and assess the relationship of the proposed bin and Alcove test programs to such issues as: the adequacy of cost and schedule to support waste disposal decisions; the approach used to evaluate the need for, and adequacy of, contingency tests; the management approach to, and influence on, testing and operational status; the definition of acceptable waste forms; barriers to regulatory compliance; the technical preparedness of WIPP to transition from standby status to testing with TRU-waste.

Examples of generic issues that can be addressed include:

M

- Startup and operational plans and procedures
- Cost estimation basis and control
- Contingency tests
- Engineered Alternatives Task Force Recommendations
- Decision processes
- Communications paths and documentation
- Roles, responsibilities and accountability
- Involvement of the public and oversight groups

Potential lines of inquiry can include independent assessments to determine:

- What additional work must be done at the WIPP site before TRU test wastes can be introduced into it?
- What is the total estimated cost of the Bin and Alcove tests? What is the total WIPP test budget?
- What percentage is the total estimated cost of the Bin and Alcove test program of the total WIPP budget? What percentage of the testing budget?
- How do the bin or Alcove test programs assist in providing a baseline for an operational test phase?

- What oversight groups could affect the bin and Alcove test programs?
- What is the approach for evaluating the need for, and adequacy of, contingency tests? What are the contingency tests contingency for?
- What, if any, waste form definition may be provided from the bin and Alcove test results? What contingencies exist to modify the waste forms to meet performance assessment requirements? Which of these can be implemented on a cost effective basis? What work is ongoing based on the Engineered Alternatives Task Force report?

<u>Task 6</u>: **Recommendations**

Per the charter...

The ITR Team will provide suggestions, recommendations and/or alternate strategies, as appropriate, on the approach and implementation of the bin and Alcove test programs, their relationship with promoting the expeditious generation of information needed for performance assessments, and demonstrating WIPP regulatory compliance.

Recommendations on the test programs or process will be developed at the end of the review, as necessary.

THIS PAGE

LEFT BLANK

INTENTIONALLY

M

M

APPENDIX G

INTERVIEWEES

Name	Organization
Anderson, R.	SNL
Arthur, W. J.	DOE/WPIO
Beauheim, R.	SNL
Brush, L.	SNL
Burrington, T.	WID
Butcher, B.	SNL
Coffey, J.	DOE/WPIO
Conway, C.	WID
Dickman, P.	DOE/WPIO
Ellis, D.	SNL
Fitch, L.	WID
Fort, P.	INTERA
Francis, A. J.	Brookhaven National Laboratory
Garcia, J.	WID
Gelbard, F.	SNL
Glora, M.	WTAC
Gorham, E.	SNL

Helton, J.	SNL
Higgins, P.	DOE/WPIO
Holmes, J.	SNL
Kehrman, B.	WID
Kircher, J. F.	WTAC
Krumhansl, J.	SNL
Lappin, A.	SNL
Lippis, J.	DOE/WPSO
Maestas, E.	DOE/WPIO
Mercer, D.	DOE/WPIO
Molecke, M.	SNL
Munson, D.	SNL
Olona, D.	DOE/WPIO
Orrell, A.	SNL
Reed, D.	ANL (Argonne, IL)
Rempe, N.	WID
Sethi, S.	WID
Sorensen, N.	SNL
Tillerson, J.	SNL
Trujillo, T.	DOE/WPIO
Vaughn, P.	SNL
Villarreal, R.	LANL
Vreeland, R.	West Chester University, PA

M

Weart, W.	SNL
Westerman, R.	Battelle-PNL

THIS PAGE

LEFT BLANK

INTENTIONALLY

M

APPENDIX H

ITR BIBLIOGRAPHY

Title	Author	Document #
3D Structure Analysis of SPDV Test Room 2 and Cross Drift Intersections at the WIPP	J. G. Arguello, P. L. Ehgartner	SAND90-1820A
1993 Q&RA Independent Review	Q&RA Independent Assessment Team	QA:93:00627
A Comparison of Brines Relevant to Nuclear Waste Experimentation	M. A. Molecke	SAND83-0516.UR.
A Letter Report by the Panel on the Waste Isolation Pilot Plant Board on Radioactive Waste Management Major Conclusions with Letter To: L. P. Duffy From: C. Fairhurst Dated 6/17/92	Panel on the Waste Isolation Pilot Plant	None
A Letter Report by the Panel on the Waste Isolation Pilot Plant Board on Radioactive Waste Management National Research Council/National Academy of Science Summary of Recommendations, April 1991	Panel on the Waste Isolation Pilot Plant	None
A Plan for the Implementation of Assurance Requirements in Compliance with 40 CFR 191.14 at the Waste Isolation Pilot Plant	Waste Isolation Pilot Plant	DOE/WIPP 87-016
A Report of Biological Investigations at the Los Medanos Waste Isolation Pilot Plant (WIPP) Area of New Mexico During FY1978	T. L. Best, S. Neubauser	SAND79-0368.UC-48
Alcove Hardware/Support System Description with a memo To: WPSO:MHM 93-0641 From: Michael H. McFadden	Waste Isolation Pilot Plant, DOE/AFO	None Pre-Decisional Draft
Alcove Test Plan	Unknown	None Pre-Decisional Draft

Anaerobic Cellulose Degradation Under A Saline and Hyper-Saline Condition	X. Tong, J. P. Black, J. Mueller-Vollmer, Stanford University	SAND91-7054A
Analysis of Failed Hardware at WIPP	N. R. Sorensen, SNL	WP077370
Analysis of Rock Bolt Material Failure at WIPP	J. P. Lucas	SAND84-0224
Annual Report on Work Performed for FY 84	N. R. Sorensen, SNL	WPO1127
Bin Case Data Package Final Report, Bin No. IDRFBN9200006, Serial No: 063, SWB No: 00711		
Bin Program - TRU Waste Tests		None
Calculations of Brine Flux and Cumulative Brine Volume for Room Q, Based on a Darcy-Flow Model	D. F. McTigue, Sandia National Laboratory	None
Chart and Narrative of the Type 1 Bins Estimated Program Cost Draft		None
Chart of the WIPP Disposal Decision Plan, Rev. 0		None
Chart on SPDV Test Room Convergence Data Combination 8001 and 14001	Unknown	None
Charts of Alcove Program Estimated Program Cost, Draft		None
Charts of Type II Bins Estimated Program Cost		None
Comments by New Mexico Attorney General Tom Udall to the Waste Isolation Pilot Plant Subcommittee of the National Advisory Council for Environmental Policy and Technology		None
Comments on the Advance Notice of Proposed Rulemaking (ANPR) attachment DOE Comments on EPA's Advanced Notice of Proposed Rulemaking for the Certification of Compliance with 40 CFR 191 Disposal Regulations	P. D. Grimm	None

Comments on the Proposed Role to amend 40 CFR 191 with attachment "U. S. Department of Energy Comments on the Proposed Amendments to 40 CFR Parts 144 and 191 -- Environmental Protection Standards for the Management and Disposal of Spent Fuel, High-Level and Transuranic Radioactive Waste	P. D. Grimm	None
Conceptual Structure of Performance Assessments Conducted for the Waste Isolation Pilot Plant	J. C. Helton, M. G. Marietta, R. P. Rechard	SAND92-2285
Conditional No-Migration Determination for the Department of Energy Waste Isolation Pilot Plant (WIPP) (Federal Register)		None
Constitutive Modeling of Salt Behavior - State of the Technology	D. E. Munson and W. R. Wawersik	SAND91-1614
Contingency Test Task Force Report Evaluation of Alternate Tests as Contingencies to Replace the Currently Planned Bin and Alcove Tests at WIPP	U.S. Department of Energy	693B:1556
Convergence Measurements in SPDV Room 1 Memo To: Thomas E. Lukow	R. F. Cook	WD:88:01426
Corrosion Analysis of TRU Drums	N. R. Sorensen, SNL	
Critical Comments on the U. S. Environmental Protection Agency Standards 40 CFR 191	C. G. Pflum, R. A. VanKonynenburg, P. Krishna	None
Design Concept Selection for the Type 2 Phase 1 Bin	C. E. Conway	Report #: WD:93:00633
Design Description of the Type 2 Bin and Systems for Wet Waste Testing	Waste Isolation Pilot Plan	DOE/WIPP 93-037
Desk Reference Manual for FY1993 Baseline Documents	Department of Energy	None
DRAFT Uncertainty and Sensitivity Analyses for Gas & Brine Migration at the WIPP, May 1992	J. C. Helton, J. E. Bean, B. M. Butcher, J. W. Garner, J. D. Schreiber, P. N. Swift, P. Vaughn	SAND92-2013

Environmental Protection Agency CFR Part 191 Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel High-Level and Transuranic Radioactive Wastes	Environmental Protection Agency	None
Equipment Design Criteria Wet Waste Testing Program, Revision 1	Unknown	WP 09-15, Rev. 1 Draft
ES&H Independent Assessment	L. L. Reed	None
Evaluating Design Procedures for Structures in Rock Salt	W. R. Wawersik, H. S. Morgan	SAND86-2597C
Evaluation of the DOE Plans for Radioactive Experiments and Operational Demonstration at WIPP	L. Chaturvedi, Environmental Evaluation Group	EEG-42
Evaluation of the Effectiveness and Feasibility of the Waste Isolation Pilot Plant Engineered Alternatives: Final Report of the Engineered Alternatives Task Force, Volume I, Revision 0	Waste Isolation Pilot Plant	DOE/WIPP 91-007
Evaluation of the Effectiveness and Feasibility of the Waste Isolation Pilot Plant Engineered Alternatives: Final Report of the Engineered Alternatives Task Force, Volume II Appendices, Revision 0	Waste Isolation Pilot Plant	DOE/WIPP 91-007
Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant	P. B. Davies	SAND90-3246
Experimental Test Program Implementation Plan		WP 09-11
Expert Judgment as Input to Waste Isolation Pilot Plant Performance-Assessment Calculations Probability Distributions of Significant System Parameters	K. M. Trauth, S. C. Hora, R. P. Rechard, SNL	SAND91-0625.
Final Draft Alcove Test Plan		DOE/WIPP 93-035
Gas Generation from Transuranic Waste Degradation: Data Summary and Interpretation	M. A. Molecke, SNL	SAND79-1245
Gas-Generation and Source-Term Programs: Technical Needs Assessment for the Waste Isolation Pilot Plant Test Phase, Revision 0	US Department of Energy, WIPP Project Integration Office	DOE/WIPP 92-062

Geotechnical Data From Site and Preliminary Design Validation Test Rm. 1	T. W. Halverson	WD:90:02204
Growth on, and Production of Organic Acids from Two Types of Common Laboratory Papers by Mixed Populations of Halophilic Bacteria	A. F. Piselli, R. H. Vreeland, West Chester University	None
Hardcopies of Vugraphs WIPP Underground Compliance/Operational Needs Test Program		None
Hardcopies of vugraphs on WIPP Integration Disposal Decision Alternatives Group	Department of Energy	None
Hardcopy of vugraphs Effects of Microbial Processes on Gas Generation from TRU Waste Under WIPP Site Test Conditions	A. J. Francis, J. B. Gillow, M. R. Giles, Brookhaven National Laboratory	None
Highlights and Issues Summary DOE/EPA Technical Exchange on the Test Phase Plan and Waste Retrieval Plan for the Waste Isolation Pilot Plant (WIPP)		None
Horizontal Darcy Flow to Room Q	D. F. McTigue, SNL	None
Hydrogen Generation by Metal Corrosion in Simulated Waste Isolation Pilot Plant Environments	M. R. Telander, R. E. Westerman	SAND92-7347
Hydrogen Uptake by Grade 12 Ti	N. R. Sorensen, SNL	
Important Parameters identified by the 1st four interactions of PA	D. "Rip" Anderson, SNL	
In response to letter to William K. Reilly on Draft Final Plant for the Waste Isolation Pilot Plant (WIPP) Test Phase; Letter To: Leo P. Duffy	R. J. Guimond and S. Lowrance	None

Information Relative to the Calculation of the VOC Source Term Utilized in the WIPP No Migration Variance Petition within Appendix A: Calculation of the Headspace Gas Concentrations of Hazardous Chemicals in the TRU Waste; and Appendix B: Operational VOC Dose Calculations taken from the WIPP FSAR; Appendix C: VOC Source Term Presentation from May 7, 1993, Technical Exchange Meeting with the EPA	Department of Energy/Waste Isolation Pilot Plant	DOE/WIPP 89-003. Rev. 1
Integrated Data Base for 1992: U. S. Spent Fuel and Radioactive Waste Inventories Projections and Characteristics	Oak Ridge National Laboratories; U. S. Department of Energy	DOE/RW-0006, Rev. 8
Integrated Systems Checkout Program Development and Implementation	R. J. Rodriguez	WP 15-AD3015
Interpretation of Brine-Permeability Tests of the Salado Formation at the Waste Isolation Pilot Plant Site: First Interim Report	R. L. Beauheim, G. J. Saulnier, J. D. Avis	SAND90-0083
Interpretation of In-Situ Pressure and Flow Measurements of the Salado Formation at the Waste Isolation Pilot Plant	S. M. Howarth, E. W. Peterson, P. L. Lagus, K-H Lie, S. J. Finley, E. J. Nowak	SPE 21840
Investigation into Coupled Fluid Flow and Mechanical Closure Behavior of Waste Disposal Rooms in Bedded Salt	F. T. Mendenhal, B. M. Butcher, P. B. Davies	SAND91-0686C
Latest draft (or documentation equivalent) of Source Term Tests	R. Villarreal, LANL, CLS-1	
WID Declaration of Readiness; Letter To: V. Daub, Chairman, WPSO Senior Review Board	C. M. Cox, Westinghouse	WD:93:00169 AA:93:1012
Long-Term Gas and Brine Migration at the Waste Isolation Pilot Plant: Preliminary Sensitivity Analyses for Post-Closure 40 CFR 268 (RCRA), May 1992	WIPP Performance Assessment Dept., SNL	SAND92-1933.
Management Assessment of WIPP Organizational Communication	Westinghouse Electric Corporation, Waste Isolation Division	None

Meeting Summary DOE/EPA WIPP Test Phase Plan Technical Information Orientation		None
Meeting Technical Summary National Academy of Sciences/National Research Council, Board on Radioactive Waste Management, Committee on the Waste Isolation Pilot Plant (WIPP)		None
Modeling of the Chemical Alteration of SPC Brine as a Function of CO2(g) Fugacity, Modeling the Fugacity of Pure CO2(g) as a Function of Pressure	J. Nowak, SNL	None
No-Migration Determination Annual Report for the Period October 1991 through August 1992	U. S. Department of Energy, Waste Isolation Pilot Plant	DOE/WIPP 92-057
No-Migration Variance from Land Disposal Restrictions for Exxon Company U.S. A. Billings, Montana New South Land Treat Unit	Environmental Protection Agency	58 FR 40134 No. 142
Panel on the Waste Isolation Pilot Plant (WIPP) Roster	Waste Isolation Pilot Plant Panel	None
Preconceptual Design Description of the Type 2 Bin and Systems for Wet Waste Testing	Test Program Engineering, Westinghouse Waste Isolation Division	None
Preliminary Comparison with 40 CFR Part 191, Subpart B for the Waste Isolation Pilot Plant, December 1991 Volume 4: Uncertainty and Sensitivity Analysis Results	J. C. Helton, J. W. Garner, R. P. Rechard, D. K. Rudeen, P. N. Swift	SAND91-0893/4.
Preliminary Comparison with 40 CFR Part 191, Subpart B for the Waste Isolation Pilot Plant, December 1991: Volume 6: Guidance to the WIPP Project from the December 1991 Performance Assessment	Sandia National Laboratory	SAND91-0893/6
Preliminary Evaluation, Uncertainties, Conclusions, and Programmatic Recommendations for Studies Concerning The Role of Gas in WIPP Compliance with Long-Term-Containment Provisions of 40 CFR 268.6 (RCRA; No -Migration Determination)		None

Preliminary Performance Assessment for the Waste Isolation Pilot Plant December 1992 Volume 5: Uncertainty and Sensitivity Analyses of Gas and Brine Migration for Undisturbed Performance	Sandia National Laboratories, WIPP Performance Assessment Department	SAND92-0700/5
Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992, Volume 4: Uncertainty and Sensitivity Analyses for 40 CFR 191, Subpart B	Sandia National Laboratories	SAND92-0700/4.
Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992; Volume 1: Third Comparison with 40 CFR 191, Subpart B	Sandia National Laboratories	SAND92-0700/1.
Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992; Volume 2: Technical Basis	Sandia National Laboratories	SAND92-0700/2.
Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992; Volume 3: Model Parameters	Sandia National Laboratories, WIPP Project	SAND92-0700/3.
Preliminary Review of the DOE Test Phase Plan for the Waste Isolation Pilot Plant (DOE/WIPP 89-011, Rev. 1, March 1993) with Letter To: W. J. Arthur, III, From: R. H. Neill, Dated: 5/15/93	New Mexico Environmental Evaluation Group	None
Process for the Waste Isolation Pilot Plant (WIPP) Disposal Decision Path Alternatives	Unknown	M93-GT-0388
Program/schedule which shows all of the current activities which are currently being carried out in preparation for bin tests	Westinghouse	
Programmer's Manual for CAMCON: Compliance Assessment Methodology Controller	R. P. Rechard, A. P. Gilkey, H. J. Luzzolino, D. K. Redeen, K. A. Byle	SAND90-1984
Public Law 96 - Original WIPP Authorization		None
Quality Assurance Plan WIPP Analytical Laboratory	Waste Isolation Pilot Plant	WP 12-13

Quality Assurance Program Plan for the Waste Isolation Pilot Plant Experimental-Waste Characterization Program (QAPP)	Environmental Restoration and Waste Management, US Department of Energy	DOE/EM/48063-1
Quality Assurance Project Plan, Revision 1		DOE Order 48063.1
Quarterly Report for WIPP Project for the Period January 1, 1984 through March 31, 1984; Memo TO: M. A. Molecke	N. R. Sorensen, SNL	None
Rates of CO_2 Production from the Microbial Degradation of Transuranic Wastes under Simulated Geologic Isolation Conditions	D. E. Caldwell, R, C, Hallet,UNM; M. A. Molecke, SNL; E. Martinez, LANL; B. J. Barnhart, Midwest Research Institute	SAND87-7170.UC-70
Rationale for Revised Bin-Scale Gas Generation Tests with Contact-Handled Transuranic Wastes at the Waste Isolation Pilot Plant	A. R. Lappin, C. A. Gotway, M. A. Molecke, R. L. Hunter, E. M. Lorusso, SNL	SAND90-2481.
RCRA Waste Profile Form, with Bin Case Data Package Final Report, Bin No. IDFRBN9100001		
RCRA Waste Profile Form, with Bin Case Data Package Final Report, Bin No. IDFRBN9100002		
RCRA Waste Profile Form, with Bin Case Data Package Final Report, Bin No. IDFRBN9100003		
RCRA Waste Profile Form, with Bin Case Data Package Final Report, Bin No. IDFRBN9100004		
RCRA Waste Profile Form, with Bin Case Data Package Final Report, Bin No. IDFRBN9100005		
Readiness Review Board Recommendation of Site Readiness	Westinghouse	RB:93:0320
Recovery for SPDV Rooms 1 and 2 Letter To; Distribution (WPO, WID, SNL, IT/WPO; From: Daryl Mercer	D. Mercer	None

Regulatory Compliance Strategy (draft document discussed by E. Maestas)	U. S. Department of Energy, WIPP Project Integration Office	DOE-WIPP 86-013, Rev. 1
Repository Convergence Process Flow Chart	Unknown	PC0586
Response to Letter from W. K. Reilly concerning review of the DOE Draft Plan for the WIPP Test Phase; Letter To: Chairman J. Bennett Jonston, Committee on Energy and Natural Resources	R. J. Guimond	None
Review Comments on DOE Document DOE/WIPP 89-011: Draft Plan for the Waste Isolation Pilot Plant Test Phase: Performance Assessment and Operations Demonstration WITH letter To; Leo Duffy;	F. L. Parker	None
Review Comments on DOE Document DOE/WIPP 89-011: Draft Plan for this Waste Isolation Pilot Plant Test Phase: Performance Assessment and Operations Demonstration with Letter To: L. Duffy; From: F. L. Parker dated: 7/20/89	WIPP Panel; C. Fairhurst, J. O. Blomeke, J. D. Bredehoeft, K. P. Cohen, F. M. Ernsberger, R. C. Ewing, D. A. Shock	None
Review Criteria for Completeness of DOE's Test & Retrieval Plans	Unknown	None
Risk, Uncertainty in Risk, and The EPA Release Limits for Radioactive Waste Disposal (Published Nuclear Technology, Vol. 101, Jan. 1993)	J. C. Helton, Arizona State University, Dept. of Mathematics	None
Roles and Responsibilities for the WPIO and the WIPP Project Site Office including Organizational Charts with a memo To: WPIO:MLM:93-0126M	W. J. Arthur III	None
Roof Conditions in SPDV Test Room 1 (Workshop Area) Memo To: Dave Rasmussen	Engineering and Repository Technology	HA:88:70007
Roof Conditions in the SPDV Test Rooms Memo To: Vince Likar	R. F. Cook, Westinghouse	HA:88:7026
Roof Stability and Closure of SPDV Rooms 1 and 2 MEMO To: Distribution (DOE, WID, IT)	R. F. Cook, Westinghouse,	WD:89:00559
Room Q Data Report: Test Borehole Data From April 1989 through November 1991	R. Beauheim	SAND92-1172

Scale CH TRU Waste Tests		S.U. Pickering and S. A. Orrell/SNL
Specifications for Standard Waste Box and Ten Drum Overpack		(Appendix of NuPac TRUPACT-II SAR – Appendix 1.3.4) Rev. 12
Status of Gamma Radiation Experiments	N. R. Sorensen, SNL	
Status Report on Iron Contamination Work	N. R. Sorensen, SNL	None
Strategy for the Waste Isolation Pilot Plant Test Phase, Revision 3	DOE/EM	DOE/EM/48063-2 Draft
Summary Description Rationale for the Bin-Scale and Alcove Waste Test Programs at the Waste Isolation Pilot Plant	Unknown	None
Summary of the WIPP Disposal Phase Decision Plan	U. S. Department of Energy	.M93-GT-0171
Summary of WIPP Materials Interface Interactions Test Data on Metals Interactions and Leachate Brine Analyses	M.A. Molecke, N. R. Sorensen, J. L. Krumhansl, SNL	SAND88-2023C
Survey of Microbial Degradation of Asphalts with Notes on Relationship to Nuclear Waste Management	C. E. Zobell, Scripps Institute of Oceanography & M. A. Molecke, SNL	SAND78-1371
Systems Analysis, Long-Term Radionuclide Transport, and Dose Assessments, Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico; March 1989	A. R. Lappin, R. L. Hunter, D. P. Garber, P. B. Davies,	SAND89-0462.UC-70
Technical Support Group Preliminary Report of Findings on the Potential for Gas Generation within the WIPP Repository and the Possible Effects of the Resultant Gas Pressure	Unknown	None Draft Predecisional Information
Test Phase Plan for the Waste Isolation Pilot Plant, Revision 1	US Department of Energy, WIPP Project Integration Office	DOE/WIPP 89-011

Test Phase Plant for the Waste Isolation Pilot Plant	DOE Waste Isolation Pilot Plant, Project Integration Office	DOE/WIPP 89-011 Revision 2
Test Plan Addendum #1: Waste Isolation Pilot Plant Bin-Scale CH TRU Waste Tests	M. A. Molecke, A. R. Lappin, Sandia National Laboratories	SAND90-2082.
Test Plan Addendum #2: Waste Isolation Pilot Plant Bin-		SAND93-1676
Test Plan for Laboratory and Modeling Studies of Repository and Radionuclide Chemistry for the Waste Isolation Pilot Plant	L. H. Brush, SNL	SAND90-0266.
Test Plan for Laboratory and Modeling Studies of Repository and Radionuclide Chemistry for the WIPP	L. H. Brush, SNL	SAND90-0266
Test Plan: Gas-Threshold-Pressure Testing of the Salado Formation in the WIPP Underground Facility	G. J. Saulnier, Jr. INTERA Inc.	105400R156
Test Plan: Waste Isolation Pilot Plant Bin-Scale CH TRU Waste Tests (Type 2 Bin)	A. C. Peterson, S. A. Orrell, J. T. Holmes/SNL	SAND93-1550
Test Plan: WIPP Bin-Scale CH TRU Waste Tests	M. A. Molecke, SNL	SAND90-1974.
Test Plan: WIPP Bin-Scale CH TRU Waste Tests (Type 2 Bin), Revision 0.1	A. C. Peterson, S. A. Orrell, J. T. Holmes, SNL	SAND93-XXX Pre-Decisional Draft
Test Plan: WIPP Bin-Scale CH TRU Waste Tests (Type 2)	A. C. Peterson, S. A. Orrell, J. T. Holmes	SAND93-1550
Test Plan: WIPP Materials Interface Interactions Test (MIIT)	M. A. Molecke, G. G. Wicks, SNL/SRL DuPont	None
Test Plant Addendum #2: Waste Isolation Pilot Plant Bin-Scale CH TRU Waste Tests	S. Y. Pickering, S. A. Orrell, SNL	SAND93-1676 Pre-Decisional Draft
Test Room Stability Plan	Waste Isolation Pilot Plan	DOE/WIPP 93-010

The Environmental Protection Agency's (EPA) Comments on DOE/WIPP 89-011, *The Draft Plan for the Waste Isolation Pilot Plant Test Phase:* Performance Assessment and Operations Demonstration With memo To: Jill E. Lytle From: R. J. Guimond and S Lowrance	R. J. Guimond, S. Lowrance	None
Total Bin Brine Formulation and Preparation for Use in Bin-Scale Tests Memo To: D. R. Schafer;	M. A. Molecke	None
TRU Waste Sampling Program: Volume I--Waste Characterization	T. L. Clements, Jr.; D. E. Kudera	EGG-WM-6503
TRU Waste Sampling Program: Volume II--Gas Generation Studies	T. L. Clements, Jr.; D. E. Kudera	EGG-WM-6503
Type 2 Bin Preconceptual Design Description		HA:93:3168
Type II Bin Test Plan	A. C. Peterson, S. A. Orrell J. T. Holmes	
Vugraph hard copy of showing comparison to the actual brine inflow results with a memo To: D. Schafer From: A. L. Jensen, dated 8/10/93 re: response to request for information by ITRT	A. L. Jensen, SNL,	None
Waste Characterization Program Plan for the Waste Isolation Pilot Plant , Revision 1	Waste Isolation Pilot Plant	DOE/WIPP 89-025
Waste Characterization Program Plan for the Waste Isolation Pilot Plant , Revision 2.0	Waste Isolation Pilot Plant	DOE/WIPP 89-025
Waste Isolation Pilot Plant (WIPP) Bibliography	None	None
Waste Isolation Pilot Plant (WIPP) Program Management Plan	Department of Energy	None
Waste Isolation Pilot Plant (WIPP): Alcove Gas Barrier Trade Off Study	M. S. Lin, L. L. VanSambeer	SAND91-7099
Waste Isolation Pilot Plant Compliance Strategy for 40 CFR 191	Westinghouse	DOE/WIPP 86-013
Waste Isolation Pilot Plant Final Safety Analysis Report Addendum Dry Bin-Scale Test	Westinghouse Electric Corporation	WP 02-9
Waste Isolation Pilot Plant No-Migration Determination Annual Report for the Period November 1990	U. S. DOE, Waste Isolation Pilot Plant	DOE/WIPP 91-059

Waste Isolation Pilot Plant Program Overview by W. John Arthur, Director, DOE Waste Isolation Pilot Plant, Project Integration Office	DOE Waste Isolation Pilot Plant, Project Integration Office	None
Waste Isolation Pilot Plant Safety Assessment Report The Inventory of Radioactive of Radioactive Material in the Event of an Underground Accident at the Point of Release, its Pathway to Station A, and the Consequence of Off-Site Dose to the Public	Westinghouse Electric Corporation	DOE/WIPP 92-017
Waste Isolation Pilot Plant Sandia Reports (This is a list of Sandia Reports Pertaining to WIPP)	Sandia National Laboratories	None
Waste Isolation Pilot Plant, Integrated Project Schedule, Predecisional Draft	U. S. Department of Energy, WIPP Project Integration Office	None
Waste Retrieval Plan for the Waste Isolation Pilot Plant	DOE, Waste Isolation Pilot Plant	DOE/WIPP 89-022
Waste-Generated Gas at the Waste Isolation Pilot Plant: Papers Presented at the Nuclear Energy Agency Workshop on Gas Generation and Release from Radioactive Waste Repositories	P. B. Davies, L. H. Brush, M. A. Molecke, F. T. Mendenhal, S. W. Webb	SAND91-2378
WID Operational Readiness Review Implementation Plan for Initiation of the WIPP Test Phase with Transuranic/Mixed Waste, Rev. 1	Unknown	None
WID Quality Assurance Program Description Approvals	Westinghouse Electric Corporation-Waste Isolation Division	WP 13-1, Revision 14
WIPP Alcove Gas Barrier Final Design Report	M. S. Lin, L. L. Van Sambeek	4060A220-TR03
WIPP Project Master Contact List	Department of Energy	None
WIPP RCRA Part B Permit Application Revision 3 (Chapter D)		DOE/WIPP 91-005

WIPP Record of Meeting Minutes Subject: Gas Masters: Review of Gas Generation Potentials and repository Response with letter To: W. John Arthur, III; From John Thies	D. Lechel	None
WIPP Supplementary Roof Support System Room 1, Panel 1 Geotechnical Field Data Analysis Bi-Annual Report	Waste Isolation Pilot Plan	DOE/WIPP 92-024
WIPP Supplementary Roof Support System Room 1, Panel 1 Geotechnical Field Data Analysis Report		DOE/WIPP 93-012
WIPP Test Phase Activities in Support of Critical Performance Assessment (40 CFR 191 B) Information Needs		None
WIPP Test Phase Activities in Support of Critical Performance Assessment (40 CFR 191 B) Information Needs	Waste Isolation Pilot Plant	None
WIPP/SRL In Situ Tests—Part II: Pictorial History of MIIT and Final MIIT Matrices, Assemblies and Sample Listings	G. G. Wicks; M. E. Weinle, M. A. Molecke	DP-1733

THIS PAGE

LEFT BLANK

INTENTIONALLY

M

APPENDIX J

INDEPENDENT TECHNICAL REVIEW TEAM AND TECHNICAL OVERSIGHT BOARD MEMBERSHIP AND CREDENTIALS

J.1. **Independent Technical Review Team Members:**

Dr. Stephan Brocoum, DOE Team Leader

Dr. Philip Thullen, ITR Team Leader

Ms. Deborah Bennett, ITR Team Leader

Mr. Richard Beddoes

Dr. Corale Brierley

Dr. Jan Docka

Dr. Joseph Farmer

Mr. Ron Guymon

Dr. Stan Kosiewicz

Dr. Abraham Lerman

Mr. John Shaler

Dr. Terry Steinborn

Mr. Dave Swale

J.2. **Technical Oversight Board Members**

Dr. Colin Heath, Chairman

Mr. Richard Baxter

Mr. William Hamilton

Dr. Mujid Kazimi

Mr. Dennis Lachel

Mr. John Maddox

Ms. Deborah Marsh

J.3. ITR Member Credentials

Name: Beddoes, Richard

Affiliation: Golder Associates

Education: B.Sc. in Civil Engineering, University of Leeds, England, 1977
M.Sc. in Civil Engineering, University of Calgary, 1980

Experience: Mr. Beddoes fields of expertise include instrumentation, rock mechanics, foundation engineering, laboratory testing, stress analysis and stability studies for underground mines. He is highly experienced in evaporates and in instrumentation of multiple level mines, and is recognized for his expert stress analysis skills of underground mines.

Name: Bennett, Deborah R.

Affiliation: LANL, N-DO/RT

Education: B.S., Mechanical Engineer, University of New Mexico, 1978
Completed coursework for M.S. M.E., University of New Mexico

Experience: Ms. Bennett has been associated with Independent Technical Reviews since early 1992, and has most recently been the Team Leader for the In-Tank Precipitation and Extended Sludge Processing ITR at Savannah River. She participated in activities for the Defense Waste Processing Facility review at the Savannah River Site, the PUREX review at Hanford, and numerous post-review activities. She was the Resident Engineer between LANL and the New Production Reactor program in WDC from 1990-91, supporting the independent safety evaluations of the proposed NPR concepts. Prior to that, she managed a team evaluating the technical capabilities of nuclear subsystems in the SP-100 Space Nuclear Power program. Experience with space nuclear power systems was based on the technical assistance provided to

DOE/NE on the general development of Space Reactor Power System (SRPS) programs, and specifically the Thermionic Fuel Element Verification Program. Other previous nuclear-related experiences at LANL have included: providing technical assistance to NRC on technical issues associated with gas-cooled reactor systems, carbide fuel experiments; and experimental evaluations of fuel/cladding relocation phenomena during decay heat modes for the Gas-Cooled Fast Reactor program.

Name: <u>Brierley, Corale L.</u>

Affiliation: Private Consultant

Education: B.S. in Biology, New Mexico Institute of Mining & Technology, 1968
M.S. in Chemistry, New Mexico Institute of Mining & Technology, 1972
Ph.D. in Environmental Sciences, University of Texas at Dallas, 1981

Experience: Ms. Brierley has over twenty years of increasingly responsible experience in mining and biotech companies. She has extensive knowledge of environmental and biohydrometallurgical process specifications, and has recommendations from mineral and metal industries. Ms. Brierley has had full management and budget responsibility for start-up biotech product and process company achieving world-wide recognition for developments and publications. She is also recognized for excellent analytical and problem solving skills.

Name: <u>Brocoum, Stephan</u>

Affiliation: Department of Energy, Office of Geologic Disposal, Director of Analysis and Verification Division.

Education: B.S. in Geology, Brooklyn College, City University, 1963

Ph.D. in Earth Science, Columbia University, 1971

Post-Doc, Columbia University, 1971-1973

Experience: Over 15 years of experience with regulators , contractors, and DOE on issues related to nuclear facilities' siting, regulations, and verification. Increasing levels of management responsibility including Director of Analysis and Verification Division, Office of Geologic Disposal HQ Division, Office Civilian Radioactive Waste Management. Responsible for major interfaces among YMPO and other OCRWM and DOE offices. Contributor to development of 10CFR60 and 10CFR72.

Name: Docka, Janet A.

Affiliation: Roy F. Weston, Inc., Department Manager, Geologic Disposal Department, Weston CRWM Technical Support Team

Education: B.A. in Geology, Knox College, 1977
M.S. in Geology, Northern Illinois University, 1979
Ph.D. in Geology, Harvard University, 1985

Experience: Fifteen years of experience as a professional geologist in the collection and evaluation of geologic and hydrologic data, including mineral/fluid phase equilibria in geologic systems; thermal stability of minerals; mass transfer diffusion; and heat flow modeling in geologic systems. Currently responsible for management and supervision of 11 professional geoscientists and engineers involved in the development and review of programmatic and technical documents, technical review of Study Plans under quality assurance procedures; technical analysis of suitability, licensing, environmental, health, and safety; and risk assessment issues relevant to site characterization and geologic disposal of spent nuclear fuel and high-level radioactive waste for the Office of Geologic Disposal, DOE Office of Civilian Radioactive Waste Management.

Name: Farmer, Joseph C.

Affiliation: Lawrence Livermore National Laboratory, Principal Investigator (C&MS) and Deputy Group Leader (SIS)

Education: B.S. in Chemical Engineering, Virginia Polytechnic Institute and State University, 1977
Ph.D. in Chemical Engineering, University of California, Berkeley, 1983

Experience: Worked on Yucca Mountain and Laser Isotope Separation Programs, as well as a variety of applied and basic research projects. Expertise includes materials development; corrosion science; electrochemistry; electrochemical engineering; treatment processes for mixed and hazardous wastes; catalysis and chemical reaction engineering; and development of various optical techniques. Numerous publications, presentations, patents, and awards from international scientific and technical societies.

Name: Guymon, Ronald H.

Affiliation: Ogden Environmental and Energy Services, Branch Manager, Environmental Sciences & Engineering

Education: B.S. in Chemical Engineering, University of Arizona, 1979

Experience: Mr. Guymon has more than 13 years experience in project management and engineering.. During the past seven years he has provided technical and management support to a variety of waste management programs for the Department of Energy (DOE) Waste Isolation Pilot Plant (WIPP) and Hanford facilities. He is thoroughly familiar with Federal environmental statutes and regulations governing the proper management (treatment, storage and disposal) of radioactive and mixed wastes. Mr. Guymon is currently the Manager of Environmental Sciences and Engineering in the Albuquerque Office, and is responsible for such areas as environmental assessments/impact statements, environmental compliance assessments, environmental permitting, risk assessments, and other similar activities.

Name: Kosiewicz, Stanley T.

Affiliation: Los Alamos National Laboratory, EM-7, Technical Staff Member

Education: B.S. in Chemistry, University of Illinois, 1967
M.S. in Analytical Chemistry, University of Wisconsin, 1969
Ph.D. in Analytical Chemistry, University of Wisconsin, 1973

Experience: An expert in the field of TRU Waste. He has worked on TRU waste characterization and TRU operations, including applied studies on gas generation. He was project manager for a drum venting system and a peer reviewer of major experiments for WIPP. Led teams to investigate root causes of corrosion of TRU waste containers and was a committee member of a National DOE Technology team for mixed waste treatment. He has developed, taught, and trained in Chemical Hazard Communication. Conducted experiments on plutonium mobility in environmental systems. Served as the technology interface for the Los Alamos National Laboratory environmental restoration program.

Name: Lerman, Abraham

Affiliation: Northwestern University, Professor

Education: M.Sc. in Geology, The Hebrew University, Jerusalem, Israel, 1960
Ph.D. in Geology, Harvard University, 1964

Experience: An expert on geochemical processes. Experience in geochemical balances and human inputs to freshwater lake systems, acid precipitation and its effects on natural materials, uptake and retention of contaminants in landfill and industrial facilities, underground injection of acidic wastes, and transport of gaseous and dissolved contaminants in waste repositories in salt. Serves on numerous panels and committees, advising on governmental and industrial waste disposal issues. Has written two books, and many book chapters and research papers.

Name: Shaler, John E.

Affiliation: Private Consultant

Education: B.S. in Civil Engineering, Clarkson University, 1970
Graduate Studies, Civil Engineering, Mississippi State University

Experience: Senior manager with over 22 years of experience in managing, engineering, construction, geotechnical and environmental programs with over 10 years experience supporting DOE and DOE cost-share programs at SAIC. Responsible for work quality of the Operation that provides environmental (NEPA, RCRA, CERCLA), geotechnical, engineering, quality assurance, and project management support to the DOE, USGS, DoD (Air Force and Corps of Engineers), EG&G, and commercial clients. Project Manager providing technical and management support services to the USGS in support of DOE's Yucca Mountain program in areas of Project Control, Quality Assurance, Training, Records Management, and technical support.

Name: Steinborn, Terry L.

Affiliation: Applied Research Associates, Inc., Group Leader and Senior Technical Advisor

Education: B.A. in Chemistry, Reed College, 1968
M.S. in Geology, University of Oregon, 1972
Ph.D. in Geology, University of New Mexico, 1976

Experience: A Professional Hydrogeologist with the American Institute of Hydrology. Presently responsible for providing technical and management guidance on large DOE-funded environmental program, including performance and risk assessment, technical reviews, responses to management (DOE and Sandia National Laboratories) information requests, management of RCRA and CERCLA projects including budget and schedule generation and analysis and workplan preparation, quality assurance, and regulatory analysis of EPA, DOE, State and other regulations, orders and guidance. Experience as a waste management specialist and as a senior staff geochemist. Managed Site Performance Assessment and all geochemistry activities on DOE Salt Repository Project.

Name: Swale, David J.

Affiliation: British Nuclear Fuels Limited, Design Integration Manager

Education: B. Tech. in Chemical Engineering, Bradford University, 1977

Experience: Over fifteen years of increasingly responsible positions in plant start-up and operation, the last twelve of which have been in nuclear waste treatment and TRU waste handling facilities. Was an Operational Manager for BNFLs alpha processing facilities and the manager for the start-up of the Waste Treatment Complex, a facility for the classification, segregation, shredding, and packaging in drums of TRU waste at BNFLs Sellafield site. Also directed a group of up to twenty seven technical people providing technical and safety support of facilities operation at Sellafield.

Currently WRAP (Waste Receipt and Processing Facility) Project Manager for the Hanford site.

Name: Philip Thullen

Affiliation: LANL, N-DO/RT

Education: B.S., Mechanical Engineering, Purdue University, 1965
M.S., Mechanical Engineering, MIT, 1967
Sc.D., MIT, 1969

Experience: From 1969 through 1976, prior to joining the Los Alamos National Laboratory, Dr. Thullen was Associate Professor of Mechanical Engineering at MIT. He was a member of the Thermal and Fluid Sciences Division performing research on the application of superconductors to electrical power equipment, and teaching classical thermodynamics, cryogenic engineering and related subjects. Since 1976 he has been at Los Alamos where he has been a staff member, Deputy Group Leader and Program Manager working principally in energy related fields. He continued to work on engineering applications of superconductivity and the design of electromagnetic systems for plasma fusion applications. From 1985 to 1991 he was the Program Manager for Construction of the Confinement Physics Research Facility (CPRF), an $80M, seven year construction project employing 70 FTEs. This experience has given Dr. Thullen a depth of experience in both applied research and in the organization and management of R&D facility construction. From January to June 1991 he was a member of the Los Alamos New Production Reactor, Safety Project Office working in the area of system integration. Since June 1991 he has been the Los Alamos Program Manager for Red Team Reviews and Hanford Support. His principle activity is management of Independent Technical Reviews for DOE-EM.