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UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF COLUMBIA

STATE OF NEW MEXICO, ex. rel. TOM UDALL, Attorney General Plaintiffs, v. JAMES D. WATKINS, Secretary of the Department of Energy, MANUEL LUJAN, JR., Secretary of the Department of the Interior DAVE O'neal, Assistant Secretary of the Department of the Interior, CY JAMISON, Director of the Bureau of Land Management, UNITED STATES DEPARTMENT OF THE INTERIOR, Defendants.	Civil Action No. 91-2527 (JGP

FEDERAL DEFENDANTS' MEMORANDUM IN SUPPORT OF
MOTION FOR SUMMARY JUDGMENT

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I. INTRODUCTION AND STATEMENT OF FACTS

A. Initial Site Selection.

Since the mid-1950's, the federal government has been exploring solutions to the national problem of nuclear waste disposal. The development of the Waste Isolation Pilot Plant (WIPP) is the result of a long and thorough search for a research facility in which to examine and demonstrate the safe, long-term management of Department of Energy ("DOE") defense-generated radioactive waste.[1] Initial laboratory research identified bedded salt as a desirable geologic medium for nuclear waste disposal, and a nationwide search for a suitable salt repository site commenced. By the mid-1970's, scientists had focused their research on the thick, 200 million year-old salt beds 26 miles southeast of Carlsbad, New Mexico. (Admin. Rec. IV.J.; II.I. (pp. 2-5 to 5-15); II.E.(pp. 4-5 to 4-73). Today, WIPP lies one-half mile below the Earth's surface in those salt beds.

WIPP was designed and constructed as a state-of-the-art research and development facility, specifically to investigate safe disposal for conventional trash--glassware, rags, disposable protective clothing, tools, etc.--and solidified wastewater sludges which have been contaminated by radioactive elements during various defense program laboratory and manufacturing processes. The type of contaminated waste to be examined at WIPP

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[1]This suit by the State of New Mexico is yet another in a long line of cases where attempts are made to prevent DOE from finding solutions to the serious problem of long-term disposal of DOE's defense-related nuclear waste.

is termed "transuranic" ("TRU") waste. There are two types of TRU waste. The first emits only alpha radiation. Alpha particles may be blocked by a single sheet of paper. These alpha-emitting forms of TRU waste are referred to as "contact-handled" ("CH") TRU waste. CH-TRU waste is packaged and handled in sealed 55 gallon steel drums. The second type of TRU waste emits beta and gamma radiation, which requires lead shielding, in addition to alpha radiation. It is handled and transported in lead casks and is referred to as "remote-handled" (RH) TRU waste. (Admin. Rec. II.I (pp. 5-3 thru 5-5); II.E. (pp. 2-8 and 2-9).) Only CH-TRU waste will be shipped to WIPP during the test phase. (Admin. Rec. II.E.(pp. 2-14); IV.R; and I.D.)

B. Early Data Collection.

In 1976, acting upon an application for land withdrawal filed by the Energy Research and Development Administration ("ERDA"), the Bureau of Land Management ("BLM") segregated, for a two-year period, some 17,200 acres of southeastern New Mexico land containing salt deposits from public entry to provide scientists an opportunity to begin studying the site characteristics. 41 Fed. Reg. 54,994 (Dec. 16, 1976). In 1978, based upon promising data from these initial studies, the Department of Energy ("DOE"), as successor to ERDA, applied for and received a two-year extension of the segregative period in order to continue preliminary studies through 1980. 43 Fed. Reg. 53,063 (Nov. 15, 1978).

By mid-1978, DOE had amassed sufficient data to begin an examination of the environmental impacts of commencing the phased development of the WIPP in these New Mexico salt beds. Pursuant to the requirements of the National Environmental Policy Act of 1976 ("NEPA"), DOE published a draft environmental impact statement in April 1979. See Notice of Availability of Draft EIS: 44 Fed. Reg. 23117 (April 18, 1979); Notice of Public Hearings: 44 Fed. Reg. 32032 (June 4, 1979); Supplemental Notice of Extension of Public Comment Period: 44 Fed. Reg. 38620 (July 2, 1979); Supplemental Notice of Additional Public Hearings: 44 Fed. Reg. 51848 (Sept. 5, 1980).

C. Legislative Authorization.

Congress, meanwhile, had been following the preliminary efforts of the DOE to explore the suitability of the New Mexico salt beds as a solution to TRU waste disposal. In December 1979, Congress enacted Public Law 96-164, section 213 of which authorized WIPP for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from federal defense activities and programs. See Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980, Pub. L. No. 96-164, § 213, 93 Stat. 1259, 1265-66 (1979). The Act's legislative history reflects Congress' balancing of a desire to preclude the State of New Mexico from effectively vetoing a project of such national importance, while still, at the same time, placing New Mexico in a position where its

legitimate concerns with respect to health and safety would be responsibly addressed. (Admin. Rec. IV.M.; IV.N.; and IV.O.) The balance was struck by adding language to the Act providing for the consultation and cooperation of the DOE with New Mexico regarding public health and safety concerns.

D. Consultation and Cooperation with New Mexico.

Congress' direction to DOE in P.L. 96-164 to consult and cooperate with New Mexico as to both DOE's respect for the State's stake in the project and the great importance placed by DOE on developing the WIPP in cooperation with the State. Five months prior to the enactment of P.L. 96-164, DOE Acting Under Secretary John Deutch testified before a subcommittee of the House Armed Services Committee that cooperation with New Mexico in undertaking the WIPP Project was absolutely essential. (Admin. Rec. at IV.P. (page 5).) In fact, one year earlier, in 1978, DOE had begun to fund the "Environmental Evaluation Group" ("EEG"), an entity whose charter was to provide an independent, critical appraisal of the environmental, health and safety impacts of the WIPP Project on behalf of the State and its citizens. Although funded by DOE, the EEG functioned, and continues to function today, as an adjunct of the State government. The EEG currently formally reports directly to the President of the New Mexico Institute of Mining and Technology. See National Defense Authorization Act, Fiscal Year 1989, Pub. L. No. 100-456, section 1433, 102 Stat. 1918, 2073-74 (1988).

During 1980, pursuant to the direction of P.L. 96-164, DOE worked with EEG and State representatives in an effort to negotiate a written agreement for consultation and cooperation. Also during 1980, while negotiations with the State were underway, the DOE prepared and published the final EIS ("FEIS") for WIPP. 45 Fed. Reg. 70,539 (Oct. 24, 1980), (Admin. Rec. at II. I.) Finally, based on the data gathered to that date, the DOE in late 1980 filed a third land withdrawal application with DOI to withdraw 10,200 acres of land in southeast New Mexico for eight years to conduct site and preliminary design validation studies.

In early 1981, the DOE issued its Record of Decision ("ROD") on the FEIS. The Department determined in the ROD to proceed with the phased development of the WIPP as a potential repository for the TRU waste stored at the Idaho National Engineering Laboratory and other national defense facilities. The DOE stated its intent to first conduct a formal Site and Preliminary Design Validation ("SPDV") program, followed by the phased construction and eventual operation of the WIPP. (Admin. Rec. II. K.) In mid-1981, DOE began drilling a 12-foot-diameter exploratory shaft at the WIPP site.

In May of 1981, the breakdown of negotiations between DOE and State representatives for a consultation and cooperation agreement led New Mexico to file suit against the DOE and the Department of the Interior. (State of New Mexico v. Department of Energy and Department of the Interior, et al., CV No. 81-0363

JB, consolidated with Citizens for Radioactive Dumping, Inc. v. Department of the Interior, et al., CV No. 81-0207 JB). The suit was resolved on July 1, 1981, with a Stipulated Agreement and the execution of an Agreement for Consultation and Cooperation Between the Department of Energy and the State of New Mexico on the Waste Isolation Pilot Plant ("C & C Agreement"). (Admin. Rec. V.J. and V.K.)

Article IX of the C & C Agreement provided for a conflict resolution process in the event that DOE failed to address any of the State's public health and safety concerns to the State's satisfaction. During the ten years in which the C & C Agreement has been in place, New Mexico has never invoked the conflict resolution process -- a testimony to the DOE's commitment to address and resolve the State's concerns regarding the safety of the WIPP project to the satisfaction of the State. (Since 1981, the DOE and the State have negotiated two modifications to the C & C Agreement, have discussed a proposed third modification since late 1990 for financial impact assistance payments to the State, and have entered into a Supplemental Stipulated Agreement to address the State's concerns on issues of liability, emergency response preparedness, transportation safety, and environmental monitoring. (Admin. Rec. V.F.; V.H., V.A., and V.M., respectively.)

On July 10, 1981, nine days after New Mexico and DOE entered into the Stipulated Agreement and the C & C Agreement, several environmental interest groups (Southwest Research and

Information Center, et al. ("Southwest Research") filed suit against the DOE and the DOI alleging that both Federal Land Policy Management Act ("FLPMA") and National Environmental Policy Act ("NEPA") violations. On December 3, 1981, the court denied Southwest Research's request for a preliminary injunction, declaring the FEIS to be adequate.

E. Administrative Land Withdrawal.

In early 1982, BLM acted upon DOE's 1981 land withdrawal application by issuing Public Land Order 6232, withdrawing 10,200 acres for the purpose of facilitating site characterization and preliminary design studies. 47 Fed. Reg. 13,340 (Mar. 30, 1982). In January 1983, DOE made application to BLM to withdraw the 10,200 acre WIPP site to permit the eventual commencement of the construction phase of the WIPP project. DOE completed the Site and Preliminary Design Validation ("SPDV") phase of the WIPP project. in March of 1983. (Admin. Rec. IV. DDD.) In commenting on the WIPP-DOE-161 SPDV Report, the EEG concluded that "...the Los Medanos site for the WIPP project has been characterized in sufficient detail to warrant confidence in the validation of the site for the permanent emplacement of the approximately 6 million cubic feet of defense transuranic waste." (Admin. Rec. IV. EEE

On June 29, 1983, the BLM acted upon DOE's January 1983 land withdrawal application by issuing Public Land Order 6403, withdrawing the requested acreage for the purpose of the construction of the WIPP facility. 48 Fed. Reg. 31,038 (July 7,

1983). DOE commenced the construction phase of the WIPP project in mid-1983.

As facility construction -- and the 1983 withdrawal -- neared an end, DOE in January 1989 made an application to the BLM for an extension and modification of the withdrawal in order to begin the project Test Phase. (Admin. Rec. I.R.) Also, in January 1989, DOE asked BLM to become a cooperating agency on the WIPP SEIS. (Admin. Rec. I.S.) DOE's application for modification and extension of P.L.O. 6403, a pre-existing land withdrawal, was filed with BLM New Mexico State Director's Office on April 7, 1989. BLM became a cooperating agency on the SEIS, and advised the public that it would apply the comments received during the SEIS process to its review of DOE's 1989 land withdrawal application. (Admin. Rec. XIII.)

DOE presented the draft Supplement to the 1980 FEIS to the public in April of 1989, ("draft SEIS"). (Admin. Rec. II.L.) DOE distributed 2,000 copies of the draft SEIS, provided a 90 day public comment period, and held public hearings in nine locations nation-wide. DOE issued a thirteen-volume final Supplement to the 1980 FEIS ("FSEIS") on February 2, 1990. (Admin. Rec. II.E.) In June 1990, BLM advised DOE that DOE's 1990 FSEIS adequately addressed the environmental impacts associated with the modification and extension of PLO 6403 for the WIPP Test Phase. (Admin. Rec. II.H.)

Having considered and responded to the oral comments of nearly 1,000 speakers and to written comments totalling 9,000

pages, DOE, in its Record of Decision on the FSEIS, determined to continue the phased develcpment of the WIPP by proceeding with the Test Phase. 55 Fed. Reg. 25,689 (June 22, 1990). In September 1990, BLM published its Record of Decision as a cooperating agency on the FSEIS. BLM adopted DOE's proposed action of proceeding with the phased development of the WIPP by conducting a Test Phase. 55 Fed. Reg. 38,584 (Sept. 19, 1990). In November 1990, BLM amended its ROD to stipulate that no waste could be brought to WIPP for the Test Phase experiments until DOE certified that it had met all applicable environmental permitting requirements. (Admin. Rec. I. N.)

On January 22, 1991, the Department of the Interior ("DOI") issued Public Land Order 6826, which modified Public Land Order 6403 to permit the conduct of a test phase using contact-handled TRU waste at the WIPP site. Public Land Order 6826 further provided that, upon certification by DOE that all applicable environmental laws and regulations had been complied with, DOI would issue a notice to proceed with the Test Phase. 56 Fed. Reg. 3038 (Jan. 29, 1991).

On October 3, 1991, Secretary of Energy Watkins certified to Secretary of the Interior Lujan that all environmental permitting requirements had been met. (Admin. Rec. I.B.) On the same day, DOI issued its Notice to Proceed with the Test Phase. (Admin. Rec. I.E.) Upon receipt of the Notice to Proceed, DOE advised the State of New Mexico on October 3, 1991, that the first shipment of CH-TRU waste could reach the WIPP site

as early as October 10, 1991 for use in the Test Phase. (Admin. Rec. I.F.)

F. The Test Phase.

During the SPDV and construction phases of the WIPP project, from 1976 to the present, DOE and its contractors intensively and systematically designed, constructed, tested and documented the WIPP facility in preparation for the next phase of the project, the Test Phase. The massive amount of data generated during this nearly twenty years of research has been analyzed extensively in scientific reports. (Admin. Rec. IV.L.; IV.K.) This detailed data has guided and informed the DOE's Test Phase.

There are two primary objectives of the Test Phase: (1) to gather scientific data that will enable the Secretary of Energy to determine whether WIPP will comply with the Environmental Protection Agency's ("EPA") regulations for long-term disposal for radioactive waste;[2] and (2) to demonstrate the ability of DOE to safely manage TRU mixed waste throughout a vertical system (from storage sites, through the transportation system, through emplacement at WIPP) in accordance with all applicable regulatory requirements. (Admin. Rec. IV.R.) The WIPP Test Phase describes and identifies the key activities for the Test Phase. It will be revised and updated periodically throughout the Test Phase. In more particular detail, scientists

[2]Some documents refer to demonstrating compliance with EPA disposal standards; it is more technically accurate to speak of determining compliance with EPA disposal regulations.

at Sandia National Laboratories have prepared two test plan documents detailing the methodology for the first type of Test Phase experiments, the dry bin-scale tests. (Admin. Rec. IV.B. and IV.QQ.)

DOE has committed to the State of New Mexico, to EPA and to BLM that all of the experimental waste will remain fully retrievable throughout the Test Phase. (Admin. Rec. at V.K.) (State: C & C Agreement, Appendix B "Working Agreement for Cooperation and Consultation" at pp. 14-15; EPA: No-Migration Determination, 55 Red. Reg. 47,700 at 47,719, Admin. Rec. at III.O; BLM: Admin. Rec. at I.K.; P.L.O. 6826). DOE has prepared a plan detailing the retrieval processes that will be implemented if a decision is made at any time during the Test Phase to retrieve the waste. (Admin. Rec. IV.JJ.).

G. Stability of Underground Test Rooms.

To assure that the Test Phase waste would be retrieved, DOE convened a panel of geotechnical experts who were required to provide an independent assessment of the life expectancy of the underground test rooms located in an area referred to as "Panel 1." During the month of April 1991, this group of eleven experts examined the WIPP underground area, were briefed by project technical personnel, and reviewed project mining and engineering data. The panel made certain recommendations that DOE implemented. The revised support system now ensures that waste can be safely tested in the Panel 1 room for a minimum period of seven-years.

To assess the validity of the supplemental support system design, the DOE, in September 1991, convened an independent External Design Review Panel composed of five experts in rock mechanics, one representative each from industry, the U.S. Bureau of Mines, the federal Mine Safety and Health Administration Technical Center, academia and from an independent design firm. The External Design Review Panel reviewed the support system design documents, made on-site observations at the WIPP, and had detailed discussions with the system design team. (Admin. Rec. IV.C) The Panel concluded that the supplemental support system will provide a useful life of at least seven years from the time that the ground support design is installed. Admin. Rec. IV.C, IV.C-1 and IV.II. (Sept. 19, 1991). In reaching this conclusion, the Panel made several observations and recommendations to enhance the overall design, all of which were incorporated into the design to the satisfaction of the Panel. (Admin. Rec. IV.C. and IV.D.)

H. Regulatory Compliance with Hazardous Waste Laws.

WIPP will be subject to numerous laws and regulations during the Test Phase. (Admin. Rec. II.E.). Particularly relevant to the commencement of the Test Phase are DOE's compliance with the "land ban" provisions of the Resource Conservation and Recovery Act, 42 U.S.C. § 6901, et seq. ("RCRA") and with the New Mexico Hazardous Waste Act, N.M. Stat. Ann. § 74-4-1, et seq. (Michie 1991)("HMA").

Amendments to RCRA in 1984 prohibited the continued land disposal of certain "hazardous wastes" unless those wastes meet treatment standards specified by EPA or EPA determines that the prohibition is not required in order to protect human health and the environment.[3] RCRA section 3004(d)(1), 42 U.S.C. § 6924(d)(1). This second determination must be based on a demonstration by the owner/operator of the facility "that there will be no migration of hazardous constituents from the disposal unit or injection zone as long as the wastes remain hazardous." Id.[4]

DOE demonstrated to EPA that no hazardous constituents in the test waste would migrate from the WIPP facility during the Test Phase. To make this determination, DOE submitted an eight volume "No Mitigation Variance Petition" to EPA in March, 1989. (Admin. Rec. III.S.) EPA performed a vigorous technical review of the Petition, considering more than 400 comments, before making a "Conditional No-Migration Determination" for the WIPP Test Phase in November, 1990. 55 Fed. Reg., 47700 (Nov. 14, 1990). The No-Migration Determination is effective for a ten-year test phase, and specifies, among other things, that the

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[3]As discussed in greater detail below, the "TRU mixed waste" to be emplaced in WIPP in the Test Phase is a mixture of radioactive materials regulated under the Atomic Energy Act of 1954, which are excepted from RCRA, section 1004(27), 42 U.S.C. § 6903(27), and RCRA hazardous substances. The resulting "mixed waste" is regulated under RCRA and the HWA.

[4]EPA has promulgated regulations specifying the standards and procedures for review of no-migration petitions at 40 CRF § 268.6.

waste volume may not exceed one percent of the design capacity; that the waste must be readily retrievable during the Test Phase; that the test waste be removed if DOE cannot demonstrate compliance with long-term no-migration standards; and that DOE must provide annual written reports on progress of the Test Phase. 55 Fed. Reg. at 47720-1. Therefore, the "land ban" provisions of RCRA will not operate to delay the Test Phase of WIPP. New Mexico does not claim that DOE's operation of WIPP is precluded by the land ban.

In addition, WIPP has "interim status" under the New Mexico Hazardous Waste Act, and may operate while its already-submitted permit applications under HWA are being considered by New Mexico.[5] Any facility managing RCRA-regulated hazardous waste must ordinarily obtain a permit issued pursuant to RCRA section 3005, 42 U.S.C. § 6925, or, in a state such as New Mexico with an EPA-authorized state hazardous waste management program, pursuant to the state law analog to that section. Because the permit review process may be lengthy, RCRA section 3005 provides that a facility may operate under "interim status" while awaiting the completion of the review process, as long as the facility has timely submitted Parts A and B of its permit application. N.M. Rev. Stat. Ann. § 74-4-9 of HWA states that facilities which have interim status under RCRA section 3005 will also be considered to have that status under HWA.

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[5]The proposition that WIPP has interim status under RCRA and HWA is shown in great detail in Section VI of this Brief, <u>infra</u>.

In July, 1988, as a result of EPA's and DOE's findings that radioactive mixed wastes were subject to RCRA, and in an effort to provide New Mexico with information regarding WIPP, DOE submitted a Part A application to New Mexico; New Mexico did not act on that application,and returned it to DOE in late 1989.

In July 1990, the State received mixed waste authorization from the EPA. 55 Fed. Reg. 28397 (July 11, 1990). One month later, in August 1990, New Mexico called for the submittal of Parts A and B of the WIPP RCRA permit application by January 22, 1991 and February 28, 1991, respectively. (Admin. Rec. III.Q.) DOE complied with this request, submitting the Part A on January 22, 1991, and the Part B on February 26, 1991. Admin. Rec. III. H., J., L., M., N. With the timely submissions of Parts A and B of its permit application, the WIPP facility obtained interim status under both section 3005 of RCRA, 42 U.S.C. § 6925, and its state law RCRA counterpart, § 74-4-9 of the New Mexico Hazardous Waste Act. WIPP is therefore in compliance with RCRA and HWA permitting requirements.

I. <u>On-Site Safety Reviews</u>.

In preparation for the Test Phase, the DOE not only utilized the scientific data acquired during the SPDV and construction phases of the WIPP project to comply with regulatory requirements, but also applied and incorporated the data in numerous internal evaluations of facility safety and Test Phase readiness. (Admin. Rec. IV.E.) Among the more important of these many pre-Test Phase safety efforts, was the conduct of an

extensive safety analysis process, which began with the issuance of a draft safety analysis report in February 1989 and culminated in the publication of the three-volume Final Safety Analysis Report (FSAR) in June 1990. (Admin. Rec. IV.H.) The FSAR process was cross-checked against a separate safety evaluation process. (Admin. Rec. IV. ZZ.; IV. AAA.; IV. BBB.; and IV. CCC.) The FSAR represents DOE's top-level safety commitments document for WIPP. It sets forth facility descriptions, design basis operational limits, and safety analyses of the facility as a whole and of individual structures, systems and components. The FSAR documents that a systematic analysis of the potential hazards associated with operating the WIPP has been performed; that potential consequences have been analyzed; and that reasonable measures have been taken to eliminate, control or mitigate the hazards.

The FSAR is a living document. During the Test Phase, it will be updated via addenda as test phase experiments are proposed that involve unreviewed safety questions. To this end, in August 1991, the DOE published an FSAR addendum for the dry bin-scale tests, the first set of underground experiments proposed for the Test Phase. (Admin. Rec. IV. I.) The FSAR process was complemented and augmented by extensive readiness reviews and systems checkouts which included evaluations of structures; mechanical and electrical equipment; employee training; radiological protection programs; emergency preparedness programs; quality assurance programs; on-site fire

protection; industrial safety; maintenance programs; management controls; and waste management programs. (Admin. Rec. IV. E.; IV.F.; and IV.JJJ.)

Numerous groups actively and productively participated in reviewing WIPP's FSAR, beginning with the publication of the draft FSAR in February 1989 and continuing through the approval of the FSAR Addendum for bin scale tests in August 1991. At the request of the Secretary of Energy, the Advisory Committee on Nuclear Facility Safety (ACNFS) conducted a number of reviews of WIPP beginning in 1989. Based upon those reviews, the ACNFS in April 1991 concluded that the dry bin scale tests can be conducted safely at WIPP and that there are no significant risks to workers, the public or the environment. (Admin. Rec. IV. KK.) The DOE committed to the ACNFS to track and resolve all the Committee's recommendations regarding the safety of conducting bin tests at WIPP prior to the start of the Test Phase. (Admin. Rec. IV. XX.)

The DOE also engaged the EEG fully in the FSAR review process, pursuant to the Department's commitment to the State in Article III of the Working Agreement, incorporated into the C & C Agreement as Appendix B. All of the EEG's comments on the FSAR were carefully and extensively considered. The New Mexico Environmental Improvement Division also reviewed the FSAR on behalf of the State. Admin. Rec. IV.E, IV.H. The FSAR, together with the FSAR Addendum, is a statement and commitment by the DOE that WIPP can be operated safely and at minimum risk.

J. Off-Site Safety Reviews.

The FSAR and SER processes, as well as the readiness reviews and systems checkouts demonstrate and document that the Test Phase at WIPP can be conducted safely. In addition to these on-site safety assessments, the DOE has also taken many careful steps to assure that the TRU waste shipped to WIPP will be transported safely. As part of the DOE operational readiness review, the transportation system was checked out, including an actual shipment from the DOE Idaho facility to WIPP. (Admin. Rec. IV.F.) At the request of the State, the DOE agreed to have the Nuclear Regulatory Commission (NRC) certify for safety the shipping container (the TRUPACT-II) in which TRU waste will be shipped to WIPP. (Admin. Rec. IV.F.) In March 1989, the DOE submitted to the NRC the TRUPACT-II design application and the Safety Analysis Report from Packaging (SARP) for the TRUPACT-II. The TRUPACT-II was rigorously tested by Sandia National Laboratories, pursuant to NRC test requirements.[6]

The transportation system itself--the truck tractors and specially designed trailers which will transport the TRUPACT-

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[6]The waste is to be transported in leak tight steel bins, which are encased within steel standard waste boxes. These boxes are then placed in a double-shelled container called the "TRUPACT II," highly advanced containers that tests have shown can withstand severe accident conditions. The container, costing an average of $300,000 each, has been certified by the United States Nuclear Regulatory Commission ("NRC") as meeting applicable safety requirements for shipment of TRU waste. (Admin. Rec. IV. PP.) The NRC certification process included subjecting the TRUPACT-II to rigorous accident tests, including exposure to significant impact, fire and water immersion, which might be expected in extremely severe accidents.

II's; the carefully selected and well-trained drivers who will man those truck tractors and; the real-time communication system which will tract the shipments as they travel to WIPP have undergone extensive safety and readiness reviews. (Admin. Rec. IV.F, IV.Q, IV.CC.) The DOE will ship TRU waste to the WIPP along highway routes selected by the State Highway Commission for the transport of radioactive materials.

The DOE has also provided emergency response training to professionals and volunteer personnel in communities along the transportation route to WIPP. As of October 1991, in excess of 7,000 persons in states along the WIPP transportation corridors have been trained in First Responder, Command and Control, Mitigation and Train-the-Trainer courses: some 2,100 of those were trained in New Mexico. Approximately 280 medical professionals in New Mexico have received training from the Radiation Emergency Assistance Center/Training Site (REAC/TS) in the provision of emergency medical services to those injured as a result of an incident involving radioactive materials. (Admin. Rec. IV. JJJ.) This training, together with the provision of additional funding and certain emergency medical equipment, is provided by DOE pursuant to its commitment in the Supplemental Stipulated Agreement, to assist the State in the area of emergency response.

K. External Review Groups.

DOE has actively sought the expertise and advice of numerous independent groups to assure a well-planned, safe

program at WIPP. All elements of the Test Phase have been carefully scrutinized by these groups. (Admin. Rec. IV. R. and II.RR.). (See also Affidavit of Chaturnedi, Exhibit A-2.) With EEG being the toughest critic of the WIPP Project, it is worth noting the following statement made by the EEG Director.

> While there are a few items that EEG believes still need to be resolved, I am pleased to report that we believe the facility and radiological safety programs are sufficiently ready to allow receipt of small quantities of transuranic (TRU) waste for the test program.

WIPP is the result of extensive research and evaluation by some of this country's most prominent scientists and technical experts. Over 1.1 billion tax dollars have already been spent on WIPP and an additional 13 million dollars will continue to be spent every month, whether or not the Test Phase goes forward. (Admin. Rec. IV.Y.) All applicable permits have been obtained and WIPP is now ready for the Test Phase to begin.

II. SUMMARY OF ARGUMENT

Plaintiff alleges a number of violations of the Federal Land Management Policy Act ("FLPMA") and the National Environmental Policy Act ("NEPA"), and the implementing regulations of each.

First, Plaintiff alleges that FLPMA was violated by "de facto" permanently withdrawing federal lands when the Secretary of the Interior is only authorized to make withdrawals for up to 20 years (plus extensions if appropriate). The Secretary purports to make an authorized temporary withdrawal and Plaintiff alleges that it will be permanent because wastes introduced into

the WIPP facility for test purposes will not be retrievable. The Secretary made his decision on an extensive administrative record which includes substantial analyses of retrievability, both by Department and outside experts. The record supports the Secretary's decision that test wastes will be retrievable. The withdrawal is not permanent. FLPMA was not violated.

Second, plaintiff alleges that FLPMA is violated if test wastes are not retrieved within the term of the present withdrawal. The Secretary of Energy intends to complete testing within the withdrawal period and have enough time left over to initiate retrieval of test wastes if a decision is made not to use WIPP as a permanent disposal site. However, FLPMA does not require that the purposes of a withdrawal be completed during any particular term. To the contrary, it specifically provides for extensions in just such circumstances. Additional extensions are possible without violating FLPMA.

Third, it is alleged that FLPMA is violated because the statute authorizes extensions when necessary to accomplish the purpose of the original extension. According to Plaintiff, that 'purpose' is to construct the WIPP facility -- while the subsequent extension and modification permits testing. That argument, we submit, requires an all too narrow reading of the Secretary's authority and the 'purpose' of the original withdrawal. The original withdrawal set aside specified public lands for the WIPP project -- closing them to a variety of otherwise available uses until Congress could withdraw the lands

permanently. When P.L.O. 6403 was about to expire while Congress continued to consider the matter, an extension was required to continue that set aside. At the same time the Secretary modified the withdrawal -- as he is authorized to do --to permit initiation of the long-planned test phase. Both the extension and modification are authorized by FLPMA.

Fourth, Plaintiff contends that the Congress was not notified of the withdrawal extension as required by FLPMA. In fact, such notification was made, as reflected in the record. Although we are uncertain, Plaintiff may be contending that a separate reporting requirement, associated with original withdrawals but not extensions, should also have been followed. That, we believe, would be an improper reading of FLPMA. The Secretary has interpreted it otherwise in practice and in implementing regulations and that interpretation should be

therefore, be followed. Although Plaintiffs make much of these points, none represents a violation of law.

III. SCOPE AND STANDARD OF REVIEW

Since neither FLPMA nor NEPA provides a private right of action for violation of its provisions, plaintiff here relies for judicial review on Section 10(a) of the Administrative Procedure Act, 5 U.S.C. § 702 (APA). That section requires, first, that there be a final agency action. Lujan v. National Wildlife Federation, 111 L. Ed. 2d 695, 712 (1990). The final actions being challenged here are the Secretary of the Interior's issuance of P.L.O. 6826 and the Secretary of Energy's decision to proceed with WIPP's test phase.

The administrative review process that culminated in these decisions produced the administrative records to which judicial review here is limited. Camp v. Pitts, 411 U.S. 138,

IV. THE SECRETARY OF THE INTERIOR DID NOT VIOLATE THE THE FEDERAL LAND POLICY MANAGEMENT ACT (FLPMA) IN ISSUING PUBLIC LAND ORDER 6826.

The WIPP project facilities are located on federally-owned lands in southeastern New Mexico. In 1983, the Secretary of the Interior acting pursuant to FLPMA section 204, issued a public land order, No. 6403, withdrawing these lands from disposal under the general land laws, including the mining laws, for an eight year period ending in June 1991. This withdrawal was made to permit the lands to be used for the construction of the WIPP facilities and to protect the lands from disposal pending a legislative withdrawal, if appropriate. 48 Fed. Reg. 31038-31039 (July 6, 1983).

In 1989, work on the project had progressed to the point where the Secretary of Energy applied for an eight-year extension of the original eight-year term of public land order 6403. Also, the Secretary requested that the order be modified in certain particulars, including changes that would permit a limited amount of radioactive nuclear waste to be introduced into the site for testing or demonstration purposes, consonant with the object of the project as envisioned by Congress when it enacted P.L. 96-164.[7]

In January, 1991, the Secretary of the Interior, acting in response to a 1989 application, issued public land order 6826. 56 F. R. 3038 (January 28, 1991). This order extended the

[7]P.L. 96-164 authorized WIPP for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes.

original term of public land order 6403 from June 1991 to June 1997 and modified the earlier withdrawal order in several respects including permission for the Secretary of Energy to use the WIPP site to conduct the experimental test phase of the project using retrievable, transuranic radioactive waste.

Like public land order 6403 which withdrew the WIPP project lands, public land order 6826, which extended and modified the original withdrawal order, was issued pursuant to FLPMA § 1204 (43 U.S.C. 1714). Plaintiff contends that the extension and modification order violates various provisions of the statute and implementing regulations.[8] As we show below, the Secretary has meticulously followed the dictates of Congress and his own regulations.

First, we highlight the requirements of section 204 that are particularly pertinent to this discussion. They are few and not particularly complicated. 43 U.S.C. 1714 (a) authorizes the Secretary to "make, modify, extend, or revoke withdrawals" in accordance with subsequently stated provisions and limitations. The latter includes a 20 year limitation on withdrawals of 5000 acres or more (applicable here), (1714(c)(1)), and a reporting requirement for the benefit of the Senate and House Interior oversight committees, (1714(c)(1) and (c)(2). Extensions may be made if the Secretary concludes that the original aims of an

[8]In addition, plaintiff makes a number of complaints concerning the withdrawal which do not appear to allege violations. Where appropriate we attempt to respond to these arguments in case plaintiff eventually ties them to legal obligations or the Court considers them relevant for any purpose.

administrative withdrawal of limited duration should be continued. (1714(f)). Extensions must be for no longer than the original withdrawal period. The Secretary must report his decision to extend a 5,000 acre or more withdrawal (1714(c)(1), as well as those of lesser amount (1714(d)), to the two Interior oversight committees, (1714(f)).

Plaintiff alleges three primary violations of these provisions. First, that P.L.O. 6826 is a "de facto" permanent withdrawal in violation of FLPMA. Second, that the withdrawal will extend beyond the six years provided because test materials cannot be retrieved in that period. And finally, that the Secretary has violated procedural requirements for withdrawal by failing to determine that an extension is necessary and failing to inform Congress of his actions. None of these contentions is accurate.

A. P.L.O. 6826 Is Not a Permanent Withdrawal.

Because of the 20-year limit prescribed in FLPMA 1714(c)(1), permanent withdrawals of 5,000 acres or more can only be made by statute. In fact, it has always been assumed that, if the results of WIPP's test phase indicate that it is suitable as a disposal facility for nuclear waste, the WIPP site would be permanently withdrawn for that purpose by Congress.

Plaintiff contends that P.L.O. 6826 is, in effect, a permanent withdrawal -- exceeding the Secretary's authority. This contention is founded solely on the assumption that the test materials cannot be retrieved from the WIPP facility. That

assumption is, of course, directly contrary to the Secretary's findings which are amply supported by the administrative record.

The contention is also directly contrary to the EPA's No-Migration Determination, which requires radioactive materials to be fully retrievable during the test phase.

It is in this argument that plaintiff most blatantly violates the provisions for judicial review provided by the Administrative Procedure Act. First, the State asks this Court to engage in a de novo review of the Secretaries' determinations -- contrary to the APA's dictate. To compound its error, New Mexico offers affidavits in support of its arguments, refusing to rely on the administrative record which was the basis of the decisions at issue.[9]

As we set out in Section III above, this is not a question of whether this Court would have arrived at the same conclusion reached by the Secretary -- given the necessary time and the same administrative record. Congress has delegated that responsibility to the Secretary. Although subject to judicial review, that review is limited by the standards set out in the APA, standards which properly afford substantial deference to the decision-maker. Likewise, the scope of judicial review is circumscribed. It is the record before the Secretary which is to

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[9]Plaintiff's approach might be understandable if we were dealing with decisions made behind closed doors in which it had no opportunity to participate. However, it is difficult to imagine a project with more public involvement than has been available here.. New Mexico has participated from the beginning; has been given every opportunity to present evidence and objections; and has had a significant affect on the process.

be scrutinized in evaluating his decision -- not newly concocted allegations which were unavailable for the Secretary's consideration. With this standard and scope of review in mind, we turn to the substance of Plaintiff's allegations.

1. Test materials will be retrievable from the WIPP site.

There is no dispute as to the intent of WIPP's test phase. Everyone understands that the purpose is to introduce transuranic wastes such that the suitability of WIPP for permanent disposal can be studied and -- if determined to be unsuitable -- those wastes can be retrieved. Plaintiff's eleventh hour allegation is that the Secretary is mistaken in believing that the wastes will be retrievable.[10]

To begin, P.L.O. 6826 specifically provides that the quantity of waste used in the test phase must not exceed that which can be "feasibly" removed should the site not be selected as a permanent repository. Retrievability has been the subject of extensive study over a period of time. DOE has prepared a Waste Retrieval Plan which includes the particulars of the

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[10]Plaintiff's separate contention that the government's test was itself a last minute proposal to comply with FLPMA's requirement that administrative withdrawals be temporary is baffling on two grounds. First, the test phase has been a part of WIPP planning for some time and New Mexico has taken an active role in preparing for it. In fact, P.L. 96-164 (note I supra) specifically envisioned a "demonstration" or test phase for the project. Second, Plaintiff should applaud the Secretary's measures to comply with FLPMA, not denigrate them. Throughout the process leading to P.L.O. 6826 the Secretary of the Interior insisted that retrievability of test materials be assured specifically because his withdrawal was temporary. Clearly plaintiff does not allege a violation of law in this particular contention.

process. This Waste Retrieval Plan was fashioned with the benefit of State review and comment. The Plan may be revised as more is learned during the testing phase. WIPP Test Phase Strategy, Admin. Rec. at IV.A.

The administrative record provides a substantial basis for the Secretary's determination that test wastes will be retrievable.[11]

Recent events do not require a different determination. New Mexico points out that there have been some rock falls in one area of the underground facility and concludes from this that test wastes will be permanently trapped underground. The government disagrees.

Collapse is, of course, the nature of the salt structures and part of the process for the eventual permanent disposal at WIPP, if that is the decision. The ability of salt to "collapse" is what led, in part, to the decision to put WIPP in this salt formation in New Mexico. This creep phenomenon of

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[11]Agreement for Consultation and Cooperation Between DOE and the State of New Mexico on the WIPP, Article IV - Key Events and Associated Milestone, L. - Retrievability Decision for TRU Waste, Admin. Rec. V.K., page 16; First Modification to the July 1, 1987 "Agreement for Consultation and Cooperation" on WIPP By The State of New Mexico and U.S. DOE", Admin. Rec. V.H., pp. 9-10; Environmental Restoration and Waste Management Operational Readiness Review of the WIPP Addendum, Revision 1, Summer 1991. Admin. Rec. IV.F. See Finding F. 2-3, page App. A-1-41; Waste Retrieval Plan, DOE/WIPP 89-022, May 1990, Admin. Rec. IV.JJ; WIPP Dry Bin-Scale Integrated Systems Checkout Plan, DOE/WIPP 90-002, Rev. 1, July 1990, pp. 3-2 and 3-9 Admin. Rec. IV.EE.1; Admin. Rec. IV.OO, See also - Affidavit of J. Parker, Ex. to Memorandum in Opposition to Preliminary Injunction.

the salt formation was expected and, in fact, is depended upon for long-term isolation of the waste.

The DOE convened an independent Geotechnical Expert Panel in April, 1991 to evaluate the effective life and opening stability of the test rooms. The Panel, after reviewing the facility, data, and rock mechanics analyses, concluded the test rooms would remain open (with high confidence) for a minimum of two additional years and perhaps as long as an additional six years. This Panel made recommendations to increase the useful life of the rooms to meet the needs of the test program. Also, this Panel concluded that the existing geotechnical monitoring program is satisfactory and would provide adequate advance warning of any impending room failure. The Panel recommended enhancements, nevertheless, to the monitoring system.[12]

After DOE developed a room support design that incorporated the Panel's recommendations, a second independent Panel (including U.S. Bureau of Mines and Mine Safety and Health Administration representatives) was convened by DOE and reviewed the design. This Panel concluded that the design meets the test program requirements and the Project has addressed all issues raised. In particular, the Panel concluded the rooms can be monitored and stabilized for the duration of the Test Phase, at least seven years. The room support system is now being

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[12]Note that the Plaintiff's affiant Parker, a member of this Panel, stated in his Panel report that WIPP is a "safe operation" and "there is no doubt in my mind that the roof will give us warnings months before collapse, at least six months of advance warning."

installed in the first test room (to be completed no later than December, 1991)[13] In the meantime, monitoring is continuous, providing information about what is necessary to maintain structural integrity and advance warning of potential problems.

Finally, DOE addressed the issue of a roof fall in the underground test area from a safety standpoint in the Final Safety Analysis Report Addendum and determined a catastrophic roof fall is not considered possible, but if it occurred, its consequences are minimal in terms of public and worker health and safety. Admin. Rec. IV.I.

Roof falls which have occurred have provided valuable data which has been useful in predicting salt behavior and improved geotechnical monitoring systems.

Substantial measures have been employed to protect against damage which would preclude retrieval and available evidence indicates that those measures will be successful. The best evidence is that the structural design assures that room integrity will be maintained for a minimum of seven additional years from the time the proposed support system is installed. Admin. Rec. at IV.II.

2. Test wastes can be retrieved without violating FLPMA.

As an alternative to its "de facto permanent withdrawal" argument, Plaintiff seems to allege that even if test

[13]June 1991, Geotechnical Panel Report (DOE/WIPP 91-023, Admin. Rec. IV.OO; 9/19/91, External Design Review Panel Report, Admin. Rec. IV.II; 10/9/91, External Design Review Panel Letter (from Chairman J. Wilson), Admin. Rec. IV.GG.

wastes can be retrieved they cannot be retrieved within the period of the present withdrawal. This, it implies, is a violation of FLPMA. Again we disagree. Our bases are two.

First, all test wastes may be retrieved before mid-1997, when the present withdrawal expires. Second, nothing in FLPMA prohibits a further extension of public land order 6826 if that should be found to be necessary.

The capacity to relieve test wastes within a given period is, of course, a function of how much waste is involved. When the Department of Energy began planning its test program it assumed that 15% of WIPP's total capacity would be involved in the test phase. That percentage has since been reduced to a current plan of 0.5% with a maximum of 1% (of capacity) allowed by EPA's No Migration Determination, Admin. Rec. IV.R; III.S and IX.E, a limit established by the EPA.

The quantity of material to be used in the test phase was determined, in part, through a public procedure conducted by the Environmental Protection Agency (EPA) in processing DOE's No-Migration Variance Petition for WIPP. After full rulemaking, including three public hearings in New Mexico and a review of hundreds of public comments, EPA granted the petition. See 55 Fed. Reg. 47700, Nov. 14, 1990. The determination limits testing to 1% of WIPP's design capacity; an amount that can be retrieved if WIPP is not selected as a permanent repository. Admin. Rec. at III.O, III.P. EPA concluded that "[a]s far as the present authorities of EPA are concerned, the DOE has met the

requirements that are necessary for it to embark on the test phase activities." Admin. Rec. at III.F.

There is no present decision to actually retrieve the test that decision would only be made as test results are evaluated. DOE's Test Phase Strategy anticipates that the necessary scientific information for a compliance determination may be available as soon as 1993 or as late as 1996. Admin. Rec. at IV.HH.

Of course the decision to retrieve test wastes might be made at any time. That will be done pursuant to a retrieval schedule provided by DOE which is required to be submitted to DOI within six months after the determination to retrieve or six months before the expiration of the withdrawal, whichever is sooner. Admin. Rec. at III.O.

The time necessary for retrieval has been considered in an Integrated Systems Checkout and discussed in the Waste Retrieval Plan. That exercise and analysis established that, with existing manpower, the bin waste could be removed in a maximum of six weeks. If the full alcove test program is implemented it could take up to eight weeks to remove all alcove waste. If all of the alcove drums are not backfilled and additional manpower is available, retrieval times could be shortened considerably. Admin. Rec. at IV.III.

It is possible that tests will extend to the maximum estimates; evaluations will continue through a subsequent year; and a decision is made to retrieve which cannot be carried out

within the current withdrawal period. However, that presents no per se violation of FLPMA. Plaintiff contends that FLPMA is violated because the Secretary failed to determine that the proposed use can be completed within the period of withdrawal. Comp. at ¶ 90. No such determination is required. In fact, Congress has anticipated that the purposes of a land withdrawal of limited duration may not always be completed within the original time provided. (Indeed, WIPP withdrawals have reflected a phased approach to the project and are a good example of how withdrawals can be modified and extended.) 43 U.S.C. 1714(f) clearly could be employed to extend the withdrawal to give the Secretary of Energy sufficient time to complete retrieval. In fact it is difficult to imagine a reason for denying such an extension if the land is to be returned to the public domain.[14]

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[14]As an adjunct to its allegations that the WIPP test phase will violate FLPMA for the reasons discussed above, Plaintiff argues at length that WIPP is not the best place for the proposed test. In response we note that the contention cites no violation of any act and we can think of none which might be argued. The decision to conduct tests at WIPP is a policy matter with no separate relevance to the legal issues raised by Plaintiff. Nevertheless, that decision is soundly based.

Although certain of the tests might be conducted elsewhere, DOE has determined that performing them at WIPP will provide results with maximum credibility. The test materials will be exposed to the actual environment and conditions under which wastes may be permanently stored.

What is more, other operations can be tested at the same time, including transportation systems and environmental monitoring. And the infrastructure (trained personnel, procedures, equipment, permits and transportation plans) are in place at WIPP, making it far more expedient and cost-effective to proceed as planned.

A decision to test elsewhere would be subject to the objection that for optimum results tests should be conducted under actual conditions whenever possible.

(continued...)

The Secretary of the Interior retains jurisdiction to extend the withdrawal if necessary. FLPMA would not be violated by such an extension.

B. P.L.O. 6826 Is A Proper Modification and Extension of P.L.O. 6403.

FLPMA authorizes the Secretary of the Interior to "make, modify, extend or revoke withdrawals". 43 U.S.C. 1714(a). In 1983 the Secretary withdrew 8,960 acres for the WIPP project. P.L.O. 6403, 48 Fed. Reg. 31038-31039. That withdrawal was for the purpose of constructing the WIPP facility. Certain activities were not permitted, including the transportation, storage or burial of radioactive materials in the site. Id. It was to remain in effect for eight years.

On January 22, 1991 that Order was "extended" as to its term for six years and it was "modified" by P.L.O. 6826 in several respects including lifting the prohibition against the introduction of nuclear wastes needed for the test phase. 56 Fed. Reg. 3038, Modification of Public Land Order No. 6403, January 28, 1991. (Admin. Rec. at I.K.)

Thus, P.L.O. 6826 is the latest step in a carefully delineated phased procedure which may or may not eventually

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[14](...continued)
Given that the purpose of the test phase is to enable the Secretary of Energy to determine the suitability of this site for permanent disposal, the Secretary's decision to test the effectiveness of WIPP at the WIPP facility is reasonable. Certainly no statute has been violated by that decision. Admin. Rec. II.F.

result in the permanent disposal of transuranic waste at the WIPP facility. That process effectively began with enactment of Public Law 96-164, which authorized WIPP "for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission." The overriding purpose of P.L.O. 6403 when it was issued was to facilitate this objective. P.L.O. 6403 and P.L.O. 6826 are but single steps in the same process.

Nevertheless, Plaintiff seeks to interpret FLPMA's extension provision so narrowly as to create a conflict in this process. 43 U.S.C. 1714(f) requires the Secretary to review withdrawals as their terminations approach and provides that they may be extended if he "determines that the purpose for which the withdrawal was first made requires the extension...." Plaintiff contends that the Secretary failed to make the necessary determination and, looking solely at the construction purpose of P.L.O. 6403, argues that the extension is for a separate purpose. From this the State concludes that P.L.O. 6826 is a violation of subsection (f). Again we must disagree.

Plaintiff's position here may be the ultimate attempt to elevate form over substance. Clearly the Secretary, in issuing P.L.O. 6826, implicitly determined that an extension of the withdrawal was required to continue the purpose of the WIPP project. To limit that "purpose" to the construction of WIPP

facilities would be too narrow an interpretation and would ignore the Congressional purpose behind the entire project and the language of P.L.O. 6403 itself.

P.L.O. 6403 specifically states its purpose as "the construction of full facilities for the [WIPP] Project ... and to protect the lands pending a legislative withdrawal if appropriate." [emphasis added] 48 Fed. Reg. 31038. The Secretary "determined" that the withdrawal should be extended until June 29, 1997, and at the same time modified the original withdrawal order to permit the next phase of the WIPP project to begin; i.e., the introduction of wastes for testing. P.L.O. 6826, para. 1.

The overriding 'purpose' of P.L.O. 6403 was, of course, to close these lands to activity which would otherwise be allowed but which would be inconsistent with the WIPP project (settlement, sale, exchange, mining, etc.) until a legislative withdrawal is made. 48 Fed. Reg. 31038. The legislative withdrawal has not yet been made but the property must continue to be closed to inconsistent uses if the purposes of P.L. 96-164 are to proceed uninterrupted. When P.L.O. 6403 expired by its own terms on June 29, 1991, it was necessary to extend the withdrawal for the 'purpose' of excluding other uses or the disposal of the BLM lands. 56 Fed. Reg. 3038.

At the same time, P.L.O. 6826 modified the provisions of the earlier withdrawal to permit the next WIPP phase-testing.

Plaintiff does not contend that the Secretary is not permitted to "modify" a withdrawal. Section 1714(a) clearly provides that authority. Nor is it argued that he cannot modify the withdrawal in respects such as those made in P.L.O. 6826. The effect of Plaintiff's allegation would be to conclude that the Secretary simply cannot make the permitted modifications as to the purpose of a withdrawal and, also, make an extension of it in the same instrument. There is nothing in FLPMA to compel that reading. The Secretary interpreted FLPMA to permit his modifications and extension in a single land order. That is a reasonable interpretation and consistent with previous modifications of land orders affecting WIPP. Clearly, nothing would be gained by remanding the matter and requiring the Secretary to issue first an order modifying the purpose of original withdrawal and then a second order extending that withdrawal. The better view must be that the Secretary can do both at once because he remains strictly within the overall purpose of this Congressionally-mandated project.

The Secretary has not violated FLPMA in his extension of P.L.O. 6403 through P.L.O. 6826.

C. DOI did not violate 43 U.S.C. §§ 1714(c)(2) or 43 C.F.R. §§ 2310.3(b)(2) in approving P.L.O. 6826.

1) The Secretary Is Obligated To Report To Congress Upon Review And Approval Of Extensions Pursuant to 43 U.S.C. § 1714(f) and 43 C.F.R. § 2310.4 only.

DOI did not violate 43 U.S.C. § 1714(C)(2) of the Federal Land Policy and Management Act or 43 C.F.R. 2310.3-

3(b)(2) by approving Public Land Order 6826. These two provisions of law apply to original land withdrawals. The present case, however, involves the approval of an application for the extension[15] and modification of PLO 6403 which withdrew the public lands at issue in 1983.[16] Accordingly, PLO 6826 does not effect an original "withdrawal" of land and should not be treated as such under the FLPMA.[17] DOI, in extending and modifying a pre-existing land withdrawal was only bound to comply with those statutory and regulatory requirements pertaining to modifications or extensions[18] under the FLPMA and its implementing regulations, and it did so.

Section 1714(f) addresses the Secretary's procedural duties when he reviews and/or approves applications seeking the extension of a pre-existing withdrawal. 43 U.S.C. § 1714(f). Accordingly, any DOI Congressional reporting requirements, when an extension is at issue, are governed by 43 U.S.C. § 1714(f) rathe than § 1714(c)(2) which applies, instead, only when an original withdrawal is at issue. See 43 U.S.C .§ 1714(f); 43 U.S.C. § 1714(c). 43 U.S.C. § 1714(f) merely requires that, if

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15 See PLO 6826 in the administrative record at I.K.

16 See PLO 6403 in the administrative record at XIII. p. 30.

17 See 43 U.S.C. §§ 1702(i) defining a withdrawal as an area of federal land being withheld from "settlement, sale, location or entry, under some or all of the general land laws....";

18 See 43 U.S.C. § 1714(a) distinguishing between the Secretary of Interior's separate and distinct powers to: 1) make, 2) modify, 3) extend, or 4) revoke, land withdrawals.

the Secretary reviews and approves an extension, "The Secretary shall report on such review and extension to the Committee on Insular Affairs of the Congress and the Senate."

Granted, § 1714(f) states that the Secretary must comply with § 1714(c)(1) or (d) when granting the extension, but there is no indication on the face of the statute that the Secretary is obligated to comply with any of the requirements of § 1714(c) when he reports the approval of an extension to Congress pursuant to § 1714(f). The implementing regulations of FLPMA, published in 43 C.F.R. § 2310.4, further support this interpretation. If the Secretary allows an extension, the regulations require that he comply, as to the extension's durational limits, with 43 U.S.C. § 1714(c) or (d), as the case may be. See 43 C.F.R. § 2310.4. "Whether or not an extension is allowed ...," the Secretary must promptly report his decision to the Congressional oversight committees. Id. The regulation does not elaborate upon the necessary content of the report; nor does it refer to any statutory provision which would define the necessary report content.

It is clear from the statute and regulations, therefore, that the Secretary's Congressional reporting obligations, regarding the approval of the extension, were governed by 43 U.S.C. § 1714(f) and 43 C.F.R. § 2310.4 only. As the Secretary was not dealing with an original land withdrawal, neither 43 U.S.C. § 1714(c)(2), nor 43 C.F.R. § 2310.3-3(b)(2) was applicable.

2) Plaintiff Repeatedly Confuses The Express Statutory Distinction Between An Extension And An Original Land Withdrawal When Making Allegations As To Congressional Reporting Obligations.[19]

Despite the clear language of FLPMA and its regulations, the Plaintiff alleges, in its complaint, that the Secretary of the Interior failed to comply with his statutory and regulatory Congressional report obligations pursuant to 43 U.S.C. § 1714(c)(2) and 43 C.F.R. § 2310.3-3(b)(2) when he approved P.L.O. 6826 which extended the withdrawal period of P.L.O. 6403 for an additional six years. In so doing, the Plaintiff confuses the reporting obligations required for original land withdrawals with those required for extensions.

First, Plaintiff incorrectly alleges that DOI's approval of P.L.O. 6826 violated 43 U.S.C. § 1714(c)(2). This assertion is simply erroneous, as the challenged action in the present case involves the extension of a pre-existing land withdrawal. The Secretary was therefore not required, as Plaintiff suggests, to make an extensive factual report to Congress pursuant to 43 U.S.C. § 1714(c)(2) which only applies to original land withdrawals.[20]

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[19] 43 U.S.C. §1714(a) expressly distinguishes between withdrawals, extensions, modifications, and revocations. Accordingly, distinct regulatory requirements may apply depending on the application submitted to BLM. Here, DOE submitted an application for an extension and modification of a pre-existing land withdrawal. Therefore, regulations which are relevant to original withdrawals are inapplicable.

[20] This point becomes even more compelling in view of the fact that the Secretary did make the required 43 U.S.C.

(continued...)

Second, Plaintiff, again, confuses the distinction between Congressional reporting obligations required for extensions with those required for approval of an original land withdrawal by alleging that DOI violated 43 C.F.R. § 2310.3-3(b)(2) which mandates that: "On the same day an order withdrawing 5,000 acres or more in the aggregate is signed, the Secretary shall advise, in writing, each House of Congress..."(emphasis added) Again, this assertion is simply wrong in view of the fact that the Secretary reviewed and approved an application for an extension rather than an original withdrawal.

Despite Plaintiff's confusion, it is clear that, in the present case, the Secretary, by reviewing DOE's application for an extension, was merely required to report to Congress pursuant to 43 U.S.C. § 1714(f) and 43 C.F.R. § 2310.4. Accordingly, the Secretary was simply obligated to "promptly" report to both Houses of Congress regarding his recent review and approval of the DOE extension application.[21] See 43 C.F.R. § 2310.4.

3) The Secretary Did Report To Congress As Required By 43 U.S.C. § 1714(f) and 43 C.F.R. § 2310.4.

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[20](...continued)
§1714(c)(2) report when he approved DOE's original land withdrawal application. As a matter of common sense, it would be illogical to require the Secretary to submit another extensive report containing identical information. The Secretary's interpretation of the interrelationship between the various subsections of 43 U.S.C. §1714 - as reflected in his implementing regulations - is clearly reasonable and should be upheld.

[21] See the discussion supra. at page 45.

The Secretary did comply with his Congressional reporting obligations under the FLPMA and its regulations. The Assistant Secretary, David O'Neal, signed and approved the extension at issue (P.L.O. 6826) on January 22, 1991. Admin. Rec. at IX.K. P.L.O 6826 was then published in the Federal Register on January 28, 1991. Admin. Rec. at I.K. In conjunction with the review and approval of the extension application, Assistant Secretary O'Neal sent the requisite report to the Committee on Insular Affairs of both Houses of Congress on January 22, 1991. Admin. Rec. at IX.K. The report stated that:

> "In accordance with Section 204(f) of the Federal Land Policy and Management Act of 1976, 90 Stat. 2752, we are hereby notifying you of the extension of the time for the withdrawal of land for the Department of Energy's (DOE) Waste Isolation Plant in New Mexico." Admin. Rec. IX.K.

It is clear, therefore, that the Department of the Interior, by making its report to Congress on January 22, 1991 satisfied its statutory and regulatory Congressional reporting requirements under the FLPMA.

4) Plaintiff Can Not Challenge The Adequacy Of The Secretary's Report To Congress Under FLPMA

If the Secretary is wrong in his interpretation of what is required in his report to Congress - no cause of action is created. Clearly, a report was provided. The only issue can be whether it contained the specifics of a § 1714(c)(2) report. Congress has specifically provided in FLPMA that "the adequacy of

reports required by this Act to be submitted to Congress or its committees shall not be subject to judicial review." 43 U.S.C. §§ 1701, note 1.

Pursuant to the express provisions of the FLPMA, the State of New Mexico can not challenge,under any provision of the FLPMA, the adequacy of the report which the Secretary sent to Congress. Accordingly, the Secretary's report to Congress complied with the Congressional reporting requirements for extensions under the FLPMA.

D. The BLM and the DOI did not violate other applicable FLPMA regulations set forth in 43 C.F.R. § 2300, et seq. in modifying and extending P.L.O. 6403.

Congress, in enacting the FLPMA, expressly authorized the Secretary of the Interior to "modify or extend" public land withdrawals. 43 U.S.C. § 1714(a). Where the Secretary makes a determination to extend a previously made public land withdrawal, he must comply with the applicable regulations published in 43 C.F.R. § 2300, et seq. 43 C.F.R. § 2300.0-3. In the present case, the Plaintiff broadly alleges that DOI and BLM have generally violated applicable regulations. Plaintiff fails to indicate, however, which specific regulations in the twelve page compilation have been violated.[22]

1) BLM As A Cooperating Agency, Participated In The Development Of, and Independently evaluated

[22]Plaintiff has not alleged anywhere in the complaint that DOI and BLM have failed to comply with the notice and hearing requirements contained in the regulations. Accordingly, while it is clear in the record that these regulations have been complied with, it is not necessary to discuss them in any detail.

and Reviewed, The Final SEIS In Accordance With The Applicable Regulations Under FLPMA.

First, it is evident, on the basis of the record, that BLM and DOI have complied with the development and processing of the case file for P.L.O. 6826 for submission to the Secretary pursuant to regulations published at 43 C.F.R.§ 2310.3-2. Subsection (b) of 43 C.F.R. § 2310.3-2 requires that the applicant provide with its application an Environmental Impact Statement (EIS) which is adequate and sufficient to meet the requirements of the NEPA (42 U.S.C. § 4332(2)(c)) and its applicable regulations. 43 C.F.R. § 2310.3-2(b)(3). The BLM is required to participate in the development of the EIS, and the applicant is required to designate BLM as a cooperating agency which must comply with the requirements and regulations of the Council on Environmental Quality (CEQ) under NEPA.[23] Id. At the very minimum, the BLM, as a cooperating agency, must "independently evaluate and review the final product." Id.

Again, while Plaintiff's complaint is extremely vague, it seems that plaintiff is alleging that DOI failed, as a cooperating agency, to independently evaluate and review DOE's Final Supplement Environmental Impact Statement (FSEIS). The record clearly shows, however, that DOI and BLM properly complied

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[23] The BLM, as a "cooperating agency," was merely required to comply with the CEQ regulations pertaining to "cooperating agencies." 40 C.F.R.§1501.6. There is no indication in FLPMA or its regulations that a "cooperating agency" was subject to the requirements of 40 C.F.R. §1507. In any event, BLM's participation in production of the draft and final SEIS clearly demonstrates that it had "sufficient capability to evaluate what others do for it..." See 40 C.F.R. §1507.2.

with both their statutory and regulatory obligations regarding receipt, development and review of the FSEIS. First, the DOI required that the DOE submit a FSEIS along with its modification application before the application would be processed by BLM. Additionally, the BLM was designated as a "cooperating agency" in the development of the FSEIS, as required by regulation. See 43 C.F.R .§ 2310.3-2(b)(3).

As a cooperating agency, the BLM participated in the development of the FSEIS, and, upon its completion, independently reviewed the final product. This assertion is repeatedly supported by the administrative record. For example, in a letter from Admiral Watkins, Secretary of DOE, to Manuel Lujan, Secretary of DOI, Admiral Watkins stated:

> The Final Supplement to the Environmental Impact Statement (SEIS) for the Waste Isolation Pilot Plant (WIPP) was filed with the Environmental Protection Agency on February 2, 1990. I want to express my appreciation for the assistance and expertise provided by the Bureau of Land Management in its role as a cooperating agency on the Final SEIS. Admin. Rec. II.G.

In a DOI comment on the draft to the SEIS, the DOI assures DOE that the BLM will continue to work closely with the DOE staff to arrive at an adequate final SEIS. Admin. Rec. II.E.

Furthermore, it is clear that the DOI "independently evaluated" the Final SEIS.[24] Volume 13 of the FSEIS includes

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[24] Not only did DOI independently review an comment on the FSEIS, but it also reviewed and commented on the Preliminary Draft SEIS, the Draft SEIS, and the Preliminary Final SEIS. Admin. Rec. at X. A-D.

comments on the Draft SEIS which include the statement that: "The Department of the Interior has reviewed the draft supplement to the final environmental impact statement for the WIPP."[25] Id. On April, 1989 the DOE provided DOI with copies of the FSEIS for review and comment. Admin. Rec. at X. D., p. 10. The DOI independently reviewed the FSEIS, and even though it was not obligated to do so, provided further comment on the final product.[26] The DOI's review of the FSEIS is further evidenced in a number of BLM records of decision.[27]

Additionally, Plaintiff seems to claim that the FSEIS reviewed and adopted by DOI does not satisfy the NEPA as required by FLPMA regulations. 43 C.F.R. § 2310.3-2(b)(3). This allegation, however is misguided. The September 19, 1990 BLM Record of Decision adopting the FSEIS expressly concludes that: "Adoption of the DOE FSEIS is in compliance with the regulations

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[25] See also June 13, 1990 Letter from Manuel Lujan, Secretary of DOI, to Admiral Watkins, Secretary of DOE, stating: "As we discussed yesterday, the Department of the Interior has further reviewed the Waste Isolation Pilot Plant (WIPP) Final Supplement to the Environmental Impact Statement (FSEIS)... I have concluded that the WIPP FSEIS adequately assesses the environmental impacts..." Admin. Rec. at I.Q.

[26] Additionally, DOI reviewed a subsequent environmental assessment, after the adoption by DOI of the FSEIS. The Assistant Secretary of DOI, after review, made a finding of no significant impact. Admin. Rec. IX.M. This careful review, again, demonstrates DOI's close involvement with DOE on the environmental assessment of WIPP, an involvement that went well beyond the regulatory requirements under the FLPMA.

[27] BLM ROD, stating: "As a cooperating agency with the Department of Energy (DOE) on the Final Supplement Environmental Impact Statement (FSEIS) for the WIPP project, the BLM has reviewed the FSEIS..." Admin. Rec. X.D., p. 1; BLM, as a cooperating agency adopts the FSEIS. Admin. Rec. XIII. p. 12.

of the Council on Environmental Quality (40 C.F.R. part 1506)". C.F.R. Vol. 55, No. 182, Sept. 19, 1990. The BLM in this Record of Decision goes on to consider in detail the alternatives analyzed in the FSEIS, before its adoption and implementation of the proposed action alternative. A more comprehensive discussion of the adequacy and sufficiency of the FSEIS is included in Section V of this brief.

It is clear, therefore, on the basis of the administrative record, that the DOI complied with all of its regulatory obligations as a cooperating agency in the development and review of the FSEIS under the FLPMA.

2) DOI Properly Developed And Reviewed DOE's Case File Prior To Making A Decision On DOE's Application.

Next, BLM complied with the final case development regulations published at 43 C.F.R. § 2310.3-2(a)-(f). These regulations require that the authorized officer develop preliminary findings and recommendations to be submitted to the Secretary of the Interior. 43 C.F.R. § 2310.3-2(e). After completing that task, the authorized officer must prepare: 1) the findings keyed specifically to the relevant portions of the case file, and 2) the recommendations to the Secretary pertaining to the application. 43 C.F.R. § 2310.3-2(f). Lastly, the authorized officer must prepare a proposed order or notice of denial for consideration by the Secretary of Interior. Id.

All of the documents, findings and recommendations of the authorized officer made pursuant to 43 C.F.R. § 2310.3-2 must

be made part of the case file. Id. When this has been accomplished, copies of the case file must be sent to the Director of BLM and the applicant. Id.

In the present case, it is clear, from the record, that BLM has complied with the case file development and processing regulations prior to submission of DOE's application to the Secretary of Interior. Plaintiff claims, however, that BLM and DOI, by approving PLO 6826, have somehow acted irrationally, and have thereby violated the FLPMA and its regulations.

Such a claim simply can not be maintained in view of the FLPMA, its regulations, and the administrative record. On July 28, 1990, the BLM prepared a Land Report to determine whether the WIPP land withdrawal should be continued, modified, or revoked. Admin. Rec. IX-G. The BLM, in the Land Report, based on analysis of the FSEIS, and other reports submitted with DOE's modification and extension application, made specific findings of fact. Id.[28] In view of the findings of fact contained in the Land Report, the BLM's New Mexico Office drew conclusions and recommended that PLO 6403 be continued and modified. Id. Having made its recommendations based on findings of fact, the BLM

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[28]BLM went beyond mere review of the FSEIS. The BLM received and reviewed the WIPP Test Phase Plan Performance Assessment, and the executive Summaries for the National Academy of Sciences, the Blue Ribbon Panel, and the Ahearne Committee. (referred to elsewhere in the brief as the ACNFS). Admin. Rec. In addition, BLM specifically requested, received, and reviewed DOE's Waste Retrieval Plan, No Migration Variance Petition from the EPA, and a certification from DOE that it had met all other State and Federal Agency requirements. Admin. Rec. I.T and Admin. Rec. I.O.

drafted a proposed modification to P.L.O. 6403. Admin. Rec. IX.B. Accordingly, on September 19, 1990, in its Record of Decision, the BLM indicated that it would adopt and implement DOE's proposed action by recommending that the Secretary of the Interior approve DOE's request for an amended administrative withdrawal. Admin. Rec. at XIII., p. 3. It is clear, therefore, based on the record that DOI strictly complied with its regulatory obligations under the FLPMA pursuant to 43 C.F.R. § 2310.3-2(e)-(f). Its findings of fact, recommendations, and proposed land order, therefore, were based on necessary and proper factual considerations supported by the record. In short, BLM's decisionmaking process was both deliberate and rational. Plaintiff's vague allegations to the contrary must therefore fail.

After making its factual findings and recommendations, the BLM transferred the Land Report, FSEIS, proposed land order and the remainder of the necessary case file to the Director of the BLM. The Director then reviewed the case file and made a recommendation to the Secretary for approval of the modification application. Admin. Rec. IX.D., p. 39. The Secretary, based on the Director's recommendation approved DOE's modification application on January 22, 1991, thus ending a lengthy, deliberative, and rational decisionmaking process. Admin. Rec. IX.D.44. P.L.O. 6826 ordering modification and extension of P.L.O. 6403 was then published in the Federal Register shortly thereafter. Admin. Rec. IX.L. Therefore, on the basis of this

record, it is evident that the Secretary and BLM, again, complied with their regulatory obligations for development and review of DOE's case file under the FLPMA. In view of the extensive information contained in the case file (now part of the administrative record), and more particularly, the FSEIS, it is clear that, in addition to complying with statutory and regulatory requirements of the FLPMA, DOI's approval of PLO 6826 was rationally based on specific findings of fact contained in the administrative record. Accordingly, Plaintiff's allegations that BLM and DOI somehow failed to develop a proper record and thus acted irrationally have no support in the administrative record.

3) DOI And BLM Possessed The Technical Expertise and Resources Necessary To Evaluate the FSEIS And Other Technical Documents Submitted By DOE With Its Application.

Next, Plaintiff's complaint is laced with allegations that the DOI and BLM lacked the technical resources to properly consider DOE's application for a modification, and accompanying reports, particularly the FSEIS. It is important to note from the outset that neither the FLPMA, nor its regulations dictate that the DOI and BLM must possess "technical expertise" when reviewing applications for modifications or extensions under 43 U.S.C.§1714(f).[29] Accordingly, the Plaintiff, in this regard,

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[29] See the discussion in footnote 18. The Plaintiff attempts to manipulate the language of the CEQ regulations to create such a requirement. The plain language of the relevant regulations, however, precludes such a fanciful interpretation. See 40 C.F.R. §1501.6.

has failed to allege a statutory or regulatory violation under the FLPMA.

Although no statutory violation has occurred, we will nonetheless briefly address Plaintiff's factual allegations on this issue. First, the record bears out the fact that BLM did, in fact, possess the technical expertise necessary to properly analyze and review reports such as the FSEIS. In fact, the BLM, through its Office of Environmental Affairs, was able to review the Preliminary Draft SEIS, the Draft SEIS, the Preliminary Final SEIS, and the Final SEIS. On all occasions, the BLM understood the technical material contained in the reports so thoroughly that it responded to DOE, making recommendations and comments for improvement.[30] Admin. Rec. at X. A-D. In fact Admiral Watkins, the Secretary of Energy extended his thanks to DOI for their aid and "expertise" in developing the FSEIS.[31]

Moreover, it is clear that the FSEIS, which addresses the issue of retrievability, and other areas of scientific specialty referenced by Plaintiff in its complaint, is written in relatively simple language which does not require technical

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[30] See February 24, 1989, and March 9, 1989 Letters from Joe Sovcik, Environment, Environmental Specialist to John Arthur, WIPP Project Leader which contained comments. Admin. Rec. X.A., p. 7. In one such comment, BLM asserts that "it is essential that retrievability be addressed in Section 3-2 in order for the Secretary to make a decision" on the modification application; Admin. Rec. X.D,, p. 18. BLM 4 letter of Jonathan Deason, Director, Office of Environmental Affairs; DOI comment to Draft SEIS, Volume 13 FSEIS at p. 606. June 13, 1990 Letter Lujan to Watkins. Admin. Rec. at I.Q.

[31] (See direct quote from letter at page 51.)

expertise for comprehensive understanding. This point is evidenced by the fact that the draft to the FSEIS prompted oral comment from almost 1,000 speakers, and written comments totalling 9,000 pages. Admin. Rec. II.E. Clearly, comprehension of the draft and final SEIS does not require technical or scientific training.

In short, both BLM's close interaction with DOE in the development of the FSEIS[32] and the existence of voluminous public comment elicited by the draft SEIS attest to the fact that the BLM possessed ample aptitude to comprehend the relevant technical and scientific issues placed before it in reviewing DOE's modification application.

Furthermore, in addition to relying on its own technical resources, the BLM, as a cooperating agency with DOE, was able to rely on the expertise of a number of outside resources in processing the DOE's application for a modification to PLO 6403. In fact, a number of expert groups and agencies were intimately involved with DOE in producing and reviewing the technical and scientific aspects of the FSEIS and the case file. Among these expert groups and agencies were: the Environmental Protection Agency, the Advisory Committee on Nuclear Facility

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[32] It is also important to note that DOE forwarded more than eight Drafts to the Decision Plan for the operation of WIPP. Each draft was commented on by DOI's Office of Environmental Review whose comments were then used to restructure the PLan. Admin. Rec. at XII.

Safety, the National Academy of Sciences, and the Environmental Evaluation Group.[33]

In short, this evidence simply confirms the fact that the DOI and BLM, contrary to Plaintiff's allegations, not only possessed adequate expertise within their own department, but also received and reviewed reports from numerous outside technical and scientific experts. These resources clearly enabled the DOI and BLM to adequately consider all relevant and technical material necessary to review of DOE's modification application.

E. The record demonstrates that DOI considered the proper factors in deciding to approve DOE's application for a modification and extension of PLO 6403

1) Plaintiffs Has Not Alleged A Violation of FLPMA By Claiming That DOI Considered Irrelevant And Extraneous Factors In Making Its Decision

The Plaintiff, in its complaint, makes the broad claim that the DOI and BLM's decision to approve P.L.O. 6826, was affected by extraneous and irrelevant factors and, therefore, should be set aside as unlawful pursuant to the Administrative Procedures Act. Plaintiff, despite the breadth of this claim,

[33] The Environmental Evaluation Group (EEG) is an independent body hired as a "watch-dog" to review and evaluate the design, construction and operation of the WIPP project as they relate to the protection of the public health and safety, and the environment. Comments from the EEG and EPA on the draft SEIS were reviewed and commented on in the FSEIS. Admin. Rec. II.E., FSEIS Vol. 7, p.26; Vol. 13, p.330; Vol.13, p. ,303. Additionally, The Wipp Test Phase Plan Performance Assessments and the executive summaries for the National Academy of Sciences, Blue Ribbon Panel, and the Ahearne Committee were received and reviewed by BLM. See Footnote 8.

has failed to allege any statutory or regulatory violation of the FLPMA. Moreover, absolutely no statutory or regulatory provision of the FLPMA is referenced by Plaintiff in support of its claim.

Additionally, after examination of the text of the FLPMA and its regulations, it is evident that Congress has not enacted a check-list of relevant factors which the BLM and the Secretary of the Interior must consider in making determinations pursuant to 43 U.S.C. § 1714(a). See 43 U.S.C. § 1700 et seq.; 43 C.F.R. § 2300 et seq. It is beyond question that the Congress has expressly delegated broad authority to the Secretary to "modify" and "extend" pre-existing land withdrawals pursuant to § 1714(a) of the FLPMA. 43 U.S.C. § 1714(a). Moreover, Congress failed to restrain the Secretary's exercise of authority under § 1714(a) by requiring him to consider certain relevant factors in making determinations pursuant to that section.[34] The absence of Congressional direction to consider mandatory factors in making determinations pursuant to § 1714(a) indicates Congress' intention to leave such determinations to the informed discretion of the Secretary of the Interior and BLM.

Moreover, since Congress has failed to establish a baseline for what considerations are necessary and relevant to determinations under § 1714(a) of the FLPMA, it is not possible,

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[34] It would seem that the only restraints on the Secretary's exercise of delegated power under § 1714(a) would be procedural in that the Secretary and BLM must comply with strict regulatory procedural requirements when adjudicating extensions or modifications under § 1714. See 43 U.S.C. §§ 1701(5); 43 C.F.R. § 2300 et seq.

on the basis of the FLPMA, for the Plaintiff to ascertain that the Secretary and BLM allowed their decision to approve P.L.O. 6826 to be affected by irrelevant and extraneous considerations. Nor would it be proper for the Plaintiff to ask the court to make such a determination in the absence of such necessary statutory guidance.

2) Plaintiff's Factual Allegations That DOI's Decision To Approve P.L.O. 6826 Was Improperly Influenced Is Without Basis In The Record.

In addition to failing to allege a statutory violation of the FLPMA, Plaintiff's factual allegation that DOI and BLM's decision to approve P.L.O. 6826 was improperly influenced by political pressure[35] is inaccurate as shown by the administrative record. Plaintiff claims that "BLM acquiesced in the DOE's refusal to amend" their modification application to allow for "adequate" retrieval time for the waste. In support of this proposition, Plaintiff cites the July 6, 1990 Memorandum of Clarence Hoagland, of BLM's New Mexico Office, which summarizes a conversation with Karen Griffith, an attorney in DOE's Albuquerque, New Mexico office. On this basis, Plaintiff concludes that the decisionmakers in BLM and DOI "gave consideration to factors which were irrelevant and ought not have been considered [political pressure] and ignored factors which were relevant and ought to have been considered," [retrievability time.]

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[35]See Plaintiff's complaint at p. 42, paragraph 110.

This argument is certainly creative and largely conclusory. Unfortunately for Plaintiff, it has absolutely no support on the administrative record. First, there is no basis for asserting that DOI acquiesced to DOE's refusal to amend their modification application. Nothing in the record, including the memorandum cited by Plaintiff, indicates that DOE "refused" to amend their application. Moreover, the assertion referred to by plaintiff in the July 6 Hoagland Memorandum was made by a DOE staff attorney who is not a senior decisionmaker for DOE. Her guess as to what the actual response of the DOE [Washington Office] <u>might</u> be to a suggestion to modify their modification application with BLM is, therefore, of no significance. Moreover, there is no other evidence in the administrative record that DOE indicated or implied to DOI that DOE would or had refused to amend their modification application. Accordingly, the DOI in reviewing the administrative record, could not have considered that "irrelevant" factor when acting on the DOE application.

3) DOI And BLM Considered All Relevant Factors Before Approving P.L.O. 6826.

Furthermore, Plaintiff's factual allegation that DOI and BLM failed to consider factors which were relevant, and in particular factors bearing on retrievability, is simply incorrect in view of the administrative record. The discussion earlier concerning BLM's development of the DOE's case file for the modification application demonstrates that DOI and BLM did in fact review all of the necessary material required by the FLPMA

and its regulations.[36] It is clear that the BLM independently reviewed both the draft SEIS and the FSEIS, and that both documents included detailed analysis of the retrievability of waste. Admin. Rec. II. E.[37] Moreover, the DOE included with its modification application a detailed Waste Retrieval Plan which specifically addresses the issue of time of retrieval for TRU waste emplaced during the Test Phase.[38] Plaintiff's factual allegation that BLM and DOI failed to consider relevant factors pertaining to retrieval of the waste, therefore, is simply inaccurate.

V. THE SECRETARY OF ENERGY IS IN FULL COMPLIANCE WITH NATIONAL ENVIRONMENTAL POLICY ACT.

NEPA requires, among other things, that government officials consider reasonable alternatives to proposed actions which may have a significant effect on the human environment. 42 U.S.C. 4332(C)(iii). Plaintiff contends that delay of the WIPP

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[36]It is clear that even the Secretary, the ultimate decision maker in DOI, considered the issue of retrievability. See discussion, Section IV.A.1., supra.; see also Admin. Rec. at I-Q; June 13 Letter of Manuel Lujan, Secretary of DOI, to Admiral Watkins, Secretary of DOE, stating: "I would also like to emphasize the importance of assuring the retrievability of wastes emplaced at WIPP for the Test Phase. I am aware that DOE issued a Waste Retrieval Plan that outlines how waste emplaced during the Test Phase would be recovered from underground, if needed. I note in your Decision Plan that emplacement and retrieval of simulated test wastes will be demonstrated through the Integrated System Checkout prior to the Test Phase..."

[37]While the FSEIS does not itself address specifically the time for retrieval of waste, it does reference the Waste Retrieval Plan which does in fact discuss the issue. Admin. Rec. IV.JJ.

[38]See footnote 22 and 23.

testing phase pending legislative withdrawal is such an alternative, should have been considered, and was not.

Contrary to plaintiff's allegations, the Final Supplement Environmental Impact Statement (SEIS) for WIPP fully complies with the requirements of the National Environmental Policy Act. The SEIS contains a detailed analysis of the environmental impacts of the proposal and all reasonable alternatives. All public comments received on the draft SEIS are summarized and responded to in Volume 3 of the SEIS. Plaintiff alleges that DOI did not analyze the alternative of legislative land withdrawal. However, the SEIS clearly states that legislative land withdrawal was analyzed as part of the proposed action and was the preferred mechanism for withdrawal of the WIPP site lands for purposes of pursuing the proposed action analyzed in the SEIS. (Admin. Rec. II.E (Vol. 3, pp. 66-67).) Administrative land withdrawal under FLPMA was being pursued parallel to the preferred legislative withdrawal. (Admin. Rec. II.E (pp.10-11).) Therefore both means of land withdrawal were analyzed in the SEIS as part of the proposed action.

The plaintiff is factually wrong in stating that DOE did not mention legislative land withdrawal in its ROD. DOE's Record of Decision (ROD) issued June 22, 1990, again reiterates that legislative land withdrawal is DOE's preferred option and discusses DOE's submission of a proposed bill to Congress on April 3, 1990. The ROD also acknowledges DOE's parallel request that the Secretary of the Interior..."modify the current Public

Land Order to allow the receipt of waste at the WIPP for the Test Phase in the event that Congress does not enact land withdrawal legislation." Id. The phased development of WIPP in a manner consistent with Public Law 96-164 under either legislative or administrative land withdrawal is in fact the proposed action of the SEIS and is extensively analyzed.

The plaintiff further alleges that the SEIS does not consider the alternative of an indefinite delay in the emplacement of wastes in WIPP for the Test Phase pending enactment of legislative land withdrawal. Contrary to this allegation, the alternative of not emplacing wastes at WIPP for the Test Phase was analyzed in the SEIS as the Alternative Action. As discussed in response to a comment of the DOI on the Admin. Rec. II.E (Vol. 3, p. 67), the impacts of delaying the receipt of waste at WIPP pending the passage of a legislative land withdrawal would result in impacts functionally similar to those of the Alternative Action analyzed in the SEIS. The Alternative Action is described in section 3.2.2 (Admin. Rec. II.E., Vol. 1, p. 3-43) and the environmental consequences of the alternative action are described in section 5.3 (Admin. Rec. II.E., Vol. 1, pp. 5-112 - 5-126). Under this alternative DOE would not proceed with the Test Phase at WIPP but would conduct the bin scale tests in a specially engineered above ground facility constructed for that purpose at an existing waste generation and storage site. This alternative encompasses the alternative (considered in the DOI Record of Decision) of

extending the WIPP land withdrawal until 1997 without modifying it to allow receipt of wastes for the Test Phase. Basically the same information could be gathered from these tests as from the bin scale experiments proposed to be conducted at WIPP. However, as noted on page 3-44 of the SEIS this alternative would delay start of the bin scale tests for about 2 years. This Alternative Action is the only reasonable alternative to proceeding with the Test Phase at WIPP and therefore bounds the impacts to postponing emplacement of radioactive wastes at WIPP. As discussed on pages 3-44 and 3-45 of the SEIS, DOE dismissed as unreasonable the alternatives of performing experiments in support of the performance assessment with simulated nonradioactive waste and proceeding with the performance assessment with no new tests. Accordingly, the SEIS does analyze the impacts of the full range of reasonable alternatives including the alternative suggested by the Plaintiff.

As already discussed, the environmental impacts of proceeding with the Test Phase under legislative land withdrawal are analyzed as part of the proposed action. Plaintiff's suggestion that the Secretary should consider differences in impacts because conditions may be imposed by Congress during the legislative process, would require DOE to engage in speculation. Such idle speculation is not required by NEPA. Further a number of the conditions suggested by the plaintiffs such as outside regulatory oversight are incapable of meaningful analysis under

NEPA. Chapter 6 of the SEIS does discuss means to mitigate impacts of the proposed Test Phase.

DOE is not aware of any significant new circumstances or information relevant to environmental concerns that require the preparation of a supplement to the SEIS at this time.[39]

The SEIS also considers the instability of WIPP's underground facilities. Geologic instability is the nature of salt formulations. The SEIS discusses the issue of retrievable and room stability in response to comments on pages 294 and 296-299 as well as in the body of the SEIS. Admin. Rec. II.E (Vol. 1, 6-3 and 6-8).) The record clearly establishes that DOE has been and is committed to assuring that the wastes are fully retrievable during the proposed Test Phase. Id. at 6-8 and Vol. 3, p. 294. In fact, it is legally required to be able to retrieve these wastes by EPA's conditional No Migration Variance Determination under RCRA. As stated in the ROD, during the Test Phase the waste will be emplaced in a fully retrievable manner. DOE convened two expert panels to review the design of the facility to assure that DOE can honor its commitment, as well as the legal requirement, that the wastes will be fully retrievable. Reports of these panels have confirmed that the design of WIPP assures that the waste will be fully retrievable during the Test Phase. Therefore, there is no significant new information that requires a supplement to the SEIS.

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[39]As stated in the SEIS and ROD, DOE has committed to another supplement to the SEIS at the end of the test phase.

In short, legislative withdrawal was considered as part of the proposed action and delay was considered as an alternative to the action taken. NEPA has not been violated.

VI. THE WIPP PROJECT HAS INTERIM STATUS UNDER THE NEW MEXICO HAZARDOUS WASTE ACT.

A. Introduction.

On August 27, 1990, the Director of the New Mexico Environmental Improvement Division wrote a letter to DOE's WIPP project manager, requiring two things so that DOE could legally test WIPP under the New Mexico Hazardous Waste Act; that DOE file a Part A hazardous waste permit application by January 22, 1991, and that it file its Part B permit application by February 28, 1991. DOE complied with both requirements, but now New Mexico claims that WIPP does not have "interim status" under the New Mexico Hazardous Waste Act.

In its "Memorandum in Support of Motion for Temporary Restraining Order", at pp. 21-23, plaintiff New Mexico claims that DOE "has not complied with, and has misrepresented its compliance with, the terms of Public Land Order No. 6826." In support of this allegation, New Mexico claims that DOE informed DOI that DOE had complied with the procedural requirements for "interim status" under the Resource Conservation and Recovery Act, 42 U.S.C. §§ 6901, et seq. ("RCRA"), when the New Mexico Environment Department had "preliminarily determined that WIPP may not qualify for interim status under the New Mexico Hazardous Waste Act." Memorandum in Support at 22. Therefore, "Presently", according to New Mexico, "DOE is not in compliance

with its RCRA or HWA responsibilities. Having procured the Notice to Proceed on false grounds, DOE may not ship waste to the WIPP." Id. at 23.

New Mexico's allegations are baseless, and in fact, defendants are entitled to summary judgment that the WIPP project has "interim status" as a matter of law under both RCRA and the New Mexico Hazardous Waste Act, N.M Stat. Ann. § 74-4-1, et seq. (Michie 1991) ("HWA").

B. Interim status under RCRA.

RCRA was enacted by Congress in 1976 to provide "cradle to grave" regulation of "solid wastes".[40] Included within that definition are "hazardous wastes", which may be either "listed" by the Administrator of the Environmental Protection Agency ("EPA"), or which may be considered hazardous by virtue of the waste exhibiting various "characteristics" of hazardous waste. RCRA section 3001, 42 U.S.C. § 6921. Subtitle C of RCRA, 42 U.S.C. § 6921, et seq., directs EPA to establish a comprehensive system governing the generation, transport, storage, treatment and disposal of hazardous wastes.

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[40] "Solid waste" is defined in RCRA as "any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved material in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under section 1342 of title 33, or source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954, as amended (68 Stat. 923) . . ." [Emphasis supplied]. RCRA section 1004(27), 42 U.S.C. § 6903(27).

RCRA specifically excludes from regulation "source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954, as amended." RCRA section 1004(27), 42 U.S.C. § 6903(27). The hazardous wastes at issue in this case are known as "radioactive mixed wastes", which are defined as "any matrix containing a RCRA hazardous waste as defined in 40 CFR 261 and a radioactive waste subject to the [Atomic Energy Act]." 53 Fed. Reg. 37045, 37046 (Sept. 23, 1988). The actual radioactive component is commonly classified as "high-level", "low-level", or "transuranic". "Transuranic" (or "TRU") radioactive wastes are those with an atomic number greater than 92, including plutonium. "TRU-mixed waste", the waste subject to testing at WIPP, is therefore composed of hazardous wastes as defined by RCRA, combined with certain radioactive materials that are regulated solely under the Atomic Energy Act. Although TRU-mixed waste thus includes some materials which are excluded from regulation under RCRA, the mixture of those radioactive materials and RCRA hazardous wastes are subject to regulation under RCRA unless health and safety concerns mandate other management. 51 Fed. Reg. 24504 (July 3, 1986).

RCRA prohibits the treatment[41], storage[42], or disposal

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[41] RCRA defines "treatment" of hazardous waste as "any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste or so as to render such waste nonhazardous, safer for transport, amenable for storage, or reduced in volume. Such term includes any activity or processing designed to change the physical form or chemical composition of hazardous waste so as to render it nonhazardous." RCRA section 1004(34), 42 U.S.C. §6903(34)...)

of[43] hazardous wastes by any facility unless the treatment, storage or disposal facility ("TSD facility") either first obtains a permit from EPA or an "authorized state"[44], RCRA section 3005(a), 42 U.S.C. § 6925(a), or satisfies the conditions for "interim status" pending processing and issuance of a permit, RCRA section 3005(e), 42 U.S.C. § 6925(e).

In its original form, "interim status", which allowed a TSD facility to operate without a permit, applied to facilities which (a) were in existence on October 21, 1976; (b) gave appropriate notification of hazardous waste activity; and (c) which had made timely application for a permit. RCRA section 3005(e), 42 U.S.C. § 6925(e). The statute was amended in 1980 to change the date upon which the TSD facility must have been in existence to November 19, 1980. The purpose of this type of interim status was to allow already existing TSD facilities to

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[42] "Storage" under RCRA means "the containment of hazardous waste, either on a temporary basis or for a period of years, in such a manner as not to constitute disposal of such hazardous waste." RCRA section 1004(33), 42 U.S.C. § 6903(33).

[43] RCRA "disposal" is "the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including ground waters." RCRA section 1003(3), 42 U.S.C. § 6903(3).

[44] Most states also have hazardous waste management laws and state permit requirements that apply in addition to RCRA. As will be explained more fully below, in order to reduce duplicative regulatory schemes, RCRA contains provisions which allow states to operate and enforce their own hazardous waste management laws in lieu of RCRA if a state passes laws at least as stringent as RCRA.

continue operating pending the permitting process. Vineland Chemical Co. v. United States E.P.A., 810 F.2d 402, 407 (3rd Cir. 1987). A facility with interim status "shall be treated as having been issued such permit until such time as final administrative disposition of such application is made", unless it is proven that the final administrative decision was not made due to the applicant's failure to provide information. RCRA section 3005(e), 42 U.S.C. § 6925(e).

On November 8, 1984, the Hazardous and Solid Waste Amendments of 1984 ("HSWA"), a major revision of RCRA, were signed into law. Under the pre-HSWA version of RCRA, only TSD facilities in existence (or whose construction activities had commenced) as of November, 1980, were eligible for interim status. HSWA added a new section 3005(e)(1)(A)(ii), 42 U.S.C. § 6925(e)(1)(A)(ii), which extended interim status to facilities "in existence on the effective date of statutory or regulatory changes under this chapter [i.e., RCRA] that render the facility subject to the requirement to have a permit under this section . . .". Thus, a facility already in existence at the time that it became subject to the permit requirements due to a change in RCRA or the regulations promulgated thereunder could obtain interim status - therefore giving it time to go through the permitting process without having to shut down in the meantime.

An application for a RCRA permit for a TSD facility is comprised of a "Part A" and a "Part B". The Part A is an abbreviated document which includes descriptions of the

activities to be conducted that require a RCRA permit; the location of the facility; identity of the owners and operators of the facility; the hazardous wastes to be treated, stored or disposed of at the facility; other permits under other programs; and the nature of the business. 40 CFR § 270.13.

The Part B application, on the other hand, is an extremely detailed document which is to include, among many other things, a description of how the facility will comply with the substantive regulations governing the operation of interim hazardous waste management facilities.[45] 40 CFR §§ 270.14 - 270.29.

In order to qualify for interim status under RCRA, owners and operators of hazardous waste management facilities "in existence on the effective date of statutory or regulatory amendments under the act that render the facility subject to the requirement to have a RCRA permit" must submit their Part A application no later than

> (i) Six months after the date of publication of regulations which first require them to comply with the standards set forth in 40 CFR Part 265 or 266, or
>
> (ii) Thirty days after the date they first become subject to the standards set forth in 40 CFR Part 265 or 266, whichever first occurs.

40 CFR § 270.10(e)(1). In the preamble to the rulemaking which established the 30 day requirement of subpart (ii), EPA interpreted that portion of the regulation to apply to facilities

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[45] 40 CFR Part 265 sets forth the interim status standards for owners and operators of hazardous waste treatment, storage and disposal facilities.

which become subject to RCRA permit requirements as a result of changes in their <u>own</u> operations, and not due to changes in the law or regulations. An example given by EPA was a small quantity generator starting to generate larger quantities of hazardous waste, so that a permit would be required. 45 Fed. Reg. 76630, 76633 (Nov. 19, 1980). The 30 day Part A submission requirement makes sense in that context, because the facility should be charged with knowledge of its own operations and when it makes <u>itself</u> subject to regulation, as opposed to the situation when a facility whose operations do not change becomes regulated as a result of revisions in the law. In the latter instance, the six month period of 40 CFR § 270.10(e)(1)(i) applies.[46] 40 CFR § 270.70(a) states that a person who owns or operates "a facility in existence on the effective date of statutory or regulatory amendments under the Act that render the facility subject to the requirement to have a RCRA permit shall have interim status and shall be treated as having been issued a permit" to the extent the person has (a) submitted a RCRA section 3010(a) notice of hazardous waste activity (if required) and (b) complied with the requirements of 40 CFR § 270.10 on Part A submissions.

The 1984 HSWA amendments to RCRA also added what are known as the "loss of interim status" provisions, section 3005(e)(3), 42 U.S.C. § 6925(e)(3), which states as follows:

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[46] In addition, a TSD facility must submit a Part B application within six months of a request by EPA. 40 CFR § 270.10(e)(4).

> (3) In the case of each land disposal facility which is in existence on the effective date of statutory or regulatory changes under this chapter that render the facility subject to the requirement to have a permit under this section and which is granted interim status under this subsection, interim status shall terminate on the date twelve months after the date on which the facility first becomes subject to such permit requirement unless the owner or operator of such facility --
>
> (A) applies for a final determination regarding the issuance of a permit under subsection (c) of this section for such facility before the date twelve months after the date on which the facility first becomes subject to such permit requirement; and
>
> (B) certifies that such facility is in compliance with all applicable groundwater monitoring and financial responsibility requirements.

The EPA regulation implementing section 3005(e)(3) is 40 CFR § 270.73(d). Under that provision, interim status would be terminated if, in the case of a land disposal facility, the owner/operator fails to submit a Part B application and certification that the facility is in compliance with groundwater monitoring and financial responsibility requirements within one year after the facility first becomes subject to permitting due to statutory or regulatory changes.

To summarize, under the RCRA/HSWA statutory and regulatory scheme, a TSD facility which becomes subject to RCRA permitting requirements as the result of a statutory or regulatory change under RCRA <u>obtains</u> interim status if it submits a timely notice of hazardous waste activity (if required) and submits Part A of its RCRA permit application within six months of the publication of the regulations which subject it to permitting. RCRA section 3005(e)(1), 42 U.S.C. 6925(e)(1); 40

CFR § 270.10(e)(1)(i). A land disposal facility which is subjected to RCRA permitting requirements under those same conditions will automatically lose its interim status unless, within 12 months after the date on which the facility becomes subject to the permit requirement, it submits a Part B application and certifies compliance with groundwater monitoring and financial responsibility requirements. Section 3005(e)(3), 42 U.S.C. § 6925(e)(3); 40 CFR § 270.73(d). These latter provisions on the loss of interim status were adopted pursuant to the 1984 HSWA amendments.

C. New Mexico's Authorized Hazardous Waste Management Program.

Pursuant to section 3006(b) of RCRA, 42 U.S.C. § 6526(b), EPA can authorize state hazardous waste programs to operate in lieu of RCRA if they meet certain criteria. The criteria for EPA authorization require that the state law program be equivalent to the federal program, be consistent with federal or other state programs, and provide for adequate enforcement. If a state hazardous waste program is so authorized by EPA, the state carries out its program "in lieu of the Federal program under this subchapter in such State [and may] issue and enforce permits for the storage, treatment, or disposal of hazardous waste. . ." Section 3006(b), 42 U.S.C. § 6926(b). In essence, when EPA authorizes a state hazardous waste program, that program, rather than RCRA itself, becomes the law which TSD facilities in that state must follow.

On January 11, 1985, EPA published a notice granting New Mexico final authorization to operate its hazardous waste program in lieu of RCRA:

> Accordingly, New Mexico is granted Final Authorization to operate its hazardous waste management program. Subject to [HSWA], New Mexico now has responsibility for permitting treatment, storage and disposal facilities within its borders and for carrying out all other aspects of the RCRA program. New Mexico also has primary enforcement responsibility, although EPA retains the right to conduct inspections under section 3007 of RCRA and to take enforcement actions under sections 3008, 3013 and 7003 of RCRA.

50 Fed. Reg. 1514, 1516 (Jan. 11, 1985).

The 1984 HSWA amendments to RCRA which related to "the generation, treatment, storage or disposal of hazardous waste" were made applicable to all states, whether the state program was authorized or not, and were to be enforced by EPA in each state until that state was finally authorized (or was granted interim authorization) to enforce state law in lieu of those HSWA requirements. RCRA section 3006(g)(1), 42 U.S.C. § 6926(g)(1). That included the loss of interim status provisions of section 3005(e)(3). EPA explained the interplay of the New Mexico authorized program and HSWA as follows:

> As a result of the HSWA, there will be a dual State/Federal regulatory program in New Mexico. To the extent the authorized State program is unaffected by the HSWA, the State program will operate in lieu of the Federal program. EPA will administer and enforce the prohibitions and requirements of the HSWA in New Mexico until New Mexico receives authorization to do so. Among other things, this will entail the issuance of Federal RCRA permits for those areas in which the State is not yet authorized. Once the State is authorized to implement a HSWA requirement or prohibition, the State program in that area will operate in lieu of the Federal provision. Until that time the State will

> assist EPA's implementation of HSWA under a Cooperative Agreement.
>
> HSWA-related requirements and prohibitions that are more stringent than the State's program apply in New Mexico. Any State requirement that is more stringent than an HSWA provision also remains in effect; thus, the universe of the more stringent provisions in the authorized State program and the HSWA define the applicable requirements in New Mexico. (New Mexico is not being authorized now for any requirement implementing the HSWA.)

50 Fed. Reg. 1514, 1516 (Jan. 11, 1985).

D. <u>The New Mexico Hazardous Waste Act and Hazardous Waste Management Regulations</u>.

The New Mexico Hazardous Waste Act adopted many of the provisions of RCRA. N.M. Stat. Ann. § 74-4-9 (Michie 1991) states that "[a]ny person owning or operating a hazardous waste facility who has met the requirements for interim status under 42 U.S.C. 6925 shall be deemed to have interim status under the Hazardous Waste Act [this article]." Therefore, if WIPP or any other facility in New Mexico would have had interim status under <u>RCRA</u>, it would also have that status under the HWA.

N.M. Stat. Ann. § 74-4-4 states that the New Mexico state regulatory entity

> A. . . . shall adopt regulations for the management of hazardous waste <u>equivalent to, and no more stringent than</u>, federal regulations adopted by the federal environmental protection agency pursuant to the Resource Conservation and Recovery Act:
>
> * * *
>
> (6) requiring each person owning and operating an existing facility or planning to construct a new facility for the treatment, storage, or disposal of hazardous waste identified or listed under this

> subsection to have a permit issued pursuant to requirements established by the board;
>
> (7) establishing procedures for the issuance, suspension and revocation of permits issued under Paragraph (6) of this subsection . . .

[Emphasis supplied.]

This determination by New Mexico to mirror the federal requirements of RCRA is reflected in New Mexico's "Hazardous Waste Management Regulations" ("HWMR"). Copies of the HWMR applicable from 1988 to the present are included in the Administrative Record at III.X. With minor exceptions, the HWMR adopted the federal substantive regulations on hazardous waste management by interim status facilities, 40 CFR Part 265. HWMR, Part VI, Rule 601.

In addition, Part IX, Rule 901, states in its entirety that "[t]he regulations of the United States Environmental Protection Agency set forth in 40 CFR Part 270, through July 1, 1990, are hereby incorporated in Part IX of the New Mexico Hazardous Waste Management Regulations." It should be recalled that 40 CFR § 270.10 governs the application of interim status to facilities which have become subject to permitting requirements due to changes in statutory or regulatory provisions, while § 270.73 governs the loss of interim status. New Mexico has not established any independent standards relating to qualification for or termination of interim status under HWA.

E. <u>Regulation of radioactive mixed wastes</u>.

As described above, RCRA excludes "source, special nuclear, or byproduct material as defined by the Atomic Energy

Act" from the definition of "solid waste". RCRA section 1004(27), 42 U.S.C. § 6903(27).[47] This exemption led to a great deal of confusion and debate as to whether "mixed wastes" (i.e., wastes which include both radioactive wastes not subject to RCRA and "hazardous wastes subject to RCRA") were regulated under RCRA.

On July 3, 1986, EPA issued a notice which stated that "wastes containing both hazardous waste and radioactive waste are subject to the RCRA regulation". 51 Fed. Reg. 24504 (July 3, 1986). The notice stated that

> Given the lack of clarity on this issue, EPA did not previously require as a condition of State authorization that the State have regulatory authority over the hazardous components of radioactive mixed wastes. In authorizing States, EPA did not inquire into State authority over the hazardous components of radioactive mixed wastes and made no determination of whether States had authority over such wastes. <u>Accordingly, the Agency has taken the position that currently authorized State programs do not apply to radioactive mixed wastes</u>. [Emphasis supplied.]

51 Fed. Reg. 24504. As a result, EPA required that authorized states revise their programs, if necessary, and apply for EPA authorization for the regulation of hazardous components of radioactive mixed wastes; "States must demonstrate to the appropriate EPA Regional Administrator that their program applies to all hazardous waste even if mixed with radioactive waste."

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[47] Similarly, section 74-4-3.1 of the HWA states that "Nothing in the Hazardous Waste Act . . . shall be construed to apply to any activity or substance which is subject to . . . the Atomic Energy Act of 1954, as amended, (42 U.S.C. 2011 et seq.) except to the extent that such application or regulation is not inconsistent with the requirements of such act[] . . .".

Id. Already authorized States which had to amend their state hazardous waste statutes in order to regulate mixed wastes had to do so within two years of July 3, 1986 in order to retain their authorization. 51 Fed. Reg. at 24505.

On May 1, 1987, DOE issued a final interpretive rule under the Atomic Energy Act, finding that "for purposes of RCRA, DOE interprets the term byproduct material to refer only to the radioactive component of a nuclear waste. The nonradioactive chemically hazardous component of the waste will be subject to regulation under RCRA." 52 Fed. Reg. 15937, 15940 (May 1, 1987). In doing so, DOE very narrowly construed the RCRA section 1004(27) provision, limiting materials regulated under the Atomic Energy Act to the radioactive component of mixed waste. 42 U.S.C. § 6903(27).

In the meantime, on April 8, 1987, New Mexico amended its Hazardous Waste Act to provide that "Nothing in the Hazardous Waste Act shall be construed to apply to any radioactive waste processed and certified for emplacement in the mined geologic repository at the waste isolation pilot plant." Section 74-4-3.2. This provision specifically excluded the mixed waste to be emplaced in WIPP from HWA regulation. As indicated above, EPA had also found, for purposes of the state hazardous waste management programs authorized by EPA to be operated by the states in lieu of RCRA itself, that radioactive mixed waste was <u>not</u> regulated under RCRA prior to mixed waste authorization being

granted to such states by EPA. 51 Fed. Reg. 24504 (July 3, 1986).

As a result of EPA's and DOE's findings that radioactive mixed wastes were subject to RCRA, and in an effort to provide New Mexico with information regarding WIPP, DOE submitted a Part A application to New Mexico and EPA on July 7, 1988. The Part A was not acted upon by New Mexico, and was returned to DOE in November, 1989, without explanation.

On September 23, 1988, EPA published a "Clarification of Interim Status Qualification Requirements for the Hazardous Components of Radioactive Mixed Waste". 53 Fed. Reg. 37045. As of the date of that notice, 44 states had obtained final authorization to administer state law in lieu of the basic RCRA hazardous waste program under section 3006 of RCRA, 42 U.S.C. § 6926, but only Colorado, South Carolina, Tennessee and Washington had received the additional authorization needed to regulate radioactive mixed waste. Id. Unlike EPA's July, 1986 notice, which set time limits for the states to revise their existing hazardous waste programs and apply for RCRA authorization to regulate radioactive mixed waste, the September, 1988 "Clarification" addressed the interplay of interim status of TSD facilities and the regulation of mixed waste.

As described above, under 40 CFR § 270.10(e), a facility which becomes subject to permitting requirements as the result of a statutory or regulatory change must submit a Part A application within six months of the regulatory change in order

to obtain interim status, and under 40 CFR § 270.73(d), in the case of a land disposal facility, such a facility must submit a Part B application within 12 months of the regulatory change to avoid termination of interim status. Therefore, the date of the regulatory or statutory change subjecting the facility to permitting requirements is of critical importance, triggering the obligations to file a Part A and Part B. EPA set the date an authorized state obtained authority from EPA to regulate mixed waste as the "trigger date" for obtaining interim status under RCRA or the authorized state programs:

> Facilities treating, storing, or disposing of radioactive mixed waste but not other hazardous waste in a State with base program authorization are not subject to RCRA regulation until the State program is revised and authorized to issue RCRA permits for radioactive mixed waste. The effective date of the State's receipt of radioactive mixed waste regulatory authorization from EPA will therefore be the regulatory change that subjects these TSDF's to RCRA permitting requirements. [Emphasis supplied.]

53 Fed. Reg. at 37047.

Still, even though a state had the basic RCRA authorization approved by EPA,

> . . . [O]wners and operators of TSDF's in authorized States are subject to all applicable State laws. A State can establish its own date for qualifying for interim status, but, in order to be no less stringent than the Federal program, that date may not be after the effective date of EPA's authorization to the State to regulate radioactive mixed waste. [Emphasis in original.]

To summarize, under state hazardous waste programs authorized in lieu of RCRA (pursuant to RCRA section 3006), a facility treating, storing, or disposing of radioactive mixed

wastes would have interim status if a Part A permit application was submitted within six months of the effective date the particular state received mixed waste authorization from EPA. A facility would retain interim status if it submitted a Part B application within one year of that date. If there was some independent provision of state law which required a more stringent schedule for obtaining interim status, a facility would have to comply with that provision.

F. WIPP has interim status as a matter of law, and is therefore in compliance with HWA.

In this case, it is clear as a matter of law that DOE obtained interim status for WIPP under the New Mexico Hazardous Waste Act, and that the interim status has not been terminated pursuant to New Mexico law, the loss of interim status provisions of RCRA section 3005(e)(3), or the related regulations.

As described above, in 1987, New Mexico amended HWA to specifically exempt the mixed wastes to be emplaced in WIPP from regulation under HWA. New Mexico was informed by EPA Region VI that that provision could lead to the termination of New Mexico's authorization to run its own hazardous waste management program in lieu of RCRA because it would make HWA less stringent than RCRA. Accordingly, effective on February 23, 1989, New Mexico repealed HWA section 74-4-3.2, which contained the exemption for WIPP.

New Mexico received EPA authorization to enforce state law in lieu of RCRA for radioactive mixed wastes effective July 25, 1990. 55 Fed. Reg. 28397 (July 11, 1990). Therefore, in

order to obtain interim status for WIPP under the authorized state hazardous waste program, DOE would be required to file a Part A application for WIPP by January 25, 1991 (i.e., six months after July 25, 1990) and to retain interim status, DOE was required to file a Part B application by July 25, 1991 (one year after the mixed waste authorization). DOE met both of these requirements.

There was and is no independent New Mexico state requirement for obtaining interim status or for termination of that status. Section 74-4-9 of HWA states that "Any person owning or operating a hazardous waste facility who has met the requirements for interim status under 42 U.S.C. 6925 shall be deemed to have interim status under the Hazardous Waste Act." Section 74-4-4 directs the New Mexico administrative authorities to adopt regulations regarding permitting "equivalent to, <u>and no more stringent than</u>, federal regulations adopted by [EPA] pursuant to the Resource Conservation and Recovery Act [emphasis supplied]." Rule 901 of the New Mexico Hazardous Waste Management Regulations incorporates 40 CFR Part 270 without reservation.[48] Therefore, the triggering date for filing a Part

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[48] Part I of the New Mexico Hazardous Waste Management Regulations is entitled "Hazardous Waste Management System - General". Rule 101 adopts and incorporates 40 CFR Part 260 (which is also entitled "Hazardous Waste Management System - General") of the federal regulations. However, those incorporated regulations are modified by Rule 102. Rule 102.B. states that "The following terms <u>not</u> defined in 40 CFR Section 260.10 have the meanings set forth herein" (emphasis supplied); included in that list is "Act" or "RCRA", which is modified in the New Mexico version of 40 CFR Part 260 to mean the New Mexico (continued...)

A and Part B was July 25, 1990, the date New Mexico received authorization from EPA to regulate radioactive mixed waste.

New Mexico apparently agreed with that assessment. On August 27, 1990, the Director of the New Mexico Environmental Improvement Division, Mr. Richard Mitzelfelt, wrote a letter to Mr. Arlen E. Hunt, DOE's WIPP project manager, which stated as follows:

> As you know, the State of New Mexico received, on July 25, 1990, final authorization from the U.S. Environmental Protection Agency for the radioactive mixed waste requirements as published in the Federal Register on July 3, 1986.
>
> This letter is to notify you that, as Director of the New Mexico Environmental Improvement Division, I am requiring the Department of Energy, Waste Isolation Pilot Plant (WIPP) Project Office, to submit by Wednesday, February 28, 1991, the Part B permit

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[48](...continued)
Hazardous Waste Act. Rule 102.B.1. The problem with that scheme is that "Act" or "RCRA" is defined in 40 CFR § 260.10. It is unclear just what is meant by Rule 102.

In any case, it is obvious that Rule 102 does not apply to Rule 901, which incorporates 40 CFR Part 270 (on permitting requirements and interim status) into the New Mexico regulatory scheme. First, the definitions of 40 CFR § 260.10 apply only to 40 CFR Parts 260 through 265 and Part 268, not Part 270. 40 CFR § 260.10. Second, Rule 901 does not refer to Rule 102 in any way, and merely incorporates all of 40 CFR Part 270 without qualification or amendment. Third, Section 74-4-9 of the Hazardous Waste Act states that a party which has interim status under RCRA section 3005, 42 U.S.C. § 6925, will be deemed to have interim status under the HWA. It is therefore logical for New Mexico to have adopted the very regulations which define interim status under RCRA as its own, since the HWA statutory test for interim status is identical to the RCRA tests. Moreover, any other interpretation would place the regulation squarely in conflict with the clear language of section 74-4-9 of HWA. Finally, HWA section 74-4-4 authorizes the state to adopt regulations, but they are specifically required not to be more stringent than those adopted under RCRA.

In sum, New Mexico has incorporated all of 40 CFR Part 270 exactly as set down in the Code of Federal Regulations.

> application for the management of hazardous waste as required by the Resource Conservation and Recovery Act (RCRA) (New Mexico Hazardous Waste Management Regulations, Part IX, 40 CFR section 270.1(b)).
>
> You are reminded of the following requirements for the WIPP facility to qualify for interim status during the review period of its Part B permit application: the Part A application must be received by Monday, January 22, 1991 and groundwater monitoring certification must accompany the Part B permit application. [Emphasis supplied.]

Admin. Rec. at III.Q.

In conformance with the law and in good faith reliance on the direction of the New Mexico administrative agency's direction, DOE timely submitted a Part A permit application for WIPP on January 22, 1991 (thus securing interim status under 40 CFR § 270.10 and Rule 901, HWMR)[49], and a Part B on February 26, 1991 (in response to the direction of the state regulators and 40 CFR § 270.1(b)). A copy of the submitted Part A is included in the Administrative Record at III.N., and a copy of the Part B application is at III.J. of the Administrative Record.[50] DOE thus qualifies for interim status at WIPP.

On July 1, 1991, Ms. Kathleen Sisneros of the New Mexico Environment Department sent a letter headed "Preliminary

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[49] In its September, 1988 Federal Register notice clarifying the interim status of TSD facilities handling radioactive mixed wastes, EPA determined that a separate notification under RCRA section 3010(a), 42 U.S.C. § 6930(a), was not required in order for those facilities to qualify for interim status. 53 Fed. Reg. 37045, 37047 (Sept. 23, 1988).

[50] See also Notice of Receipt of Part A DOE WIPP permit application by N.M. Environmental Improvement Division, Admin. Rec. at III.M.; Transmittal Letter from DOE to N.M. Environmental Improvement Division; submittal of RCRA Part B application for WIPP, Admin. Rec. at III.H.

Determination and Request for Information" to Mr. Arlen Hunt, the DOE WIPP project director, and Mr. A. Lamar Trego, general manager of Westinghouse Electric Corporation (DOE's contractor on WIPP). The letter, Admin. Rec. at III.E., states that "Based on the record as outlined below, NMED has preliminarily determined that WIPP may not qualify for interim status under the New Mexico Hazardous Waste Act." New Mexico contradicted its position of a year earlier and now argued that the change in law or regulation which triggered the one year period for the filing of a Part B was not the date EPA granted New Mexico mixed waste authorization, but the earlier date upon which New Mexico repealed the WIPP exemption from HWA (February 23, 1989). NMED closed the letter by inviting DOE and Westinghouse to "submit their factual and legal arguments in support of a determination of interim status by July 19, 1991." DOE did so on July 18, 1991. Admin. Rec. at III.C.

After receiving DOE's reply, NMED wrote to EPA's Region VI Regional Administrator on July 26, 1991, seeking "confirmation of the legal standard that EPA would use to determine whether WIPP has federal interim status for mixed waste under [RCRA]." Admin. Rec. at III.B. While couched in terms of inquiry, NMED's letter was actually a legal argument: "As NMED reads EPA's September 1988 notice [53 Fed. Reg. 37045], WIPP will be eligible for RCRA interim status only if WIPP is in compliance with applicable state law at the time of the State's authorization for mixed waste." New Mexico claimed that <u>state law</u> required the

filing of a Part B within one year of the repeal of HWA section 74-4-9, in February, 1989.

Mr. George Alexander, EPA Regional Counsel, Region VI, responded to NMED's inquiry by letter of August 20, 1991, Admin. Rec. at III.A. EPA stated that

> The repeal of the state law exempting WIPP from the State's hazardous waste program was not the relevant regulatory change for determining interim status under RCRA Subsection 3005(e) because the regulatory changes referred to at RCRA Subsection 3005(e)(3) are changes under "this Act" -- i.e., RCRA. The change in state law was not a change under RCRA until the State became authorized to regulate radioactive mixed waste under RCRA. <u>As a result, to the extent that State interim status mirrors federal interim status requirements, WIPP would have been eligible for interim status on July 25, 1990, when the state received its authorization to regulate radioactive mixed waste</u>. [Emphasis supplied.]

It is clearly the case that New Mexico's interim status statute and regulations are identical to the interim status requirements of RCRA. As EPA concluded, under federal law, "if WIPP's Part B application, and other certifications required by the statute, were filed before July 25, 1991, WIPP retained interim status under RCRA." That being the case, then WIPP also has interim status under HWA, because DOE filed the required applications well in advance of July, 1991. New Mexico's claims that there is no interim status, and that WIPP would therefore be in violation of HWA permit requirements, is clearly an after-the-fact rationalization and is unsustainable.

There are no disputed issues of material fact, and DOE is entitled to judgment as a matter of law that WIPP has interim status under HWA.

CONCLUSION

Because there are no disputed issues of material fact, and because defendants are entitled to judgment as a matter of law, summary judgment must enter in their favor, dismissing the Complaint with prejudice. The Court should also grant summary judgment that WIPP has interim status under the New Mexico Hazardous Waste Act.

Respectfully submitted,

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WIPP Library

UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF COLUMBIA

STATE OF NEW MEXICO, ex. rel. TOM UDALL, Attorney General, Plaintiffs. v. JAMES D. WATKINS, Secretary of the Department of Energy, et al., Defendants.	Civil Action No. 91-2527 JGP

PLAINTIFF'S REPLY AFFIDAVITS SUBMITTED IN OPPOSITION
TO DEFENDANTS' MOTION FOR SUMMARY JUDGMENT
AND IN SUPPORT OF PLAINTIFF'S MOTION FOR A
TEMPORARY RESTRAINING ORDER
AND PRELIMINARY INJUNCTION

VOLUME I

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SUMMARY OF AFFIDAVIT OF
JOHN F. ABEL, JR.

Dr. Abel is a Professor in the Mining Engineering Department at the Colorado School of Mines in Golden, Colorado. He has extensive teaching and consulting experience in the field of rock mechanics. He has had five consulting assignments in 1976 through 1985 concerning the design and construction of the WIPP. In April 1991 the DOE's operating contractor invited Dr. Abel to participate in the expert panel on the life of Room 1, Panel 1, but he had to decline because of teaching obligations. (¶¶ 9-10).

Dr. Abel testifies that the introduction of radioactive waste into Room 1, Panel 1 creates a needless and imprudent risk because of roof instability. The room already shows acceleration in a closure, which is the best known indication of a potential roof fall. The risk of collapse is a present risk, and the risk increases with time. (¶ 2).

Room 1, Panel 1 can be expected to fail by mechanisms similar to those which caused the failure of SPDV Test Room 1 (¶¶ 16-27). Because of demonstrated acceleration in closure, Room 1, Panel 1, is now as unsafe as SPDV Test Room 1 when it was closed (¶¶ 28-29). The risk of collapse increases with time. (¶ 30).

The DOE's supplementary roof support system is not likely to prevent the failure of the roof or to significantly delay that failure. It is an unsound engineering design, based upon erroneous assumption. (¶¶ 31-43).

Waste is almost certain to become non-retrievable due to loss of the necessary headroom to retrieve the waste. (¶ 44).

The DOE's design document says almost nothing about warning of roof failure. There is no quantified and dependable definition of impending failure, which describes circumstances which require the room to be abandoned and also allows sufficient time to retrieve the waste. The DOE disregards acceleration in closure and fracturing, which ought to foreclose use of the room. Mining engineers do not know the indications of imminent -- i.e., soon, but not sooner than six months -- failure of underground openings in salt. (¶¶ 45-47).

Also, a support system will to some extent damp closure acceleration, reducing if not eliminating one possible warning signal. (¶ 50).

It is scientifically irresponsible, without a reliable criterion of failure, to introduce radioactive waste into Room 1, Panel 1 simply in the hope that a gravity support system will work and no adverse consequences will result. (¶ 46). It is imprudent mine engineering practice to place radioactive waste in Room 1, Panel 1. (¶ 51).

AFFIDAVIT OF JOHN F. ABEL, JR.

John F. Abel, Jr., under penalty of perjury, states as follows:

1. I am a Professor in the Mining Engineering Department at the Colorado School of Mines in Golden, Colorado.

2. I make this affidavit to show the Court that the introduction of radioactive waste into Room 1, Panel 1, of the Waste Isolation Pilot Plant ("WIPP") creates a needless and imprudent risk because of the instability of the roof of that room. The room already shows an acceleration in the rate of closure--convergence between the roof and the floor--which is the best known indication of a potential roof fall. The risk of collapse of the roof of the test room is a present risk, and that risk increases with time.

3. Concerning my qualifications, I graduated with high honors from the Colorado School of Mines as an Engineer of Mines in June 1956. In 1959 I received my M.S. degree in Mine Engineering, and in 1966 I received my D.Sc. degree in Mine Engineering, both from the Colorado School of Mines. I have received a Brunton Compass Award for meritorious work in mine engineering (1956) and the Robert Peale Memorial Award of the American Institute of Mine Engineers for achievements in authorship in the fields of mining and geology (1967).

4. My employment experience includes tunneling in ice in Greenland; mine engineering at a 700 ton per day coking coal mining facility near Carbondale, Colorado; and planning and supervision of rock mechanics instrumentation programs for

Terrametrics, Inc., of Golden, Colorado. I have done part-time work for the United States Geological Survey involving investigations of stresses around underground rock excavations.

5. In 1962-63 I lectured at King's College, The University of Durham, Newcastle upon Tyne, England. The subjects included metal mining methods and rock mechanics instrumentation.

6. In 1966-74 I was an Associate Professor at the University of Arizona College of Mines and taught mining engineering and engineering geology. During this period I returned to Newcastle upon Tyne as a Visiting Professor of mine engineering during a sabbatical in 1972-73.

7. From 1974 to the present I have been a Professor at the Colorado School of Mines in the Department of Mining Engineering and have taught rock mechanics and mine engineering to graduates and undergraduates. During this period I also taught as a Visiting Professor in the Universities of New South Wales, Queensland, and Melbourne and Western Australia in 1978, and earlier in 1991 taught at the Universidad de Guanajuato on the Facultad de Minas, Metalurgia y Geologia at Guanajuato, Mexico.

8. While teaching, I have maintained an active consulting practice. A client list and enumeration of prior and current work is attached to my resume (ex.A). Instances of my experiences in connection with underground excavations in evaporites (i.e., salt, gypsum, potash, trona) are as follows:

d. Borns, D.J., and J.C. Stormont, An Interim Report on Excavation Effects Studies at the Waste Isolation Pilot Plant: Delineation of the Disturbed Rock Zone, SAND 87-1375 (1988)

e. Stormont, J.C., Discontinuous Behavior Near Excavations in a Bedded Salt Formation, SAND 89-2403 (1989)

f. Design Criteria Waste Isolation Pilot Plant, Revised Mission Concept -IIA, WIPP DOE-71, Rev. 4 (extracts)

g. Cook, R.F., Position Paper: Life Expectancy of Room 1, Panel 1, Draft (1991)

h. Brunwald, H.P., and H.C. Howarth, Compression Tests of Roof-Salt Slabs Supported by Potash Salt Pillars, RI-3386, U.S. Bureau of Mines (1938)

i. Brockman, T.R., Panel 1 Roof Bolting, Design Calculations, EWP-51-0-0433

12. I have reviewed the Report of the Geotechnical Panel on the Effective Life of Rooms in Panel 1, DOE/WIPP 91-023 (June 1991), the report entitled Waste Isolation Pilot Plant, Supplementary Roof Support System, Underground Storage Area, Room 1, Panel 1 (August 1991), and the report entitled Room 1, Panel 1, Supplementary Roof Support External Design Review (Sept. 19, 1991). The first report (the June 1991 report) contains the individual reports of members of an expert panel

which examined the room stability problems at the WIPP. The second report (the August 1991 report, ex. B hereto) contains the proposed roof support system, to be installed in an effort to prolong the life of Room 1, Panel 1. The third report (ex. C hereto) contains the Design Review Panel's appraisal of the support system and recommendations.

13. I have also reviewed the affidavits of Jack Parker and Gabriel Fernandez-Delgado, filed in this case.

14. In have made several visits to the WIPP in connection with my consulting work, most recently in 1985.

15. I explain herein (a) the mode of roof failure which can be expected in Room 1, Panel 1, (b) the deficiencies of the proposed roof support system in preventing such failure, and (c) the lack of any system to warn of impending failure.

16. When an underground room is excavated the horizontal and vertical stresses which exist at depth can no longer be transmitted through the void space which was formerly filled with rock. These horizontal stresses must pass above and below the excavated room. Horizontal stresses therefore become concentrated in the roof beam and in the floor of the room.

17. The exterior ribside (the wall) of a room at the end of a panel is subjected to the highest vertical stress, because the end pillar is essentially infinite in width and can support the total vertical stress present in the strata above the partially excavated panel. SPDV Test Room 1 and Room 1, Panel

1, are both end rooms and, therefore, subject to maximum vertical stress in their exterior ribs.

18. Certain rocks, such as clay, are incapable of transmitting substantial amounts of shear stress. In the case of Room 1, Panel 1, there are thin clay seams 2.12 meters and 3.96 meters above the roof of the test room. These underlie the anhydrite "b" and anhydrite "a" seams. (ex. B, Fig. 2.2). The presence of the clay seam closest to the roof -- the seam underlying anhydrite "b" -- limits the amount of horizontal stress that can be transmitted above that plane to the overlying strata. Thus, the rock mass between the roof of the room and the lower clay seam is, in effect, the only roof beam available to carry horizontal stress, and it is only 2.12 meters thick.

19. The concentration of horizontal stress within the 2.12-meter-thick roof beam causes the roof beam initially to move in shear between the pillar ribs and the plane of the clay seam underlying the anhydrite "b" layer. Horizontal stresses therefore are transmitted primarily through the roof beam, and not much, if any, can be transmitted across the lower clay seam to the overlying rock. Shallow angle shear effects are depicted in Figure 5.6 and 5.8 of ex. B.

20. As the ribside shear fractures grow upward over the room, progressively concentrated stresses result in separation of the roof beam from the overlying clay seam and anhydrite "b" layer, as shown in Figure 5.6 of ex. B.

21. The SPDV test rooms show the behavior that can be anticipated in Room 1, Panel 1. In SPDV Test Room 1 extensometer data, measuring separation of overlying strata, show that the strata overlying edges of the roof began to move downward more rapidly and accelerate as the roof beam began to separate from the anhydrite "b" layer in mid-1986 (Figures 5-8, 5-9), when the room was three years old. The immediate roof beam overlying the center of the room began to move downward more rapidly and accelerate, once the shallow shear fractures reached the clay seam in mid-1987 (Figure 5-5), when the room was four years old. Thus, the separation of strata progressed from edge to center and from shear to tension. (These figures are contained in the Geotechnical Field Data and Analysis Report, Vol. II, March 1991, DOE/WIPP 91-012; the "GFDA Report"). By comparison, Room 1, Panel 1, is now more than five years old.

22. The strata separation apparent in SPDV Test Room 1 did not only involve the clay contact at the anhydrite "b" layer; rather, it involved the contact at that layer, the clay layer under the overlying anhydrite "a" layer, and still other strata as high as fifty feet above the room. (Figures 5-5, 5-8, 5-9, GFDA Report).

23. Lateral movement is also to be expected, particularly as the result of the progressive shearing, and the data so show. It can be anticipated that the roof of Room 1, Panel 1, will first shear downward and outward, and the outside edges of the

roof will move outward with relation to the overlying strata. Such lateral movement was observed in SPDV Test Room 1 (Figures 5-26, 5-27, GFDA Report). Notably, the lateral movement involved not only the clay seam underlying the anhydrite "b" layer, 2.12 meters above the roof, but also the clay seam underlying the anhydrite "a" layer, which lies 1.79 meters higher. In other words, detectable lateral movement involved strata overlying the roof beam as well as the roof beam itself.

24. The closure rate is also important data. This measures the convergence of the roof and the floor. Table 5.1 of ex. B shows that the closure rate of SPDV Test Room 1 began to accelerate between years 4-5 and 5-6.

25. According to Figure 5.1 (ex. B), which plots convergence data in detail for the room, routine activities were suspended in SPDV Test Room 1 in mid-1989, six years and two months after excavation. Thus, the DOE clearly concluded that SPDV Test Room 1 was unsafe at that time, and one infers that the determination was based upon evidence of accelerating closure.

26. Low angle roof fractures, commencing near the walls and progressing upward, led to the failure of the roof in SPDV Test Room 1 (ex. B at A-6). I note that Mr. Parker (aff.¶24, 31) and Dr. Fernandez (aff. ¶12) observed similar fractures in the roof of Room 1, Panel 1. These correspond to the roof fractures which were observed in SPDV Test Room 1 and led to its

failure. Fractures are also reflected in Figure 5.8 of ex. B, depicting Room 1, Panel 1.

27. SPDV Test Room 1 experienced a massive roof fall on February 4, 1991, about seven years and ten months after excavation (ex. B, Fig 5.1). The shape of the fractured roof section suggests that fracturing progressed from the walls toward the center until the roof separated on the clay seam under anhydrite "b" and fell. (ex. B, Fig. 5.7). A similar failure can be expected to occur in Room 1, Panel 1.

28. It is difficult to predict the timing of deformation and failure of pillars and rooms excavated in salt. It is not safe to make broad assumptions about the timing of the behavior of a given room based on a small sample, such as the single example of SPDV Test Room 1. Moreover, it has not been established that the roof over SPDV Test Room 1 and the roof over Room 1, Panel 1, are geologically similar, and the available geologic sections show dissimilarities (Figures 2.2, 2.3, 5.2, ex. B). Moveover, Room 1, Panel 1, underwent "staged" development different from SPDV Test Room 1 (ex. C at 2), which can affect the mode of fracturing and failure and thus also the timing.

29. Based upon the available data it appears that Room 1, Panel 1, which is five years and four months old, has begun to show the acceleration in closure that appeared in the data for SPDV Test Room 1 at the end of year six. Specifically, the closure rate for the first nine months of year five has

increased substantially from the previous year's rate (Table 5). This behavior resembles the acceleration of closure which led to termination of routine activities in SPDV Test Room 1. If closure acceleration was the criterion applied in deciding to close SPDV Test Room 1, then Room 1, Panel 1, should similarly be regarded as unsafe for entry. In my opinion, because of demonstrated acceleration in closure, Room 1, Panel 1, is now as unsafe as SPDV Test Room 1 when it was closed.

30. The risk of collapse, moveover, increases with time, because the failure of the roof of a room involves progressive shear fracturing, leading to rapid failure when the downward force bearing upon the fractured portion of the roof exceeds the capacity of the remaining roof beam to carry the horizontal stress and gravity load and to bear the buckling and shear stresses as well.

31. I have also reviewed the proposed supplementary roof support system. From the data available to me, this design is not likely to prevent the failure of the roof or to significantly delay that failure. The design principally relies upon 13 foot Dwyidag rock bolts anchored with resin grout to the rock salt layer above the anhydrite "b" layer and below the anhydrite "a" layer. Below the anhydrite "b" layer these bolts are placed in three-inch-diameter clearance holes, which run top-to-bottom through the roof beam. The bolts protrude 18 inches down from the roof. The bolts run through a 1-1/2" hole in a transverse steel channel set, which is comprised of three

nine foot sections. The channel sets are placed transversely at eight to ten foot intervals along the room. There is also a lacing and wire mesh system, as described in the report (ex. B at 4-6 through 4-8).

32. The support system design places the entire gravity load of the weight of the roof beam, plus the additional downward forces caused by shear and buckling, upon the rock immediately above the 2.12 meter roof beam. This overlying rock is, in effect, a second beam, 1.79 meters thick, and is itself overlain by a second clay layer which cannot transmit any significant shearing stress. It is unsound engineering design to place all reliance on that single overlying beam. The August 1991 report says that no separation has been detected at the anhydrite "a" layer (ex. B. at A-7), but the data on the SPDV rooms clearly shows both strata separation and lateral movement at that point (Fig. 5-5, 5-8, 5-9, 5-26, 5-27, GFDA Report). The rock where the bolts are anchored is not competent ground, as the report assumes. (ex. B at A-10).

33. In addition, the support system is designed to carry only the weight of the roof beam, and it is not designed to absorb more than this gravitational force (ex. B at A-9, D-1). But the system will also be called upon to absorb downward thrust from both buckling and shear forces. Horizontal stress concentrated in and acting on the roof beam will cause it to bulge downward near the ribs and buckle downward in the center. When fracturing develops, horizontal stress will cause the

fractured part of the roof to shear against the overlying rock, and the roof will display "rotation" outward and downward (ex. B at 6-3). These forces are very substantial but difficult to quantify, partly because roof failure is usually asymmetrical (Id.) The buckling and shear forces will probably overload the support system and result in collapse unless released as developed.

34. It should also be noted that the channel sets constitute a rigid structure, flexing only at the joints between sections. Such rigidity, trying to fit straight steel sections to a curve, may make it impossible to shift load from an overloaded bolt to an adjacent bolt, resulting in continued overloading of individual bolts.

35. The support system assumes that the rock bolts will be loaded in tension, but in fact they will be loaded in tension and shear, a configuration which reduces their ability to carry the gravity load of the roof beam. The shear fractures developing near the ribs will result from lateral movement of the roof beam which the bolt penetrates. The lateral movement will cause the bolt to be bent outward at the point of rock slippage, at or below the anhydrite "b" layer. The bolt will also be bent back inward where it penetrates the steel channel set, when the roof beam moves relative to the channel set. Such shear forces will cause bending stresses in the bolt and the bolt to fail sooner than it would under pure gravitational tensile load.

36. The three inch clearance hole for the rock bolt is inadequate, contrary to the design assumptions (ex. B at 3-2). The support system design assumes that there will be only 1/2" of lateral movement per year (ex. B at 4-3). This assumption is unfounded, to begin with, because the inclinometer data in the August 1991 report itself shows more than 1/2" per year lateral movement (Fig. 5-4), and other data show more than 1/2" per year of lateral movement in SPDV Test Room 2 (Fig. 5-50, 5-51, GFDA Report).

37. Even if 1/2" per year were the limit of lateral movement, the three inch clearance hole is insufficient. The rock bolt will have only one inch of available clearance, since the bolt itself is approximately one inch in diameter, and it is anchored in the center of the hole by resin grout. Consequently, 1/2" of lateral movement per year will eliminate all available annular clearance in two years, at which time the rock will bear directly against the bolt.

38. The DOE's Design Review Panel saw the need to enlarge the clearance hole "to accommodate the shear displacement without imposing shear and bending effects on the one-inch diameter anchor" (ex. C at 3). That panel recommended a 4-1/2" hole (Id.), 2-inch annulus or 4-year life. However, to accommodate 1/2" of lateral displacement per year, all outward from the center of the room, for seven years, an eight-inch hole would be necessary, 3-1/2" annulus or 7-year life. The shear forces are likely to be applied near the resin-anchored shaft of

the bolt, where the bolt cannot move laterally with the clearance hole. The bend will be sharp and the bending stresses high. An eight-inch clearance hole would raise still further technical questions as to the size and type of bearing plate which could carry the bolt tension across an open eight inch hole.

39. Shear forces applied to a bolt are likely to result in bolt failure by breakage at the bending point. In addition, shear and bending at the anhydrite "b" level would probably result in yielding on one side of the anchor, contrary to the intention of the design, as the Design Review Panel observed. (ex. C at 3). Moreover, shear forces applied by the roof beam as it slides over the bolt result in additional downward pressure on the bolt itself, adding to the vertical load that the system must bear, in addition to gravity, shear, and buckling forces.

40. The support system will shift stresses to the overlying member, imposing loads on the thinner overlying beam which has not been subject to design. When the roof beam fractures, either partially or entirely, it becomes incapable of transmitting the horizontal stresses which it previously carried. Those stresses will then flow into the overlying rock beam between the anhydrite "b" and the anhydrite "a" layer. In other words, the same forces that led to the failure of the original roof beam would be applied to the overlying beam. That beam would be even more vulnerable to failure under stress than

the original roof beam, because the stresses in question cannot be shared with an overlying member, because the beam is thinner (only 1.79 meters), and because the beam must carry not only its own weight but also the weight of the fractured roof, suspended below it. There are no estimates in the August 1991 report of the time to failure of the overlying beam in such conditions; the Design Review Panel says only that it is "critical" that the situation be "continuously monitored" and that "alternative supplemental support systems may be needed to assure Room 1, Panel 1 stability." (ex. C at 6). The implication is clear that the proposed support system is incapable of accomplishing that task. This conclusion is correct, for the support system will collapse if its anchor points are overloaded, and that will be the case.

41. The support system includes several erroneous design assumptions. It is clear that the rock behavior which leads to roof failure involves fracturing in salt beds (ex. B, Fig. 5.6 and p.A-6). The DOE has established a "model" that purports to explain the performance of underground openings and was used to design the support system (Id. A-1). This model incorporates a conception of the "steady state creep" behavior of salt (Id. A-4), but it does not incorporate the critical element of the brittle behavior of salt --i.e., fracturing -- under stress (Id.). The report itself acknowledges that evaluation of the performance of a support system using the model must allow for

the limitations of the model. (Id.). There is no indication that this has been done.

42. There are other mistaken assumptions underlying the support system. The design assumes that, once shear fractures have developed, roof movement is increasingly associated more with gravity than with "salt creep." (ex. B at 4-1). In fact, after fractures begin, shear stresses and shear displacement continue to play a major role in the progression of fractures toward failure and continue to generate downward forces on the roof beam in addition to the force of gravity alone. These forces are not anticipated by the DOE's support system.

43. The support system is based on the assumption that the zone of rock between anhydrite "b" and "a" is sufficiently stable to provide a good anchor for the support system (ex. B at 3-2). This is erroneous, as I have described above. Moreover, I am concerned that the designers were inhibited by Sandia National Laboratory's stated preference that the anchors not penetrate to a height above anhydrite "a" (Id. 4-3) and by the designers' own desire to avoid the difficulties of setting the long rock bolts necessary to reach that height (Id. 4-4). These extraneous considerations may have led to adoption of an inadequate design.

44. In addition, even with the support system the waste is almost certain to become non-retrievable due to loss of the headroom that the DOE deems necessary. One of the design criteria for the support system is maintenance of 3.45 meters or

11' 4" of "minimum access height" (ex. B at 3-1). A typical test room is 3.94 meters high (Id. Fig. 2.2). If one adds roof bolts protruding 18" (450mm) down from the ceiling, the available clearance becomes 3.49 meters, which means that there is only a scant four centimeters of excess clearance as soon as the roof bolts are installed. It would be foolish to assume that this necessary headroom will not rapidly disappear, given that the roof and floor of Room 1, Panel 1, are converging at the rate of 3-1/2 " per year (Id. Table 5).

45. Given the shortcomings of the roof support system, it is obviously important to know what warning will be provided if roof failure threatens to render the radioactive waste non-retrievable. The August 1991 report says almost nothing on this subject. It is known that, in an emergency, the test bins and apparatus can be removed in approximately six months (June 1991 report at 3-3). It is also known that the roof will fail at some point. What is missing is a quantified and dependable definition of "impending failure," backed up by data, which conservatively describes the circumstances which both (a) require the room to be abandoned and (b) allow sufficient time to dismantle and remove the test equipment. Given that acceleration in closure of Room 1, Panel 1, has already been observed (ex. B, Table 5.1), and roof fractures have appeared in the roof adjacent to the ribs, the DOE evidently does not regard such acceleration and fracturing as sufficient warning of failure to bar use of the room or tests with radioactive waste.

It should be noted that Dr. William Thompson, a member of the DOE's expert panel, recommended that upon acceleration of closure which proceeds for six months, "waste removal should be started." (June 1991 report, Thompson report at 20). Dr. Ian Farmer, also on the expert panel, recommended that waste be removed upon "an increase in roof convergence, associated with parting dilation, which is not controlled or reduced quickly by installation of cribs or additional roof supports." (Id., Farmer report at 12). I concur with these criteria, which are met by the recent increase in convergence recorded in Room 1, Panel 1. This danger signal ought to foreclose the use of the room, in the absence of any better indicator of impending failure.

46. The DOE in fact barred use of SPDV Test Room 1, from mid-1989, presumably based on acceleration in convergence rate (ex. B, Fig. 5.1). If the DOE has any other criterion of impending failure which assures six months time to remove waste, it must disclose it and provide the data which support its use. This has not been done. Without any such reliable criterion of failure, it is scientifically irresponsible to introduce radioactive waste into Room 1, Panel 1, where convergence is accelerating, simply in the hope that a gravity support system will work and no adverse consequences will occur.

47. In fact, mining engineers are not able to predict imminent failure and do not know the indications of imminent -- i.e., soon, but not sooner than six months -- failure of underground openings in salt. To the contrary, when failure

occurs, it appears to happen quickly after the first obvious warning signals. Gross acceleration over a period of days, not years or months, generally precedes roof failure, but when such acceleration takes place it is no longer safe to enter the room; thus, it is far too late to retrieve radioactive waste. Moreover, even long-lived mines with numerous well-documented roof failures sometimes experience unexpected roof falls, and in the case of the WIPP there is no such long-term detailed history. Instead, there is only SPDV Test Room 1, a sample of one, which is insufficient data to generalize.

48. Dr. S. D. McKinnon, a member of the DOE's expert panel, has stated:

> "Based on the experience with Room 1 of the SPDV area, up to two year's advance warning of a failure was seen by examining the results of monitoring. As a forward process, however, there is always difficulty in discriminating signs of failure from other sources of noise, for example seasonal variations. Furthermore, once 'failure' has started, the process will take place at different rates in different rooms due to variations in geology etc. There is insufficient data available, based on only one failure event, to know the variability of this time to failure once warning signs have started. Depending upon when it is decided that indeed failure is going to take place, six months required to remove bins may be inadequate.
>
> Given that the mechanism of failure is not well defined, and instrumentation based on an understanding of this mechanism has not been placed, it is considered that additional instruments should be installed. Only when the failure mechanism is reasonably well understood, and instruments have been placed to monitor the process, will there be adequate tools to provide reliable warning. Criteria to determine when waste should be removed could be developed after the preceding steps have been carried out, and only then could any meaningful estimate be made of how long a warning period could be given." (June 1991 report, McKinnon report at 22-23)

I am in agreement with these statements. Other than acceleration of closure, no valid warning system, as Dr. McKinnon discuses, exists at this time. Nor is there any meaningful estimate of how long a warning period could be given.

49. Similarly, Dr. Hamish Miller, who sat on the DOE's expert panel and later consulted concerning the design of the support system has stated:

> "It is felt that not enough data has been observed to date to be sure of describing a criterion for certain failure at a given moment in time." (Id., H. Miller report, statement 5).

Dr. Miller recommended further study:

> "It is recommended that a special study be made of the data recorded to date, the objective of which should be to develop a valid and workable criterion for the prediction of 'critical conditions' at the WIPP site. The term 'critical conditions' should also be defined." (Id.)

Without such a study, Dr. Miller concluded, "it is impossible to say at what stage removal of waste (or human operations) would be necessary." (Id.) I am in agreement with Dr. Miller on this point. Other than closure acceleration, there is no valid definition of conditions which require the removal of waste, much less conditions which will ensure that such removal can be safely completed.

50. In this connection, it should be noted that a support system such as the DOE proposes will to some extent damp closure acceleration, which provides one indication of progressive fracturing, and thus will reduce, if not eliminate, one possible

warning signal. Any proposed warning criterion must account for this damping factor, which is an unknown quantity.

51. In light of the clear probability of roof failure in Room 1, Panel 1; the probability that the same room will demonstrate such warning signals (e.g., closure acceleration) that it must be evacuated without retrieving radioactive waste; the near certainty of loss of essential access clearance; and the lack of any clear and supportable criteria for retrieval of waste and abandonment of the room, it is imprudent mine engineering practice to place radioactive waste in that room.

I declare under penalty of perjury that the foregoing is true and correct. Executed: October 23, 1991.

John F. Abel, Jr.

JOHN F. ABEL, JR.

EXHIBIT A

JOHN F. ABEL JR.
MINING ENGINEER

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RESUME

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PROFESSIONAL ENGINEER: Colorado 5642

JOB HISTORY:

27 August 1974 - Present

Department of Mining Engineering
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Professor. Undergraduate and graduate instruction in rock mechanics and mining engineering. Sabbatical to Facultad de Minas, Metalurgia y Geologia at the Universidad de Guanajuato, Spring Term 1991. Visiting Professor in Mining Departments of Univ. of New South Wales, Univ. of Queensland, Univ. of Melbourne and Western Australia School of Mines during summer 1978.

20 September 1965 - 15 November 1975

United States Geological Survey
Engineering Geology Branch
Denver Federal Center
Denver, Colorado 80225
Research Mining Engineer - GS 13. Part-time (usually summers) Investigation of geologic effects on stresses around underground rock excavations.

1 September 1966 - 15 June 1974

Department of Mining and Geological Engineering
College of Mines
The University of Arizona
Tucson, Arizona 85721
Associate Professor. Undergraduate and graduate instruction in mining engineering and engineering geology. Visiting Professor, Dept. of Mining Engineering, The University, Newcastle upon Tyne, England 1972-73. Sabbatical leave.

4 February 1963 - 15 July 1964

Terrametrics, Inc.
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Rock Mechanics Engineer. Planned and supervised rock mechanics instrumentation programs for surface and underground rock excavations.

JOB HISTORY (Continued):

1 July 1962 - 1 January 1963

Department of Mining Engineering
Kings College, The University of Durham
Temporary Junior Lecturer in Metalliferous Mining. Undergraduate instruction in metal mining methods. Applied rock mechanics instrumentation and physical property research. Newcastle upon Tyne 1, England

1 December 1960 - 1 July 1962

Thompson Creek Coal and Coke Corp.
703 Farmers Union Bldg.
Denver, Colorado 80203
Mine Engineer. Engineering for 700-Tpd, three-mine, 120-man coking coal operation near Carbondale, Colorado

9 September 1957 - 20 February 1960

United States Army Snow, Ice and Permafrost Research Establishment
1215 Washington Ave.
Wilmette, Illinois (now USA CRREL, P.O. Box 282, Hanover, NH 03755)
Mining Engineer - GS 11. Planning and direction for 37-man arctic tunneling research projects.

1 June 1957 - 1 September 1957

Denver Research Institute
The University of Denver
Denver 10, Colorado
Assistant Project Leader. Ice tunneling project in Greenland.

28 January 1957 - 18 March 1957

Climax Molybdenum Corp.
Climax, Colorado
Engineering trainee on mine crew.

1 June 1956 - 1 September 1956

Denver Research Institute
The University of Denver
Denver 10, Colorado
Shift boss for 10-man ice mining crew in Greenland.

EDUCATION:

Colorado Springs High School, Colorado Springs, CO - Class of 1949

Colorado College Colorado Springs, Colorado	Sep 1949 - Jun 1950	
Colorado School of Mines Golden, Colorado	Sep 1952 - Jun 1956	Engineer of Mines
	Sep 1956 - Jan 1957	
	Feb 1959 - Jun 1959	MS - Mining Engrg
	Sep 1964 - Jun 1966	DSc - Mining Engrg

AWARDS AND HONORS:

1956	Graduated Colorado School of Mines with "High Honors".
1956	Brunton compass award "Meritorious Work in Mining Engrg".
1964-66	Boettcher Foundation Fellowship for graduate study.
1967	Robert Peele Memorial Award of AIME for "Achievement in Authorship in the Fields of Mining and Geology".
1975-76	Sigma Gamma Epsilon "Outstanding Professor" award at Colorado School of Mines.
1983-84	Hanna Mining Co. Lecturer.

PROFESSIONAL SOCIETIES:

SME/AIME, Assoc. of Engineering Geologists, Int'l Society for Rock Mechanics, Colorado Mining Assoc., Tau Beta Pi, Sigma Xi

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Minority Enterprise Service Assocs., Inc.; evaluation of coal mine roof stability determination methods (UT)
Jenny Engineering Corp.; (1) Storm King Mines Wheeler Seam Project New Castle (CO), (2) Culver Sewer Tunnel rehab design review (NY), (3) Detroit Sewer Tunnel bypass rehab design review (MI)
Dravo Corp.; (1) Carbon County Coal Co. Hanna Mine underground coal mine design review (WY), (2) WIPP Project instrumentation peer review panel (NM), (3) Dobrudza Project shaft lining & deep coal mine design review (Bulgaria), (4) WIPP Project shaft station stability evaluation (NM)
D'Appolnia Consulting Engineers, Inc.; (1) engineering geology & rock mechanics for underground coal mine design project (WY), (2) Dugout Canyon/Sage Point Project underground coal mine design review (UT)
Ingersoll Rand Research Institute, Inc.; USBM Project rock mechanics analysis for OFFCAT coal extraction method (NJ) design (CA)
Advanced Engineering Resources, Inc.; USBM Project cable bolting roof support study (CA)
Gates & Fox, Inc.; (1) San Fernando Tunnel support analysis, (2) Carlin Tunnel support analysis & design (NV)
Centennial Silver Co.; Auburn Joint Venture tunnel rehab (CO)
Eastern Tunneling Corp.; (1) Orchard Tunnel support design & litigation (CO), (2) Tyzack Tunnel support analysis & design (UT), (3) Northglenn Sewer Tunnel support analysis (CO)
Phillips Uranium Corp.; Nose Rock Mine shaft station design (NM)
Rock Mountain Consultants, Inc.; Stanley Canyon testing (CO)
Empire Iron Mining Partnership; shear strength testing (MI)
Dunn Assocs.; Loyalhana fm quarry rock testing & design (PA)
U.S. Forest Service; Migmatite testing for fish ladder slope (AK)
Kennecott Communications Corp.; Alligator Ridge Mine rock testing (NV)
Staal, Gardner & Dunne, Inc.; rock testing Santa Barbara fm, Ronald Reagan Library foundation rock, Seminole Tank rock, Chatsworth fm, Modelo fm (CA)
Tenneco Minerals Co.; testing of Westcliff pit rock (CO)
Chrome Corp. of America; Mt. View Mine rock core testing (MT)
Arch of Kentucky; compression testing of High Splint Seam (KY)
Gold Bond Building Products; Shoals Mine gypsum & dolomite testing (IN)
Goodson & Assocs., Inc.; testing of coal measure rocks (WV)
Gormley Consultants Inc.; (1) testing of pit rock (WY), (2) testing of Argo Tunnel rock (CO)
CSMRI, Inc.; testing of pit rock (CO)
Nat'l. Inst. for Petroleum & Energy Research; core testing (TX)
Standard Oil Production Co.; core testing (TX)
Argee Corp.; testing of chrome mine rock (MT)
Associated Universities for Research in Astronomy (AURA); Kitt Peak National Observatory foundation reinforcement for 150-in. telescope (AZ)

EXHIBIT B

DRAFT
09/10/91

WASTE ISOLATION PILOT PLANT

SUPPLEMENTARY ROOF SUPPORT SYSTEM

UNDERGROUND STORAGE AREA

ROOM 1, PANEL 1

RECEIVED
SEP 16 1991
ENVIRONMENTAL EVALUATION GROUP

WESTINGHOUSE ELECTRIC CORPORATION
WASTE ISOLATION DIVISION
CARLSBAD, NEW MEXICO
AUGUST 1991

ROOM 1, PANEL 1, SUPPLEMENTARY ROOF SUPPORT SYSTEM

EXTERNAL DESIGN REVIEW

Tuesday, September 17, 1991
6:45 a.m.
Meet at Stevens Motel Lobby
(1829 South Canal, Carlsbad, NM 88220)

AGENDA

7:00 a.m.	Depart for site after visiting Greene Street Office (Subhash Sethi, Chris Chmura, and Hamish Miller to escort the panel members).
8:15 a.m.	Security check-in.
9:00 a.m.	Safety briefing for underground tour (Support Building, Project Manager's Information Center (PMIC) room).
9:30 a.m.	Introductions and welcome.
10:00 a.m.	WIPP overview presentation.
10:30 a.m.	Surface tour.
11:30 a.m.	Lunch (cafeteria).
12:30 p.m.	Prepare for underground tour.
1:00 p.m.	Underground tour. A. Experimental area. B. Storage area.
3:30 p.m.	Return to surface
4:00 p.m.	Wrap-up meeting (Support Building, PMIC room).
4:30 p.m.	Depart for Stevens Motel.

ROOM 1, PANEL 1, SUPPLEMENTARY ROOF SUPPORT SYSTEM

EXTERNAL DESIGN REVIEW

Wednesday, September 18, 1991, through Friday, September 20, 1991
Motel Stevens
(1829 South Canal, Carlsbad, NM 88220)

Wednesday, September 18, 1991

8:00 a.m.	Presentation on Design Review Scope and Deliverables.
8:30 a.m.	Presentation on Geology and Rock Mechanics - Roy Cook.
9:15 a.m.	Break.
9:30 a.m.	Presentation on Design Requirements - Hamish Miller.
10:00 a.m.	Presentation on System Design and Installation - Chris Chmura.
10:45 a.m.	Break.
11:00 a.m.	Presentation on Monitoring and Instrumentation - Roy Cook.
	Additional presentations will be made, if required.
12:00 p.m.	Lunch.
1:00 p.m.	Panel discussions.
2:30 p.m.	Break.
2:45 p.m.	Panel discussions.
4:45 p.m.	Adjourn.

Thursday, September 19, 1991

8:00 a.m.	Panel discussions continued. Westinghouse provides responses to resolve issues raised by panel members.
	Finalize panel report and sign off.

Friday, September 20, 1991

8:00 a.m.	Panel meetings to continue, if required.

EEG

From Engineering
WIN 887-8182
Date September 9, 1991
Subject ROOM 1 PANEL 1 SUPPLEMENTARY ROOF SUPPORT SYSTEM - EXTERNAL DESIGN REVIEW 91-05

To T. W. Halverson

cc: F. G. Ashford, WID
J. E. Atchenson, WID
H. L. Bibby, WID
T. P. Burrington, WID
W. H. Caplinger, WID
K. M. Chmura, WID
R. F. Cook, WID
C. M. Cox, WID
L. R. Fitch, WID
J. J. Garcia, WID
J. P. Hale, WID
C. R. Kelley, WID
T. F. Kocialski, WID
J. M. Kowalski, WID
R. Kuginskie, WID
B. S. Kuntz, WID
J. L. Lee, WID
H. D. Miller, WID Consultant
F. Padilla, WID
M. L. Petermann, WID
L. L. Reed, WID
L. M. Rencehausen, WID
H. D. Ripley, WID
A. L. Trego, WID

V. Daub, WPO
J. E. Gilbert, WPO
E. K. Hunter, WPO
B. L. Lilly, WPO
J. A. Mewhinney, WPO
R. L. Wise, WPO

S. A. Orrell, SNL
T. M. Schultheis, SNL

The Design Verification Plan of August 19, 1991, (HA:91:5636) requires an External Design Review to be completed. The details of the External Design Review (No. 91-05) are given below:

1.0 EXTERNAL DESIGN REVIEW

1.1 SCOPE: The scope of this review will be to ensure that the roof support system shall perform to its designed function per the requirements established in Design Spec. 0087.

9230

1.2 TYPE OF VERIFICATION: This will be a Formal Design Review.

1.3 STAGE OF VERIFICATION: This will be the Final Design Review by technically competent reviewers who are not a part of the WIPP Project.

1.4 REVIEWERS: The External Design Review Panel shall include:

Chairman	Dr. John Wilson	Chairman, Mining Engineering, University of Missouri, Rolla
Member	Dr. John Byrne	Golder Associates, Inc. Redmond, WA.
Member	Mr. Tony Iannacchione	U. S. Bureau of Mines, Pittsburgh Research Center, PA (was member of WIPP Geotechnical Panel)
Member	Dr. Parvis Mottahed	Head of Mining Technology Canada Center for Mineral & Energy Technology, Elliot Lake, Canada (was member of WIPP Geotechnical Panel)
Member	Mr. Gary Peterson	Engineering Manager, Cayuga Rock Salt Mine, Cargill Salt
Member	Mr. Robert Stahl	MSHA Safety & Health Technical Center, Denver, CO

Mr. M. R. Brown, Manager, Special Projects, WID Engineering, will act as the Secretary for Design Review Panel. His role is to support the chairman in the performance and documentation of the Design Review, including recording Design Review minutes and documenting action items, and assisting the Chairman in preparing the Design Review Report.

1.5 DATE AND PLACE OF REVIEW MEETING: Tuesday, Sept. 17, 1991 - WIPP site and underground visit

Wednesday, Sept. 18 through Friday, Sept. 20, 1991 - Design Presentation and Design Review, at Motel Stevens, Carlsbad, NM (887-2851).

CONCURRENCE:

S. C. Sethi, Manager
Mine Engineering

T. W. Halverson, Manager
Engineering

tw

HA:91:5657

ROOM 1, PANEL 1 SUPPLEMENTARY ROOF SUPPORT SYSTEM

EXTERNAL DESIGN REVIEW PANEL

Dr. John Byrne specializes in geotechnical engineering. He has over 16 years of experience in the civil, mining and waste disposal industries. Dr. Byrne's technical and managerial experience is broadly based and includes projects involving rock engineering (hydro, pumped storage and compressed air storage caverns; nuclear waste disposal facilities; tunnels; mine openings; rock slopes), soils engineering (foundations, tailings dams, water supply dams, tunnels, soil slopes, leach heaps, hazardous and municipal landfills, dynamic analysis), and off-shore engineering (oil platform foundations).

Mr. Tony Iannacchione is the supervisor of the Rock Mechanics Group at the U.S. Bureau of Mine, Pittsburgh Research Center. He has conducted research on mining related problems for over 16 years and is the author of over 35 technical papers on the subject. Currently, he is responsible for managing research projects concerned with the design and reinforcement of pillars, rock mass characterization, rock burst control, mine-wide monitoring, and rockfill characterization. He has also had considerable experience evaluating gas outbursts within Louisiana and New Mexico salt and potash mines. Mr. Iannacchione served on the panel of geotechnical experts convened by Westinghouse and Department of Energy in April 1991 to evaluate the effective life of underground rooms in Panel 1 of the waste storage area.

Dr. Parviz Mottahed is the head of the Mining Technology Section at the Canada Center for Mineral and Energy Technology, based in Elliot Lake, Canada. Previously, he was the head of the Earth Sciences and Mining Department for the Potash Corporation of Saskatchewan, where he provided technical services in the fields of rock mechanics, geology, and geophysics to four potash mines. He has published over twenty papers in the fields of rock mechanics and mine design in potash and gypsum rocks. Dr. Mottahed was a member of the panel of geotechnical experts convened by Westinghouse and Department of Energy in April 1991 to evaluate the effective life of the underground rooms in Panel 1 of the waste storage area.

Mr. Gary Peterson received a Bachelor of Science degree from Michigan Technological University in 1975. He has worked for 16 years at the Cayuga Rock Salt Mine for Cargill Salt. He developed a successful yielding pillar design at a mining depth of 2300 feet.

Dr. John Wilson is currently the chairman of the Mining Engineering at the University of Missouri-Rolla. He also is a Professor in this department. He received his PhD. in Mining Engineering from the University of the Witwatersrand, South Africa in 1971. His career began as a coal miner in England. He has since served in technical and management positions in production and service companies with operations in the United States, Europe, and Africa. His technical experience includes development and introduction of mechanized mining techniques in hardrock, application of mining techniques to hardrock and coal mines. He has also served in management capacity at operating mines and technical services companies. His projects have included economic analysis and feasibility, geo-engineering, hazardous waste, and mining generation start-up.

ROOM 1, PANEL 1 SUPPLEMENTARY ROOF SUPPORT SYSTEM

—EXTERNAL DESIGN REVIEW PANEL CONT.....

Mr. Robert Stahl received a Bachelor's Degree from the University of Colorado in 1961. He has worked for the United States Bureau of Mines as a research geologist testing geophysical techniques for locating geologic structures in the earth's crust. Mr. Stahl is currently working with MSHA's Ground Support Division in Denver, Colorado.

DRAFT
09/10/91

WASTE ISOLATION PILOT PLANT

SUPPLEMENTARY ROOF SUPPORT SYSTEM

UNDERGROUND STORAGE AREA

ROOM 1, PANEL 1

WESTINGHOUSE ELECTRIC CORPORATION
WASTE ISOLATION DIVISION
CARLSBAD, NEW MEXICO
AUGUST 1991

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54-D-003-W3	Supplementary Roof Support Room 1, Panel 1, *Steel Set Fabrication*
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A	Geology And Rock Mechanics
B	Destructive Tests
C	Support System Design * Anchor Design * Chanel Design
D	Geomechanical Monitoring Program

1.0 EXECUTIVE SUMMARY

WIPP is designed to provide a full-scale facility to demonstrate the technical and operational principles for permanent isolation of defense-generated transuranic waste. It is also designed to provide a facility in which studies and experiments can be conducted.

Dry Bin-Scale Tests are being planned as a portion of the WIPP Test Phase Performance Assessment Program described in the WIPP Test Phase Plan: Performance Assessment (DOE 1990 b). These Tests are anticipated to be conducted for a period of up to seven years. Room 1 of Panel 1 of the Underground Storage Area is to be used as the location of the Bin Scale Tests to investigate the generation of gas from the waste that is proposed to be stored at the WIPP in the near future.

The original design for the waste storage rooms in Panel 1 provided for a limited period of time during which to mine the openings and to emplace waste. Room 1 was scheduled to be filled in fewer than five years before being sealed. Initially mined to rough dimensions in 1986, Room 1 was later mined to finished dimensions in 1988. Information obtained from the Site and Preliminary Design Validation (SPDV) program indicates that the rooms in Panel 1 should remain stable without ground support and that creep closure would not adversely affect equipment clearances during at least five years following excavation.

The demonstration phase was later deferred and an experimental program including Bin Scale Tests was added for Panel 1. Delays in the test schedule have revised the date for first waste receipt. Therefore, based on the timing and scope of the test phase, an additional seven years of useful life may be required to complete the tests in Room 1, Panel 1.

To assess the long term stability of Panel 1, a panel of geotechnical experts was convened in April, 1991. The final report of the panel was issued on June 5, 1991. The panel agreed that the WIPP geotechnical monitoring program as used in the SPDV Test Rooms is adequate to provide early warning of deteriorating conditions in Panel 1. The panel reviewed the design and stability of the rooms in Panel 1 and concluded that these rooms could be expected to provide a useful life of at least seven years from the time of excavation (up to 11 years with a decreasing level of confidence) with routine maintenance (DOE, 1991). However, the panel also agreed that ground support measures could be used that would allow the Bin Scale Tests to be carried to completion. The test period as currently defined is up to seven years, thus requiring a room life of up to 12 years from when the room was mined. The following options or their combinations recommended by the Expert Panel have been evaluated to extend the life of Room 1 of Panel 1 and to provide added confidence in its ability to support the test program:

- Relying on the currently installed rock bolt system and upgrading, if necessary, based on the results of the geomechanical monitoring program.
- A ground support system using resin anchored rock bolts.
- Interlaced grout anchored wire cables and wire mesh to control rock falls.
- Cutting slots in the back and/or floor to relieve the lateral stresses.

- Yielding support system such as timber cribs or steel yielding supports.
- Roof truss system.
- Mine new rooms.

In order to extend the life of Room 1, Panel 1, a ground support system needs to consider the past history of Room 1, the on-going deformations in the room, and the potential roof failure mode. Also, the support system must be designed to accommodate the bins and test equipment, including forklift access for bin installation and subsequent monitoring activities.

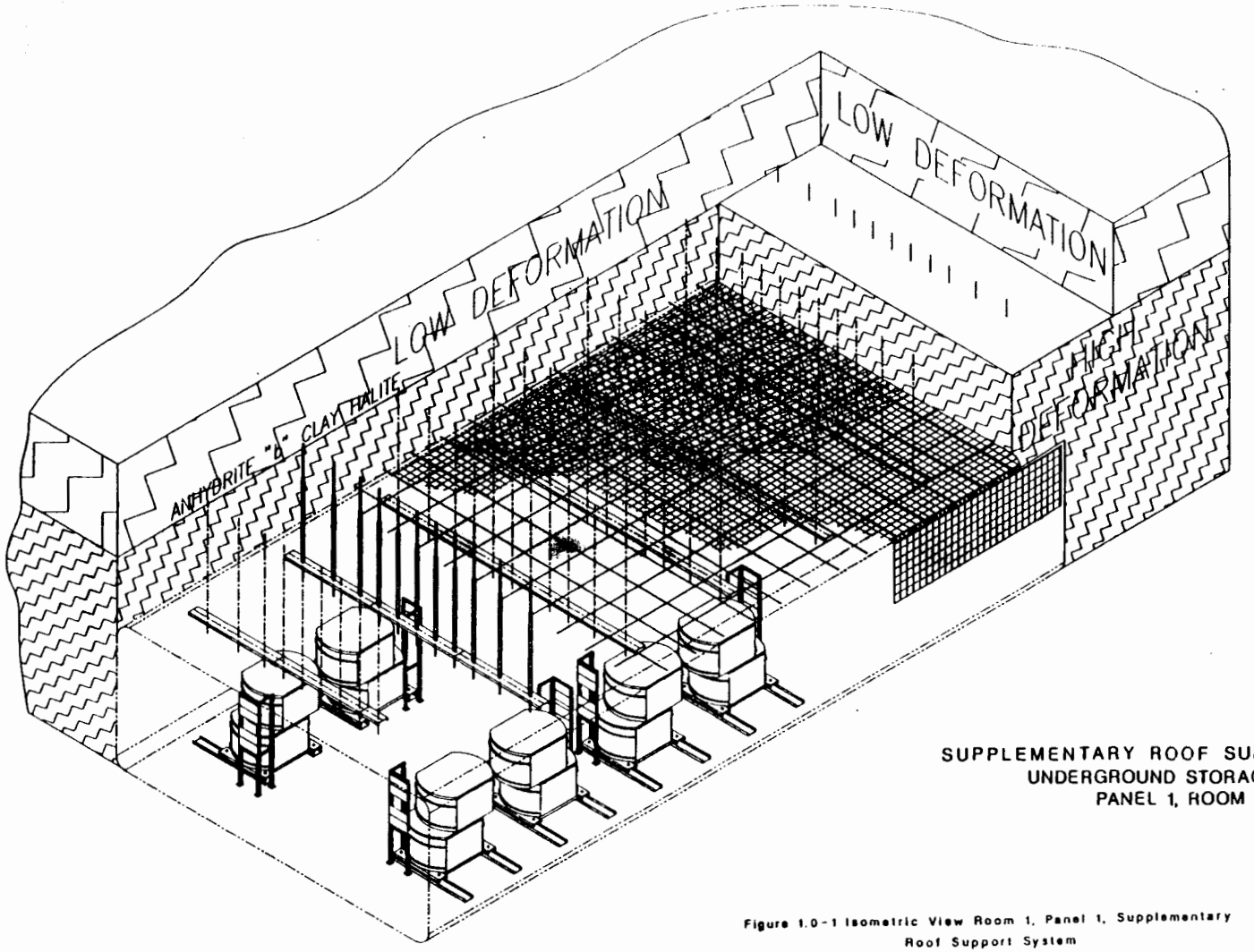
To be acceptable, the ground support system must:

- Be capable of fully supporting the anticipated roof wedge such as that produced in SPDV Room 1.
- Be capable of yielding in a manner which would accommodate the future closure and deformation of the roof rock.
- Accommodate the bin scale equipment, including forklifts and ancillary equipment.
- Extend the life of Room 1 to allow completion of the experiments, for an additional period of up to seven years (from July 1991).

The initial roof support concept developed for Room 1 of Panel 1 involved timber "crib sets" with interconnected steel beams. After further analysis, timber crib supports were abandoned in favor of yieldable roof supports which would provide more uniform roof support. These supports consisted of resin anchored steel rock bolts and steel cross beams, with yielding steel columns as commonly used in the coal mining industry. More importantly, the rock bolts could be continuously monitored using load cells and adjusted to accommodate further room creep.

As the design process proceeded, it became clear that the majority of the load would be carried by the rock bolts. The yielding columns were therefore eliminated. The steel beam was modified from an initial I beam configuration to an inverted channel, thus eliminating the complex attachment plate structure needed for the I beam.

The final roof support design contained in this document consists of 8.23m (27 feet) long 15 x 40 steel channel support sets installed laterally across Room 1 on 2.44m (8 feet) to 3.05m (10 foot) centers. Each channel set is divided into three nine foot long segments which are bolted together in place using connecting plates. Each support set is secured by eleven 3.96m (13 feet) long Dywidag steel tendons (anchor bolts) that are resin anchored in relatively stable ground above the Anhydrite "b" clay horizon. The channel support anchor bolts are designed so that their loads can be monitored and adjusted to accommodate continuing roof deformation. To allow for differential lateral deformations, each tendon is located in an oversized .076m (3 inch) diameter hole which extends from the hole collar to the Anhydrite "b" clay horizon.



SUPPLEMENTARY ROOF SUPPORT SYSTEM
UNDERGROUND STORAGE AREA
PANEL 1, ROOM 1

Figure 1.0-1 Isometric View Room 1, Panel 1, Supplementary Roof Support System

ROOF SUPPORT SYSTEM DESIGN AND IMPLEMENTATION

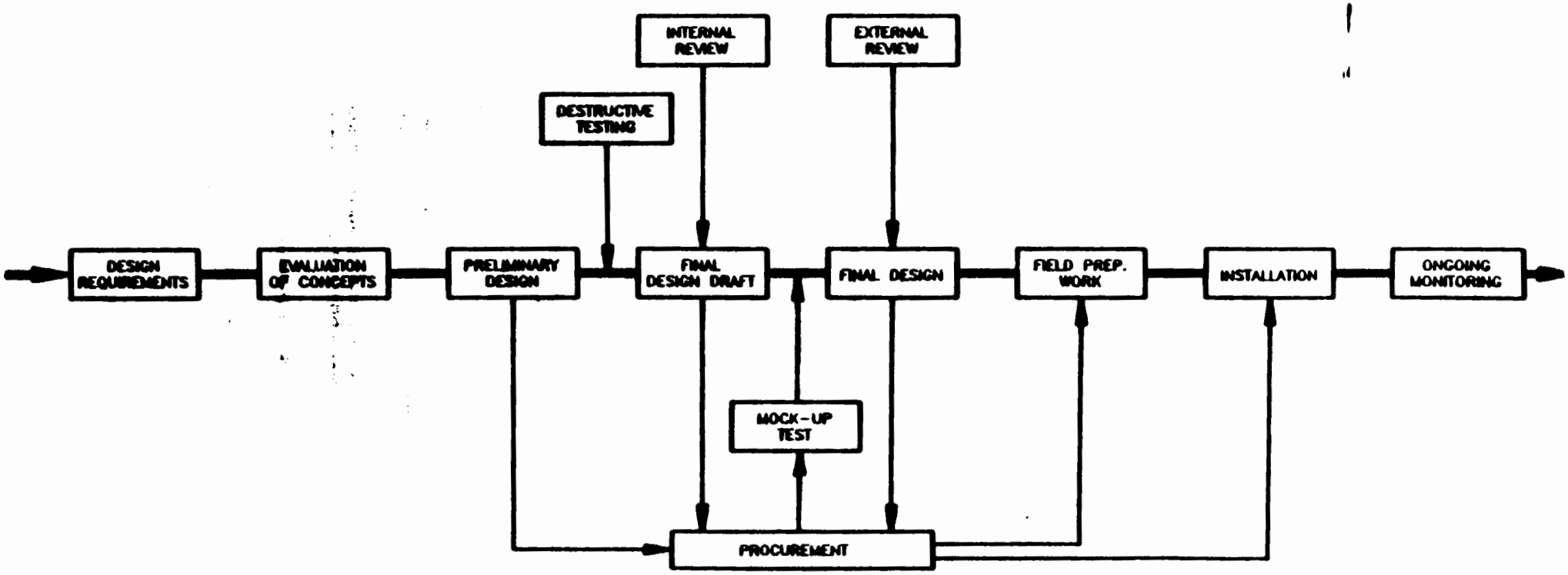


FIGURE 2.0-1 Room 1, Panel 1

The area between the channel support sets is covered by a network of steel wire lacing cables underneath a mat of steel welded wire mesh and expanded metal. This mat is held in place by the channel support sections. Its function is to contain loose rock in between the channel support sets.

Chainlink wire mesh pinned to the ribs (sidewalls), is provided to contain any minor spalling down to approximately 2.13m (7 feet) above the floor.

A conservative approach has been used throughout the design process. Areas where this has been done include the following:

- A minimum .76m (3 foot) grouted bolt length has been used where tests have shown 18 inches to be sufficient.
- The manufacturer's minimum yield load has been used for bolt design - tests give results 22-28% higher.
- The support effect of the existing 3.04m (10 feet) mechanically anchored rockbolts and the meshing and lacing has been disregarded.
- The wedge-shaped salt beam has inherent strength which has been disregarded.

As designed, the supplementary roof support system incorporates the four acceptance criteria stated above as well as five out of the seven Expert Panel recommendations. The support system can also be installed concurrently with bin operations. Figure 1.0-1 provides an isometric view of the support system for Room 1, Panel 1.

The geomechanical monitoring system represents an integral part of the roof support system design. The monitoring system is designed to monitor loads on each rock bolt, measure continuing creep and deformation in and around the room, identify stress loads on the rock and deflections of the steel channel supports.

The monitoring system allows for adjustment of loads in the rock bolts to accommodate room creep and to provide early indication of any unusual closure activity.

The test bins, within the standard waste boxes, are stacked two high along the ribs of the test room. The spacing is sufficient to allow personnel access between the bins for ground support installation, inspection, and routine ground control maintenance tasks.

In addition to the monitoring program, a testing program was implemented to confirm the validity of rock anchor calculations and installation procedures. The testing program included destructive testing of rock anchors and a mock-up installation of a portion of the entire system.

The WIPP is committed to safely providing long term roof support.

2.0 INTRODUCTION

WIPP is designed to provide a full-scale facility to demonstrate the technical and operational principles for permanent isolation of defense-generated transuranic waste. It is also designed to provide a facility in which studies and experiments can be conducted.

Bin Scale Tests are being planned as part of the WIPP Test Phase Performance Assessment Program described in the WIPP Test Phase Plan: Performance Assessment (DOE 1990 b). These Tests are anticipated to be conducted over a period of up to seven years.

Room 1 of Panel 1 of the Underground Storage Area is to be used as the location of the Bin-Scale Tests to investigate the generation of gas from the waste that is proposed to be stored at the WIPP in the near future.

The original design for the waste storage rooms in Panel 1 provided for a limited period of time during which to mine the openings and to emplace waste. Room 1 was initially mined to rough dimensions in 1986. Information obtained from the Site and Preliminary Design Validation (SPDV) program showed that the rooms would remain stable without ground support and that creep closure would not adversely affect equipment clearances during at least five years following excavation.

The demonstration phase was later deferred and an experimental program including Bin Scale Tests was added for Panel 1. Delays in the test schedule have revised the date for first waste receipt. Therefore, based on the timing and scope of the test phase, up to seven years of useful life are required to complete the tests in Room 1, Panel 1. This document presents the design for a supplementary roof support system for Room 1 of Panel 1 of the Underground Storage Area. System design and its implementation process is presented in Figure 2.0-1.

3.0 DESIGN REQUIREMENTS

3.1 DESIGN CRITERIA/CONSIDERATIONS

The support system must be designed to accommodate the following criteria:

1) Provide a suitable supplementary roof support system to ensure that the Bin Scale Tests conducted in Room 1, Panel 1, of the Underground Storage Area will not be interrupted during the seven year period starting July 1991.

2) The basic design parameters are determined by geotechnical considerations such as the age of Room 1, existing and future ground deformations in and around Room 1, and the prevailing stratigraphy and stress conditions.

3) The support system takes cognizance of the recommendations of the Geotechnical Expert Panel.

4) The support system takes cognizance of Design Spec. No. D-0087.

3.2 DESIGN SPECIFICATIONS

Design specifications are contained in Document entitled "Design Spec., No. D-0087, Supplementary Roof Support for Room 1 of Panel 1."

3.3 DESIGN BASES

The Supplementary Roof Support System for Panel 1, Room 1, is a yieldable type support that consists of evenly spaced sets of 15 x 40 inverted steel channel sections supported by eleven rock anchors.

The design for the Supplementary Roof Support System for Room 1, Panel 1, is based on the following:

3.3.1 GENERAL

- The support system is able to be installed concurrently with bin operations.
- Safe access is provided for a minimum of seven years from July 1991.
- A minimum access height of 3.45m (11 feet, 4 inches), is provided after seven years.
- Support installation procedures take into account working within RMA boundaries.

- Corrosion is a non-impactive factor for the duration of the system installation, based on experience gained at the WIPP and in the potash basin mines.

- Because of accessibility limitations and RMA requirements during the testing program, only the center portion of Room 1 located between the ventilation bulkheads has been considered in this supplementary roof support design. Roof control for the remainder of the room will be addressed elsewhere at a later date.

3.3.2 ROCK MECHANICS

- The zone of rock between Anhydrite "b" and Anhydrite "a" is sufficiently stable to provide a good anchoring base for the support system rock anchors.

- Horizontal and vertical virgin stresses are equal at the repository horizon of 655m (2150 feet).

- The geology and stratigraphy at Room 1, Panel 1, are similar to those in the SPDV Test Room area.

- Observations and measurements from the SPDV Test Rooms will be used as the bases for describing the deformation mechanisms occurring in Room 1, Panel 1.

- Creep deformations arise from differential stresses created as a result of excavating and widening of the given shape.

- Low-angle shear fractures will occur in the immediate roof rock, and once these have formed, roof movements into the excavation are increasingly associated with gravity rather than salt creep.

- The supplementary support system accommodates past and future room deformations.

- The roof failure mode is that of a detaching wedge, triangular in section, 10m (33 feet) wide and 2.13m (7 feet) high at the center.

- The density of the immediate roof rock above Room 1, Panel 1, is 2,160 kg/m^3 (135 pound per foot^3) for all calculations.

- The rock anchor holes have a 7.6mm (3 inch) reamed-out section below the grouted portion that will be sufficient to prevent shearing of the tendons that may arise from differential lateral deformations that might take place in the roof rock.

- The roof expansion between the anchor horizon and hole collar is assumed to be 38mm (1.5 inch) per year.

- The maximum lateral differential deformation below Anhydrite "b" is assumed to be 12mm (0.5 inch).

3.3.3 SYSTEM DESIGN

- The system of rock anchors consist of resin grouted rock anchors, grade 60 steel, anchored above Anhydrite "b" horizon.
- Minimum resin bond length between anchor and salt is 0.91m (3 feet).
- The steel channel set assembly would act as a surface plate system that:
  - is capable of accommodating the design load
  - is capable of accommodating monitoring devices that would allow continuous monitoring of bolt load
  - allows detensioning of anchor loads as and when required
  - assists in distributing the load between bolts
  - is capable of supporting the lacing and meshing.
- Each rock bolt anchor extends downwards through the channel section plate for a distance of 18 inches to provide for a downward adjustment life of seven years. This accommodates the expected 38mm (1.5 inches) per year of roof expansion as well as the bearing plates and load cell assembly. If required, couplings will provide for additional adjustment.
- Rock spalling in between sets is controlled by a system of wire mesh and lacing.
- Floor maintenance will be carried out as and when required.
- The transverse 16 mm (5/8 inch) diameter wire lacing ropes will be adjustable.
- Rib spalling that may occur is contained by a wire mesh system that extends down to a height of approximately 2.1m (7 feet) above the floor.
- No stability problems are expected from fracturing of the ribs, based on experience gained at the WIPP since the opening of the project.

3.3.4 INSTALLATION AND MAINTENANCE

- The bolt loads are readjusted when the load on a bolt reaches 1.1 times the design load.

- Existing 3.04m (10 foot) rockbolts may be removed in order to facilitate installation of the supplemental rockbolt supports.

- Existing instrumentation fixtures, installed cables, and piping will be relocated to the sides of the room to avoid damage during system installation and maintenance.

- Rock anchor holes will be drilled vertically with a tolerance of ± 2 degrees measured in such a way that the ends of the holes will not be closer than 0.5m (20 inches).

- Drilling tolerance for the depth of the hole is ± 25mm (1 inch).

3.3.5 TESTING AND MONITORING

- A complete full-scale mock-up test will be carried out in Room 2. This will have at least five channel sets.

- Quality control and creep tests will be carried out on each bolt. The test load will be taken to 1.33 times the maximum design load.

- The monitored data from Room 1 will be evaluated on an ongoing basis.

- The design loads for the rockbolts and associated anchoring system have been confirmed by the destructive tests that have been conducted.

- The geomechanical monitoring system is designed as an integral part of the support system and will:

  - monitor the load on every rockbolt

  - measure ongoing creep and deformation

  - allow an assessment of the length of room life that might be obtained beyond seven years.

4.0 SYSTEM DESIGN

4.1. GEOLOGY AND ROCK MECHANICS

4.1.1 ROCK MECHANICS

Much of the understanding regarding the performance of excavations in salt at the WIPP has been gained from observations taken in the Site and Preliminary Design Validation (SPDV) Test Rooms. The case study presented by the roof fall in SPDV Test Room 1, together with numerical modelling results, provides the information for defining the size and shape of the rock wedge that must be supported by roof support system. This is assumed to have a triangular cross-section as shown in Figure 4.0-1.

The virgin in-situ stresses are one of the basic determining factors governing the rate of deformation in and around the mined opening.

The initial stress state at the repository horizon is established from Heims Rule for weak rocks (Hoek and Brown, 1980). This rule establishes the vertical stress as dependent on the depth of overburden and its average density, and the horizontal stresses to be equal to the vertical stress. Taking the average density for the overburden at the WIPP site as 2130 kg/m^3 (144 $pound/foot^3$), the initial stresses at the repository horizon are about 2000 psi.

When a room is excavated in salt, the local virgin in-situ stress field is disturbed. The immediate initial response of the rock is to set up stress as if it were in an elastic rock, the so-called "time zero" response. Differential stresses are created around the excavation and it is these stress differences that drive the subsequent creep deformations that result in closure of the room.

With time, the stresses close to the excavation are relieved by creep of the salt into the excavation. Shear stresses develop at the strata interfaces due to the differences in the mechanical properties of the different rock types and lead to slippage at these contacts and eventually to bed separation. The presence of these strata interfaces further leads to the concentration of lateral stresses in the roof and floor beams leading ultimately to the development of low angle shear fractures. Once the shear fractures have developed, roof movements in an excavation are increasingly associated more with gravity effects than with salt creep. At this stage there are two processes at work in the strata above the excavation. These are:

- Creep of the salt - Salt creep is still occurring in the competent salt above the rock wedge and above the ribs.

- Kinematic movement of the immediate rock due to gravity - The rock wedge, if it is unsupported, will move down under its own weight. Figure 4.0-1.

PANEL 1, ROOM 1

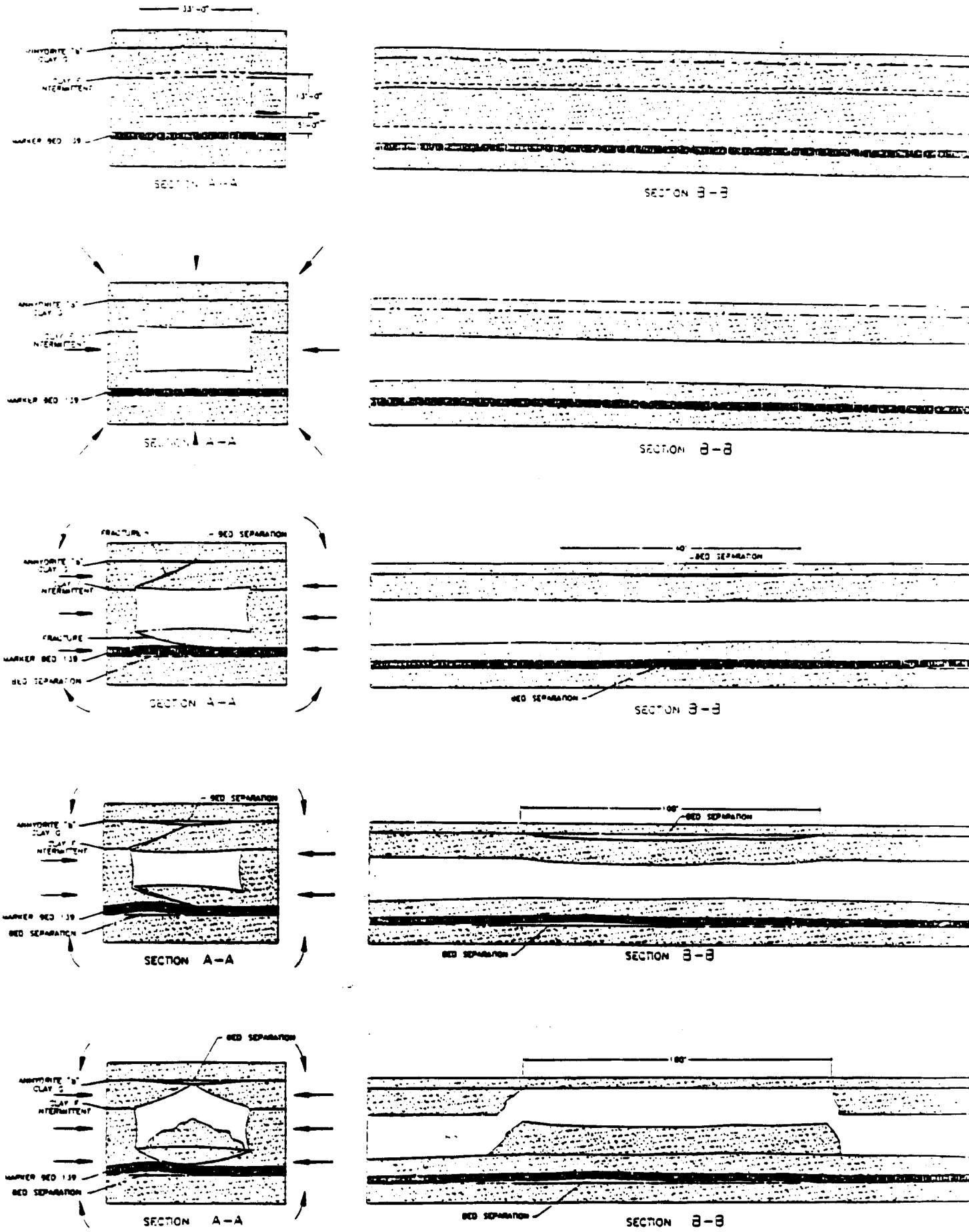


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Figure 4.0-1 Kinematic Movement of the Rock Wedge

UNDERGROUND STORAGE AREA
PANEL 1, ROOM 1

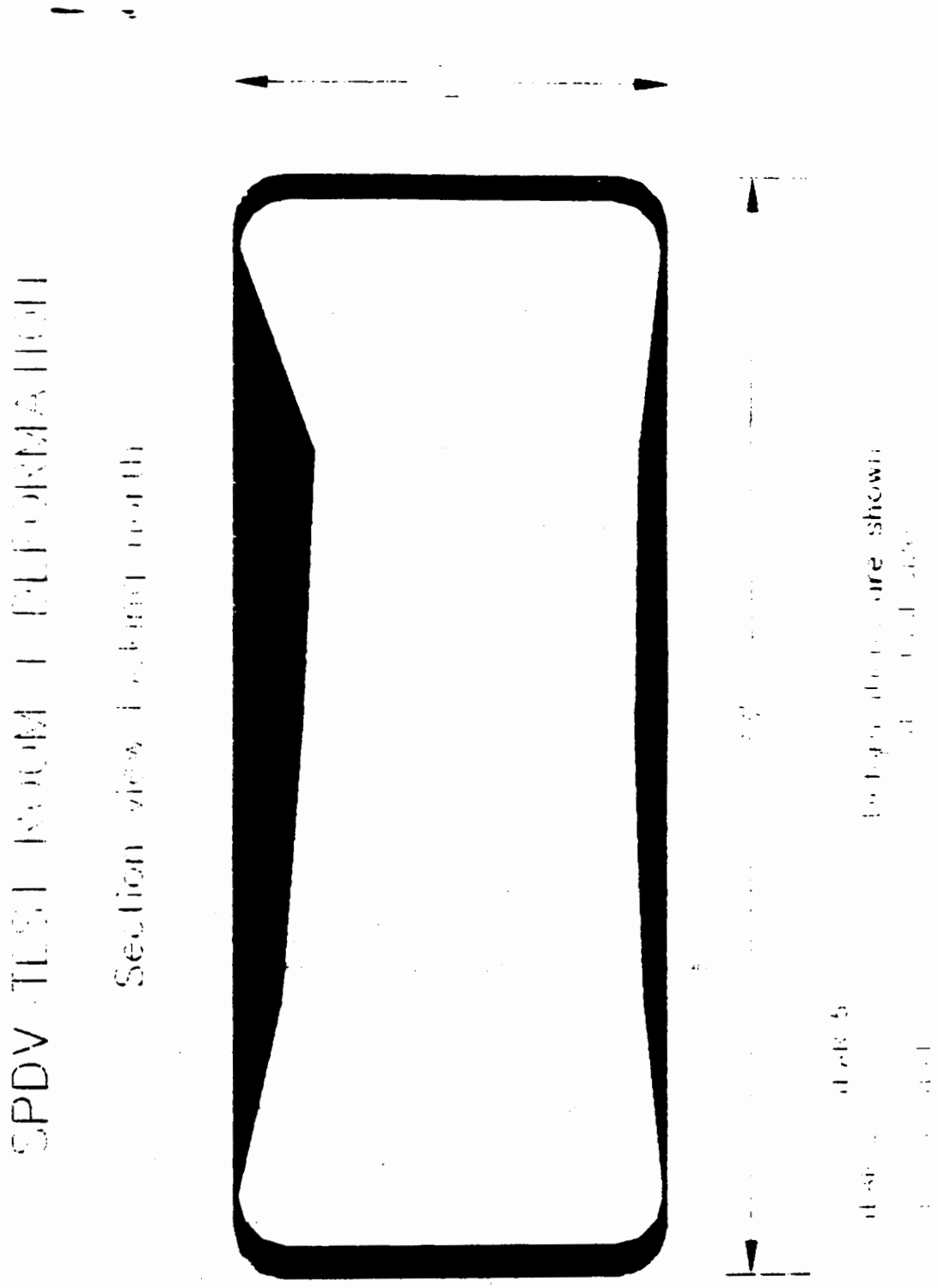

Figure 4.0-2 SPDV Test Room 1 Deformation

SUPPLEMENTARY ROOF SUPPORT SYSTEM
UNDERGROUND STORAGE AREA
PANEL 1, ROOM 1

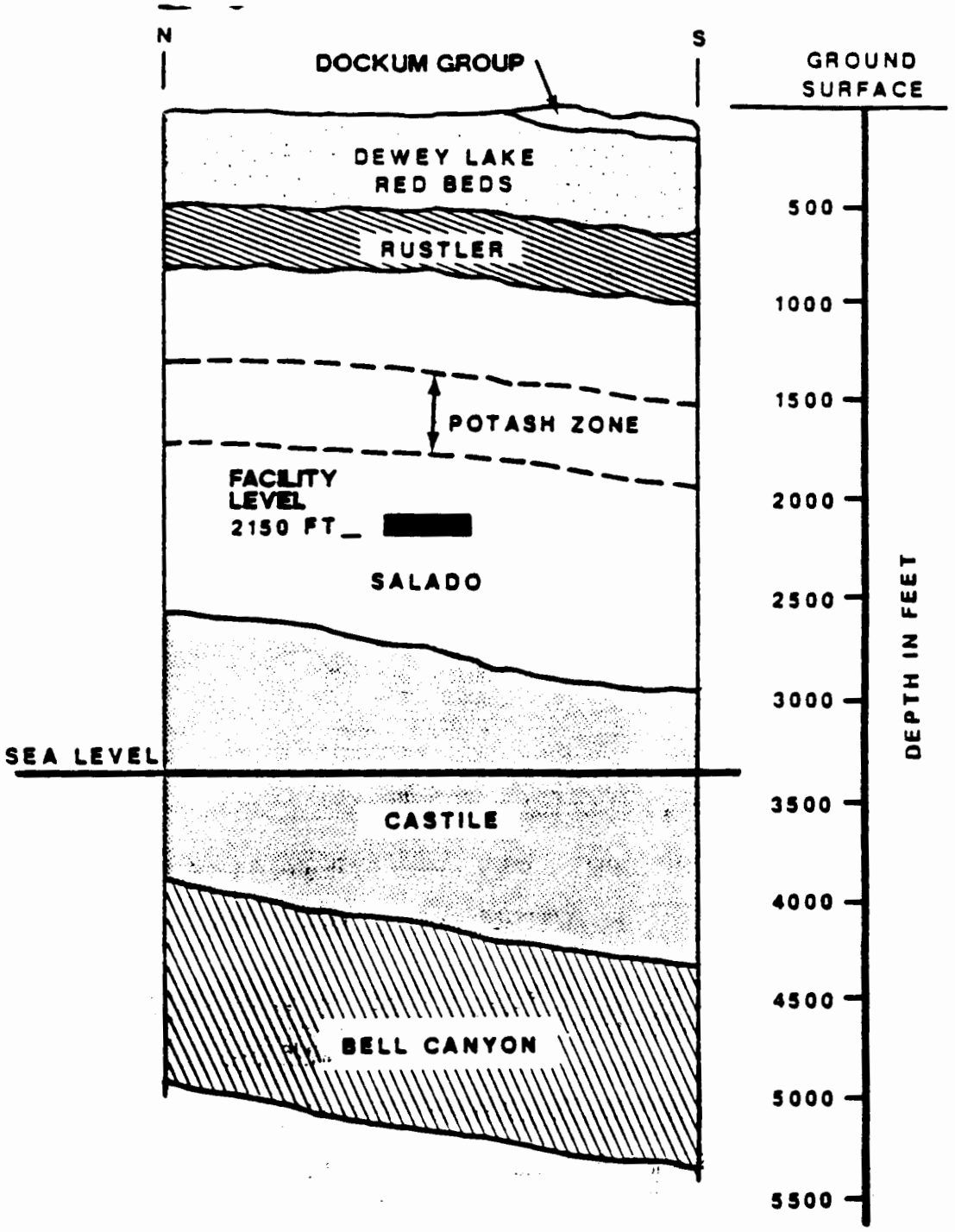

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Figure 4.0-3 Generalized Site Stratigraphy

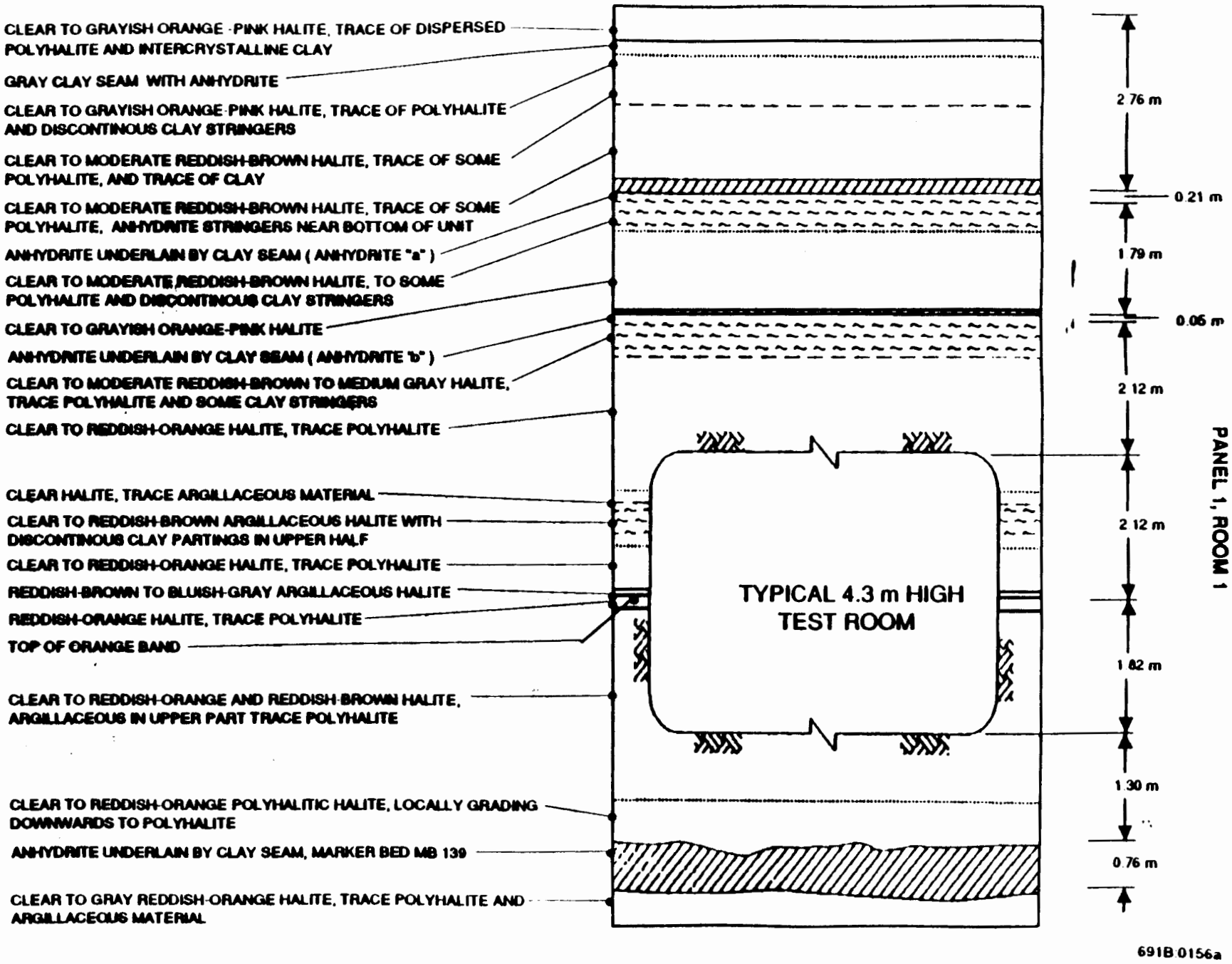


Figure 4.0-4 Stratigraphy of the WIPP Repository Horizon

Inclinometer measurements, in vertical and horizontal boreholes, give the horizontal and vertical deflections of these boreholes in the rooms roof and ribs respectively. The effect of the 2.13m (7 foot) clay seam can clearly be seen as a large relative horizontal difference in the movement of the salt immediately below the clay seam.

Extensometers located in the roof, ribs and floor measure the extensions at different distances along the lengths of their boreholes. Closure meters measure the closure of the rooms, either between roof and floor or rib to rib. A composite picture of how the rock is deforming and moving into the excavated room is obtained when inclinometer, extensometer, and closure measurements are put together. The Expert Panel unanimously agreed that the mechanism of deformation at Room 1, Panel 1 would be very similar to that experienced at the SPDV Test Rooms. For further detailed discussion and information on Geology and Rock Mechanics at WIPP, refer to Appendix A.

4.1.2 STRATIGRAPHY

The proposed underground storage facility is located 655m (2,150 feet) below the surface in bedded salt of the Permian Salado Formation. This formation consists primarily of halite, argillaceous halite, minor anhydrite, and minor polyhalitic units. Over 365m (1,200 feet) of impermeable evaporitic deposits separate the facility horizon from the first overlying sedimentary rocks and 620m (2,034 feet) of evaporites lie below the facility horizon and provide a barrier to Permian limestones and sandstones. Figure 4.0-3.

The facility horizon lies within a 12m (39.4 feet) thick unit consisting of halite, argillaceous halite, and polyhalitic halite (Figure 4.0-4). A thin, 0.3m (.98 feet) to 0.5m (1.64 feet) thick layer consisting of anhydrite and polyhalite, and identified as Marker Bed 139 lies about 1.5m (4.92 feet) below the floor level. Anhydrite beds (less than 10mm [.03 feet] thick), called anhydrite "a" and "b" occur about 4m (13.12 feet) and 2m (6.56 feet) above the roof. Thin clay seams called Clay G and Clay H are associated with the bottom of these beds. In addition, an intermittent thin clay layer identified as Clay F is found in the immediate roof of excavations.

The anhydrite and clay layers have a significant impact on the mechanical performance of excavations. The clay layers provide interfaces along which slip can occur whereas the thick layers can provide a stiff anhydrite band within the strata sequence that does not deform plastically with time. For further detailed discussion and information on Geology at the WIPP, refer to Appendix A.

4.1.3 VERTICAL MOVEMENTS

The vertical movement that the roof support must accommodate are a combination of salt creep, dilation of the salt due to fracture development, and gravity effects once fractures have formed.

The total roof expansion that has to be accommodated has been taken as 38mm (1.5 inches) per year at midspan.

4.1.4 LATERAL MOVEMENTS

Lateral displacements occur at strata interfaces and within the immediate roof beam where discrete fractures have formed. These lateral differential displacements have been observed up to 15m (50 feet) into the roof at strata changes particularly the clay/salt contacts. The largest shifts are found at the clay/salt contact below the Anhydrite "b" layer. Lateral shifts can also be expected within the immediate roof beam where fractures form. The support system has been designed to accommodate a lateral shift of 12mm (.5 inch) per year and bed separation of 25mm (1 inch) per year at the clay/salt contact below the Anhydrite "b" layer once the bond at the interface is disrupted.

4.1.5 ANCHOR HORIZON

The zone in which rock anchors were to be installed had to satisfy three main criteria:

- It had to be relatively stable, in that the creep deformations occurring in it should be low.
- The effect of installing anchors in it should not induce loading conditions that would increase the creep deformations significantly or reduce the overall strata stability at that horizon.
- Penetration of roof stratigraphy should be kept to a minimum.

The reasons for going into the zone above Anhydrite "b" can be summarized as follows:

- Rock mechanics data from extensometers, inclinometers and borehole surveys have shown that the zone above Anhydrite "b" is relatively stable. This was in part due to the fact that the well-defined clay seam associated with Anhydrite "b" served to concentrate differential stresses in the immediate roof rock below Anhydrite "b". The reason for this phenomenon arose from the inability of the clay seam to sustain shear stress.
- Large numbers of 3.04 m (10 feet) mechanically anchored rock bolts had been installed at a fairly precisely defined horizon, some .91m (3 feet) above Anhydrite "b". After more than two years of installation, during which time the rock bolts were known to have developed load, there was no evidence from rock mechanics measurements of roof strata deformations that this concentration of anchoring load was causing any separation to occur.
- Sandia have a requirement that Anhydrite "a" should not be penetrated if this can be avoided.

- No separation has been observed to date across the Anhydrite "a" layer.

- The difficulties involved in drilling, reaming, and installing the grout anchored rockbolts increase rapidly with depth. In order to meet the required design requirements with a high degree of confidence the anchor horizon chosen is that above Anhydrite "b".

4.2 CONCEPTUAL DESIGN

Room 1 of Panel 1 is currently five years old and must remain accessible for an additional seven years in order to support the Bin Scale Testing program without interruption. In order to extend the life of Room 1, a supplementary roof support system has been developed to minimize the possibility of any roof fall during testing.

On February 4, 1991, a substantial section of roof fell in Room 1 of the SPDV area. Geotechanical instrumentation had indicated accelerated room closure rates for some time, and the roof fall had been anticipated for several months. At that time, the room had been open for almost eight years. The four SPDV rooms had been mined to exactly the same dimensions as the waste storage (and disposal) rooms 91.4m (300 feet) long, 10.05m (33 feet) wide, 3.96m (13 feet) high in Panel 1, in order to simulate, monitor, and study their behavior in response to lithostatic (overburden) pressure over time. No ground support, such as rock bolts, had been installed.

In response to the roof fall in SPDV Room 1 and to assess the long-term stability of Panel 1, Westinghouse convened a panel of geotechnical experts in April 1991. The final report of this panel was released on June 5, 1991. The expert panel agreed that the WIPP geotechnical monitoring program as used in the SPDV Test Rooms is an adequate tool for giving early warning of deteriorating conditions in Panel 1. Based on collected geotechnical monitoring data, panel members concluded that the rooms in the panel are likely to have a total life of seven to eleven years from the time of excavation using the currently installed roof support system, consisting of 3.04m (10 feet) long mechanically anchored rock bolts. Mining of Room 1, Panel 1, began during the second half of 1986. Therefore, as of July 1991, the remaining life of Room 1 is anticipated to be between two and six years. However, the panel agreed that measures could be taken in Panel 1 that would give a reasonable assurance that the Bin Scale Tests could be carried out to completion. In order to carry out the Bin Scale Tests, a solution to the support problem had to be found to extend the required life of Panel 1 for up to seven years. The expert panel suggested alternative actions which included use of the following:

- The use of full column resin or resin anchor bolts;
- Grout anchored cable with lacing and wire mesh;
- Slotting and/or relief entries;
- Yielding support;
- Rely on currently installed support and upgrade when necessary;

- o Roof trusses;
- o Mining new rooms.

They also indicated that the measures should be augmented by a monitoring program that would regularly assess the geomechanical conditions and that maintenance should be carried out as a routine activity in the rooms as they aged.

The WIPP project has evaluated the support systems suggested by the Geotechnical Expert Panel.

The initial evaluations looked at support systems (wooden cribs, wooden cribs with steel beams) that could be installed within the room and would provide a passive support as the rock deforms into the room. These systems were eventually abandoned because they interfered with the functional use of the room largely as a result of the physical size of the supports. They limited the number of bins that could be placed in the rooms and more importantly, the support could not be placed where it was most needed (i.e., midspan where the largest loads are developing) without eliminating equipment access to the bin locations.

Another form, a yielding support system, was then considered. This eliminated any need for bin removal and provided a more uniform support of the roof strata. The yielding system consisted of deep grout anchored rock bolts supporting a steel cross beam with supplemental support being provided by yielding steel columns. The beam anchor bolts were designed so that their loads could be continually monitored and adjusted to accommodate room deformation by lowering the beam. As the design process became more detailed, it became clear that the major share of the load was carried by the beam support bolts; the yielding columns were in fact unnecessary and were therefore eliminated from the design. The beam itself was also modified from an initial I-beam to a more structurally convenient inverted channel section. This eliminated complex attachment plate structures needed for the I-beam suspension system. Any roof rock spalling between the steel sets is contained by a network of steel wire rope lacing underneath a mat of steel meshing and expanded metal.

As designed, roof support for Room 1, Panel 1, is providing the following:

- o Progressive support of the detaching triangular wedge of roof rock as it develops.
- o Containment of the detaching wedge of roof rock and safe control of the rate at which the detaching section moves downward based on the creep rate produced by the roof strata above.
- o Accommodation of lateral movements in the roof strata above.

Throughout the design process, a conservative approach was used wherever possible. The design is largely based on the room deformations and subsequent roof fall that took place in SPDV Test Room 1, which is seen as a worst case scenario. Previous resin grout anchor tests have shown that an eighteen inch bond length of grout would be sufficient, whereas a minimum .91m (3 feet) bond length is used in this design. The rock bolt design is based on the manufacturer's minimum yield strength of

209,000N (47.4 kips), whereas the destructive tests carried out in Room 2, Panel 2 gave actual minimum yield strengths 22% to 26% higher. A continuous channel section beam is used where individual plates would have been sufficient. Very little support capability has been assigned to the meshing and lacing, whereas it is certain that this will be capable of a considerable load carrying capacity. No strength has been assigned to the wedge-shaped rock salt beam formed as a result of roof fracture formation. It will have an inherent strength, this effect being enhanced by the existing 3.04m (10 foot) mechanically anchored rockbolts as well as the steel meshing and lacing. The existing system of 3.04m (10 foot) mechanically anchored rockbolts, installed on a 1.2m (4 foot) by 1.5m (5 foot) spacing have considerable load bearing capability which has been disregarded in the design.

The net effect of all the above factors when added together means that the design is very conservative, thus reducing the risk of potential failures.

4.3 DESIGN DESCRIPTION

The yielding roof support system for Room 1 of Panel 1 is designed to contain and support the detaching load while allowing it to be lowered. The system is not designed in any way to prevent the creep of rock into the room. The roof support consists of 27 steel channel support sets installed laterally across the room on 2.37m (7.8 feet) to 3.04m (10 foot) centers. The actual location of the channel sets will be determined in the field during their installation based on the location of the existing roof bolts which are installed on a 1.2m (4 foot) by 1.5m (5 foot) pattern. This is to minimize interference with the existing roof bolts.

Each support set is secured by 11 Dwyidag steel tendons (anchor bolts) that are 4.0m (13 feet) long. The resin grouted anchor bolts are anchored in between the Anhydrite "a" and the Anhydrite "b" horizons. The channel support anchor bolts are designed so the load of each bolt can be monitored and adjusted to accommodate continuous roof deformation. System adjustment is accomplished by keeping the tension on each anchor bolt within the design limits which are calculated to support the detaching load. Once the tension in the anchor bolt reaches the design limits, the bolt load is then relieved. Each anchor bolt extends .46m (18 inches) below the roof to accommodate downward movement of the roof due to creep. Roof strata extension measurements have shown that the anchor bolts will have to accommodate approximately 38mm (1.5 inches) of movement per year. To allow for differences in lateral deformations, each tendon is located in an oversized .08m (3 inch) diameter hole extending from the hole collar to the Anhydrite "b" clay horizon.

The roof area between the channel sets is covered by a network of steel wire lacing cables underneath a mat of steel wire mesh and expanded metal. This mat is held in place by the channel support sets. Its function is to contain any rock spalling in between the channel support sets.

4.3.1 STEEL CHANNELS

Each roof support set consists of a structural steel channel placed with the web flat against the roof, running across the room (rib to rib) and 11 rock anchor bolts. The set is designed to accommodate the triangularly distributed wedge load, which has a weight of 8,000N (1,800 pounds) per foot near the ribs and 45,150N (10,150 pounds) per foot in the middle of the room. Eleven rock anchor bolts are required to support the channel.

5.0 DESIGN IMPLEMENTATION

5.1 SURVEYING AND MARKING

The locations of currently installed rock bolts, and instrumentation equipment that may interfere with support installation has been accurately surveyed and is shown on a map of Room 1 (Drawing No. 54-D-003-W1 and 54-D-003-W2). These drawings will be used to locate the positions of the channel support sets and their associated rock anchors. Roof profiles will be determined at each channel support set location. Once the channel set locations have been plotted on the room map, they will be transferred underground and marked on the roof and ribs of the room. Individual rock anchor holes will then be accurately marked to determine precise locations of the anchor bolts. Experience has shown that a minimum accuracy of ± .063m (.25 inch) will be achieved while marking the positions of the boreholes.

5.2 RELOCATION OF INSTRUMENTATION, CABLES AND PIPING

Any damage to the existing instrumentation installations consisting of electric cables, gas piping, distribution boxes and lighting fixtures must be avoided during installation of the support system. For that reason, the suspended cabling will be moved to the side of the room and attached to the rib, and the piping will be lowered. Relocation of these fixtures will not affect the testing and monitoring program. Conveyor belting suspended from the rib will also be used to provide additional protection to the existing equipment.

5.3 SYSTEM INSTALLATION

5.3.1 ROCK DRILLING

5.3.1.1 STEEL CHANNEL ANCHOR BOLTS

Each channel set has been designed for 11 bolt anchor holes which are to be installed vertically. It is required that all bolt anchor holes are drilled to a specified depth of 3.55m (11.5 feet), measured from the hole collar. An allowable vertical alignment tolerance of 2 degrees and a depth tolerance of .025m (1 inch) are expected. Deviations of anchor bolt holes are to be addressed on a hole-by-hole basis so that the distance apart at hole ends will not be less than 20 inches. In order to achieve the specified vertical tolerance, collaring alignment holes are required. The holes shall be drilled as accurately as possible to vertical and to a minimum depth of .076m (3 inches). After completing the collar alignment drilling, a .035m (1.375 inch) diameter pilot holes of the correct length will be drilled. These will then be reamed to .076m (3 inch) diameter to a depth of approximately 2.13m (7 feet). To ensure that there is an acceptable annulus in the anchorage zone, all .035m (1.375 inch) ±0.030 diameter finishing bits will be properly gauged. Drawing No. 54-D-003-W2 provides details of the drilled hole.

5.3.1.2 CABLE LACING ANCHORS

The support system requires that lacing across the room width and length be terminated with resin grouted rock anchors and be provided with means for tensioning the cables. Lacing cable termination anchors will consist of a truss plate fastened to the roof by a .016m (5/8 inch) diameter and 2.4m (8 feet) long resin grouted bar. An adjustable eyebolt will pass through a truss plate and the lacing cable will be terminated through this eyebolt as shown on Drawing No. 54-5-003-W5. The termination anchor holes will be drilled at 45° angle to a depth of 2.4m (8 feet) with drilling accuracy of $\pm$.025m (1 inch). Drilling detail for lacing holes anchors are shown on Drawing No. 54-5-0003-W4.

5.3.1.3 RIB SUPPORT ANCHORS

The rib anchors are installed to hold the chainlink wire mesh against the rib from the top corner down to approximately 2.13m (7 feet) above the floor. The chainlink meshing is installed to support small pieces of loose or broken salt. Chainlink meshing is currently used at the WIPP as a standard practice for rib maintenance underground. The rib anchors are standard 1.22m (4 feet) long mechanical anchors. Rib support anchor holes are drilled on approximately 1.52m (5 foot) pattern and are 1.22m (4 feet) deep to accommodate the anchors.

5.3.1.4 RECOVERY OPERATIONS

In the event that drilling tolerances or anchorage capacities are not met, the hole depth will be extended an additional .91m (3 feet). The anchor will be reinstalled at this depth.

5.3.2 INSTALLATION SEQUENCE

5.3.2.1 STEEL ANCHOR BOLTS

Installation of the roof support system in Room 1, Panel 1, will commence with drilling of the steel channel anchor holes and installation of Dywidag anchor bolts.

Correct installation of the Dywidag anchors is critical to the whole support system. The minimum bond length of .91m (3 feet) is required in order to maintain design load capacity of the support system. This has been confirmed by the destructive tests described in Appendix B of this report. A minimum of .457m (18 inches) of the anchor bolt measured from the hole collar will protrude from the mouth of the drill hole. Both the Dywidag tendons and the resin will be installed according to the manufacturers specifications. Following anchor installation, each bolt will be quality checked to confirm its anchorage capacity. Details regarding quality control testing are included in Section 6.1.2.

5.3.2.2 WIRE MESH AND LACING

The wire mesh and lacing will be installed after testing of the anchor bolts is completed and advanced enough to provide adequate working space for wire mesh hanging operations. This would allow for simultaneous installation of wire mesh, cable lacing, and drilling of anchor holes. The wire mesh system consists of two layers, a layer of .10m x .10m (4 inch x 4 inch) welded wire mesh and another layer of expanded metal which is installed directly against the salt and above the welded wire mesh layer.

Both layers are attached to the existing 3.04m (10 foot) rock bolt plates in order to provide temporary suspension until the lacing and channel supports are finally installed. Drawing No. 54-D-003-W5 shows the installation detail of the meshing and lacing. The wire lacing rope will be doubled back through one of the eyebolts attached to the anchor plate, and the free end clamped with three crosby clamps. The loose end will then be passed through the opposite eyebolt and snug tensioned by means of a come-along and clamped with three crosby clamps. The transverse lacing will be installed before the longitudinal ropes.

5.3.2.3 STEEL CHANNEL SETS

The .381m (15 inch) by 177.92N (40 pound) channel steel set will be installed in three 2.74m (9 foot) long sections with the flanges down. Each section will be joined in place by the splice plates located along the flanges. An .356m (14 inch) wide by 2.743m (9 foot) long by .0191m (.75 inch) thick treated plywood gasket will be placed on top of the channel with .038m (1.5 inch) holes drilled to coincide with the hole pattern of the channel. The plywood gasket will first be fitted over the anchor bolt ends, thus forcing them to be correctly aligned before installation of the steel channel is attempted. The steel channel sections will be installed next, by passing the protruding Dywidag anchor ends through the .0381m (1.5 inch) pre-drilled holes. The final step will be the installation of the fastening nut assemblies, together with their associated plates and load cells. Drawing No. 54-D-003-W3 shows the channel support details. A setting load of 4448.22N (1000 pound) will be applied to the anchors. Steel spacers will be used to ensure contact at the rock anchor positions.

5.3.2.4 RIB SUPPORT

Installation of the rib support system will commence with drilling of the rib anchor holes followed by hanging of the

chainlink mesh together with anchor installation. Approved current WIPP installation procedures for rib bolting will be followed.

Since the rib support system is intended for protection against small scale flaking and peeling of small rock which are of nuisance value, its installation sequence will depend more on convenience than on a rigid schedule.

6.0 TESTING AND MONITORING

The most important component of the roof support system described herein is the rock anchor system. After each Dywidag rock anchor is grouted, both in the mock-up test as well as during actual Room 1 installations, the rock anchors will be subjected to performance tests. The testing will be carried out using as a guideline the specifications laid down in "Recommendations For Prestressed Rock And Soil Anchors", 1989, produced by the Post-Tensioning Institute of Phoenix, Arizona.

Monitoring of the loads on the rock anchors will be done during the test phase as well as prior to the actual installations. The information will be used to determine when and by how much the loads should be adjusted in order to keep pace with the deformation of the salt rock into the room. In addition to monitoring rock anchor loads, deformations in and around the room as well as deflections of the supporting channels will also be monitored. These measurements will enable a clear picture of the room stability to be obtained.

6.1 TESTING

6.1.1 MOCK-UP TEST

A mock-up test will be performed in Room 2 of Panel 1 and will include installation of five complete channel sets. The objectives of the mock-up tests are as follows:

- Provide information necessary to evaluate existing equipment;
- Establish practical and safe installation procedures;
- Install and test monitoring equipment;
- Check the performance of the overall system as well as individual components;
- Establish procedures for rock anchor performance tests, and ensure that personnel are proficient in the use of these tests.

6.1.2 QUALITY CONTROL TESTING

The purpose of Quality Control testing is to ensure that every rock anchor installed is capable of handling at least 1.1 times the maximum design load. Because of the large number of bolts (approximately 300) to be installed, these tests have to be done as quickly as possible.

After a rock anchor has been installed for a minimum of 8 hours, it will be loaded to 26 kips (1.1 times the design load). The loading arrangement is shown in Drawing No. 54-D-003-W2. The load will be measured by the load cell and conveniently displayed during loading. After reaching 26 kips, the nut will be tightened and the loading ram removed. The load will be continually monitored for a minimum of 1 hour to check whether there is any loss of load due to creep. If there is a load loss, the load will be reapplied and monitored. This will be repeated until all "slack" in the

system has been removed, or the rock anchor installation is deemed to be unsatisfactory. Recovery operations as detailed in Section 5.3.1.4 may then be instituted. The above procedure may be modified based on field experience.

6.1.3 DESTRUCTIVE TESTS

The main component of the support system described in this design document is the rock anchor system.

The primary emphasis of the anchorage system testing program is to guard against the most probable modes of movement that may lead to its failure. The importance of field validation tests of the anchorage system has been recognized as essential to the success of the whole support system.

The rock anchor system was tested by loading correctly installed bolts to destruction. These destructive tests determined that the anchorage capacity of the No. 8 Dywidag rockbolts tested in Room 2 of Panel 1, are equal or greater than guaranteed manufacturers specification of (47.4 KIPS) yield load or (71.1 KIPS) of ultimate load used for support system design. Details of the tests and the results obtained are given in Appendix B.

6.2 MONITORING

Since the support system will be adjusted during its operational life, it is essential to ensure that the loads on the anchors do not exceed the working loads specified by the design. The two main parts of the monitoring program will be observations of room performance and of support performance.

Room stability will be determined from data that will establish the rock mechanics performance of the excavations in terms of room closure, rock deformations in and around rooms, the development of fractures and bed separation at strata interfaces.

The support system performance will be determined from tests that will provide input data from field tests for the design, from tests to prove quality during installation, and from a program that will monitor loads that develop in the rock anchors and on the lacing during the working life of the support. The evaluation of the rock mechanics data characterizing room performance and of the support performance data will establish the effectiveness of the support system. A description of the Geomechanical Monitoring Program including specifications for the instruments is given in Appendix "D".

6.2.1 GEOTECHNICAL MONITORING

Geomechanical instrumentation can adequately establish the performance of excavations at the WIPP and provide adequate warning of deteriorating conditions. This has been demonstrated by the early warnings provided in SPDV Test Room 1 prior to its roof fall, and was confirmed by the views expressed by the Geotechnical Expert Panel convened to establish an estimate of the life of Panel 1 (US DOE, 1991 91-023). The geomechanical

instrumentation for Room 1, Panel 1, has been upgraded based on a monitoring program presented to the Geotechnical Expert Panel (US DOE, 1991 91-023). The basis of the revised monitoring program is:

- The measurement of deformations across the Anhydrite "a" and "b" layers in the roof in order to assess the development of bed separations at these strata interfaces.

- The measurement of room closure in order to assess the development of closure rates that exceed bounding levels and to establish the development of assymmetric room closure that may be an indication of fracture development along one rib and rotation of the roof slab. These measurements will be made by convergence measurements of roof/floor and wall/wall closure.

- The observation of conditions in the roof in observation boreholes in order to establish the extent of fracturing and bed separation.

- The measurement of lateral deformations within the pillars to establish the competency of the pillars. These measurements will be made by means of borehole extensometers.

6.2.2 SUPPORT SYSTEM MONITORING

Monitoring of the support system under working conditions in the field is an integral element to ensure its successful performance. The monitoring program consists of measurement of:

- The load that develops in each rock anchor. This provides the basis for adjusting the tension on the anchor so that the load build-up does not exceed the design limits of 1.1 times the design load while accommodating the continued movements of the salt. The load will be measured by means of load cells located at the anchor nut.

- The load that develops on the lacing and mesh. This will be evaluated over selected lengths of the room. The load will be measured by means of hydraulic flat jacks located at cross-over points of the lacing.

- The extension of the cables due to the development of the load due to the detaching wedge. The cable deformation will be measured by means of a calibrated standard length and dial indicator.

- The deflection of the channel support arising from the action of the rock anchor supports and the load transferred by the lacing and meshing. The deflection will be measured by precise surveying techniques.

The purpose of the monitoring of lacing and meshing loads and extensions is to gather information for later analysis. Initially, the monitoring will be carried out daily but this frequency will be adjusted as data becomes

available on the load changes with time. The measurement frequency will be based on observing load changes equivalent to 2 percent of maximum working load. The measurements of the loads will be compared with the criteria presented in Appendix "D" to establish when loads in the rock anchors must be adjusted, and the extent of that adjustment:

It should be noted that these criteria are preliminary. Field tests and analytical computations will be performed in order to more effectively define these criteria and the method of load adjustment that will be based on them.

The criteria and the adjustment to the loads will be reviewed as data becomes available and may be changed to be more effective. The process by which these factors become adjusted will require approval by the manager of Engineering for the Managing and Operating Contractor with concurrence from the managers of Operations and Safety.

6.2.3 INSTRUMENTATION

Geomechanical Instrumentation installed in Room 1 of Panel 1 will include:

- Beam support rock bolt load cells - Rock bolt load cells will be used to monitor the axial loading on the rock bolts. Loads on the cells are measured by means of resistance strain gages bonded to the cell in a full bridge configuration. The load cells are capable of monitoring loads of up to 444,800N (50 tons) with an approximate instrument sensitivity of 88.9N (20 pounds). In order to maximize the adjustment range of the support system, a low profile type cell will be used.

- Pressure cells or flat jacks - will be used to monitor loading on the cable lacing and mesh as a result of creep displacement. Pressure cells will be constructed of stainless steel and be capable of monitoring the range from 0 to 70 MPa (0 to 10,000 psi) with sensitivity of 0.4 per cent.

- Extensometers - Five borehole extensometers are installed in Panel 1, Room 1, to monitor rock mass deformation adjacent to the excavation. Three extensometers are installed in the roof to monitor possible bed separation within the roof beam. These extensometers are installed along the centerline in the middle at approximately 1/4 length locations of the room. Horizontal extensometers are installed in each wall at the center of the room.

- Convergence points - Convergence measurements will be taken from installed convergence points throughout the room. These measurements are used to determine the amount and rate of closure at selected points. Monitoring of horizontal and vertical convergence will allow for a comparison of the performance of the support system in response to the actual room closure.

- Level survey - Changes in elevation will be monitored at selected locations along the support beams and the rock surface. The elevation surveys will identify areas of differential movement which, in addition to the results from installed geomechanical instrumentation, will establish the response of the system to creep closure.

Due to the large number of instruments, a data acquisition system will be installed. This system will be capable of monitoring up to 330 resistance strain gaged rock bolt load cells. The data loggers will be incorporated into the Geomechanical Instrumentation System which will allow for timely monitoring and reporting.

7.0 ADDITIONAL REQUIREMENTS

Quality of installation and monitoring is of key importance to the successful performance of the support system.

- In order to provide continuity to all the activities and assure future system performance a Project Control Group shall be assembled to oversee all installation and monitoring activities. This group shall include representatives from Mine Engineering, Geotechnical Engineering, Mine Operations, Quality Control, Safety and an outside project consultant.

- Collected monitoring data shall be routinely reviewed and results compared with design parameters.

- Periodic progress reveiws shall be conducted to evaluate system performance and to define possible changes to the system not forseen during design stage.

- Possible further testing might be required to define performance of individual components.

- Further steps shall be taken to develop and validate a mathematical or numerical model which would more easily describe the behavior of the support system.

LIST OF MATERIAL

QTY REQ (QR1)	(QR2)	(QR)	ITEM NO.	ORDERING INFORMATION	NOTE	DRAWING NO. OR PART NO.	MATERIAL SPECIFICATION MATL	STD	NUMBER	COMP	FORM
	–	–	1	ENHANCED ROOF SUPPORT ASSEMBLY		54-D-003-D-001					
	–	AR	2	STEEL SET ASSEMBLY	*	54-D-003-D-002					
–	1		3	STEEL SET CORNER PIECE ASSEMBLY		54-D-003-D-003					
*			4	BAR FLAT .38 THK STK	A		CS	ASTM	A36		
1	2		5	CHANNEL, C13X40							
	4		6	BOLT, .63–11 UNC–2A X 2.50 LG, HEX HEAD	B	91249A788	CS	ASTM	A325		
	4		7	NUT, .63–11 UNC–2B, HEX HEAD	B	90473A035	CS	ASTM	A563		
		AR	8	PLYWOOD, .75 THK STK 4'X16' SHT	F		CDX				
		AR	9	METAL, EXPANDED 10 GA 4'X16' SHT	C		CS				
		AR	10	WIRE, MESH .25 W/4X4 OPENINGS 5'X14' SHT	C		CS				
		AR	11	FENCING, CHAINLINK 9 GA.	H		GAL.	ASTM	A392		
		AR	12	CABLE, 0.63 6X25 IWRC	B	3435T15					
		AR	13	CLAMP, CABLE	B	3485T18					
		AR	14	ROCKBOLT, 1.5' LONG	D						
		AR	15	ROCKBOLT, 4' LONG	D						
		AR	16	PLATE, STEEL 6X6X.50 THK STK	D		CS				
		AR	17	PLATE, TRUSS	C						
		AR	18	LOADCELL							
		AR	19	RESIN, EPOXY	E	3212H80					
	8		20	WASHER, FLAT .63	B	91804A035	CS	ASTM	F436		

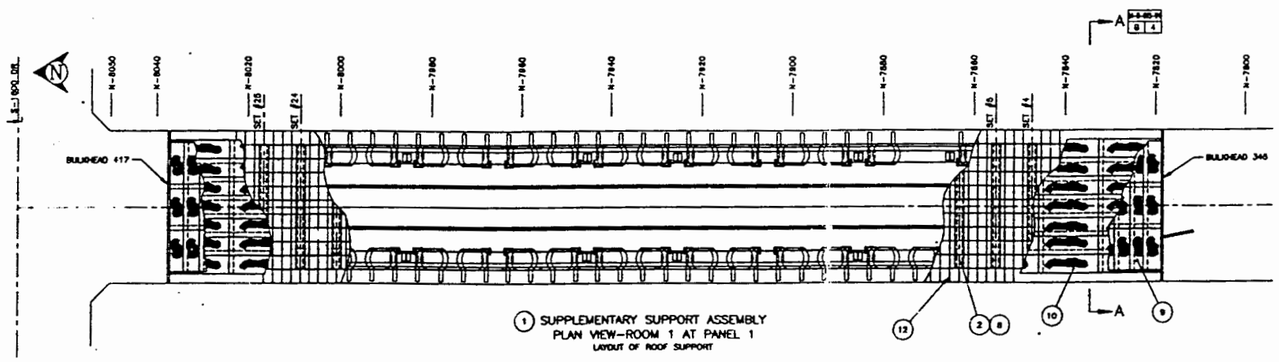
SUPPLIERS:

A. RYERSON OR APPROVED EQUAL
B. McMASTER–CARR OR APPROVED EQUAL
C. JOHNMAR CORP. OR APPROVED EQUAL
D. DYWIDAG OR APPROVED EQUAL
E. CELTITE OR APPROVED EQUAL
F. TEXAS LUMBER OR APPROVED EQUAL
G. RAYNELL OR APPROVED EQUAL
H. ACME FENCE OR APPROVED EQUAL

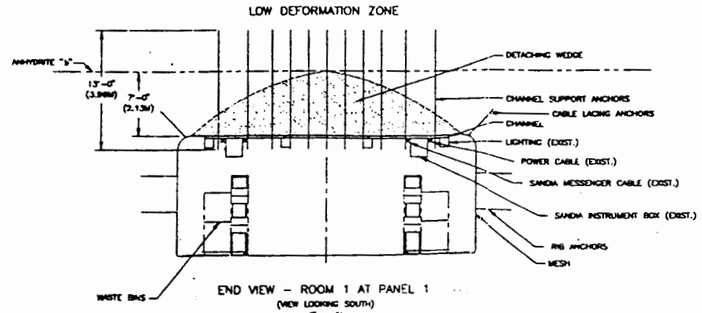
KEY PLAN

REFERENCE DRAWINGS

BIN–SCALE TESTING PANEL 1 ROOM 1 POWER AND LIGHTING	53–J–053–W
UNDERGROUND UTILITIES PANEL 1–PROFILES ALONG ROOM 1 AND S1850 DR	51–W–088–W
BIN SCALE TESTS VOC MONITORING AIR RETURN STATION DETAILS	53–L–002–W
BIN–SCALE TESTS ROOM 1 LAYOUT	52–W–001–W



1 SUPPLEMENTARY SUPPORT ASSEMBLY
PLAN VIEW–ROOM 1 AT PANEL 1
LAYOUT OF ROOF SUPPORT



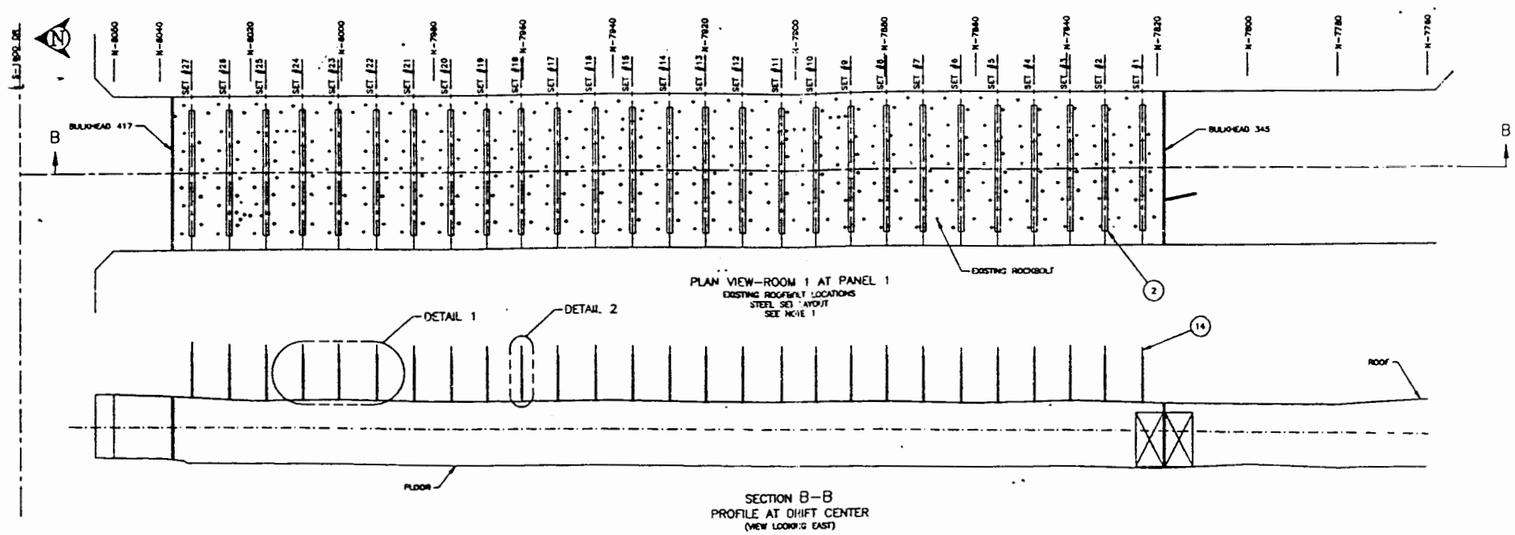
END VIEW – ROOM 1 AT PANEL 1
(VIEW LOOKING SOUTH)
1" = 5'
(.03M = 1.52M)

REV	ISSUE DESIG	DFTR DATE	CHK DATE	COG DATE	APPD MGR DATE	ECO	PWR

U.S. DEPARTMENT OF ENERGY
Westinghouse Waste Isolation Division
Waste Isolation Pilot Plant
CARLSBAD, NEW MEXICO

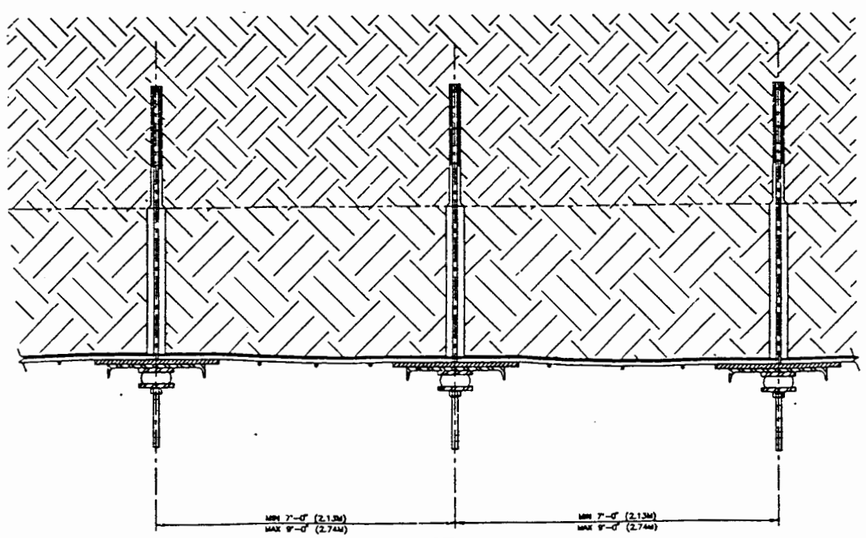
SUPPLEMENTARY ROOF SUPPORT
ROOM 1, PANEL 1
GENERAL ARRANGEMENT

SYS. AU06 | DWG. NO. 54–D–003–W1 | REV. NEW | DWG. 1 OF 2

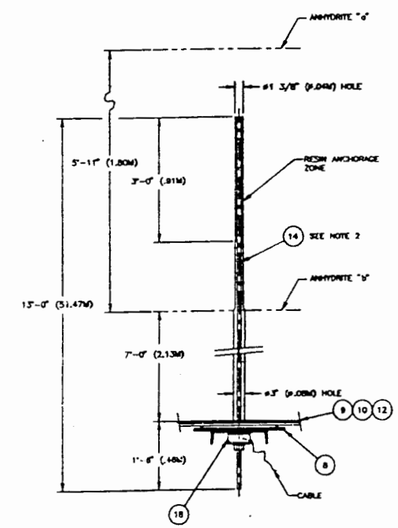


PLAN VIEW—ROOM 1 AT PANEL 1
EXISTING ROOFBOLT LOCATIONS
STEEL SET LAYOUT
SEE NOTE 1

SECTION B—B
PROFILE AT DRIFT CENTER
(VIEW LOOKING EAST)



DETAIL 1
WIRE MESH AND LACING
N.T.S.



DETAIL 2
ROCKBOLT INSTALLATION & ASSEMBLY
N.T.S.

NOTES:

1. LOCATION OF STEEL SETS (ITEM 2) TO BE DETERMINED IN FIELD.
2. INSTALL ROCKBOLTS (ITEM 14) PER MANUFACTURER'S INSTRUCTIONS.

REV.	ISSUE DESCRIPTION	DFTR DATE	CHK DATE	DDG DATE	DFTG MGR DATE	ECO	PWR

B-2 DRAWING CREATED BY ENGINEERING CHANGE ORDER (ECO) : SAME

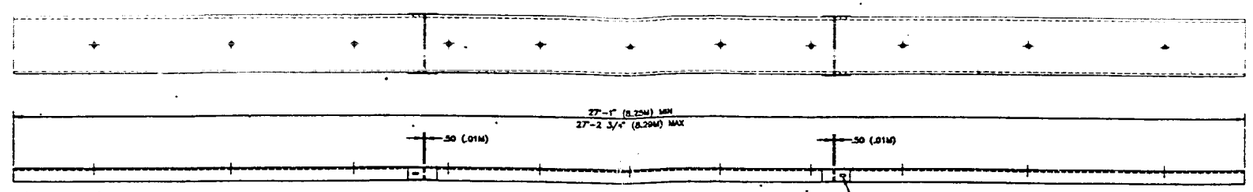
DFTR DLA/TPA 8/3/91
CHKR D. ALLEN 9/09/91
DDG CHIEF DWG CHKR 9/9/91
DDG MGR S.SETH 9/10/91
D.L. R.YOURCHAK 9/10/91
SFTY MGR GREGT 9/10/91
DFTG MGR A.BOLINE 9/10/91
DLC JACK GILBERT 9/10/91
SCALE 1" = 10' U.N.O.

U.S. DEPARTMENT OF ENERGY
Westinghouse Waste Isolation Division
Waste Isolation Pilot Plant
CARLSBAD, NEW MEXICO

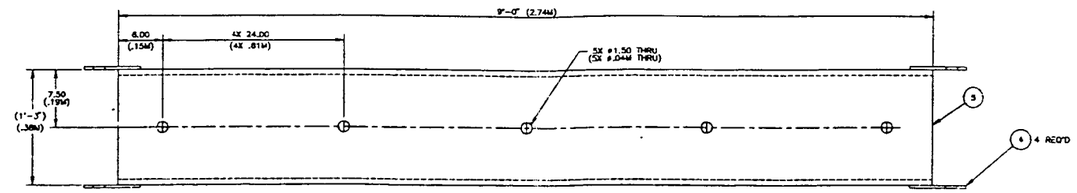
SUPPLEMENTARY ROOF SUPPORT
ROOM 1, PANEL 1
STEEL SET LOCATIONS & DETAILS

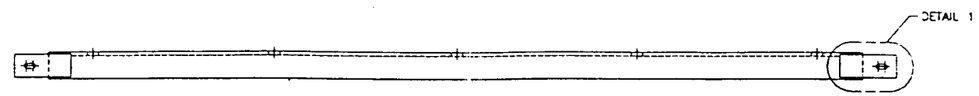
SYS. AU06 | DWG. NO. 54-D-003-W2 | REV. NEW | DWG. 2 OF 3

INTERPRET DWG. PER ANSI Y14.5
DIM. IN INCHES BASED ON 68°F
UNLESS OTHERWISE SPECIFIED TOLERANCES
J. R. ROLLA JR. SEC. MANAGER
FRACTIONS
ENGINEERING RELEASE
BY: WSB-WIPP
ECO ____ DATE

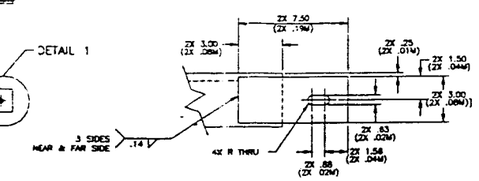


2 STEEL SET ASSEMBLY GR2
1" = 1'
(.03M = .35M)

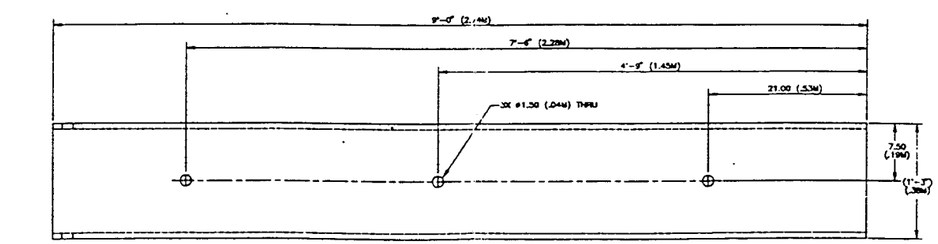


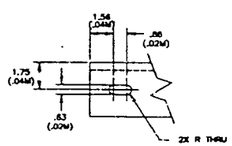


3 STEEL SET CENTER PIECE ASSEMBLY GR3
1" = 6"
(.03M = .15M)

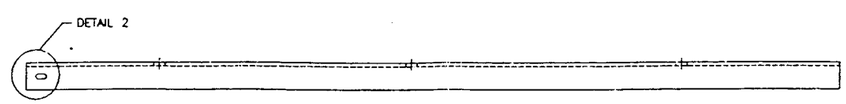


DETAIL 1
1" = 3"
(.03M = .08M)
(SIM OPPOSITE END)

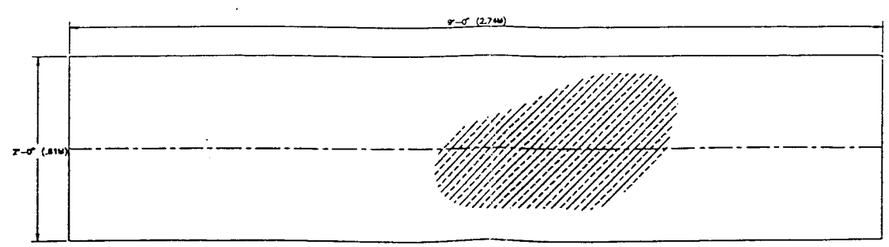




DETAIL 2
1" = 3"
(.03M = .08M)
(SIM OPPOSITE SIDE)



5 STEEL SET END PIECE
1" = 6"
(.03M = .15M)



8 PLYWOOD STRIP
1" = 6"
(.03M = .15M)
SEE NOTE 1

NOTES:

1. USE ITEMS 3 AND 5 AS A TEMPLATE TO DRILL HOLES IN ITEM 8.
2. FINGER TIGHTEN ITEMS 6 AND 7 UPON INSTALLATION.

REV	ISSUE DESCRIPTION	DFTR DATE	CHK DATE	COG DATE	DFTG MGR DATE	ECO	PMR

THIS DRAWING CHECKED BY ENGINEERING CHANGE ORDER (ECO) : SHEET

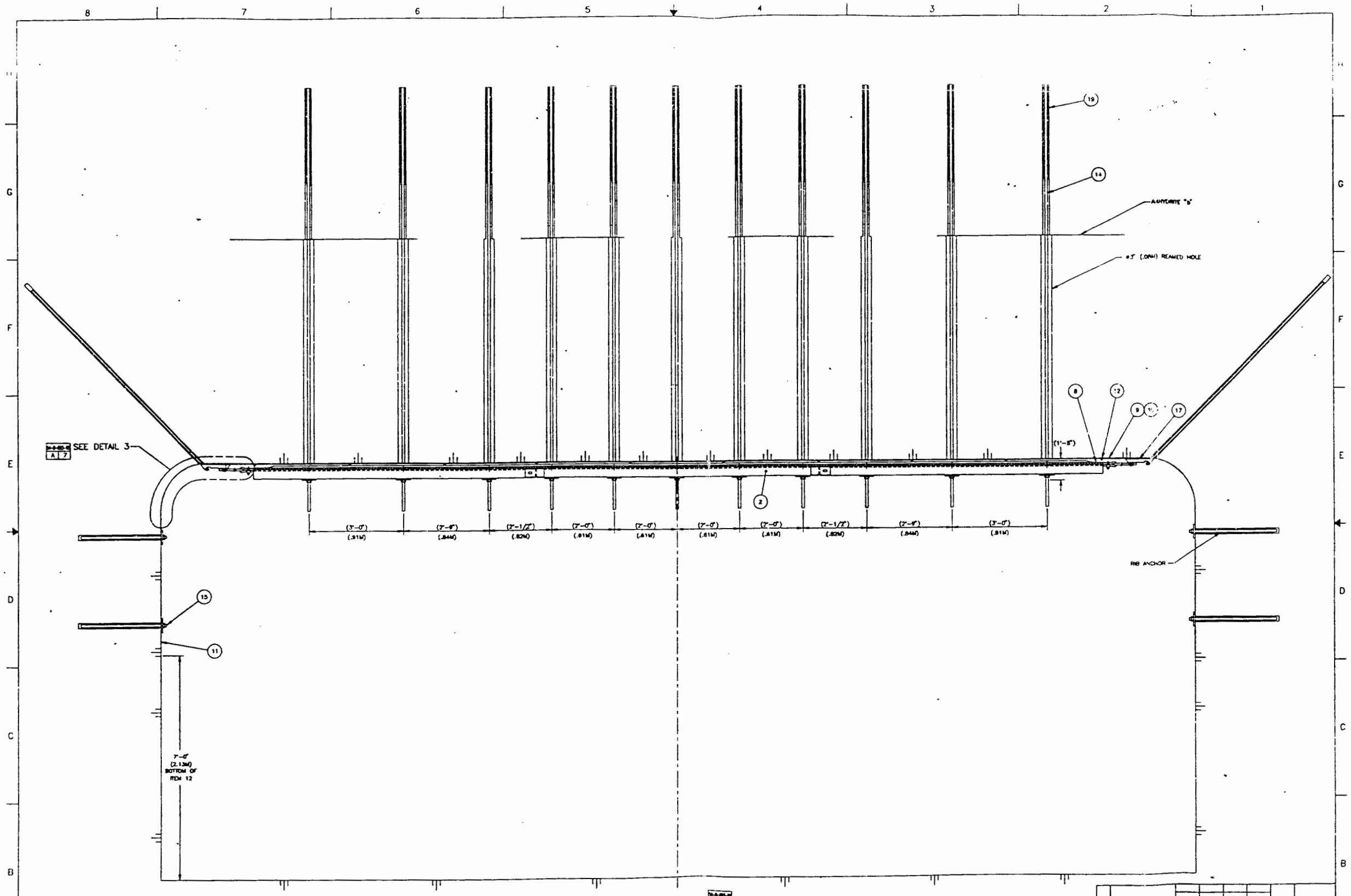
DFTG DLM/DRL 8/3/94
CHKR B. ALLEN 9/09/94
COG. ENG CHIS DAMS 9/9/94
COG. MGR S.SETTHI 9/9/94
Q.A. R.YOUNGSMA 9/16/94
SAFETY ENG CHRIST 9/16/94
APPR.
APPR.
DFTG MGR KUDURS 9/16/94
ODE JACK GLBOW 9/16/94
SCALE AS NOTED

UNLESS OTHERWISE SPECIFIED TOLERANCES
3 PL. DEC. ± 1 PL. DEC. ANGLES
±.01 — —
FRACTIONS ±1/8
ENGINEERING RELEASE
BY
ECO DATE

U.S. DEPARTMENT OF ENERGY
Westinghouse Waste Isolation Division
Waste Isolation Pilot Plant
CARLSBAD, NEW MEXICO

SUPPLEMENTARY ROOF SUPPORT
ROOM 1, PANEL 1
STEEL SET FABRICATION

SYS. AU06 DWG. NO. 154-D-003-W3 REV. NEW
DWG. 3 OF 3



SECTION A–A
ROOM 1 AT PANEL 1
(VIEW LOOKING SOUTH)
STEEL SUPPORT

REV	ISSUE DESCRIPTION	DFTN DATE	CHK DATE	CDC DATE	OFTC MGR DATE	ECO	PWA

THIS DRAWING CREATED BY ENGINEERING CHANGE ORDER (ECO): 3482

DFTL DLH/TMA 6/3/91
CHKR. & ALLD. 5/08/91
CDC ENG RHB 6/18/91
CDG MGR S.SETH 6/19/91
S.A. R.TRUJILLO 6/19/91
SAFETY NORM GUSS 6/19/91
APPD
APPD
DFTL MGR NORM GUSS 6/19/91
DOE MGR GILBERT 6/19/91
SCAL/

INTERPRET DWG PER ANSI Y14.5M 1982 IF INCHES BASED ON 25.4 MM
UNLESS OTHERWISE SPECIFIED TOLERANCES
2 PL DECS | 3 PL DECS | ANGLES
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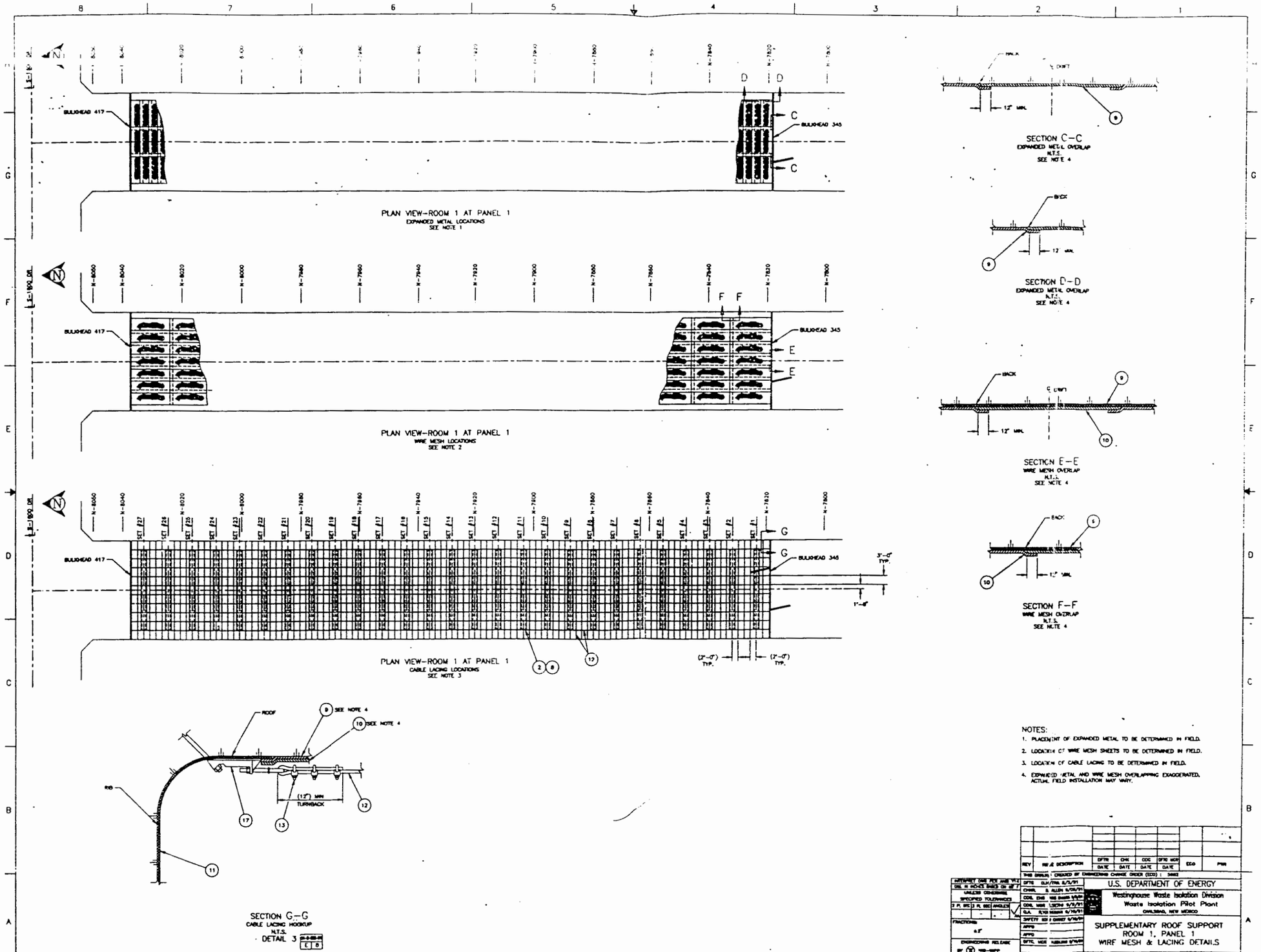
ENGINEERING RELEASE
BY (W) WIPP-WTP
ECO ____ DATE ____

U.S. DEPARTMENT OF ENERGY
Westinghouse Waste Isolation Division
Waste Isolation Pilot Plant
CARLSBAD, NEW MEXICO

SUPPLEMENTARY ROOF SUPPORT
ROOM 1, PANEL 1
ROOM 1 CROSS SECTION

SYS AU06 | DWG NO 54-D-003-W4 | REV NEW | DWG 4 OF 8


PLAN VIEW-ROOM 1 AT PANEL 1
EXPANDED METAL LOCATIONS
SEE NOTE 1
PLAN VIEW-ROOM 1 AT PANEL 1
WIRE MESH LOCATIONS
SEE NOTE 2
PLAN VIEW-ROOM 1 AT PANEL 1
CABLE LACING LOCATIONS
SEE NOTE 3
BULKHEAD 417
BULKHEAD 345
SECTION C-C
EXPANDED METAL OVERLAP
N.T.S.
SEE NOTE 4
SECTION D-D
EXPANDED METAL OVERLAP
N.T.S.
SEE NOTE 4
SECTION E-E
WIRE MESH OVERLAP
N.T.S.
SEE NOTE 4
SECTION F-F
WIRE MESH OVERLAP
N.T.S.
SEE NOTE 4
SECTION G-G
CABLE LACING HOOKUP
N.T.S.
DETAIL 3
ROOF
SEE NOTE 4
(12") MIN TURNBACK
NOTES:
1. PLACEMENT OF EXPANDED METAL TO BE DETERMINED IN FIELD.
2. LOCATION OF WIRE MESH SHEETS TO BE DETERMINED IN FIELD.
3. LOCATION OF CABLE LACING TO BE DETERMINED IN FIELD.
4. EXPANDED METAL AND WIRE MESH OVERLAPPING EXAGGERATED. ACTUAL FIELD INSTALLATION MAY VARY.
U.S. DEPARTMENT OF ENERGY
Westinghouse Waste Isolation Division
Waste Isolation Pilot Plant
CARLSBAD, NEW MEXICO
SUPPLEMENTARY ROOF SUPPORT
ROOM 1, PANEL 1
WIRE MESH & LACING DETAILS
AU06
54-D-003-W5

APPENDIX A

DRAFT 09/10/91

WASTE ISOLATION PILOT PLANT
SUPPLEMENTARY ROOF SUPPORT SYSTEM

APPENDIX A

Geology and Rock Mechanics

Westinghouse Electric Corporation
Waste Isolation Division
Carlsbad, New Mexico
August 1991

GEOTECHNICAL DESIGN SUMMARY REPORT

FOR ROOF SUPPORT SYSTEM IN ROOM 1, PANEL 1

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1.0 INTRODUCTION

The purpose of this report is to provide the geotechnical basis for the design of a system to support the rock in the roof of Room 1, Panel 1. The system must ensure that the room meets the functional requirements necessary to support its use as an underground laboratory for the study of gas generation from CH TRU radioactive waste (Molecke, 1990). This research program, called the Bin Scale Testing Program, is under development at the present time and the experiments are expected to start in the second half of 1991. The Geotechnical Design Summary Report interprets the geologic and rock mechanics data presented in the annual Geotechnical Field Data and Analysis Reports (US DOE, 1991a; US DOE, 1990) and other occasional reports (US DOE, 1991b) and presents the geotechnical assumptions that have been made for the design.

The geotechnical investigations at the WIPP are comprehensive and provide detailed information on the site conditions that is not typically available for an engineering design. This has enabled the Geotechnical Engineering Section, Westinghouse, WID to establish a phenomenological model that explains the performance of openings. This model establishes the mechanisms that must be addressed by the design of the support system in order to control the roof conditions in Room 1, Panel 1.

1.1 BACKGROUND

Room 1 of Panel 1 is currently 5 years old and must remain accessible for a further 7 years in order to support the bin scale testing program. Following the collapse on February 4th, 1991 of the roof in the Site and Preliminary Design Validation (SPDV) Test Room 1 that confirmed the concerns raised by the Geotechnical Engineering Section concerning the capability to maintain the Panel 1 room for the period of the bin scale tests, a panel of Geotechnical experts was formed to evaluate the life expectancy of the underground room in which the tests will take place.

The panel concluded that if no additional remedial measures were taken, the rooms in Panel 1 are likely to have a total life of seven to eleven years from the time of excavation using the currently installed roof support system, consisting of rockbolts. Mining of Room 1, Panel 1 began during the second half of 1986. Therefore the remaining life of this room is anticipated to be between two and six years (US DOE, 1991b). The most current geotechnical field data from this room (US DOE,1991, in preparation) does not indicate that its geomechanical performance differs significantly from that observed in SPDV Test Room 1. On this basis, the remaining life for Room 1 as currently supported is about two to three years.

The panel members agreed that measures could be taken that would provide reasonable assurance that the bin scale tests could be carried out to completion in Panel 1. They suggested a number of alternative actions that could be taken and recommended that the WIPP project evaluate the alternatives and select one, or a combination, of measures that would assure continued use of the rooms over the period of the tests. They also indicated that the measures should be augmented by a monitoring program that would regularly assess the geomechanical conditions and that maintenance should be carried out as a routine activity in the rooms as they aged.

The WIPP project has evaluated the support systems suggested by the Geotechnical Expert Panel. The initial evaluations looked at support systems that could be installed within the rooms and would provide a passive support as the rock moved into the excavation. These systems were eventually abandoned because they interfered with the functional use of rooms as a location for the bin scale tests. Problems were associated not only with the physical size of the supports which limited the number of bins that could be placed in a room but more importantly, the support could not be placed where it was needed (i.e. midspan, where the largest loads develop) without eliminating access to the bin locations.

The project has then assessed the installation of additional rock reinforcement in the roof of Room 1, Panel 1 as a means of extending the life of the room. Rock bolts as normally installed do not provide the capability to establish with any level of confidence either a support system with a specific working life or a measure of performance on an ongoing basis. Therefore, a composite system of support has been designed that incorporates beams at nominal nine feet centers along the length of the room, supported by a system of tendons anchored in competent salt in the roof with lacing and meshing. The rock reinforcement system (i.e. anchored steel tendons) has been designed as rock anchors, where appropriate, because rational design approaches are available for their design and extensive field testing programs are typically used to confirm the design.

1.2 DESIGN METHODOLOGY

The primary emphasis of the anchorage system is to guard against the most probable modes of movement that may lead to collapse. The design requires detailed site specific geologic information, the study of information from relevant case studies, design calculations based on available data for the rock and the anchorage systems and field tests. Field proving tests of the anchorage system and the monitoring of support performance during its operational life are essential considered to the success of the system.

The bases for the design approach are the recommendations prepared by the Post-Tensioning Institute (Post-Tensioning Institute, 1986) that provide guidance in the design installation and testing of rock anchors. In addition, information from other publications that relate to the design of rock anchors and their field performance have been used, where appropriate (BS 8081, 1989; Corps of Engineers, 1980;) Littlejohn and Bruce, 1976). These publications provide guidelines to rationalize procedures for the design of rock anchors. As far as possible, the guidelines given in these documents have been followed but where the recommendations have not been, the reasons are discussed in this document.

Although the support requirements for underground excavations at the WIPP are not as great as that typically needing rock anchor support, the rigor of the design approach for ground anchors and the extent of the proof testing that accompanies the installation of every anchor justify this approach for the design of the roof support system in Room 1, Panel 1.These anchor systems are designed to be effective for extended periods of time and consequently require special design and quality control in installation. The design approach requires the performance of each anchor to be establish quality control in installation so that the performance of the overall support system is effective. This is in contrast with the design for rock bolting which does not generally attempt to determine the performance of every bolt or to determine system performance.

2.0 STRATIGRAPHY OF REPOSITORY HORIZON

The proposed underground storage facility is located 655m below the surface in bedded salt of the Permian Salado Formation. A generalized stratigraphy showing the facility level is given in Figure 2.1. Over 365m of impermeable evaporitic deposits separate the facility horizon from the overlying sedimentary rocks and 620m of evaporites lie below the facility horizon and provide a barrier to Permian limestones and sandstones.

Halite is the most abundant mineral in the Salado and occurs in thick beds intercalated with thinner beds of polyhalite and anhydrite. Salado halite is rarely pure and usually contains trace and minor amounts of foreign material including clay, anhydrite and polyhalite. Halite crystal size and morphology vary considerably, and various large and small scale sedimentary features are abundant throughout out all of the Salado Salt. A detailed discussion of the Geology of the Salado formation can be found in the Geologic Mapping of the Air Intake Shaft at the Waste Isolation Pilot Plant (U. S. DOE, 1991c).

The facility horizon lies within a 12m thick unit consisting of halite, argillaceous halite, and polyhalitic halite. Figure 2.2 identifies the typical geology within this unit. Observations indicate that these geologic conditions are consistent across the site at the repository horizon. Figure 2.3 a, b, and c provide the stratigraphy exposed in Room 1, Panel 1.

A 0.3m to 0.5m thick layer persistent bed of sulfate (anhydrite and polyhalite), identified as Marker Bed 139 lies about 1.5m below the floor level. Considerable lateral variability in composition and thickness exists within this sulfate bed at both the regional and repository scale. The variability in thickness is associated with the top of the deposit and undulations of the order of 6 inches have been observed in 4 inch diameter bore (Holt, 1991). The bottom of the Marker Bed is sub horizontal and is underlain by Clay "E".

Anhydrite beds (less than 10mm thick), called anhydrites "a" and "b" occur about 4m and 2m above the roof. Thin clay seams called Clay G and Clay H are associated with the bottom of these beds. In addition, a thin clay layer identified as Clay F is found intermittently in the immediate roof of excavations.

The Marker Bed 139 and the clay layers can have a significant impact on the mechanical performance of excavations. The clay layers provide surfaces along which slip can occur whereas the Marker Bed acts as a unit that does not deform plastically with time. In addition, the undulating nature of the top of the Marker bed will resist shear movements along the interface with the overlying salt.

3.0 PROPERTIES OF ROCKS AT REPOSITORY HORIZON

The reference material properties for the repository horizon rocks are provided in Table 3.1. These properties are based on laboratory tests carried out during the site characterization phase of the WIPP Project (Kreig, 1983). The tests have demonstrated the range of mechanical properties associated with the WIPP strata, and in particular have defined the time dependent behavior of the salt.

Salt is a material that flows when subject to deviatoric stress conditions. This behavior has long been recognized in the mining industry (Baar, 1977; Dreyer, 1981) and considerable efforts have been made to characterize this response from laboratory creep tests. However,

extensive experience within the mining industry has demonstrated the difficulties involved in establishing in situ performance based on the laboratory characterization of salt creep (Baar, 1977).

The mechanical response of the salt at the WIPP has been characterized by a steady state creep law that was developed in the early 1980's by laboratory creep tests on the Salado salt (Hansen, 1979; Hansen and Mellegard, 1979; Heitmann et al, 1980). This constitutive law relates creep strains to stress and temperature. The relationship ignores transient creep effects that will influence early time deformations and does not include dilation of the salt that will occur when the rock is subject to deviatoric stresses and low confining pressures. The steady state creep law has been used in the model studies to establish predictions of the structural performance of the openings.

Field observations at the WIPP (Cook and Roggenthen, 1991) and in the Carlsbad Potash Basin (Greenwald and Howarth, 1938) have shown that the brittle behavior of salt under deviatoric stresses with low confinement can be a significant factor contributing to the mechanical performance close to excavations. However, the brittle behavior of salt has not been characterized by laboratory studies and constitutive laws for salt do not include fracture development or rock dilation. The evaluation of performance based on the steady state stress law must take into consideration the limitations of the constitutive law applied to the salt. Provided that these limitations are understood, and the structural responses of other stratigraphic zones are properly modelled, it will be possible to establish useful models with which to predict the structural performance of excavations at the WIPP.

4.0 IN SITU STRESS REGIME

The initial stress state at the repository horizon is established from Heims Rule for weak rocks (Hoek and Brown, 1980). This rule establishes the vertical stress as dependent on the depth of overburden and its average density, and the horizontal stresses to be equal to the vertical stress. Taking the average density for the overburden at the WIPP site as 2130 kg/m^3, the initial stresses at the repository horizon are about 2000 psi.

Measurements of virgin in situ stress in salt are difficult to achieve since the measuring techniques assume that rock behaves in an elastic manner (Hoek and Brown, 1980) whereas salt deforms plastically. However, hydraulic fracturing tests have been carried out in boreholes in salt at the WIPP in order to estimate the stresses (Wawersik and Stone, 1986). Although data interpretation was difficult, it was concluded that the virgin in situ stress state at the WIPP is approximately uniform in all directions and that the stress magnitudes correspond to the weight of the overburden. This conclusion confirms, the assumptions normally made for the far field stress distribution in salt, and with theassumptions used on for design the WIPP Project (DOE, 1986).

5.0 STRUCTURAL RESPONSE OF EXCAVATED ROOM

Field observations form the basis for a phenomenological model of the structural performance of the underground excavations. This performance is best characterized by data from the SPDV Test Room Panel. These test rooms are among the oldest excavations underground, having been constructed in March and April, 1983. The rooms have the same size and shape as those

in the proposed waste storage panels and are located at the same geologic horizon. They are relatively large excavations with each room having a nominal height of 3.95m, width of 10m, and a length of 91m. The rooms are separated by 30m wide pillars. This configuration results in an extraction ratio in the Test Room panel of about 25 percent. The rooms were excavated in order to confirm the geology, validate design assumptions for the underground, and provide data, where necessary for revision of the design.

Observations of the performance of these rooms have been routinely made over the past eight years. They have established room performance in terms of room closure, rock movements and the development of fractures in the immediate vicinity of openings (US DOE, 1989; US DOE, 1990; Cook and Roggenthen, 1991). SPDV Test Room 1 has provided the most complete picture of the structural performance of an excavation. Measurements were taken in this room over a period of almost eight years, from immediately following its excavation until a major roof fall occurred. Different stages in the performance of the room can be related to its roof/floor closure history (see Figure 5.1). Other rooms are showing the same general behavior but none others (outside of the SNL experimental area) have yet failed. SPDV Test Room 1 provides the most detailed example of the performance that can be expected from other rooms having similar geometries.

In addition, numerical analyses have been carried out to evaluate the structural performance in terms of stress and strain redistribution taking place about excavations with time. The analyses have used the near repository horizon stratigraphy described in Section 2.0 and the mechanical properties of the rock types provided in Section 3.0. Of particular significance to the interpretation of the model, are:

- the time dependent relationship governing the mechanical response of the salt
- the properties that control bed separations at the strata interfaces

The field observations and the numerical analyses have been used to develop a model of the mechanisms that occur in the roof of an excavation with time. The model is primarily based on the performance monitored in SPDV Test Room 1. The various stages through which the room passes according to the model are shown in Figure 5.2. The field and analytical data supporting this phenomenological model are given in the following sections of the report. It is expected that rooms having a geometry similar to the SPDV Test Rooms and the waste storage rooms will eventually pass through all the stages identified in Figure 5.2 unless remedial actions are taken to control roof deterioration and roof movements. The roof support system for Room 1, Panel is based on the need to control the conditions identified by the model.

5.1 ROOM DEFORMATION

Rooms with similar geometries have shown relatively consistent deformation characteristics. Although actual magnitudes of the room closures show a range of values. The variability in the closure rates is demonstrated in Table 5 which lists rates of closure at mid room, mid span for the SPDV Test Rooms and the rooms in Panel 1 all of which have similar geometries. The highest closure rates appear to be related to the room closest to the barrier pillar and are lower in the middle of a panel and at the solid abutment. At present, no correlation has been established between closure rate and variables such as mining and variations in stratigraphy that might explain these differences. The variability in composition and thickness of the Marker Bed 139 may provide another explanation.

Table 5.1

CLOSURE RATES BY TIME SINCE EXCAVATION

Room	Date of Excavation at Instrument	Excavation Completed To Final Dimensions	Year 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
Panel 1:														
Room 1	June 1986	August 1986	4.13	4.26	4.60	3.24	(3.57)							
Room 2	March 1987	March 1988	3.02	6.71	3.33	2.26								
Room 3	February 1987	March 1988	1.60	9.85	3.34	2.71								
Room 4	February 1988	March 1988	8.33	3.14	2.56									
Room 5	February 1988	March 1988	9.19	2.76	2.28									
Room 6	February 1988	May 1988	8.36	3.41	2.76									
Room 7	March 1988	March 1988	9.26	3.22	2.70									
SPDV:														
Room 1	April 1983	April 1983	6.79	3.75	2.93	2.88	2.85	3.36	4.70	12.77				
Room 2	March 1983	March 1983	7.69	3.16	2.39	2.19	2.14	2.33	2.74	2.87				
Room 3	March 1983	March 1983	7.59	3.65	2.64									
Room 4	April 1983	April 1983	5.70	3.18	2.65	2.33	2.13	2.33	2.42	2.31				
Working Assumptions for Room Closure:														
Case 1			7.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Case 1 Revision 1			7.0	3.0	3.0	3.0	3.0	3.0	5.0	5.0	5.0	5.0	5.0	5.0
Case 2			7.0	3.5	3.0	3.0	3.0	3.5	4.5	5.5	6.5	7.5	8.5	9.5

Closure rates in (inches/year)

"Year" is determined from date of excavation of instrument

Room 1, Panel 1, rate for year 4-5 is based on 9 months' data

Data for Rooms 1 through 7 in Panel 1 and SPDV Test Rooms is from data published up to June 30th, 1990 (DOE/WIPP 91-012). Data for period from July 1, 1990, through March 1991 is unpublished

Design cases and estimates are unpublished

5911-5149a

The changes in roof profile with time are shown in Figure 5.3 based on data from SPDV Test Room 1. The room deformation, initially symmetrical about the room center but after about five years, the roof/floor closure, become assymmetric with one side closing faster than the other side. This behavior identified from SPDV Test Room 1 has been measured in other locations within the facility, and may be considered typical of the performance in the wider span excavations at the WIPP.

5.2 ROCK DEFORMATIONS ABOUT ROOM

FIELD DATA

Deformation measurements show that the rock mass deforms with time and that rock movements generally reduce with distance from an excavation surface although this behavior is modified at strata interfaces. Movements occur both normal and parallel to excavation surfaces. In particular, the Anhydrite 'b' in the roof and the Marker Bed 139 in the floor are associated with relatively large vertical and lateral deformations. Typical inclinometer data from a room cross section are shown in Figure 5.4 for inclinometers, and in Figure 5.5 for extensometers.

Bed separation has been identified at the Anhydrite 'b' in the roof after approximately three years. Separation at the clay/salt interface beneath the anhydrite 'b' appears to increase at a rate of about 25mm per year once the bond across the interface is broken.

The geotechnical data show that the roof and floor of an excavation act as a series of flexing beams separated by zones or planes across which differential movement occurs. This is largest at the anhydrite 'b' but does occur at other horizons above and below the excavations in association with strata interfaces, generally clay/salt interfaces. Lateral shifts in the roof indicate that beam flexure was still occurring at a depth of 15m. In the floor, deflections were not as pronounced, and have largely disappeared at a depth of 15m. Differential lateral movements of about 12 mm per year have been were measured in the immediate roof beam, five years after excavation. These rates of movement have been confirmed by the monitoring of lateral displacements in old excavations (Francke, 1991). Rock deformations about a room also is governed by fracture development. The typical fracture development observed in the wide excavations is shown in Figure 5.6. The most significant fractures are low angled shear fractures develop at the rib/roof interface of excavations. In SPDV Test Room 1, these fractures became sufficiently persistent and continuous that a detached wedge formed the roof in SPDV Test Room 1 fell in eight years after the excavation of the room. Precise surveys of the roof in SPDV Test Room 1 following the rock fall are shown in Figure 5.7 and indicate the geometry of the roof cross-sections to be arch shaped. The condition of the roof in Room 1, Panel 1 is shown in Figure 5.8 as of the summer 1991.

MODEL DATA

Roof/floor closure for the model is compared with the field data in Figure 5.9. Roof/floor closure rate is 0.1 m per year (4 inches per year) and does not vary significantly with time.

Bed separation provided by the model at the anhydrite 'b' level indicate that the separation is at a maximum above the mid span of the excavation and increases at about 12mm per year. The model is compared with the field data in Figure 5.9b. The model also shows that bed separation is occurring at the clay beneath the anhydrite 'a' layer.
This is not consistent with the field observations which do not indicate bed separation at this level. The model has therefore shown good agreement in the vicinity of the opening but may not be accurate with regard to performance at the anhydrite 'a' layer.

The shear strains are shown in Figure 5.10. They build up with time as creep occurs under relatively constant compressive stress in the immediate roof beam and the contours of effective strains indicate potential failure planes. These planes are consistent with the fracture development that occurs in the roof of excavations with time.

5.3 STRESSES AROUND ROOM

Prior to excavation, the strata at the repository horizon are subject to an in situ stress field that is uniform in all directions and has a value of about 2000 psi which is equivalent to the overburden loading. Immediately the excavation is made, the stresses adjust to an elastic distribution. Of particular importance are the high shear stress concentrations that develop in the corners of the excavation (Miller, 1991). These may provide incipient fracturing that later develop into discrete fracture planes. With time, the stresses in the immediate vicinity of the excavation reduce due to stress relief as the salt moves into the opening. The excavation disturbs the stresses and the redistribution continues over time dependent properties of the salt. The principal maximum and minimum stresses induced at 0, 3 and 5 years following excavation are shown in Figures 5.11 & 5.12. These plots indicate the changes in stress that take place with time.

The influence of the stratigraphy on the stress distributions is evident immediately that the excavation is formed. The Marker Bed 139 modifies the structural performance of the floor and the anhydrite 'b' effects the stress distribution in the roof.

In the floor, the Marker Bed 139 acts as a stiff unit which does not exhibit time dependent behavior. The variable elevation in the upper boundary of the Marker Bed indicates that a high resistance to shear movements at this boundary develops. These immediate effects were also observed in numerical analyses presented by Mckinnon (WIPP/DOE 91-023) at the Geotechnical Expert Panel Meeting The salt above and below the Marker Bed will deform with time and depending on the slippage between the salt and the anhydrite will maintain high compressive stress into the Marker Bed. These high stresses may cause brittle fracture of the Marker Bed 139 and its failure which would result in floor heave.

The clay beneath the anhydrite 'b' introduces a plane of low frictional resistance into the strata sequence. The plane will not support shear stresses, and this isolates the immediate roof beam. The plastic flow of the clay ensures that high shear stresses cannot develop at the interface and the low bond strength between the clay and the salt leads to separation at the interface. Once the immediate roof beam becomes isolated, the lateral movements of the pillars maintain induce lateral stresses into the beam. With time, the shear strain build up in the beam eventually results in the development of failure.

Failure relieves the lateral stresses in the beam. However, due to the continued lateral creep of the salt the roof beam continues to be subject to residual compressive stress. As the shear failures propagate in the longitudinal direction, the weight of the unsupported section of the roof spanning increases. At some critical length, the strength of the beam cross section is exceeded and the roof fails as a unit.

6.0 PERFORMANCE REQUIREMENTS FOR SUPPORT SYSTEM

The performance requirements can be divided into two sets. These relate to the functional requirements imposed by the experiments and the geotechnical considerations that emanate from the functional requirements.

6.1 PERFORMANCE

The functional requirements in order to support the bin scale experiments in Room 1 of Panel 1 are as follows:

1. Room 1, Panel 1 must remain accessible for a total life of 12 years based on the current five year age of the room and the requirement for a further effective life of seven years to support the bin scale experiments (FSAR Addendum).

2. The bin locations are established along each rib of the room and a central access way 17 feet wide is maintained down the center of the room.

These functional requirements mean that not only must room stability be maintained but also that creep closure of the room should not impinge upon the envelopes for the access ways and for maintenance of the bins.

6.2 GEOTECHNICAL DESIGN BASIS FOR THE ROOF SUPPORT SYSTEM FOR ROOM 1, PANEL 1

A geotechnical design basis has been developed from the discussions presented in Section 5. The design provides a system support of the roof in Room 1, Panel 1 to meet the functional requirements described in Section 6.1. The geotechnical design basis is as follows:

- The support system shall support the weight of the detached rock wedge that forms in the roof as a result of the development of low angled fractures from the ribs.

- The support system shall accommodate vertical movements of the roof that include both differential and total displacements.

- The support system shall accommodate lateral shifts

These requirements are discussed in the following sections in terms of the bounding values that encompass the conditions expected to be encountered in the field.

6.2.1 ROCKLOAD TO BE SUPPORTED

The weight of the detached rock wedge that forms in the roof depends on the orientation of the fractures that develop. An estimate for the geometry of the cross-section of the wedge that must be supported is given in Figure 6.1a. The estimate is based on the observations of the rock fall geometry seen in SPDV Test Room 1 and the interpretation contours of shear strain in the roof (Miller, 1991). The wedge geometry consists of an arched shape that forms from low angled fractures starting at the the ribs whose propagation are bounded and controlled by the bed separation occurring at the Anhydrite 'b'.

The design load for each rock anchor has been based on the maximum weight of rock that is predicted from the rock fall data. This only develop at midspan and it can be expected that the loads requiring support will reduce towards the ribs. A representation of the expected loads that will develop in each row of anchors across a cross-section is given in Figure 6.1b. Based on these estimates, the design load for each anchor has been taken as 20,000 lb.

The rock load will be supported in suspension by the rock anchors from overlying competent rock. The concept of transfer of part of the weight of weaker or thinner beds to flexures more rigid strata by rock bolts was originally described by Panek (1962, RI 6138). The mechanism is relatively simple and calculations based on it cover the problem os stabilization completely (Habenicht, 1983) However, despite the simple nature of the suspension process and the relatively simple analysis associated with the design approach, the calculations have a limited role in the design and must be supplemented by performance tests on the anchors. This is due to the uncertainties associated with rock mechanics data, such as rock properties their heterogeneity, stress fields and rock mass composition. Design calculations are made to provide a theoretical background, while the practical details of the design rely on practical site specific tests, field experience and field observations (Habenicht, 1983). For instance, it is possible that the irregularity in the shape of the planes of separation that outline a rock body and the unpredictability of potential fracture planes can significantly alter the volumes and therefore the weights of the rock load that is being designed to be held.

6.2.2 VERTICAL MOVEMENTS

The vertical movements that the roof must accommodate are a combination of salt creep, dilation of the salt due to fracture development, and gravity effects once fractures have formed.

The total displacement has been taken as 38mm per year vertical lowering of the roof at midspan. The differential movement is taken as the difference between displacement of the roof at mid span and that close to the ribs. The differential movement to be accommodated by the design has been taken as a maximum of 25mm per year. Roof displacements are not always a maximum at mid span. Once fracturing becomes visible in the roof along one rib, then the field data shows that the roof deforms asymmetrically with one side lowering more rapidly than mid span or the other side.

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Fig 6.1 goes away

Fig 6.1a goes away completely

Fig 6.1b is replaced by Fig 4.1 of the Appendix D Geotechnical Monitoring Plan.

The rock between the anchors may break up as a result of the constraint being applied by the rock anchors. The broken rock will be supported by the system of lacing and mesh emplaced on the roof between the rows of rock anchors. In reality, it is expected that the roof rock will retain much of its inherent strength and the rock will bridge between the ground anchor supports located at nominal nine centers along the length of the room. This expectation is substantiated by the performance in SPDV Test Room 1 where the detached wedge remained a single unit and fell essentially intact.

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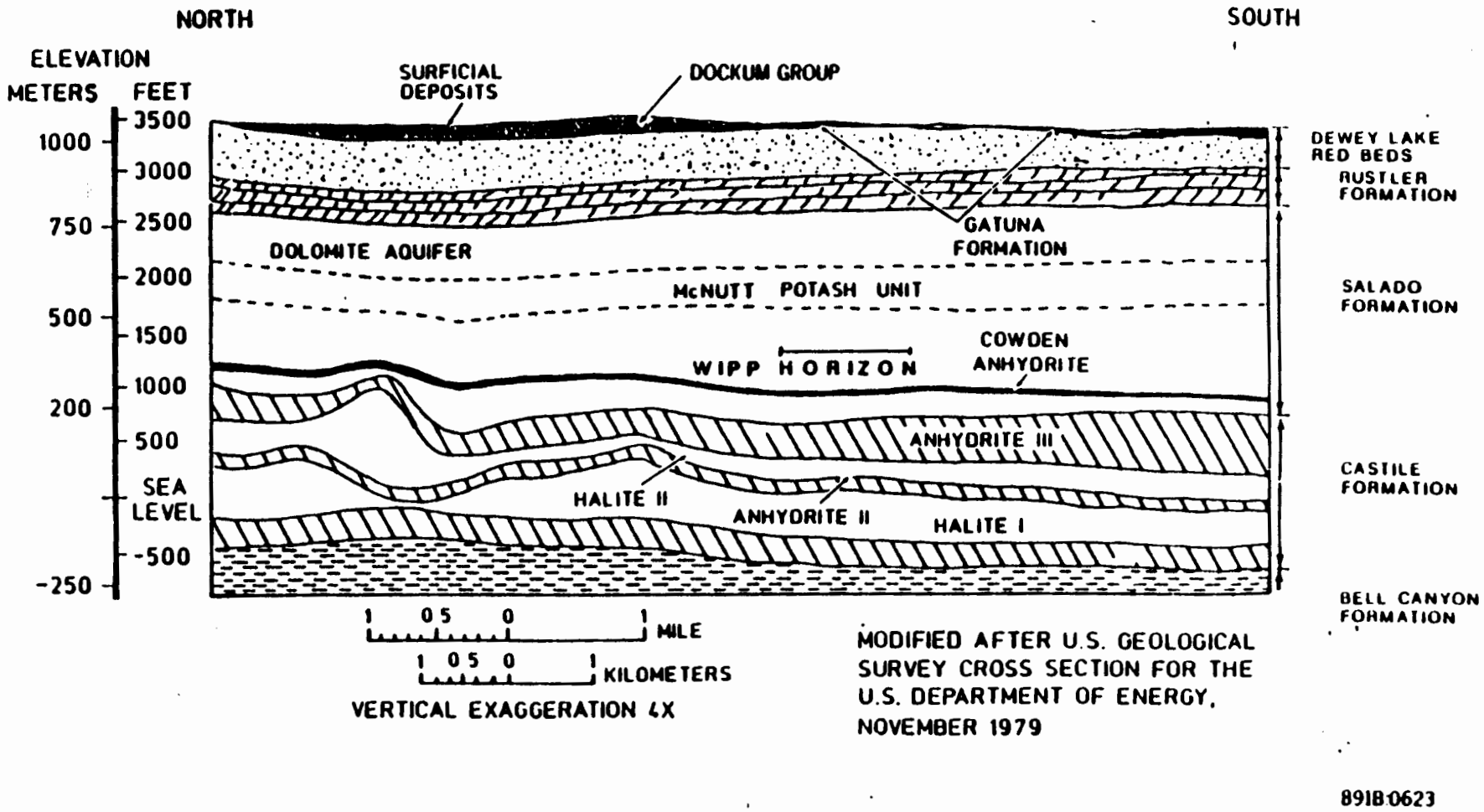


Figure 2.1 WIPP Site Stratigraphy

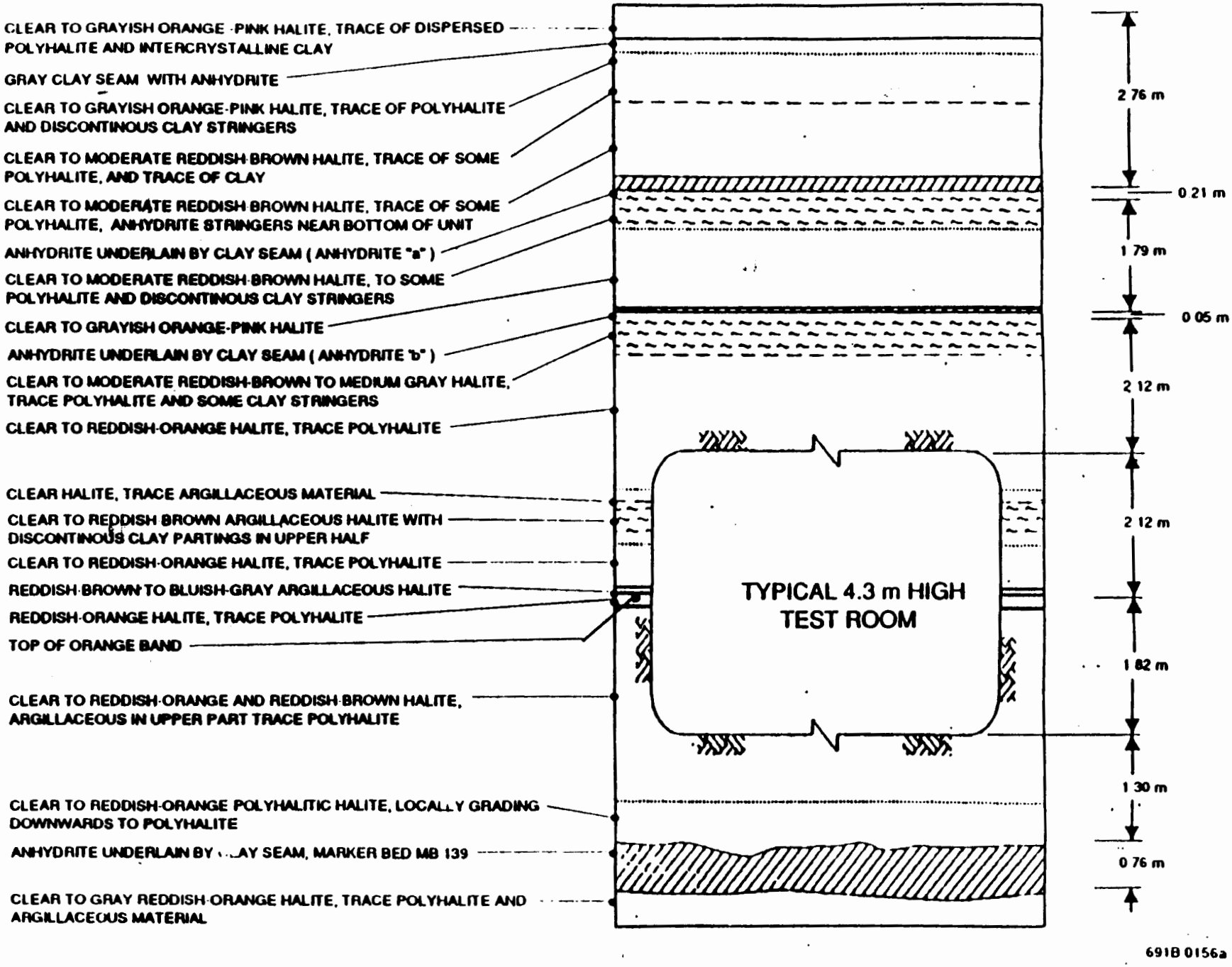


Figure 2.2 Stratigraphy of the WIPP Repository Horizon

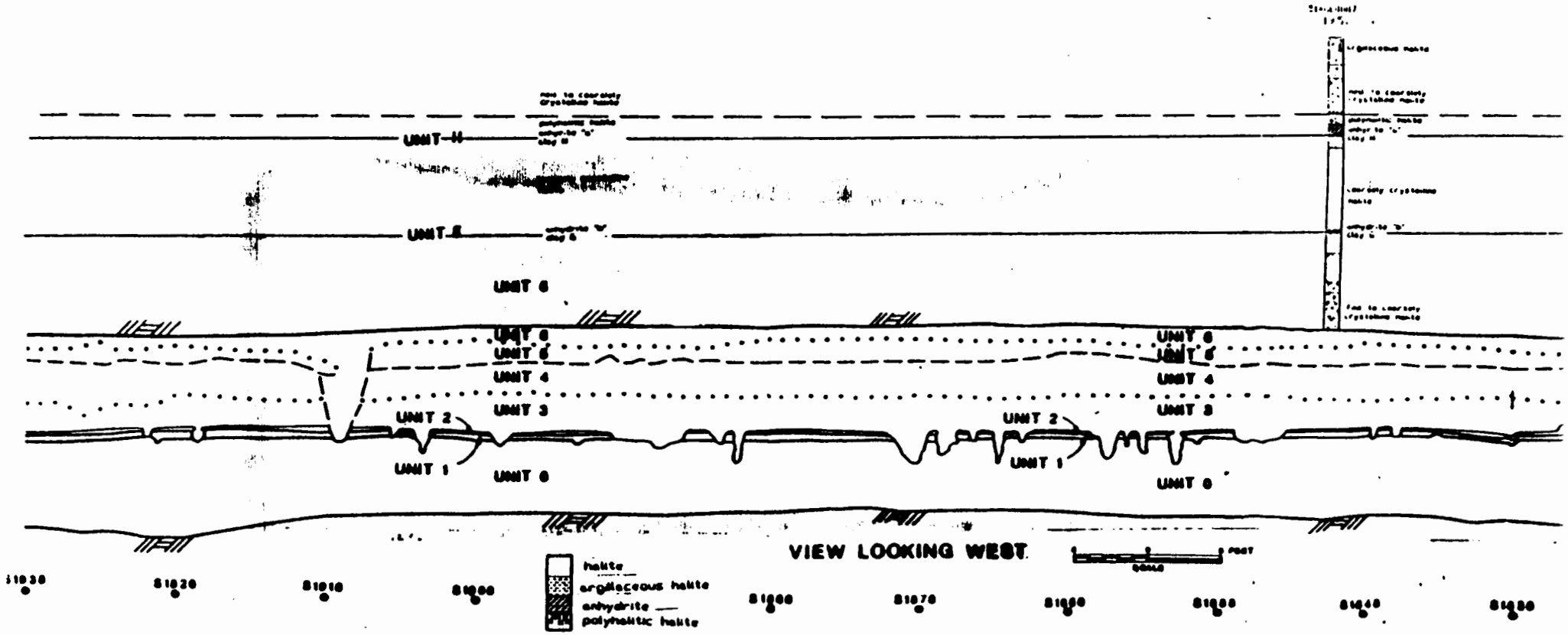


Figure 2.3a PANEL 1 - ROOM 1

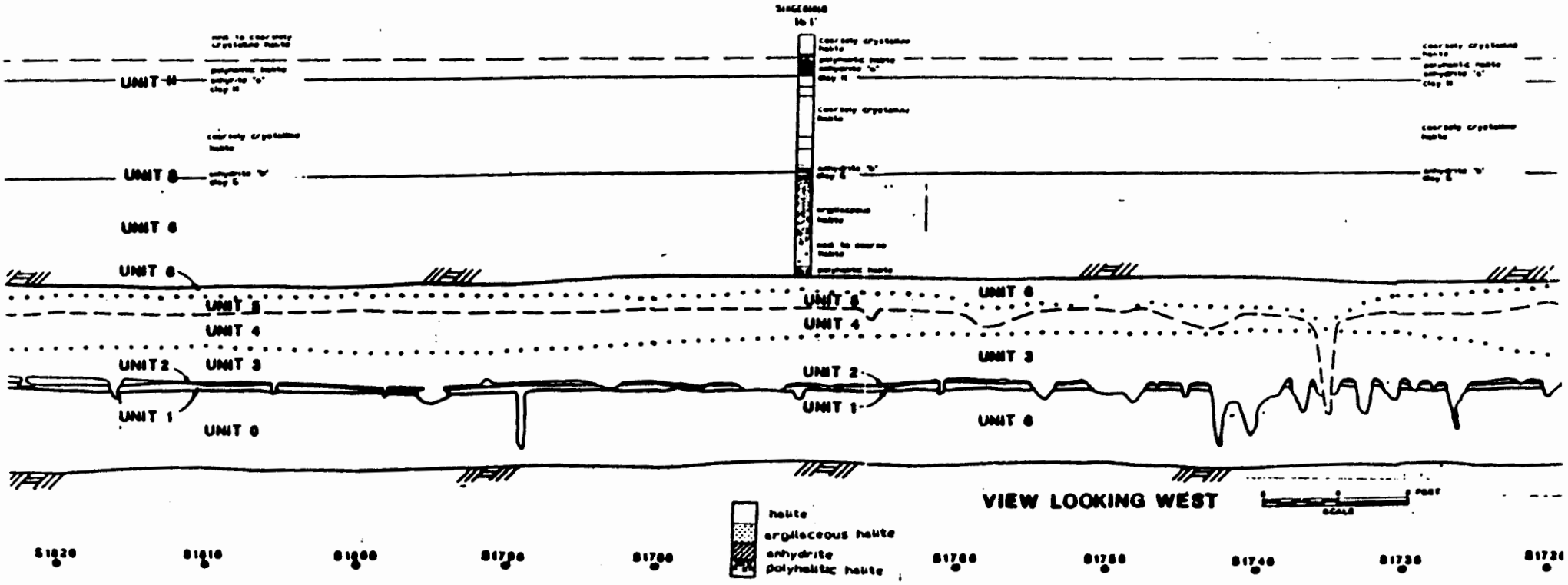


Figure 2.3b PANEL I - ROOM I

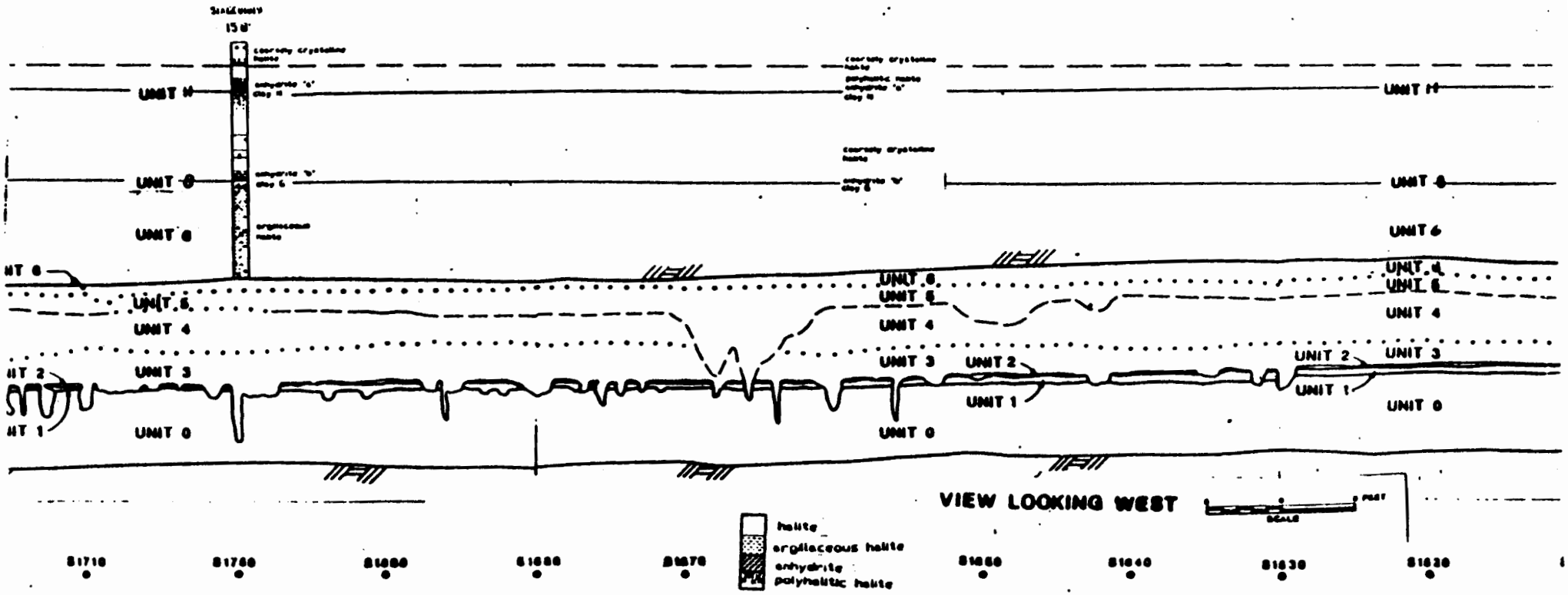


Figure 2.3c PANEL I - ROOM I

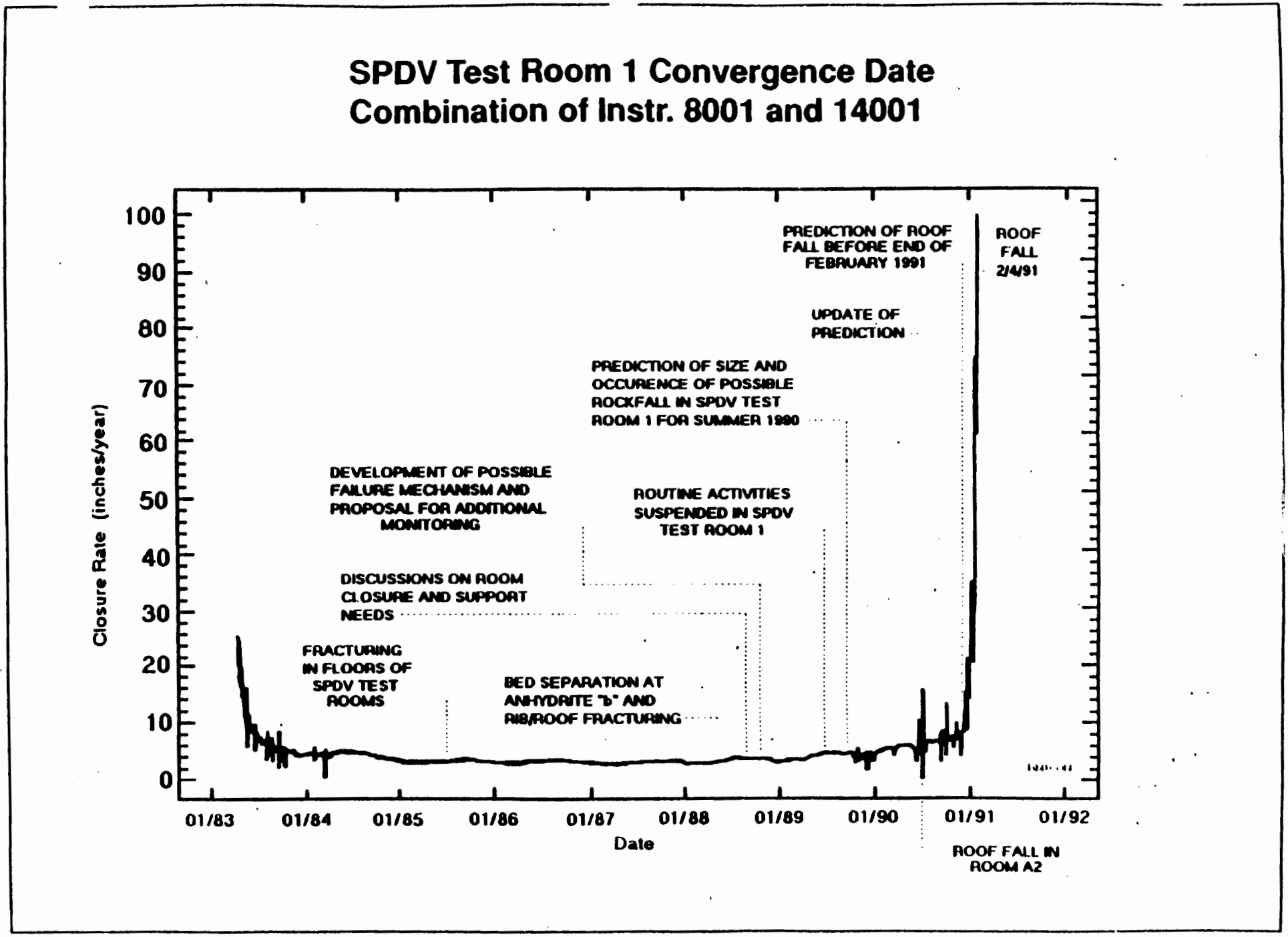
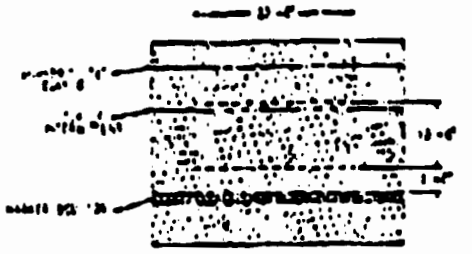
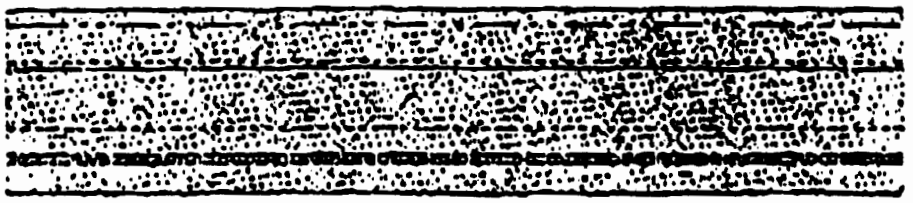

SPDV Test Room 1 Convergence Date
Combination of Instr. 8001 and 14001
Closure Rate (inches/year)
100
90
80
70
60
50
40
30
20
10
0
01/83
01/84
01/85
01/86
01/87
01/88
01/89
01/90
01/91
01/92
Date
PREDICTION OF ROOF FALL BEFORE END OF FEBRUARY 1991
ROOF FALL 2/4/91
UPDATE OF PREDICTION
PREDICTION OF SIZE AND OCCURENCE OF POSSIBLE ROCKFALL IN SPDV TEST ROOM 1 FOR SUMMER 1990
DEVELOPMENT OF POSSIBLE FAILURE MECHANISM AND PROPOSAL FOR ADDITIONAL MONITORING
ROUTINE ACTIVITIES SUSPENDED IN SPDV TEST ROOM 1
DISCUSSIONS ON ROOM CLOSURE AND SUPPORT NEEDS
FRACTURING IN FLOORS OF SPDV TEST ROOMS
BED SEPARATION AT ANHYDRITE "b" AND RIB/ROOF FRACTURING
ROOF FALL IN ROOM A2
891B 0438

Figure 5.1



SECTION A-A



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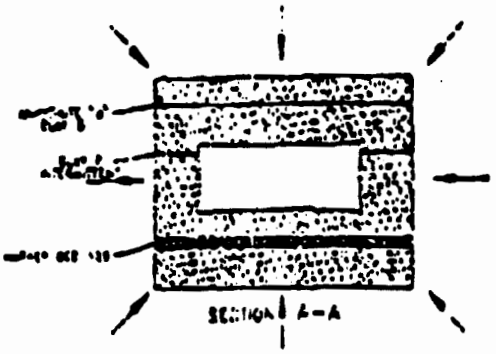

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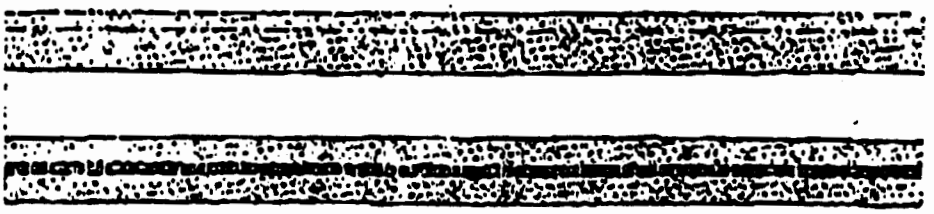

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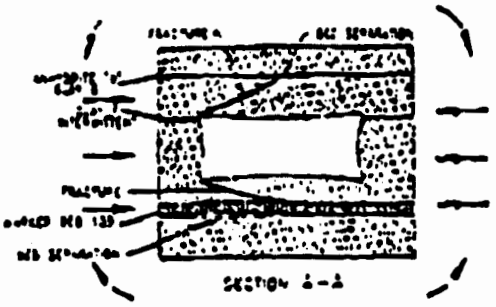

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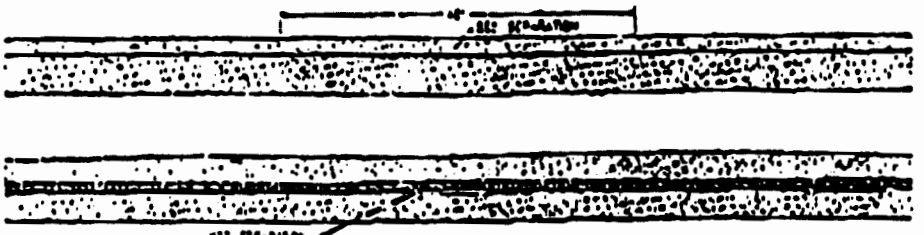

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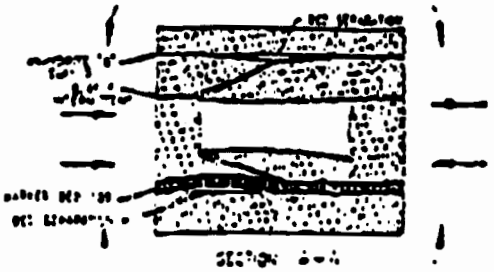

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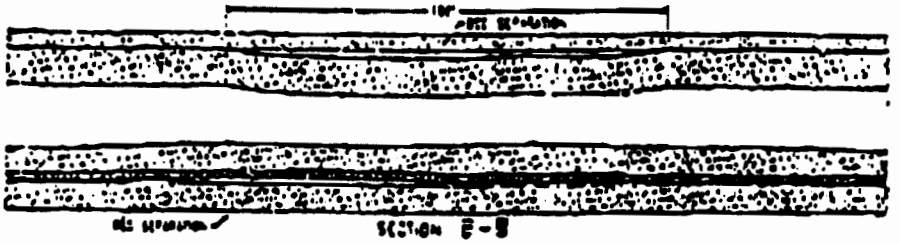

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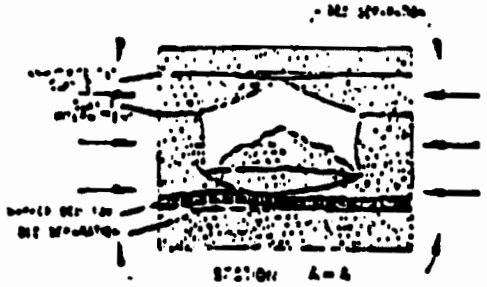

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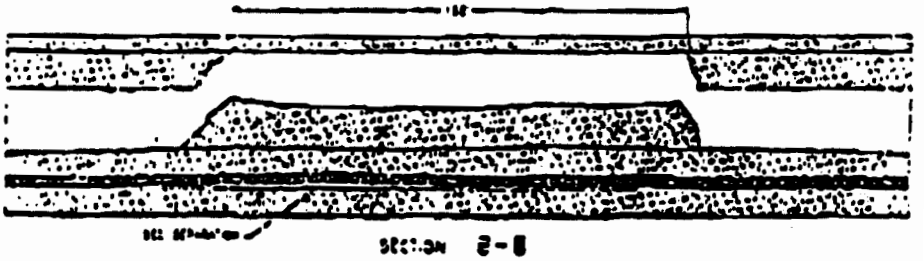
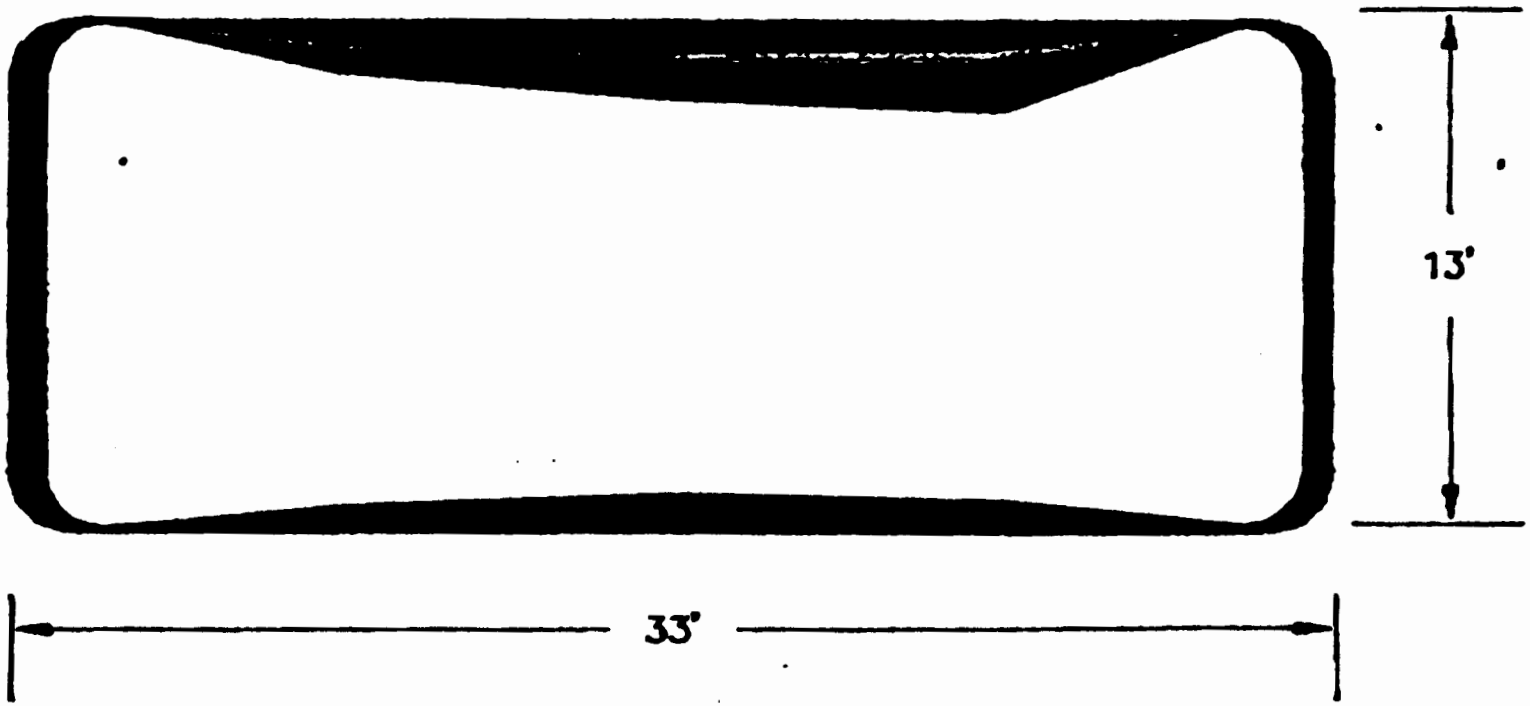


SECTION B-B

SPDV TEST ROOM 1 DEFORMATION

Section view looking north



YEAR 1 YEAR 5
YEAR 2
YEAR 3 YEAR 7
YEAR 4 YEAR 8

Deformations are shown at actual size.

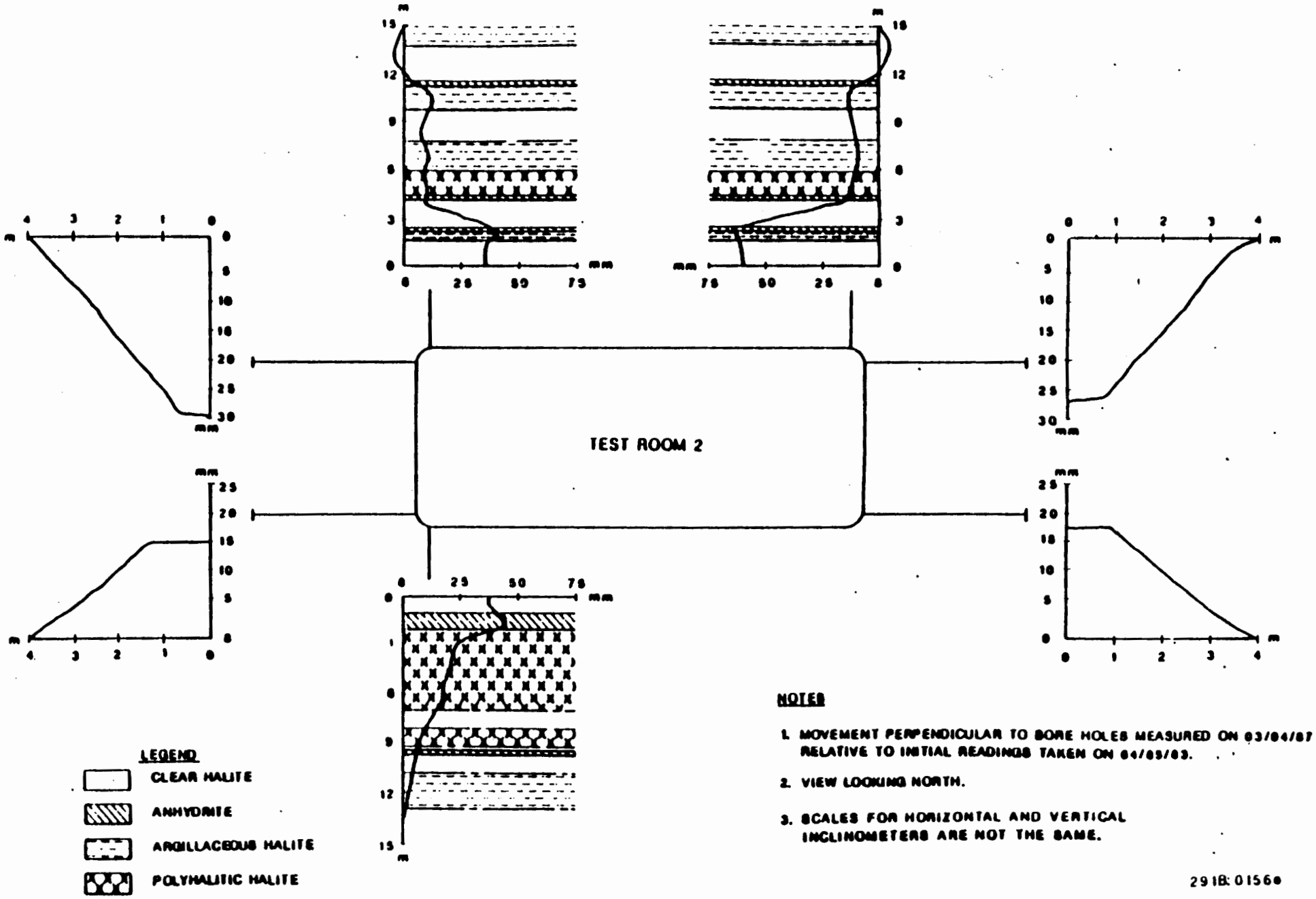


Figure 5.4 Inclinometer Data from SPDV Test Room 2

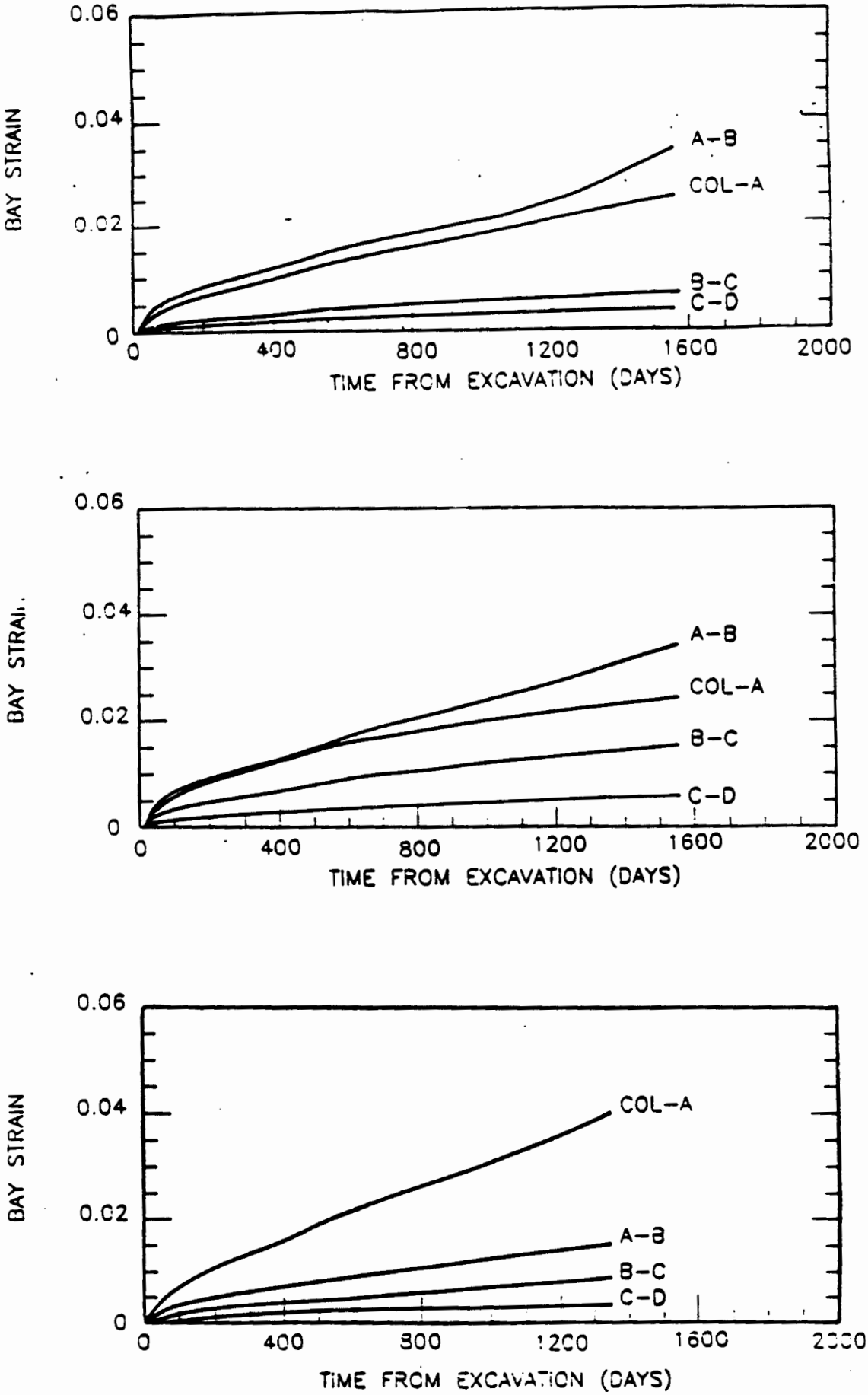
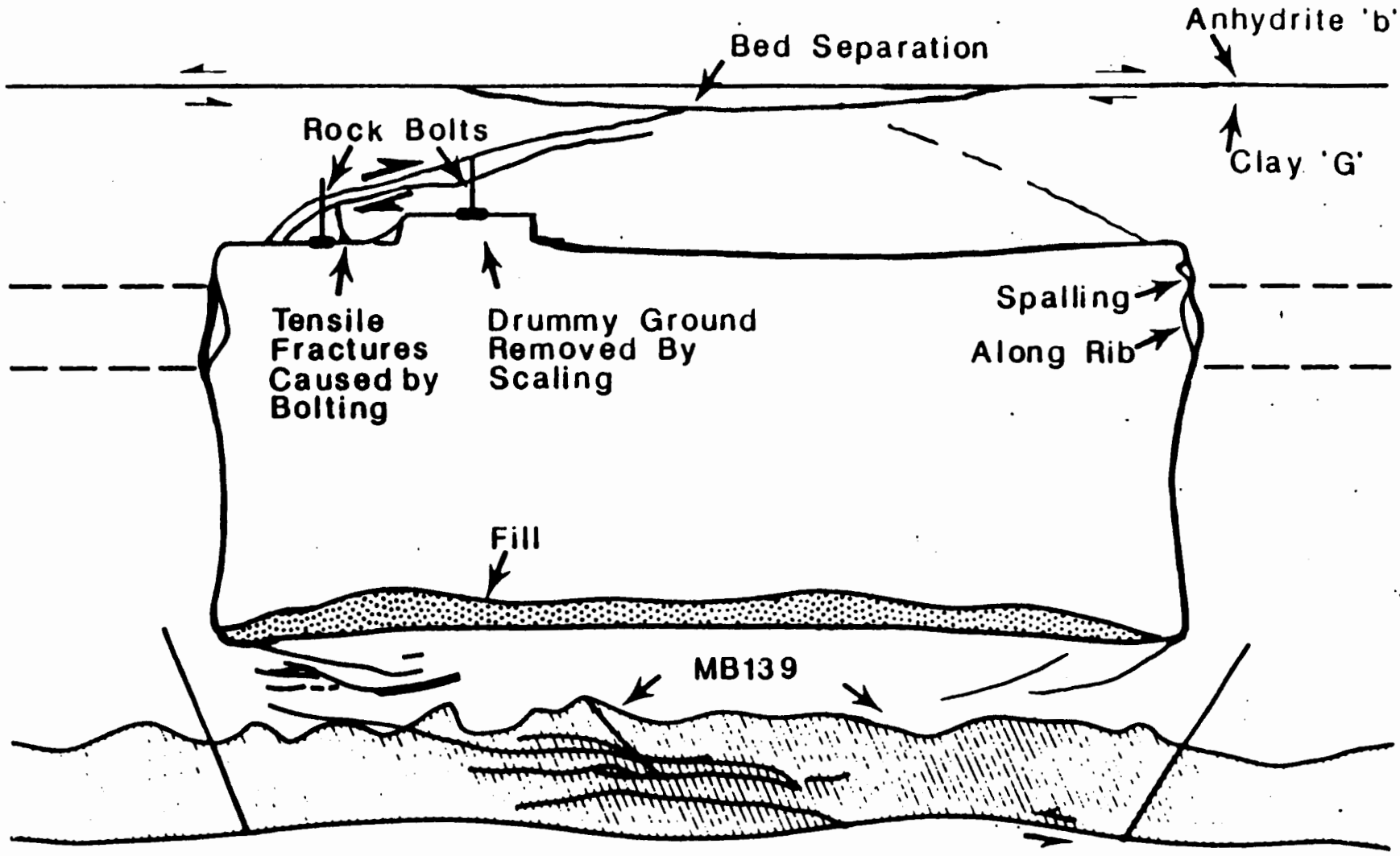
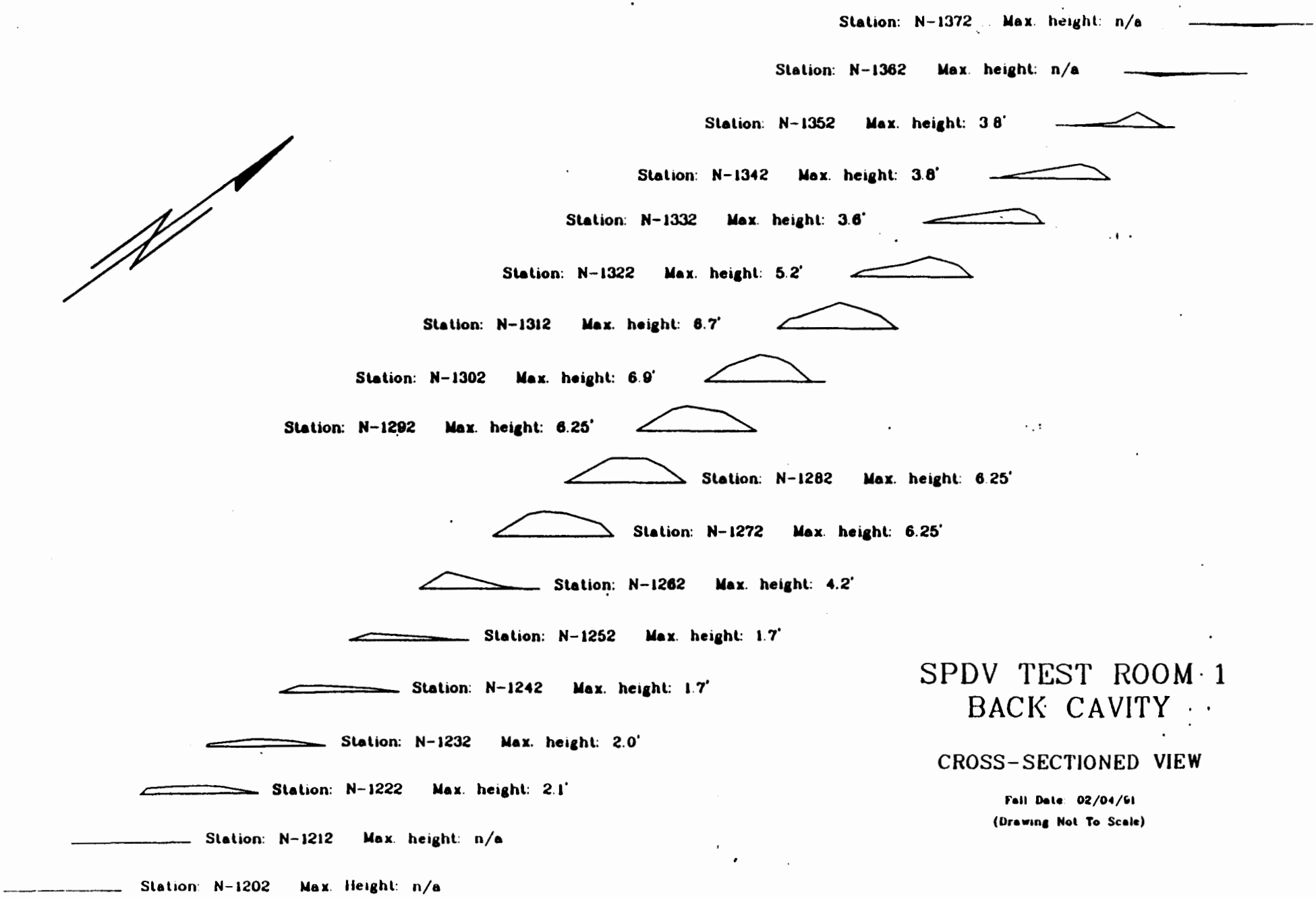


Figure 5.5 Extensometer Data from SPDV Test Rooms



29 IB 0156b

Figure 5.6 Patterns of Fracturing (Idealized excavation effects modified from Borns & Stormont, 1987)


Station: N-1372 Max. height: n/a
Station: N-1362 Max. height: n/a
Station: N-1352 Max. height: 3.8'
Station: N-1342 Max. height: 3.8'
Station: N-1332 Max. height: 3.6'
Station: N-1322 Max. height: 5.2'
Station: N-1312 Max. height: 6.7'
Station: N-1302 Max. height: 6.9'
Station: N-1292 Max. height: 6.25'
Station: N-1282 Max. height: 6.25'
Station: N-1272 Max. height: 6.25'
Station: N-1262 Max. height: 4.2'
Station: N-1252 Max. height: 1.7'
Station: N-1242 Max. height: 1.7'
Station: N-1232 Max. height: 2.0'
Station: N-1222 Max. height: 2.1'
Station: N-1212 Max. height: n/a
Station: N-1202 Max. Height: n/a
SPDV TEST ROOM 1
BACK CAVITY
CROSS-SECTIONED VIEW
Fall Date: 02/04/91
(Drawing Not To Scale)

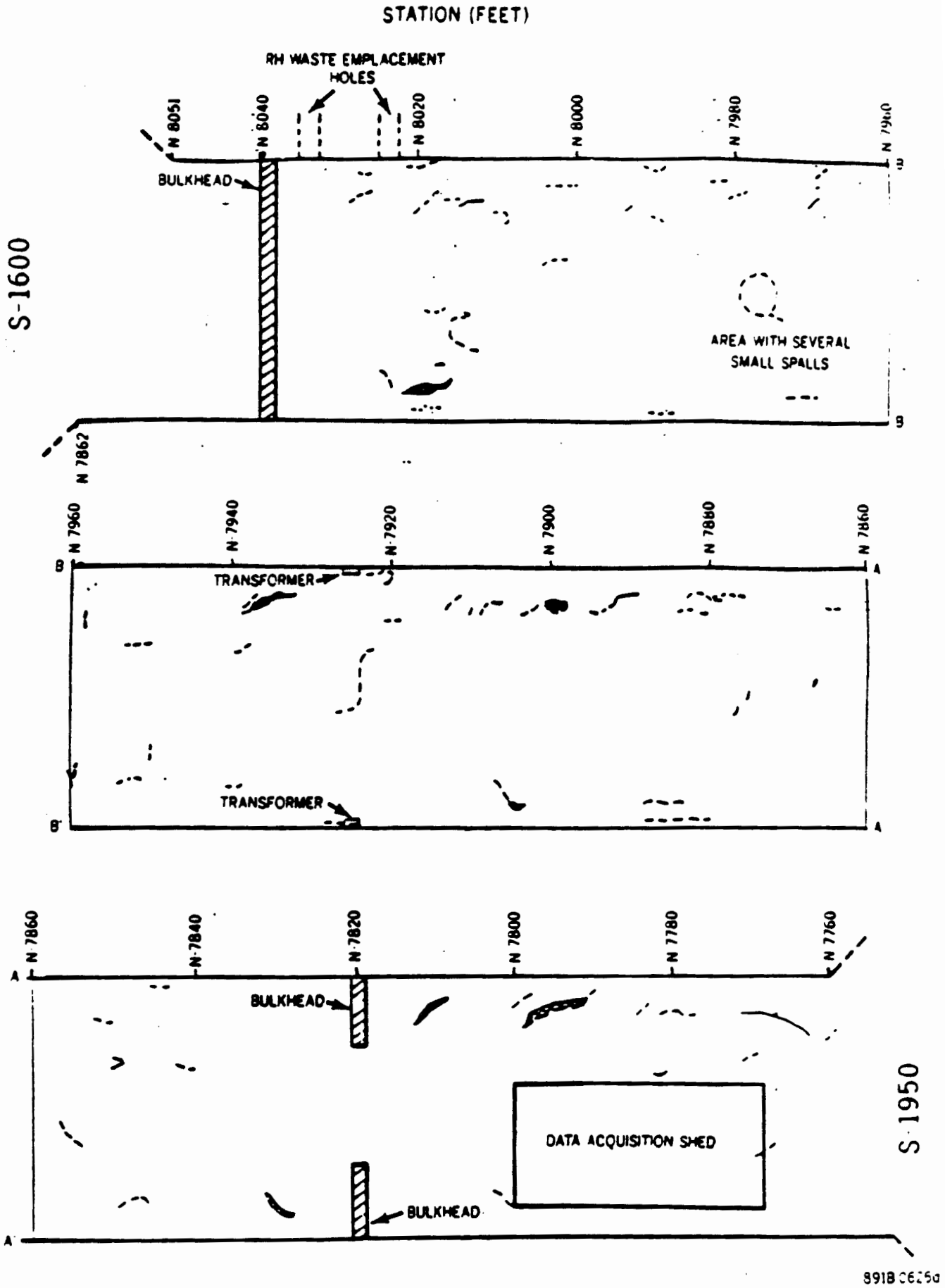
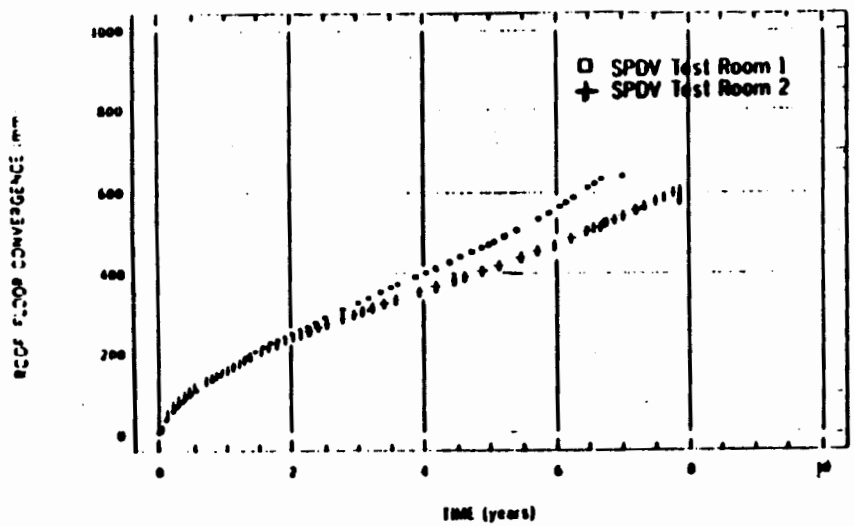


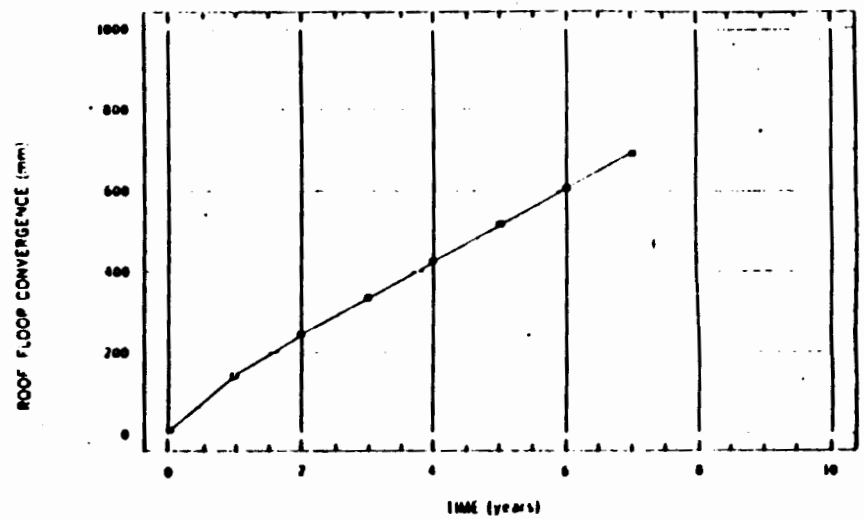
Figure 5.8 Back Fractures, Panel 1, Room 1 mapped on 2/12/91

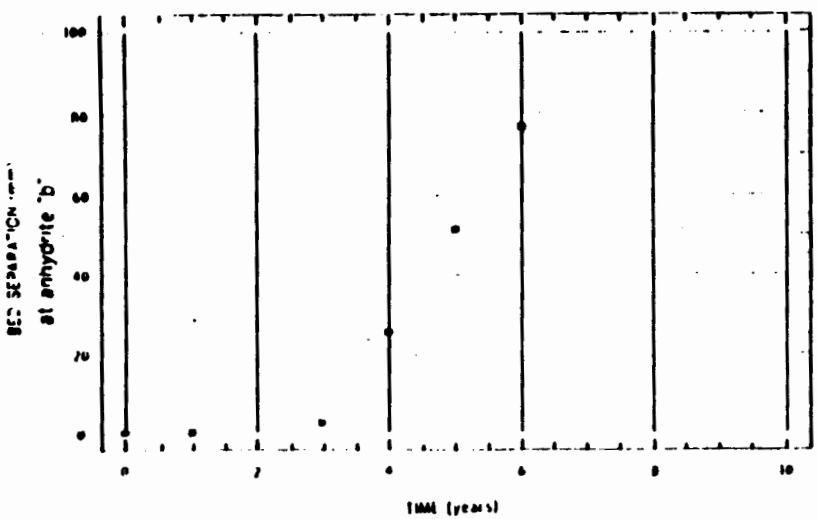
Figure 5.9

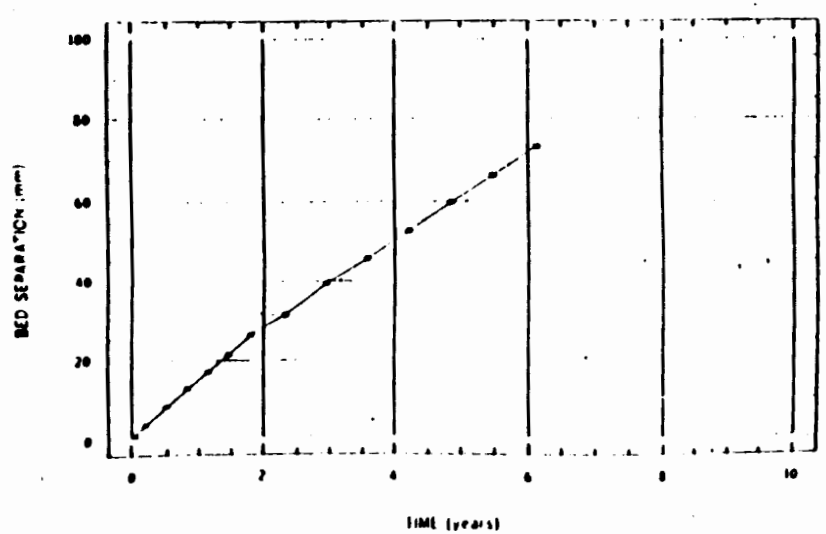
FIELD MEASUREMENTS

MODEL RESULTS

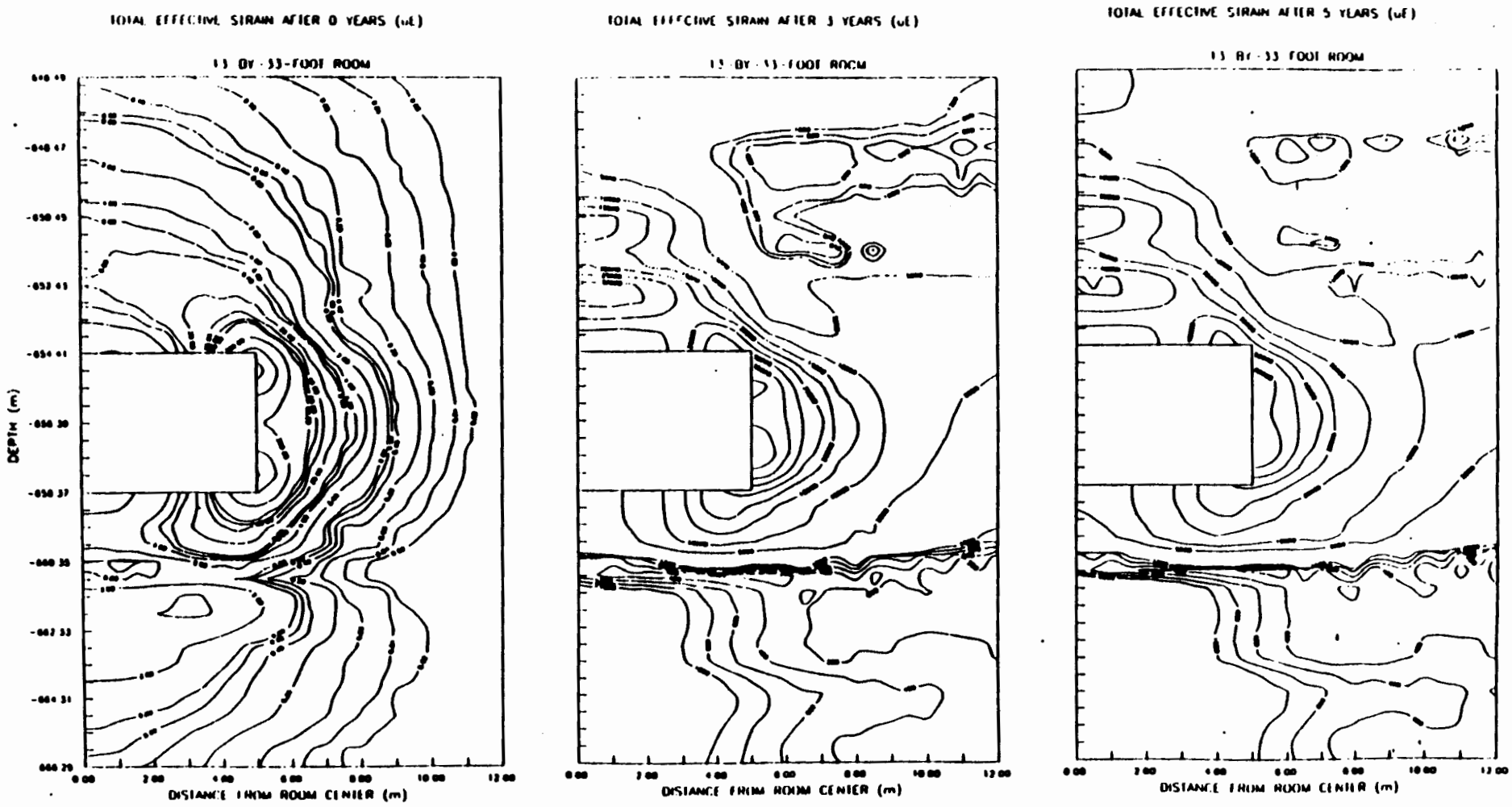




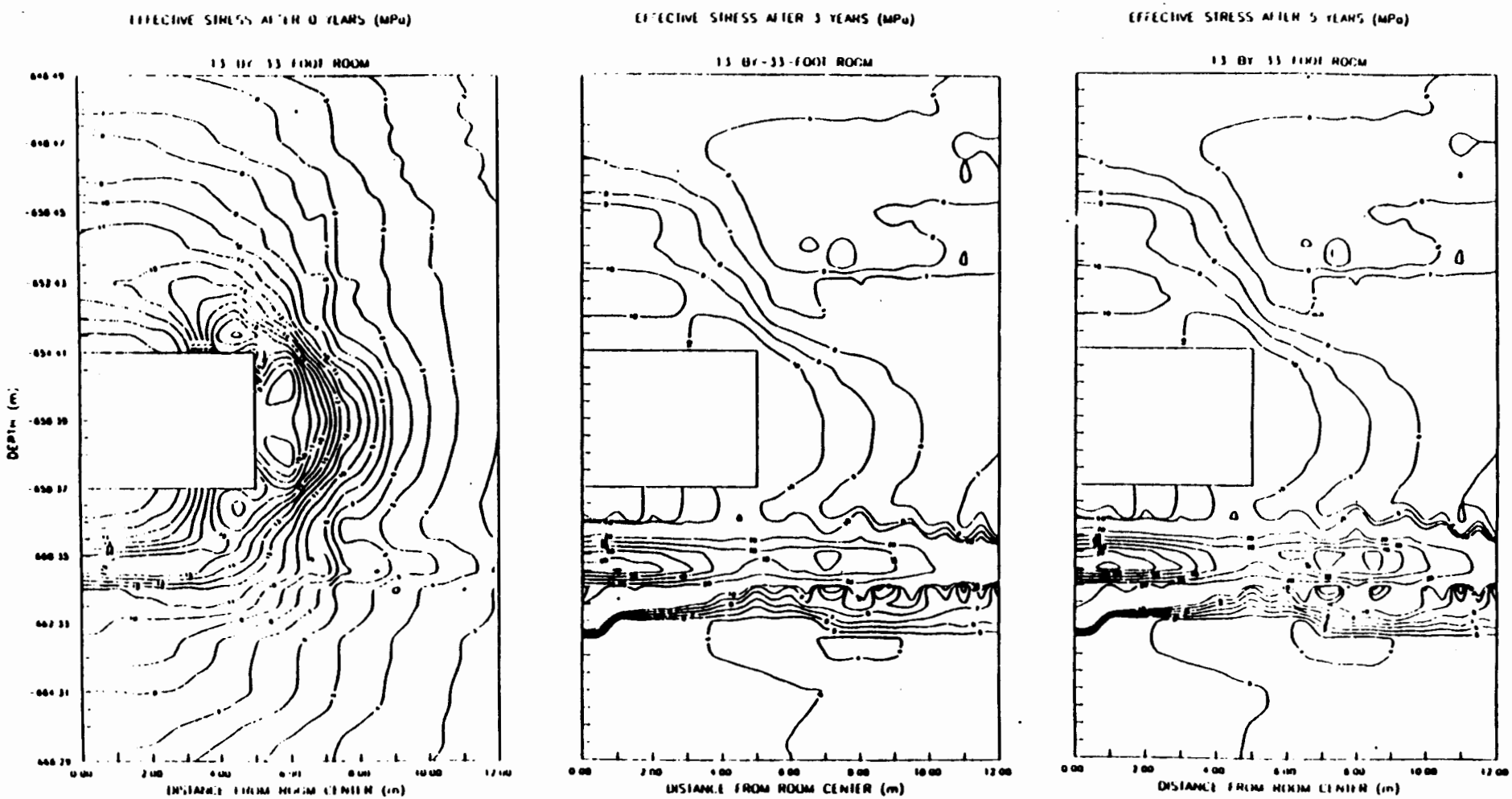




Figu. 5.10



8910606e


EFFECTIVE STRESS AFTER 0 YEARS (MPa)
13 BY 33 FOOT ROOM
DEPTH (m)
DISTANCE FROM ROOM CENTER (m)
EFFECTIVE STRESS AFTER 3 YEARS (MPa)
13 BY 33-FOOT ROOM
DISTANCE FROM ROOM CENTER (m)
EFFECTIVE STRESS AFTER 5 YEARS (MPa)
13 BY 33 FOOT ROOM
DISTANCE FROM ROOM CENTER (m)

89L0606c

APPENDIX B

DRAFT 09/10/91

WASTE ISOLATION PILOT PLANT
SUPPLEMENTARY ROOF SUPPORT SYSTEM

APPENDIX B

Destructive Tests

Westinghouse Electric Corporation
Waste Isolation Division
Carlsbad, New Mexico
August 1991

INTERNATIONAL MINING SERVICES INC.
RETYPED FAX RECEIVED FROM HAMISH MILLER

CONCLUSIONS FROM DESTRUCTIVE ROCKBOLT TESTS

The curves of load vs. extension were plotted for the 10 rockbolts that were tested to "failure". The points beyond which non-linear behavior occurred, were noted and these values are given in Table 1 below.

TABLE 1

TEST NO.	"YIELD" LOAD X 1,000 LB	BOLT STRESS AT "YIELD" PSI X 1,000
1	58.045	73.475
2	58.045	73.475
3	56.81	71.911
4	56.81	71.911
5	60.52	76.608
6	58.045	73.475
7	58.045	73.475
8	58.045	73.475
9	58.045	73.475
10	58.045	73.475

NOTE: "Yield" represents the point on the LOAD-EXTENSION curves where the curve departed from linearity. (see attached test results). The manufacturers of the Dywidag bolts give the "Yield Load" as 47.4 KIPS, which with a cross-sectional area of 0.79 sq. ins., gives a yield stress of 60,000 psi.

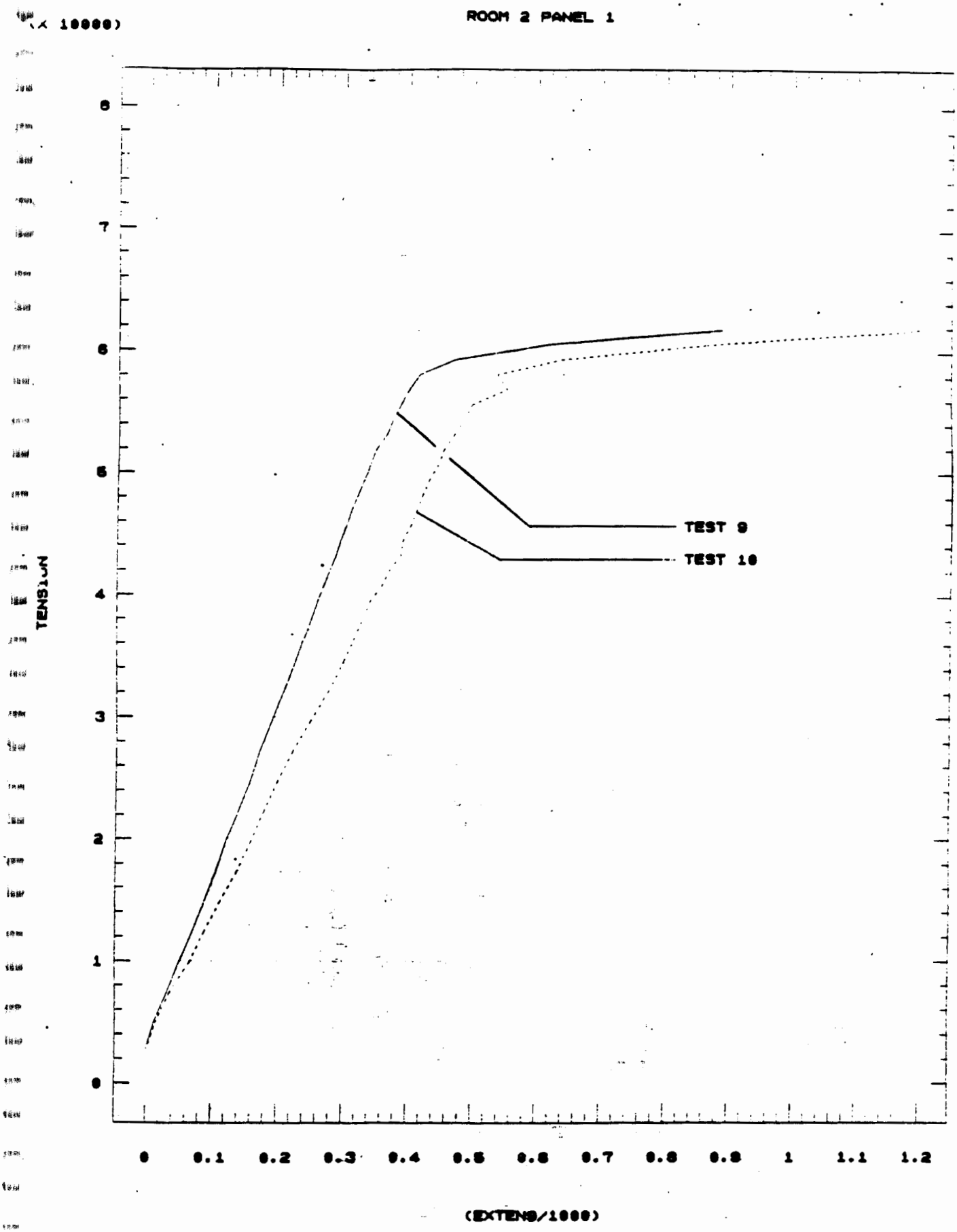
The results thus indicate that the mode of failure is that of bolt yield and not failure of the resin anchor bond.

There are slight indications of non-linearity in some of the test results, but it is felt that these are due to deformations of the plate and the "bedding-in" of the plate on the salt.

The test "yield" stresses are between 22% and 28% higher than the ASTM yield stress of 60,000 psi.

BOLT TENSION VERSUS EXTENSION

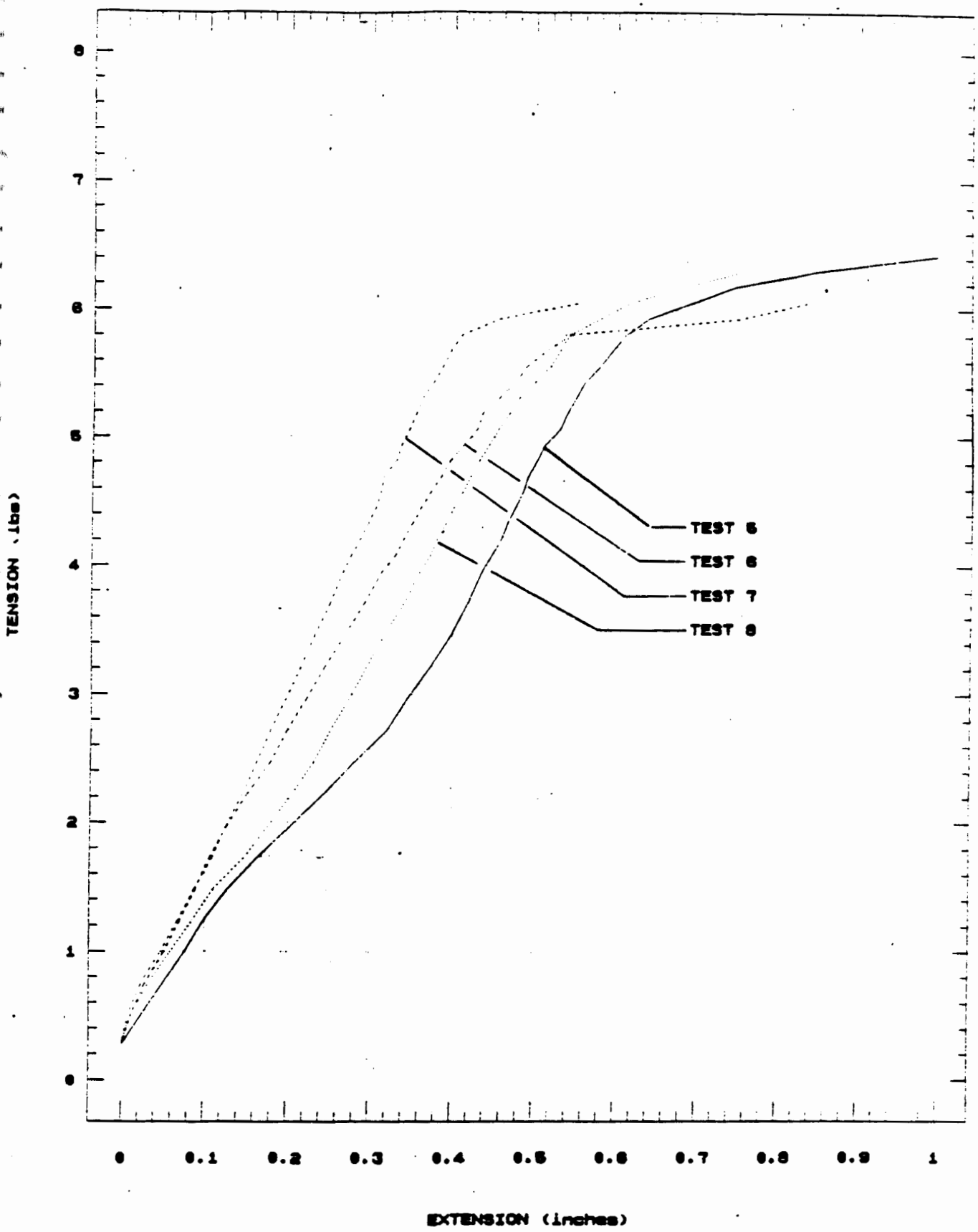
ROOM 2 PANEL 1



2 AND 3 DAYS CURE

BOLT TENSION VERSUS EXTENSION

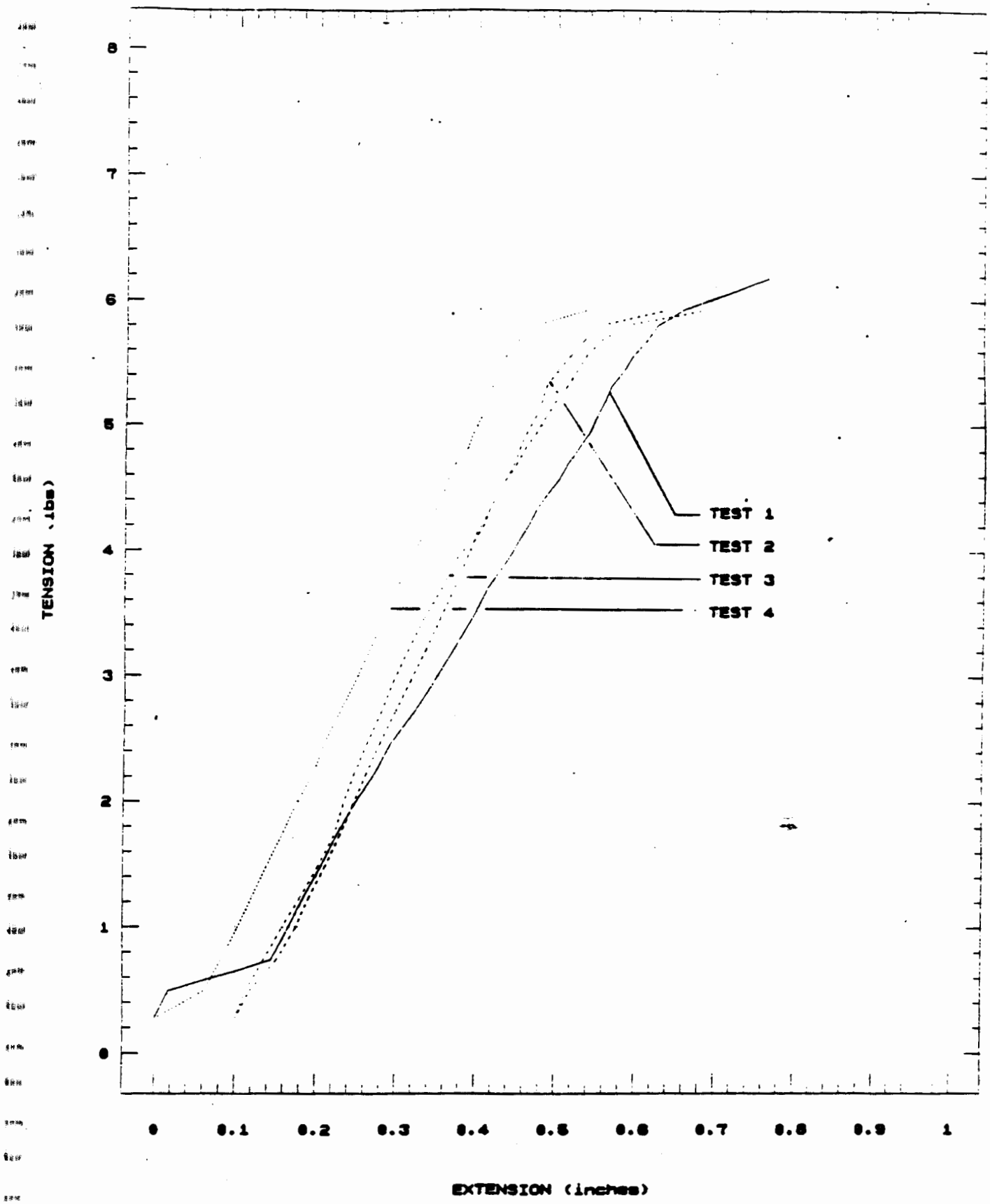
ROOM 2 PANEL 1



25 HOURS CURE

BOLT TENSION VERSUS EXTENSION

ROOM 2 PANEL 1



26 HOURS CURE

UNDERGROUND DRILLING HOLE FIELD DATA SHEET

Date: 8/13/91

Room/Drift: ROOM 2 - PANEL 1

Purpose of Hole: PULL TEST: DESTRUCTIVE (PWR 120172)
P+081391-7

Location: N. END 4+/ W Rand 45-50 FT. FROM N. BULKHEAD

Depth at Completion: 11'-7"

Diameter: 1 3/8" ϕ

Approximate Collar Coordinates

Vertical Angle: VERT. (5° TOLERANCE)

Direction/Azimuth:

Remarks: RESIN / ROCK ANCHOR TEST AT 1:05 PM (
AND COMPLETED AT 2:00 PM FOR
CERTIFICATION.

Signature/Department: D. Gallegos 8/16/91

Test 10

ROCK BOLT CERTIFICATION TEST
DATA SHEET

Mine _____ Rock _____ Rock Bolt No. PT081391-7
Hole Location PANEL - ROOM 7

Hole Length - ____ Dia. - @ Anchor _____/@ midpoint _____/@ collar ____
Orientation - _____

Bolt Grade - _____ Length - _____ Diameter - _____

Shell Manufacturer - _____ Model - _____ Diameter - _____
Length - _____

Resin Manufacturer - _____ Model - _____ Diameter - _____
Length - _____ No. Cartridges - _____

Installation Date - _____ Time - _____ Torque - _____ ft/lb

Test Date - _____ Time - _____ Torque - _____ ft/lb
Test Jack - _____ Test Pump - _____
Dial Indicator - _____ Calibrated - _____
Pressure Gauge - _____ Calibrated - _____

Pump Pressure	Bolt Tension	Extensometer Reading	Displacement	Remarks
~~52~~			Ram 2 ft	At 5800 Holding at 5500 / 8100 psi
~~58~~				/ 67,000#
~~56~~				
~~57~~				

Test Results _____ Maximum Pull Force - _____
Displacement at Maximum Pull Force - _____
Nature of Failure/Yield - _____
Other Remarks _____
Tested By - D. Bellwant Approved By - [illegible]

ROCK BOLT CERTIFICATION TEST
DATA SHEET

Mine WIPP Rock HALITE Rock Bolt No. PT081391-6 Hole Location PANEL 1 - ROOM 2

Hole Length - 11'-7" Dia. - @ Anchor GAUGED /@ midpoint N/A /@ collar N/A
Orientation - VERT. (5° TOLERANCE) SMOOTH

Bolt Grade - GD60 Length - 12'-11 7/8" Diameter - #8

Shell Manufacturer - N/A Model - N/A Diameter - N/A
Length - N/A

Resin Manufacturer - CELTITE Model - HSD-0204 Diameter - 1 1/4"
Length - 12" No. Cartridges - 3

Installation Date - 08/13/91 Time - 11:04 am Torque - N/A ft/lb

Test Date - 8/15/91 Time - 12:50 PM Torque - N/A ft/lb
Test Jack - RC-60-CH 9.5A Test Pump - RC-60-CH 9.5 SN 23886
Dial Indicator - AMES CD-0040 Calibrated - DUE 10-4-91
Pressure Gauge - U.S. GAUGE DSI # 001 Calibrated - 08/06/91

PSI x 100 Pump Pressure	Bolt Tension LBS	Extensometer Reading	Displacement	Remarks
2	2470	0.000		
4	4940	0.012		
6	7410	0.032		
8	9880	0.050		
10	12350	0.070		
12	14820	0.088		
14	17290	0.105		
16	19760	0.121		
18	22,230	0.140		
20	24,700	0.158		
22	27,170	0.172		
24	29,640	0.190		
26	32,110	0.207		
28	34,580	0.224		
30	37,050	0.244		
32	39,520	0.260		
33	40,755	0.267		
34	41,990	0.275		
35	43,225	0.280		
36	44,460	0.285		
37	45,695	0.304		
38	46,930	0.311		
39	48,165	0.321		
40	49,400	0.331		
41	50,635	0.340		
42	51,870	0.347		
43	53,105	0.365		
44	54,340	0.375		
45	55,575	0.387		
46	56,810	0.392		
47	58,045	0.416		
48	59,280	0.470		
49	60,515	0.616		
50		0.886 *		
51				
52				
53				

Block to 4900 PSI
Remove Dial Indicator 8/15/91
Block to 4700 PSI
After 5 min. Block to 4900 PSI
Remove Dial Indicator *
Bolt Yield @ 34800
Terminate Test @ 1:20 PM

Test Results - ACCEPTED Maximum Pull Force - 59,280# 64,220#
Displacement at Maximum Pull Force - Approx. .886 in
Nature of Failure/Yield - Bolt Yield @ 34800 PSI
Other Remarks @ 49.8 HRS AFTER INSTALLATION: HELD AT
Tested By - D. Dettmann Approved By - [signature] 8.16.91

UNDERGROUND DRILLING HOLE FIELD DATA SHEET

Date: 8/13/91

Room/Drift: PANEL 1 - ROOM 2

Purpose of Hole: PULL TEST: DESTRUCTIVE (PWR120177)
DT081391-6

Location: N END 4' W ROOM & 36-40 FT. FROM N. BULKHEAD

Depth at Completion: 11'-7"

Diameter: 1 3/8" ϕ COMPLETION

Approximate Collar Coordinates

Vertical Angle:

Direction/Azimuth: VERT. (5° TOLERANCE)

Remarks: RESIN / ROCK ANCHOR TEST AT 12:50 PM AND COMPLETED AT 2:45 PM FOR CERTIFICATION.

Signature/Department: D. Galbraith 8/15/91

ROCK BOLT CERTIFICATION TEST
DATA SHEET

Mine _____ Rock _____ Rock Bolt No. PT081391-6 Hole Location _____

Hole Length - ____ Dia. - @ Anchor _____/@ midpoint_____/@ Collar ____
Orientation - _____

Bolt Grade - _____ Length - _____ Diameter - _____

Shell Manufacturer - _____ Model - _____ Diameter - _____
Length - _____

Resin Manufacturer - _____ Model - _____ Diameter - _____
Length - _____ No. Cartridges - _____

Installation Date - _____ Time - _____ Torque - _____ ft/lb

Test Date - _____ Time - _____ Torque - _____ ft/lb
Test Jack - _____ Test Pump - _____
Dial Indicator - _____ Calibrated - _____
Pressure Gauge - _____ Calibrated - _____

Pump Pressure	Bolt Tension	Extensometer Reading	Displacement	Remarks
~~54~~				CONTINUE 1:30 PM
~~55~~			ATP 4900	Holding AT 4900 PSI 1 1/2" RAM 59200# 1:35 PM
~~56~~				
~~57~~			ATP 5000	Holding AT 4900 PSI 1 3/4" RAM 60315# 1:40
			ATP 5200	Holding AT 5000 PSI 1 3/4" RAM 61350# 1:46 PM
			ATP 5200	Holding AT 5000 PSI 1 3/4" RAM 61760# 2:00 PM
			5300 ATTEMPTING	Holding AT 5100 PSI 1 3/4" RAM 62985 2:07 PM
			ATP. 5400	Holding AT 5200 PSI 2" RAM 64200# 2:13 PM
			ATP. 5500	Holding AT 5300 2 1/8" RAM 65455# 2:25 PM
			ATP 5600	Holding AT 5400 PSI 2 1/4" RAM 66690# 2:33
			ATP 5700	Holding AT 5500 PSI 2 3/16 RAM 67925# 2:40
			ATP 5800	Holding AT 5600 PSI 2 1/2" RAM 69160# 2:45
			ATP 5900	Holding AT 5700 PSI 2 5/8" RAM 70395#
			08/16/91	BLED TO 5200 PSI 12:40 PM 64320#
				MAX PULL FORCE

Test Results - _____ Maximum Pull Force - _____
Displacement at Maximum Pull Force _____
Nature of Failure/Yield - _____
Other Remarks _____
Tested By - D. Palmer Approved By - [illegible]

ROCK BOLT CERTIFICATION TEST
DATA SHEET

Mine WIPP Rock HALITE Rock Bolt No. PT081391-1
Hole Location PANEL - ROOM 2

Hole Length - 11.50" Dia. - @ Anchor GAUGED /@ midpoint N/A /@ collar N/A
Orientation - VERTICAL (5° TOLERANCE) SMOOTH

Bolt Grade - G80 Length - 13'-0" Diameter - #8

Shell Manufacturer - N/A Model - N/A Diameter - N/A
Length - N/A

Resin Manufacturer - CELTITE Model - HPD-0204 Diameter - 1 1/4"
Length - 12" No. Cartridges - 3

Installation Date - 08/13/91 Time - 10:16 Torque - N/A ft/lb

Test Date - 8/14/91 Time - 11:30 Torque - N/A ft/lb
Test Jack - RC-60-CH 95A Test Pump - RC-60-P95 SN# 23886
Dial Indicator - AMES 4422 CD-0040 Calibrated - DUE 10-14-91
Pressure Gauge - US GAGE PSI #001 Calibrated - 08-06-91

PSI Pump Pressure	LBS Bolt Tension	Extensometer Reading	Displacement	Remarks
200	2470	0.000		
400	4940	0.062	08/14/91	
600	7410	0.082		
800	9880	0.102		
1000	12350	0.120		
1200	14820	0.138		
1400	17290	0.157		
1600	19760	0.174		
1800	22230	0.194		
2000	24700	0.210		
2200	27170	0.229		
2400	29640	0.248		
2600	32110	0.266		
2800	34580	0.282		
3000	37050	0.300		
3200	39,520	0.319		
3300	40755	0.328		
3400	41990	0.338		
3500	43225	0.347		
3600	44460	0.356		
3700	45695	0.363		
3800	46930	0.372		
3900	48165	0.388		HOLD 1 MIN - BLEED SLIGHTLY TO 3900
4000	49400	0.399	0.394 DB 8-14-91	
4100	50635	0.404		
4200	51870	0.409		
4300	53105	0.419		
4400	54340	0.425		
4500	55575	0.435		
4600	56810	0.451		HELD - BLED BACK TO 4600 B.J.
4700	58045	0.474		REMOVED DIAL INDICATOR DB 8/14/91
4800	59280	0.539		ATTEMPTED 4900 BLED TO 4700
4900				REMOVED DIAL INDICATOR
5000				HELD FOR 5 MIN. BLED TO 4600
5100				PUMPED 4800 PSI HELD AT 4800
5200				WORD BY GO TO 4900
5300				TEST TERMINATED @ 12:05 PM

39,520#

Test Results - ACCEPTED Maximum Pull Force - 59280 #
Displacement at Maximum Pull Force - .539 in.
Nature of Failure/Yield - BOLT YIELD 4600 PSI to 4700 PSI
Other Remarks - 28.3 HRS AFTER INSTALLATION
Tested By - D. Ballinger Approved By - R.E. Bundy

UNDERGROUND DRILLING HOLE FIELD DATA SHEET

Date: 8/13/91

Room/Drift: PANEL 1 - ROOM 2

Purpose of Hole: PULL TEST: DESTRUCTIVE (PWTR 120177)

PT081391-1

Location: N. END APPROX 4'-1" W ℄ ROOM ℄ APPROX. 4-6 FT FROM BULKHEAD

Depth at Completion: 11'-7"

Diameter: 1-3/8" ϕ COMPLETION

Approximate Collar Coordinates

Vertical Angle: VERT. (5° TOLERANCE)

Direction/Azimuth:

Remarks: RESIN/ROCK ANCHOR TESTED AT 11:30 am COMPLETED AT 12:05 PM FOR CERTIFICATION.

Signature/Department: D. Ballmann 8/14/91

ROCK BOLT CERTIFICATION TEST
DATA SHEET

Mine WIPP Rock HALITE Rock Bolt No. PTOB1391-2
Hole Location PANEL 1 - ROOM 2

Hole Length - 11.58' Dia. - @ Anchor GAUGED /@ midpoint N/A /@ collar N/A
Orientation - VERTICAL (5° TOLERANCE) SMOOTH

Bolt Grade - GR60 Length - 13'-0" Diameter - #8

Shell Manufacturer - N/A Model - N/A Diameter - N/A
Length - N/A

Resin Manufacturer - CELTITE Model - H90-0204 Diameter - 1 1/4"
Length - 12" No. Cartridges - 3

Installation Date - 08/13/91 Time - 10:31 AM Torque - N/A ft/lb

Test Date - 8/14/91 Time - 1:37 PM Torque - N/A ~~ft/lb~~
Test Jack - RC-60-CH 9.5A Test Pump - RC-60-CH 9.5 SN 28886 2382
Dial Indicator - AMES 4822 CD-0040 Calibrated - DUE 10.4.91
Pressure Gauge - USG 4815 PSI 8001 Calibrated - 08-06-91

PSI x100 Pump Pressure	LB Bolt Tension	Extensometer Reading	Displacement	Remarks
2	2470	0.000		
4	4940	0.023		
6	7410	0.049		
8	9880	0.075		
10	12350	0.098		
12	14820	0.138		
14	17290	0.169		
16	19760	0.209		
18	22230	0.248		
20	24700	0.281		
22	27170	0.320		
24	29640	0.349		
26	32110	0.373		
28	34580	0.398		
30	37050	0.418		
32	39520	0.435		
33	40755	0.447		
34	41990	0.458		
35	43225	0.466		
36	44460	0.475		
37	45695	0.485		
38	46930	0.491		
39	48165	0.502		
40	49400	0.512		
41	50635	0.516		
42	51870	0.535		
43	53105	0.550		
44	54340	0.560		
45	55575	0.579		
46	56810	0.595		
47	58045	0.611		REMOVE DIAL INDICATOR
48	59280	0.638		BLEED TO 4700 PSI
49		0.652		BLEED TO 4700 PSI 2 min
50	08/13/91	0.746		
51		0.846		
52		0.996		BLEED TO 4700 PSI
53				TERMINATED TEST 1:55 PM

Test Results - ACCEPTED Maximum Pull Force - 59280 #
Displacement at Maximum Pull Force - 0.996 in.
Nature of Failure/Yield - BOLT YIELD AT 1 4800 PSI
Other Remarks 22# 27.1 HCS AFTER INSTALLATION
Tested By - D. Ballinger Approved By - [illegible]

UNDERGROUND DRILLING HOLE FIELD DATA SHEET

Date: 8/13/91

Room/Drift: PANEL 1 - ROOM 2

Purpose of Hole: PULL TEST: DESTRUCTIVE (PWR 12017T)
PT081391-2

Location: N. END APPROX 4" W OF ROOM ℄ APPROX 12 FEET FROM N. BULKHEAD

Depth at Completion: 11'-7"

Diameter: 1 3/8" ϕ COMPLETION

Approximate Collar Coordinates

Vertical Angle: VERT. (5° TOLERANCE)

Direction/Azimuth:

Remarks: RESIN/ROCK ANCHOR TESTED AT 1:37 PM
AND COMPLETED AT 1:55 PM FOR
CERTIFICATION

Signature/Department: D. Ballweiler 8/14/91

ROCK BOLT CERTIFICATION TEST
DATA SHEET

Mine WIPP Rock NALITE Rock Bolt No. PT081391-3
Hole Location PANEL 1 - ROOM 2

Hole Length - 11'-7" Dia. - @ Anchor GAUGED /@ midpoint N/A /@ collar N/A
Orientation - VERTICAL (5° TOLERANCE) SMOOTH

Bolt Grade - GR60 Length - 13'-0" Diameter - #8

Shell Manufacturer - N/A Model - N/A Diameter - N/A
Length - N/A

Resin Manufacturer - CELTITE Model - H90-0204 Diameter - 1¼"
Length - 12" No. Cartridges - 3

Installation Date - 08/13/91 Time - 10:41 Torque - N/A ft/lb

Test Date - Time - 2:00 PM Torque - N/A 08/13/91 ft/lb
Test Jack - RC-60-CH 9.5A Test Pump - RC-60 CH95 SN 29886 23136
Dial Indicator - AMES CD-0040 Calibrated - DLF 10-4-91
Pressure Gauge - LG GAGE DSI ±001 Calibrated - 05-06-91

DSI x100 ~~Pump~~ Pressure	LBS ~~Bolt~~ Tension	Extensometer Reading	Displacement	Remarks
2	2470	0.000		
4	4940	0.011		
6	7410	0.028		
8	9880	0.050		
10	12350	0.069		
12	14820	0.088		
14	17290	0.106		
16	19760	0.127		
18	22230	0.151		
20	24700	0.179		
22	27170	0.199		
24	29640	0.222		
26	32110	0.244		
28	34580	0.268		
30	37050	0.292		
32	39520	0.313		
33	40755	0.329		
34	41990	0.335		
35	43225	0.352		
36	44460	0.360		
37	45695	0.372		
38	46930	0.385		
39	48165	0.396		Bled to 3800 PSI
40	49400	0.413		
41	50635	0.424		
42	51870	0.435		
43	53105	0.456		
44	54340	0.475		
45	55575	0.497		
46	56810	0.519		
47	58045	0.549		Bled to 4600 PSI ~~Remove Dial Indicator~~
48		0.749		Bled to 4600 PSI
49		0.834		Exceeded 4700 Bled to 4700 PSI
50				
51				
52				
53				Terminate Test 2:15 PM

Test Results - ACCEPTED Maximum Pull Force - 58045#
Displacement at Maximum Pull Force - 0.834 in.
Nature of Failure/Yield - Bar Yield 4700 PSIg
Other Remarks - 27.3 HRS AFTER INSTALLATION
Tested By - D. Ballmann Approved By - [illegible]

UNDERGROUND DRILLING HOLE FIELD DATA SHEET

Date: 8/13/91

Room/Drift: PANEL 1 - ROOM 2

Purpose of Hole: PULL TEST: DESTRUCTIVE (PWR 12017T)
PT081391-3

Location: N. END APPROX 4+' W ROOM ℄ APPROX. 15 FT FROM BULKHEAD

Depth at Completion: 11'-7"

Diameter: 1-3/8" ⌀ COMPLETION

Approximate Collar Coordinates

Vertical Angle: VERT. (5° TOLERANCE)

Direction/Azimuth:

Remarks: RESIN/ROCK ANCHOR TEST AT 2:00 pm AND COMPLETED AT 2:15
FOR CERTIFICATION

Signature/Department: D. Ballsiaw 8/14/91

ROCK BOLT CERTIFICATION TEST
DATA SHEET

Mine WIPP Rock HALITE Rock Bolt No. PT081391-4
Hole Location PANEL 1 - ROOM 2

Hole Length - 11'-7" Dia. - @ Anchor GAUGED /@ midpoint N/A /@ collar N/A
Orientation - VERT. (5° TOLERANCE) SMOOTH

Bolt Grade - GR 60 Length - 13'-0" Diameter - #8

Shell Manufacturer - N/A Model - N/A Diameter - N/A
Length - N/A

Resin Manufacturer - CELLITE Model - H90-0204 Diameter - 1 1/4"
Length - _____ No. Cartridges - _____

Installation Date - 08/13/91 Time - 10:51 am Torque - N/A ft/lb

Test Date - 08/14/91 Time - 2:25 PM Torque - N/A 08/13/91 ft/lb
Test Jack - RC-60-C49.5A Test Pump - RC-60-9.5 SN ~~23886~~ 23886
Dial Indicator - AMES CD-0040 Calibrated - DUE 10-8-91
Pressure Gauge - LEG GAGE DSN #001 Calibrated - 08/08/91 08/13/91
08/06/91

PSI X100 Pump Pressure	LBS Bolt Tension	Extensometer Reading	Displacement	Remarks
2	2470	0.000		
4	4940	0.007		
6	7410	0.023		
8	9880	0.046		
10	12350	0.067		
12	14820	0.089		
14	17290	0.109		
16	19760	0.126		
18	22230	0.146		
20	24700	0.162		
22	27170	0.179		
24	29640	0.197		
26	32110	0.215		
28	34580	0.232		
30	37050	0.250		
32	39520	0.266		
33	40755	0.275		
34	41990	0.286		
35	43225	0.295		
36	44460	0.305		
37	45695	0.311		
38	46930	0.313		
39	48165	0.330		
40	49400	0.336		
41	50635	0.346		
42	51870	0.354		
43	53105	0.362		
44	54340	0.375		
45	55575	0.386		
46	56810	0.396		Bled to 4600 PSI
47	58045	0.410		~~Remove Dial Indicator~~
~~48~~ 48	N	0.456		Bled to 4700 PSI
~~49~~ 49		0.518		
50				
51				
52				
53				TERMINATE TEST 2:35

Test Results - ACCEPTED Maximum Pull Force - 58045#
Displacement at Maximum Pull Force - 0.556
Nature of Failure/Yield - BOLT YIELD @ 4700 PSI
Other Remarks - N/A
Tested By - D. Fatheuer Approved By - [illegible]

UNDERGROUND DRILLING HOLE FIELD DATA SHEET

Date: 8/13/91

Room/Drift: PANEL 1 - ROOM 2

Purpose of Hole: PULL TEST : DESTRUCTIVE (PWR 120MT)
PT 081391-2

Location: N. END 4th W ROOM & APPROX. 28-30 FT FROM W. BULKHEAD

Depth at Completion: 11'-7"

Diameter: 1 3/8" ϕ COMPLETION

Approximate Collar Coordinates

Vertical Angle: VERT. (5° TOLERANCE)

Direction/Azimuth:

Remarks: RESIN/ROCK ANCHOR TEST AT 2:25 PM
AND COMPLETED AT 2:35 PM FOR CERTIFICATION.

Signature/Department: D. Balhram 8/14/91

ROCK BOLT CERTIFICATION TEST
DATA SHEET

Mine WIPP Rock HALITE Rock Bolt No. PTO81391-5
Hole Location PANEL 1-ROOM 2

Hole Length - 11'-7" Dia. - @ Anchor GAUGED /@ midpoint N/A /@ collar N/A
Orientation - VERT. (5° TOLERANCE) SMOOTH

Bolt Grade - GR60 Length - 13'-0" Diameter - #8

Shell Manufacturer - N/A Model - N/A Diameter - N/A
Length - N/A

Resin Manufacturer - CELTITE Model - H90 .020 Diameter - 1 1/4"
Length - 12" No. Cartridges - 3

Installation Date - 08/13/91 Time - 10:54 am Torque - N/A ft/lb

Test Data - 08/14/91 Time - 2:38 pm Torque - N/A ft/lb
Test Jack - RC-60-CH 9.5A Test Pump - RC-60-CH 9.5 SN 23886
Dial Indicator - AMES CD-0040 Calibrated - DUE 10-4-91
Pressure Gauge - US GAGE DSI 41001 Calibrated - 08/06/91

PSI x 100 Pump Pressure	LBS Bolt Tension	Extensometer Reading	Displacement	Remarks
2	2470	0.000		
4	4940	0.010		
6	7410	0.058		
8	9880	0.058		
10	12350	0.084		
12	14820	0.111		
14	17290	0.148		
16	19760	0.177		
18	22230	0.206		
20	24700	0.231		
22	27170	0.251		
24	29640	0.274		
26	32110	0.295		
28	34580	0.316		
30	37050	0.340		
32	39520	0.360		
33	40755	0.372		
34	41990	0.380		
35	43225	0.391		
36	44460	0.400		
37	45695	0.411		
38	46930	0.421		
39	48165	0.432		
40	49400	0.443		
41	50635	0.455		
42	51870	0.468		
43	53105	0.470		
44	54340	0.479		
45	55575	0.518		
46	56810	0.530		
47	58045	0.542		
48	59280	0.580		
49	60515	0.645		Bind TO 4800 PSI
~~50~~ 8/14/91		0.685		Bind TO 4800 PSI
51		0.755		
52				
53				TERMINATE TEST 2:55 PM

Test Results - ACCEPTED Maximum Pull Force - 60515#
Displacement at Maximum Pull Force - 0.755
Nature of Failure/Yield - BOLT YIELD @ 4700 PSIg
Other Remarks N/A
Tested By - D. Hallmark Approved By - T.E. Bruce

UNDERGROUND DRILLING HOLE FIELD DATA SHEET

Date: 8/13/91

Room/Drift: PANEL 1 - ROOM 2

Purpose of Hole: PULL TEST: DESTRUCTIVE (PWR 12017T)
PT081391-5

Location: N. END 4th W ROOM @ 30-35 FT. FROM N. BULKHEAD

Depth at Completion: 11'-7"

Diameter: 1 3/8" ϕ COMPLETION

Approximate Collar Coordinates

Vertical Angle: VERT. (5° TOLERANCE)

Direction/Azimuth:

Remarks: RESIN/ROCK ANCHOR TEST AT 2:38 PM
AND COMPLETED AT 2:55 PM FOR
CERTIFICATION.

Signature/Department: D. Sellman 8/14/91

ROCK BOLT CERTIFICATION TEST
DATA SHEET

Mine WIPP Rock HALITE Rock Bolt No. PT080891-1
Hole Location PANEL 1 - ROOM 2

Hole Length - 11.58 Dia. - @ Anchor GAUGED /@ midpoint N/A /@ collar N/A
Orientation - VERTICAL (5° TOLERANCE) SMOOTH

Bolt Grade - GR 60 Length - 13'-0 1/4" Diameter - #8

Shell Manufacturer - N/A Model - N/A Diameter - N/A
Length - N/A

Resin Manufacturer - CELTITE Model - H90-0204 Diameter - 1 1/4" (32mm)
Length - 12" No. Cartridges - 3

Installation Date - 08/08/91 Time - 12:46 pm Torque - N/A ft/lb

Test Date - 08/09/91 Time - 1:42 pm Torque - N/A ft/lb
Test Jack - RC-60-CH9.5A Test Pump - RC-60-CH9.5A 23806
Dial Indicator - AMES 4822 CD-0040 Calibrated - 10-4-91 DUE
Pressure Gauge - 42 GAGE Calibrated - 8-6-91

Pump Psi Pressure	LBS Bolt Tension	Extensometer Reading	Displacement	Remarks
200	2470	0.000		
400	4940	0.017		
600	7410	0.144		
800	9880	0.165		
1000	12350	0.184		
1200	14820	0.205		
1400	17290	0.225		
1600	19760	0.246		
1800	22230	0.272		
2000	24700	0.293		
2200	27170	0.322		BLED TO APPROX. 2100
2400	29640	0.347		NO IG. PG
2600	32110	0.371		
2800	34580	0.394		
3000	37050	0.414		
3200	39520	0.441		BLED BACK TO 3100 AFTER 2 MIN.
~~3400~~	~~41990~~	0.464		* MISSED READING AT 3300 PSI
~~38~~				
~~40~~				
~~42~~				
3500	43225	0.474		HELD AT 2 MIN.
3600	44460	0.487		BLED BACK 3500 PSI AFTER 2 MIN
3700	45695	0.502		
3800	46930	0.513		• PLATE AT BACK DEFORMING
3900	48165	0.527		BLED TO 3800 AFTER 2 MIN.
4000	49400	0.540		HOLDING 4000 AFTER 2 MIN BLED 3800 AFTER 3 MIN.
4100	50635	0.549		BLED TO 4000 AFTER 2 MIN
4200	51870	0.559		HOLDING AFTER 2 MIN
4300	53105	0.567		BLED TO 4200 HOLD AT 4200 AFTER 3 MIN
4400	54340	0.583		HOLDING AFTER 2 MIN
4500	55575	0.594		HOLDING AFTER 2 MIN
4600	56810	0.612		HOLDING BLED SLIGHTLY
4700	58045	0.626		HOLDING AFTER 2 MIN
4800	59280	0.657		HOLD BLED TO 4700 AFTER 2 MIN
~~4900~~		0.712		ATTEMPT TO GO TO 5000
		0.765		BLED BACK TO 4800

59,320

Test Results - ACCEPTED Maximum Pull Force - 59280#
Displacement at Maximum Pull Force - 0.765 in. 0.842 in.
Nature of Failure/Yield - BOLT YIELD ~~4800 PSI~~ 4800 PSI
Other Remarks - CONTINUED PULL ON 8/12/91 TO 6700 PSI WITH APPROX 2.3" elongation (apparent elongation)
Tested By - D. Wattman Approved By - [signature]

ROCK BOLT CERTIFICATION TEST
DATA SHEET

Mine WIPP Rock HALITE Rock Bolt No. PT080891-1
Hole Location

Hole Length - ____ Dia. - @ Anchor ____/@ midpoint ____/@ collar ____
Orientation -

Bolt Grade - ____ Length - ____ Diameter - ____

Shell Manufacturer - ____ Model - ____ Diameter - ____
Length - ____

Resin Manufacturer - ____ Model - ____ Diameter - ____
Length - ____ No. Cartridges - ____

Installation Date - ____ Time - ____ Torque - ____ ft/lb

Test Date - ____ Time - ____ Torque - ____ ft/lb
Test Jack - ____ Test Pump - ____
Dial Indicator - ____ Calibrated - ____
Pressure Gauge - ____ Calibrated - ____

Pump psi Pressure	Bolt Tension	Extensometer Reading	Displacement	Remarks
~~5000 psi~~		0.842		ATTEMPTED 5000 psi BLEEDS BACK TO 4800
				BOLT YIELD - ~~NATURE OF FAILURE UNKNOWN~~ 12/26/91
				TEST TERMINATED 2:30 pm

Test Results - ____ Maximum Pull Force - ____
Displacement at Maximum Pull Force - ____
Nature of Failure/Yield - ____
Other Remarks - ____
Tested By - D. Pettibone Approved By - C.E. Brooks

UNDERGROUND DRILLING HOLE FIELD DATA SHEET

Date: 08/08/91

Room/Drift: PANEL 1 - ROOM 2

Purpose of Hole: PULL TEST : DESTRUCTIVE (PWR 12017T)
PT080891-1

Location: NORTH END: APPROX. 4' E OF ROOM & APPROX. 10 FROM NORTH BULKHEAD

Depth at Completion: 11'-6.5" (+1" -0) 11'-6.5"

Diameter: 1 3/8 COMPLETION

Approximate Collar Coordinates

Vertical Angle: VERTICAL (5° TOLERANCE

Direction/Azimuth:

Remarks: BOLT ROCK/RESIN ANCHORS TESTED ON 8-9-91 AT 1:45 p
TEST COMPLETED 2:30 pm FOR CERTIFICATION.

Signature/Department: D. Ballrait / Mine Engineering

ROCK BOLT CERTIFICATION TEST
DATA SHEET

Mine WIPP Rock HALITE Rock Bolt No. PT080891-2
Hole Location PANEL 1 - ROOM 2

Hole Length - 11.55' Dia. - @ Anchor GAUGED/@ midpoint N/A /@ collar N/A
Orientation - VERTICAL (5° TOLERANCE) SMOOTH

Bolt Grade - GR60 Length - 13'-0 1/4" Diameter - #8

Shell Manufacturer - N/A Model - N/A Diameter - N/A
Length - N/A

Resin Manufacturer - CELTITE Model - H90-0204 Diameter - 1 1/4" (32mm)
Length - 12" No. Cartridges - 3

Installation Date - 08/08/91 Time - 1:13 pm Torque - N/A ft/lb

Test Date - 08/09/91 Time - 2:56 pm 08/8-9-91 Torque - N/A ft/lb
Test Jack - RC-60-CH-95 Test Pump - RC-60-CH9.5 23886
Dial Indicator - AMES 4322 CD-0040 Calibrated - 10-4-91 DLE
Pressure Gauge - U.S. GAGE DS1#001 Calibrated - 8-6-91

Pump Pressure (psi)	Ex. Rod ~~Bolt Tension~~	Δ Ex Rod ~~Extensometer Reading~~	Tension ~~Displacement LBS~~	Remarks
200	0.100	~~0.100~~ 8-9-91	2470	
400	0.118	~~0.100~~ 8-9-91	4940	
600	0.151	~~0.100~~ 8-9-91	7410	
800	0.174	~~0.100~~ 8-9-91	9880	
1000	0.191	~~0.100~~ 8-9-91	12350	
1200	0.211		14820	
1400	0.229		17290	
1600	0.245		19760	
1800	0.262		22230	
2000	0.279		24700	
2200	0.299		27170	
2400	0.317		29640	
2600	0.336		32110	
2800	0.354		34580	
3000	0.372		37050	
39,520# 3200	0.388		39520	HOLD FOR 2 MIN - BLED TO 3000 psi
3300	0.396		40755	HELD AT 3400
3400	0.406		41990	HOLDING AFTER 2 MIN.
3500	0.415		43225	08/9/09/91
* 3600	0.425	0.326 *	44460	ADJUST TO ~~0.328~~ 0.326
3700		0.337	45695	GAUGE CAME OFF BOLT
3800		0.347	46930	• PLATE AT BACK DEFORMED
3900		0.354	48165	
4000		0.362	49400	HELD FOR 2 MIN. BLED TO 3900
4100		0.373	50635	
4200		0.381	51870	
4300		0.387	53105	
4400		0.400	54340	
4500		0.417	55575	
4600		0.434	56810	
4700		0.455	58045	
~~4800~~		~~0.530~~ 8-9-91		BOLT YIELD - PUMP BLEEDS TO 4700. BACK (4600) 0.577 AT 4700 psi
				TEST TERMINATED 2:05 pm 08/9/91

Test Results - ACCEPTED Maximum Pull Force - ~~56810~~ 58045#
Displacement at Maximum Pull Force - 0.530 in.
Nature of Failure/Yield - BOLT YIELD ~~(APPARENT)~~ 08/8-9-91 4700 psig
Other Remarks - 24 HOURS AFTER INSTALLATION
Tested By - D. Bellman Approved By - R.E. [illegible]

UNDERGROUND DRILLING HOLE FIELD DATA SHEET

Date: 08/08/91

Room/Drift: PANEL 1 - ROOM 2

Purpose of Hole: PULL TEST : DESTRUCTIVE (PWR 120177)
PT080891-2

Location: NORTH END: APPROX. 4+' E OF ROOM 2 APPROX. 15' FROM NORTH BULKHEAD

Depth at Completion: 11'-6" (+1" -0") 11'-7"

Diameter: 1-3/8" COMPLETION

Approximate Collar Coordinates

Vertical Angle: VERTICAL (5° TOLERANCE)

Direction/Azimuth:

Remarks: ROCK/RESIN ANCHOR TESTED ON 8.9.91 AT ~~3:05 pm~~ 2:55 pm.
COMPLETED AT ≈ 3:05 pm FOR CERTIFICATION.

Signature/Department: D. Balkwill / Mine Engineering

ROCK BOLT CERTIFICATION TEST
DATA SHEET

Mine WIPP Rock HALITE Rock Bolt No. PTOB0091-3
Hole Location PANEL 1 - BOOM 2

Hole Length - 11.58 Dia. - @ Anchor GAUGED /@ midpoint N/A /@ collar N/A
Orientation - VERTICAL (5° TOLERANCE) SMOOTH

Bolt Grade - GR60 Length - 13'-0 1/4" Diameter - #8

Shell Manufacturer - N/A Model - N/A Diameter - N/A
Length - N/A

Resin Manufacturer - CELTITE Model - H90-0204 Diameter - 1 1/4" (32 mm)
Length - 12" No. Cartridges - 3

Installation Date - 08/08/91 Time - 1:46 pm Torque - N/A ft/lb

Test Date - 08/09/91 Time - 3:30 pm Torque - N/A ft/lb
Test Jack - RC-60-CH95A Test Pump - RC-60.H95 23886
Dial Indicator - AMES 4822 CD-0040 Calibrated - 10-4-91 DUE
Pressure Gauge - USGAGE DS1#001 Calibrated - 9-6-91

~~Pump~~ PSI Pressure	~~Bolt~~ LBS Tension	Extensometer Reading	Displacement	Remarks
200	2470	0.100		
400	4940	0.113		
600	7410	0.135		
800	9880	0.157		
1000	12350	0.180		
1200	14820	0.202		
1400	17290	0.222		
1600	19760	0.238		
1800	22230	0.247		
2000	24700	0.263		
2200	27170	0.281		
2400	29640	0.296		
2600	32110	0.314		
2800	34580	0.334		
3000	37050	0.356		
3200	39520	0.376		HELD FOR 2 MIN. 3000
3300	40755	0.393		HOLDING
3400	41990	0.405		
3500	43225	0.415		HOLDING AFTER 1 MIN
3600	44460	0.425		HOLDING
3700	45695	0.436		HOLDING AFTER 1 MIN.
3800	46930	0.449		
3900	48165	0.460		
4000	49400	0.478		
4100	50635	0.485		
4200	51870	0.497		HOLDING AFTER 1 MIN
4300	53105	0.511		
4400	54340	0.524		HOLDING AFTER 1 MIN.
4500	55575	0.536		HOLDING
4600	56810	0.555		HELD FOR 2 MIN BLED TO 4500 #
4700	58045	0.585		HELD 1 MIN. BB 4600 X PLATE DEFORMA
~~4800~~	~~59280~~	0.686		BOLT YIELD - FAILURE APPARENT
4800 ATTEMPTED				CONTINUED ~~LOADING~~ PUMPING
				DEF. .686 AT 4600 GAUGE
				.702 AT 4600 READING
				~~TEST TERMINATED~~ @ 3:45 PM

39,520 #

Test Results - ACCEPTED Maximum Pull Force - 58045 #
Displacement at Maximum Pull Force - ~~0.686 in~~ 0.702 in
Nature of Failure/Yield - BOLT YIELD @ 4700 psi (58045 lbs) ~~APPARENT~~
Other Remarks - 24 HOURS AFTER INSTALLATION
Tested By - D. Rathbun Approved By - R.E. Brown

UNDERGROUND DRILLING HOLE FIELD DATA SHEET

Date: 08/08/91

Room/Drift: PANEL 1 - ROOM 2

Purpose of Hole: PULL TEST: DESTRUCTIVE (PWR 12017T)
PT080891-3

Location: NORTH END: APPROX. 4' E OF ROOM ℄ APPROX. 20-25 FT FROM NORTH BULKHEAD

Depth at Completion: 11'-6" (+1" -0) 11'-7"

Diameter: 1-3/8" COMPLETION

Approximate Collar Coordinates

Vertical Angle: VERTICAL (5° TOLERANCE)

Direction/Azimuth:

Remarks: ROCK/RESIN ANCHOR TESTED ON 8-9-91 AT 3:30 pm.
COMPLETED AT 3:45 pm FOR CERTIFICATION

Signature/Department: D. Ballmann / Mine Engineering

WORK CHANGE NOTICE

1. WCN No.: 1	2. Critical System Yes ☐ No ☑
3. Work Request: 12017-T	4. Originated By / Phone No.: T.E. Brockman 8304 Date: 8/7/91
	5. Incorporated By / Phone No.: T.E. Brockman 8304 Date: 8/7/91

6. **DESCRIPTION OF CHANGE** (Print or Type Proposed Change)

Page	Step or Paragraph	Instructions: Rewrite Paragraph Changes, Draw Illustration Changes
Attachment 6		Change large reamed hole from 3" to 3-4".
5	7.2.4b	Change load from 1,000# to 200 p.s.i.
5	7.2.6	Change all reference of 1,000# to read 200 p.s.i.
5	7.2.7b	Change 40,000# to read 3,200 p.s.i.
5	7.2.7	Change 500# to read approximately 100 p.s.i.

7. Reason for Change:

To accomodate for available equipment. Change does not affect scope nor intent or design

8. **DESIGN CLASSIFICATION**

☑ Class II or IIIA ☑ Class IIIB or Non-Facility

9. Required Approval

Signature	Date
PIC All Classes: M. Campbell	8/8/91
Originator All Classes: T.E. Brockman	8/7/91
Safety As Required: T. Brockman	8/8/91
Quality Assurance II or IIIA: [illegible]	8/8/91
Cognizant Engineer II or IIIA: D. Gonzales	8/7/91
Cognizant Operations Mgr. All Classes: T.E. Brockman	8/7/91
Other	
Other	

2908:3919

DESTRUCTIVE TESTING OF RESIN ANCHORS

1.0 SCOPE

A representative sample of resin anchored Dywidag tendons will be pull tested to destruction. This will be achieved by installing the rock anchors in Room 2, Panel 1 in conditions as similar to those in Room 1 as possible. The results will be used as basic input data in the design of the supplemental support system proposed for Room 1, Panel 1.

2.0 OBJECTIVES

The objectives of the destructive testing are expected to yield results that:

- o provide data on both the mode and load at failure of the halite/resin/tendon bond.
- o establish the allowable design load for the rock anchor system.

In addition, other in situ tests are expected to provide results that:

- o check for interaction effects between rock anchors.
- o provide short term creep response of the rock anchor system.

3.0 SAFETY REQUIREMENTS

3.1 Personnel Safety - All personnel participating in or observing destructive testing shall be properly equipped.

3.2 For the safety of observers, personnel not actively participating in the destructive testing are requested to stay outside the designated work area. The boundary for a designated work area is to be established at least fifty (50) feet away.

3.3 During the performance of the destructive tests, safety chain or cables shall be attached to each item of test equipment weighing more than 10 lbs. that may be violently released or fall as a result of testing.

4.0 TEST MATERIALS

4.1 Resin: Celtite Lockset Polyester Resin Cartridge
High Viscosity, Code (H)
Gel Time, Two-to-Four Minutes Code (90)
Cartridge, 3212

0204 DG 8.7.91

QA Verification: KA Lacy

For additional information refer to Attachments 1, 2, and 3 for Material Safety Data Sheets, installation instructions, and product information.

4.2 Tendons: Dywidag Post-Tensioning System
#8 THREADBAR (LHT), ASTM A615 GR 60
FULL LOAD ANCHOR NUTS FOR GRADE 60 THREADBAR

QA Verification: KA Lacy

For additional information refer to Attachments 4 and 5.

5.0 TEST EQUIPMENT AND TEST REQUIREMENTS

5.1 A minimum of ten (10) rock anchors shall be installed, and loaded to failure. Initially, only one set (of five) rock anchor installations shall be tested in any given twenty-four (24) hours. The load will be recorded all the way to failure.

5.1.1 The failure mode is to be determined by pulling tendons completely of the hole.

5.1.2 For the purpose of destructive testing, failure is defined as an increasing or continuous deformation with no increase of the applied load.

5.2 There is to be a waiting period of at least twenty-four (24) hours between resin/anchor activation and the commencement of destructive testing. The waiting period assures that the resin has cured and is approaching ultimate strength. Fully cured resin develops compressive strength of 14,000 psi and tensile strength of 5,000 psi or more.

QA Verification: Mike Lopez

5.3 The testing equipment includes a hydraulic ram with a 60 ton capacity, a pressure gauge readable in 200 psi increments, and a dial indicator gauge for measuring deformation in increments of 0.001 inch. Rock/resin anchor deformation will be measured by means of the dial indicator.

QA Verification: Mike Lopez

5.4 Installation of properly calibrated Geotechnical instrumentation may be used where required.

5.5 All instruments and devices used for measuring or recording loads or deformation during the test shall have been properly calibrated with tags affixed indicating calibration due date.

QA Verification: Mike Rogers

6.0 DRILLING AND ANCHOR/RESIN INSTALLATION INSTRUCTIONS

6.1 Drill each test hole as per Attachment 6 in accordance with applicable sections as prescribed in WP 04-220 and provided by factory representative's instructions.

6.1.1 Test hole locations shall have not less than four (4) feet spacings.

6.1.2 The 1-3/8 inch diameter bits shall be gauged prior to drilling above Anhydrite "b". Gauging assures the annular tolerance needed for a minimum bond length of three (3) feet.

6.1.3 Holes shall be drilled to a depth of 11 feet 6 inches with 1 inch tolerance, for test purposes only.

6.1.4 The perpendicular hole tolerance shall be 5 degrees as shown on Attachment 6.

6.2 Initially, only one set (of five) rock anchor installations shall be tested in any given twenty-four (24) hours. This may be changed subject to improved installation performance gained by experience and signed by cognizant engineer or his designee.

6.3 Resin and threadbar will be installed in accordance with the manufacturers' recommendations. A manufacturer's representative will be present during resin/anchor installation and destructive testing.

6.4 Insert required number of resin cartridges (3 minimum) through plastic or steel pipe and fed into the end of the hole. The resin is then followed by the threadbar with spin adapter.

Care must be taken to avoid rupturing the resin cartridges.

6.5 Start rotation at about 50 rpm or more and gradually insert the threadbar bolt into the resin cartridge to rupture the cartridge. *

6.5.1 Advance threadbar bolt at an approximate rate of 2 to 4 inches per second or as recommended by the factory representative.

* DUE TO AVAILABLE EQUIPMENT AND PER CONTRACTOR INSTRUCTIONS THE BAR IS TO BE INSERTED TO FULL DEPTH THEN

6.5.2 Hold bolt in the hole and hold until the resin sets, approximately for two (2) to four (4) minutes.

6.5.3 Threadbar should have approximately eighteen (18) inches of thread protruding from the hole in its final position.

6.5.4 Thorough mixing of the resin ingredients is essential.

6.6 There is to be a waiting period of at least twenty-four (24) hours between resin/anchor activation and destructive testing.

A waiting period assures that the resin has cured and is approaching its ultimate strength. When fully cured, the resin develops a compressive strength of 14,000 psi and tensile strength of 5,000 psi or more.

QA Verification: Mike Bogner

7.0 FULL TEST INSTRUCTIONS

7.1 Preparation for tests

7.1.1 All instruments and devices used for measuring or recording loads or deformation during the testing shall have been properly calibrated with tags affixed indicating calibration due date.

7.1.2 Prepare data sheets. Applicable information and test data shall be recorded on data sheets, Attachment 7. See Section 8 for QA verification.

7.1.2.1 Record at least the following: rock bolt number (i. e., PTmmddyy-#); mine; rock type; hole location; orientation; hole length and diameter; bolt grade, length, and diameter; installation date and time; test date and time; resin type, manufacturer, number of resin cartridges; and, identify test equipment by serial number and indicate calibration due date.

7.1.2.2 Measure the hole length and record.

7.1.2.3 When testing is complete, submit the data sheet to Mine Engineering.

7.1.2.4 When testing is complete, submit WP Form 2014 to Mine Engineering, Attachment 8.

7.1.2.5 Mark the final depth of the threadbar at 11 feet 6 inches with 1 inch tolerance from the anchor end and record.

7.1.2.6 Estimate hole orientation and roughness (i.e., vertical and smooth) and record.

7.2 FULL TEST

7.2.1 Install a bearing plate against the rock followed by placing the ram over the threadbar followed by another bearing plate and load cell and bearing plate, and finally torque the anchor nut.

The anchor nut shall be tightened to the manufacturer's recommended torque values (150 ft-lbs to 300 ft-lbs).

7.2.1.1 Fasten safety chain or cable to all equipment weighing more than 10 lbs and anchor to adjacent rock bolt plates.

7.2.2 The ram alignment should be near parallel to the axis of the tested bolt and within the limits allowed by the installation.

7.2.3 Make hose connections from the hydraulic pump to the ram.

7.2.4 a Make load cell and other instrumentation connections to data logger.

7.2.4 b Apply 1,000 lb load on the ram to eliminate apparatus slack.

7.2.5 Attach a magnet mounted dial indicator gauge on the ram with the point set in place on the bolt or to a fixed reference point in the salt. Adjust the dial indicator gauge to zero.

7.2.6 Test loading shall continue to be applied starting with 1,000 lbs and increased by 1,000 lb increments up to 40,000 lbs. Loads are to be held for approximately one (1) minute before recording the load and deformation data. Record the test data, Attachment 7.

7.2.7 From 40,000 lbs, the load shall be applied in 500 lb increments. While approaching failure, data readings may be taken more often.

7.2.8 Testing the resin/rock anchor to failure is the acceptance criteria. The test is accepted as complete at failure.

7.2.8.1 For the purpose of destructive testing, failure is defined as an increasing or continuous deformation with no increase of the applied load.

7.2.9 Terminate testing.

7.2.10 Remove equipment and pull bolt from hole, if possible

7.2.11 Continue testing of the next installation.

8.0 TEST DATA, ILLUSTRATIONS AND REPORTS

8.1 The data sheet form (Attachment 7) shall be filled out for each test bolt installation. The data sheet shall be keyed to match the rock anchor pull test number (PTmmddyy-#).

QA Verification: Mike Rogers

8.2 Each test shall be identified by rock anchor number and plotted on an appropriate scale. Each data point shall be plotted with the horizontal (x) axis showing displacement while the vertical (y) axis indicates load.

8.3 Photographs of a typical rock anchor installation shall be referenced to the rock anchor test number.

8.4 A report shall be prepared by Mine Engineering summarizing the test results and certifying the installation procedures and resin/rock anchors that have been tested and approved for installation at the WIPP.

8.5 The results will be used as basic input data in the design of the supplemental support system proposed for Room 1, Panel 1.

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CONCURRENCE BY:

D. Galbraith, Senior Engineer
Mine Engineering

J. A. Gonzalez, Cognizant Engineer
Mine Engineering

8/7/91

P.F. Broadway 8/7/91

S. C Sethi, Manager
Mine Engineering

SEC TON 7 - PREVENTIVE MEASURE

SPECIAL PROTECTION INFORMATION:
RESPIRATORY: Use MSHA (NIOSH) approved respirator if application produces vapors, mists, or fumes above the TLV.
VENTILATION: Adequate to prevent vapor build-up above the TLV.
PROTECTIVE GLOVES: Chemical resistant polyethylene or equivalent.
EYE PROTECTION: Safety glasses or goggles as required to prevent eye contamination.
OTHER: Use protective clothing to minimize contact with skin. Wash contaminated clothing before reuse.

SPILL OR LEAK PROCEDURES:
SPILL: Ventilate area. Remove all sources of ignition. Absorb with inert material and collect.
WASTE DISPOSAL METHOD: Dispose of in accordance with Federal, State, and local regulations.
STORAGE: For maximum shelf-life avoid storage in direct sunlight, elevated temperatures or near sources of heat such as steam pipes and radiators. Store in a cool, dry well-ventilated area.
OTHER: Since the product is a sealed cartridge, handling hazards are minimal unless product is damaged or misused.
SHIPPING INFORMATION: Not Applicable

SECTION 8 - FIRST AID MEASURES

EYES - Flush with water for at least 15 min. Consult a physician.
SKIN - Wash thoroughly with soap and water.
INGESTION - Consult a physician immediately.
INHALATION - Remove to fresh air if effects occur. Call a physician if effects persist.

SECTION 9 - PREPARATION DATE OF MSDS

Revision date: 12/11/89
Previous revision date: 01/01/89
For further information contact: Leo Hickam
Phone number: (502) 863 - 6800

SUPPLEMENT:

HAZARDOUS INGREDIENTS Continued...

The following chemicals are subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA) and 40 CFR Part 372.

Chemical Name	CAS#	Maximum % by Weight
Benzoyl Peroxide	94-36-0	1.5%
Styrene	100-42-5	10.0%

Dy / G. Sealy & G. Greenfield Celtite

GEORGETOWN, KY : 150 CARLEY CT. 40324
502/863-6800
PRINCETON, WV Rogers St & Caperton Ave 24740 304-425-7501
GRAND JUNCTION, CO 1440 Winters Ave 81501 303-245-4007

INSTALLATION INSTRUCTIONS FOR CELTITE RESIN CARTRIDGES

1. Measure and mark drill steel 1" longer than bolt length. Note: The bore hole should be shortened accordingly when headers or thick plates are used.
2. Insert required number of cartridges and place bolt into the base of the hole behind the resin.
3. With the head of the bolt placed firmly in the chuck of the bolter or in a spin-in wrench, push the bolt into the hole. Slow rotation is recommended but not required for adequate mixing.
4. When the bolt reaches just below the roof, stop upward movement and spin the bolt rapidly for five to ten seconds. (See note for stoper.)
5. Stop rotation and push the bolt upward with the full thrust from the machine and hold until the resin sets.
6. If the bolt tends to drop out of the hole after the chuck or adapter is removed, simply push it back up into the hole and hold until the resin sets.
7. NEVER re-rotate the bolt after the final spin, as damage to the partially-set resin may occur.
8. Always wear safety glasses or eye shields when installing resin bolts.
9. To achieve maximum performance, selection of bolt diameter, cartridge type and related hole diameter are very important. Celtite® technical representatives are available to assist in the selection of the correct combination of components based on specific applications.
10. Note for stoper: Contact Celtite® technical representative.
11. For applications other than fully grouted bolts, Celtite® technical representatives will instruct mine personnel in correct installation procedure.
12. Cartridges should be stored in a cool, well-ventilated and dry area away from direct sunlight. High temperature conditions can reduce shelf life of cartridges. Stock rotation is recommended so that oldest stock is used first.

CAUTION: Do not open or puncture cartridges. Contents of cartridges may cause mild irritation and should be avoided. Eye protection should always be used when bolting. If resin contacts the eyes, flush immediately with water for at least 15 minutes. Call a physician.

We believe that the information contained herein (which supersedes all previous information on this subject) is true and reliable. We cannot be held responsible for any loss, injury, or damage resulting from its use, as, of necessity, the information given is of a general nature, so that users are advised to consult us about their specific problems.

Celtite® warrants that its products, at the time of shipment, conform to the applicable descriptions herein and are free from defects in materials and workmanship. NO OTHER WARRANTY, WHETHER EXPRESS, IMPLIED OR STATUTORY, INCLUDING ANY WARRANT OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, SHALL EXIST IN CONNECTION WITH THE SALE OR USE OF ANY CELTITE® PRODUCT, AND ALL SUCH WARRANTIES ARE HEREBY EXPRESSLY EXCLUDED.

IN NO EVENT SHALL CELTITE® BE LIABLE FOR INJURY TO PERSON OR PROPERTY, LOSS OF BUSINESS OR PROFIT ON ANY OTHER DIRECT, INDIRECT, INCIDENTAL, SPECIAL OR CONSEQUENTIAL DAMAGES.

U.S. Patent Nos. 3731791, 3915297 Canada No. 972075 Other World Patents

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04-22-86

ATTACHMENT 2

The Lokset® Polyester Resin Cartridge Anchor System

This system's simplicity of application enables bolts of various lengths to be anchored and grouted in one easy operation, with no need for injection equipment.

The Celtite Technik system consists of an easily handled "cartridge," containing a highly reinforced polyester resin component, together with its catalyst, in accurately measured quantities. The components are isolated from each other by a *physical-chemical barrier* which prevents reaction between the components until required. The cartridges are sausage-shaped and designed for rapid insertion into a range of bore hole sizes, where they may be readily pushed to the extremity at any angle above or below the horizon. Therefore, optimum bolt anchorage in a wide range of rock or concrete strengths is easily achieved simply by adjusting the length of the resin anchor zone.

No reaction takes place until the roof or rockbolt is rotated through the cartridge, mixing the components and initiating the curing action. The chemical nature (thixotropy) of the Lockset® cartridge allows the contents to be easily mixed yet minimizes resin displacement after mixing is complete.

The mixed resin totally fills the area (annulus) around the bolt, which for standard "point" anchorages will be firmly bonded to the substrate and bolt within minutes.

The setting time of the resin components can be controlled. A combination of fast and slow-setting cartridges makes possible the simultaneous operation of anchoring, grouting and tensioning a rockbolt. The simplicity of this method of anchoring grouting eliminates the need for cumbersome injection equipment.

APPLICATIONS

- **Rock bolting in mines and tunnels.**
- **Permanent rock reinforcement on highway rock cuts, dams and underground rock structures (power-houses and machinery galleries).**
- **Integral ties between reinforced concrete and rock faces above or below water.**
- **Vibration resistant anchorages for attachment of "critical" equipment to concrete or rock.**
- **Anchorage for electrical transmission towers.**
- **Uplift anchorages for near surface structures.**
- **Immediate post-tensioning of steel reinforcements in rock or concrete structures.**

Celtite Technik's Lokset® Polyester Resin Cartridge.

ADVANTAGES

Accuracy. All Anchorages can now be accurately designed with Celtite Technik resins having reproducible strength characteristics.

Speed. The fast-gelling Lokset® resins enable rapid installation to be carried out, a significant advantage in the area of tunnel bolting and rock slope stabilization. Application of load can be completed within minutes.

Permanence. The resins protect the embedded bolt from corrosion due to acid-bearing water, sea or ground water. Atmosphere is precluded from the bore hole, preventing further deterioration of the strata.

Safety. Millions of Lokset® resin anchors are used every year for critical jobs such as roof support or permanent rock reinforcement in mines, tunnels and foundations.

Vibration. Celtite Technik anchors are not affected by vibration and require no retensioning even after close proximity blasting.

Stress-free. No internal stresses are set up in the rock or concrete by resin anchors.

TECHNICAL SERVICE

Celtite Technik is available to discuss with you both installation techniques and the selection of proper Lokset® cartridges for your project. Our field representatives are ready to review your applications and help you to develop successful, economical anchoring systems.

ATTACHMENT 3

Anchoring

INTRODUCTION

Installation of Celtite Technik polyester resin cartridges in rock and concrete have ranged from application of short 3/4-inch rebar "starter bars" into concrete to 1 3/8" diameter bolts for rock reinforcement, measuring 55' in length, weighing over 300 pounds and fully embedded in resin!

ANCHORAGE STRENGTHS

To achieve maximum anchorage strength between bolt and concrete or rock, the difference in diameter between hole and bolt should be kept to a minimum. This also insures better mixing of both catalyst and resin.

Standard Rebar or Threadbar-bolts (conforming to ASTM A-615 specifications) are used without further refinement. Deformations on the bar serve to effectively mix the cartridge components during the "spin-in" or insertion cycle. (SEE BOLT SELECTION ON PAGE 6).

Spin adaptors are available from several manufacturers. *Consult CELTITE® TECHNIK for source information.*

UNDERWATER ANCHORAGES

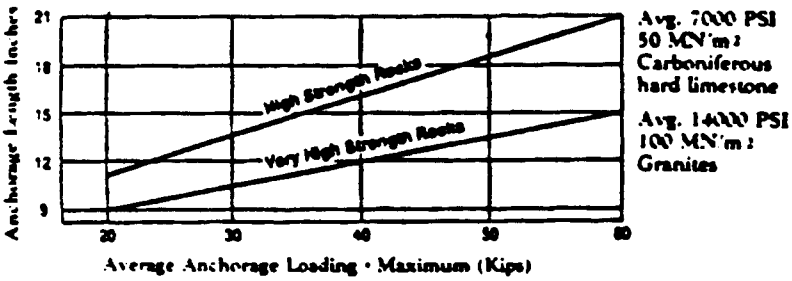
Lokset® cartridges can be applied in underwater anchorage applications over 24 inches in length, in both concrete and rock. *Consult CELTITE® TECHNIK for your specific job requirements.*

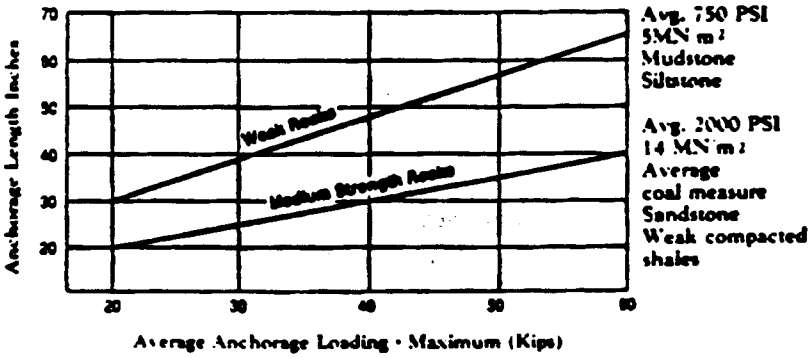
APPLICATION EQUIPMENT

The hole-drilling equipment mentioned in this brochure is generally suitable for spinning in bolts. This equipment should be rotary percussive and have provision for independent rotation to maintain 100 rpm under load. Under no circumstances should the bolt be simply pushed through the resin cartridges as improper mixing can result, providing for possible anchorage failure.

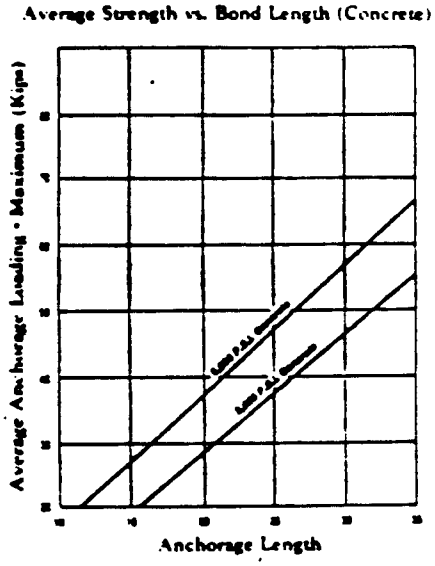
RESIN ANCHORAGE CHARTS

Typical anchorage loadings* in rock for point anchored rockbolts used in accordance with the manufacturer's recommendations. Intended as a guide for site trials, which will establish the working specifications in the actual ground conditions. **Shown in Kips (1000 lbs. = 1 Kip).*





Rock strengths are in uniaxial compression terms. Information based on trials conducted by Imperial College, London (1970), J. A. Franklin, B.S.C., M.Sc., Ph.D, D.I.C.



UNDERGROUND DRILLING HOLE FIELD DATA SHEET

Date: _____

Room/Drift: _____

Purpose of Hole: _____

_____

_____

_____

_____

_____

_____

Location: _____

Depth at Completion: _____

Diameter: _____

Approximate Collar Coordinates _____

Vertical Angle: _____

Direction/Azimuth: _____

Remarks: _____

_____

_____

_____

Signature/Department: _____

WP Form 2014; 10/15/90
Page 1 of 1

10/15/90

LEFT HAND THREAD

PHYSICAL PROPERTIES	
EFFECTIVE AREA:	0.79 SQ.IN.
ULTIMATE STRENGTH:	90 KSI
ULTIMATE LOAD:	71.1 KIPS
YIELD LOAD:	47.4 KIPS
WEIGHT:	2.67 LBS./FT.
MAX. BAR Ø INCL. RIBS:	1.12 IN.
AVERAGE CORE Ø:	0.95 IN.
PITCH:	0.492 IN.

ATTACHMENT 4

DYWIDAG POST-TENSIONING SYSTEMS	DIMENSIONS: INCH/mm mm FOR REFERENCE ONLY		REV.	DATE	NAME
[redacted]	TOLERANCES: ± .02 UNLESS NOTED				
DATE: 08-13-90 DRAWN: B. HALFORD APPROVED:	MATERIAL: ASTM A615, GR 60	SCALE NTS			

This drawing, the pertinent specifications, descriptions, standards etc. and their contents are the

TABLE: COMPARISON OF BAR MECHANICAL PROPERTIES

Bar Size/Grade ASTM	#7/GR 60 A 615			#7/GR 75 F 432			#8/GR 60 A615		
	Yield (kips)	Tensile (kips)	Elong. (%)	Yield (kips)	Tensile (kips)	Elong. (%)	Yield (kips)	Tensile (kips)	Elong. (%)
Guaranteed .er ASTM	36	54	8	45	60	8	47.4	71.1	8
g. actual .er mill cert.	42	65	12	47	72	9	55	83	13

6/24/91

ATTACHMENT 4.1

NORTH STAR STEEL MINNESOTA

P.O. Box 64189
1678 Red Rock Road
Saint Paul, Minnesota 55164

CERTIFIED TEST REPORT

Heat # B-42393
Size #8 Tb.
Grade 7432-55
Date Rolled 5/3/90
P.O.
M.O. #

CHEMICAL ANALYSIS

C	MN	P	S	SI	SN	CU	NI	CR	MO	CB	V
.43	.98	.043	.035	.22	.017	.42	.13	.16	.032	.019	

AL				

JOMINY END-QUENCH HARDENABILITY RESULTS (HRc)

J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12

J13	J14	J15	J16	J18	J20	J22	J24	J26	J28	J30	J32

PHYSICAL TEST REPORT

SPECIMEN AREA (in²)	YIELD KIPS	YIELD P.S.I.	TENSILE KIPS	TENSILE P.S.I.	GAUGE LENGTH (in)	% ELONG	BEND	% R.A.	Specification/Grade
.79	54.9	69.5	88.6	112.2	8.0	13.7	OK		7432-55
.79	54.8	69.4	83.6	105.8	8.0	13.7	OK		7606

Grain Size: _____ Cleanliness: _____

Macro Etch: Specification: _____ Results: _____

Impact Test	Temp (F)	ft./lb.	% Shear*	% L.E.*

* By specification or request only

This material has been produced and tested in accordance with the requirements of applicable specifications unless otherwise listed below. We hereby certify that the above test results are representative of those contained in the records of the company.
Any modification to this certification as provided by North Star Steel Minnesota without the expressed written consent of North Star Steel Minnesota negates the validity of this test report.
North Star Steel Minnesota is not responsible for the quality of this material to meet specific applications.

SIGNED _____

DATE 5/3/90

SWORN AND SUBSCRIBED TO BEFORE ME

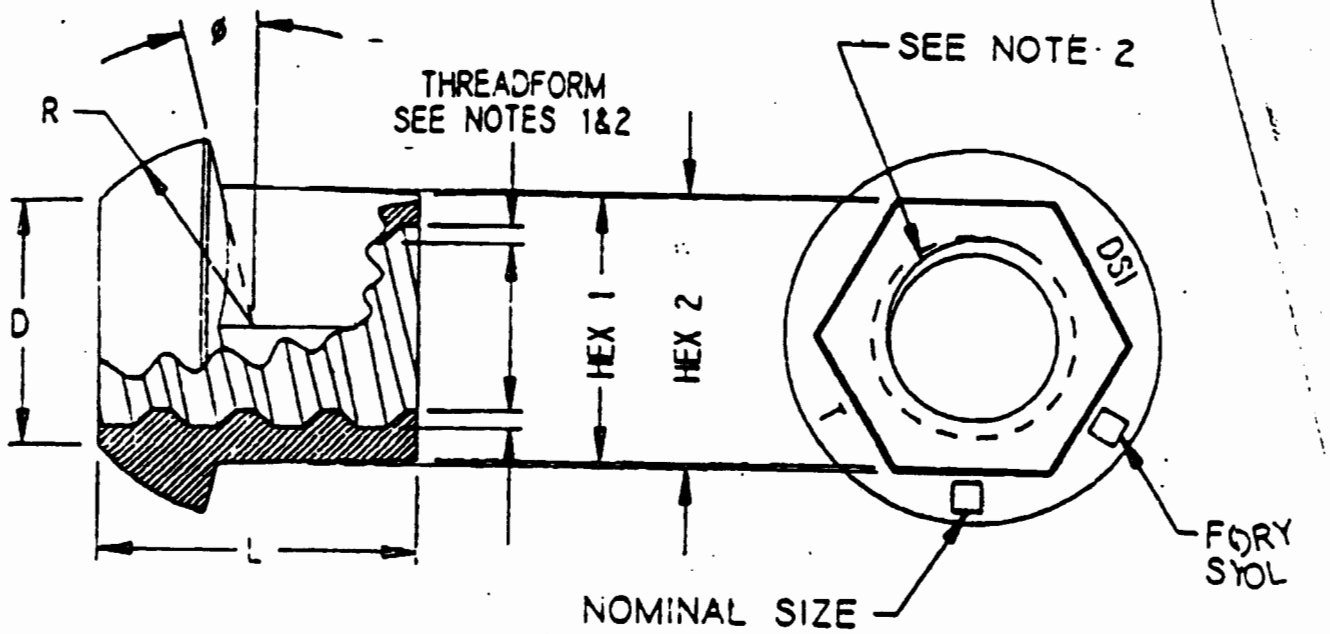
THIS _____ DAY _____

_____
NOTARY PUBLIC

MY COMMISSION EXPIRES _____

THIS CERTIFICATE IS NOTORIZED ONLY WHEN REQUESTED.

ATTACHMENT 4.2



NOMINAL SIZE	#6	20mm	#7	[redacted]	#9	#10	#11 (PRELIMINARY)
PART NUMBER	B06U28810	B20U28810	B07U28810	B08U28810	B09U28810	B10U28810	B11U28810
L (IN./mm)	1.375/34.9	1.625/41.3	1.625/41.3	1.750/44.5	2.125/54.0	2.250/57.2	2.625/66.7
HEX 1 (IN./mm)							
HEX 2 (IN./mm)	1.250/31.8	1.375/34.9	1.375/34.9	1.500/38.1	1.688/42.9	1.813/46.0	2.063/52.4
R (IN./mm)	0.865/22.0	1.000/25.4	1.000/25.4	1.120/28.4	1.250/31.8	1.419/36.0	1.530/38.9
D (IN./mm)	1.063/27.0	1.188/30.2	1.188/30.2	1.313/33.4	1.438/36.5	1.641/41.7	1.821/46.3
Ø DEG.	14	14	14	14	14	14	14
THREADFORM: 8341/	743	785	744	745	746	747	724
MINOR Ø MIN. (IN./mm)	0.730/18.5	.782/19.9	0.858/21.7	0.974/24.7	1.096/27.8	1.238/31.4	1.406/35.7
MINOR Ø MAX. (IN./mm)	0.742/18.8	.794/20.2	0.868/22.0	0.986/25.0	1.108/28.1	1.252/31.8	1.420/36.1
WEIGHT LBS	0.27	0.54	0.5	0.72	0.89	1.20	1.77

4 → L FOR #11, AND WEIGHTS FOR #9, #10 & #11 CHANGED.

MATERIAL:

AUSTEMPERED DUCTILE IRON
OR CAST STEEL
MIN. YIELD: 100 KSI
MIN. TENS: 120 KSI
MIN. EL. IN 2": 6%

TOLERANCES:

FOR HEX1, HEX2, R, D:
+0/-0.040"

FOR L: +0.125/-0"

FOR Ø: ±1°

NOTES:

1. THREADFORM AS SPECIFIED WITH EXCEPTION OF MINOR DIAMETER (MINOR Ø) WHICH IS SPECIFIED IN TABLE.
2. AT BOTH ENDS OF NUT THREADFORM IS MODIFIED OVER LAST 1/2 TURN AS FOLLOWS: MINOR Ø OPENS UP TO MAJOR Ø AT CONSTANT RADIUS.

ATTACHMENT 5

DYWIDAG POST-TENSIONING SYSTEMS

[redacted]

DATE: 2-08-89 DRAWN: S. HALPOG APPROVED:

DIMENSIONS: INCH/mm
mm FOR REFERENCE ONLY

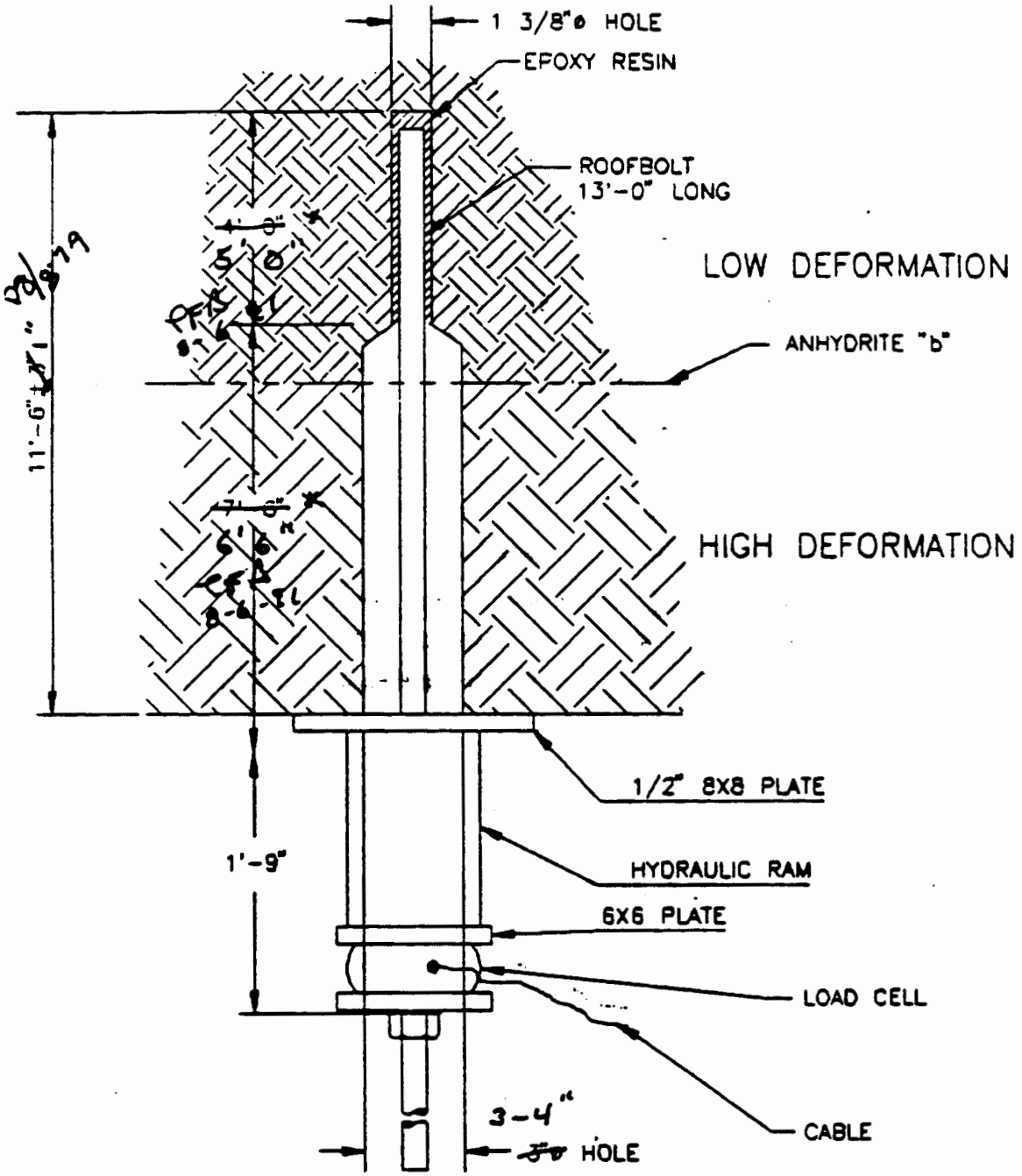
MATERIAL: SEE ABOVE

SCALE 1:1 FOR #7

REV.	DATE	NAME
1	02-20-90	K.L.
2	08-01-90	K.L.
3	09-28-90	K.L.
4	01-29-91	K.L.

DRAWING NUMBER B00U28810

* CHANGE MADE DUE TO AVAILABLE EQUIPMENT
CRB
8/6/21



ROOFBOLT DETAIL
VERTICAL ALIGNMENT (TOL. 5°)

ATTACHMENT 6

APPENDIX C

T.T.B. BOLT WORKING LOAD FOR 10' x 2' SPACING				PAGE 3
PROJECT	AUTHOR C. FRANCKE	DATE 9/8/91	CHK'D BY	DATE / CHK'D BY
S.O.	CALC NO		FILE NO	GROUP

CALCULATIONS: (CONT'D)

WORKING LOAD

THE WEIGHT OF THE ROCK SUPPORTED BY A B
IS DETERMINED BY THE FOLLOWING EQUATION:

$$W = \rho V$$

WHERE: W = WEIGHT OF ROCK (WORKING LOA
ρ = DENSITY OF ROCK
V = VOLUME OF ROCK

Checker Note:
Salt density changed to that used in the "Design Basis" report for consistency

$$W = (135\ lb/ft^3)(140\ ft^3)$$

$$W = 18.9\ kip = 84.1\ kN$$

DISCUSSION:

THE MAXIMUM LOAD ON A BOLT IN THE PROPOSED 2'x10' LAYOUT WILL BE ~~80~~ 18.9 kip.

REV NO	REV DATE	AUTHOR	DATE	CHK'D BY	DATE	CHK'D BY

FROM "DESIGN BASIS - UNDERGROUND EXCAVATIONS" BECHTEL DOC. # D-51-W-01

3.1.9 Excavation shall permit early installation and start up of experiments in one or more rooms while excavation continues in the remainder of the experimental areas. The design shall permit access to, and utilization of, both waste and nonwaste experimental areas.

3.2 Configuration and Essential Features

3.2.1 General Location Underground

All depths assume ERDA No. 9 drill hole surface elevation as datum. This is 3409 ft above mean sea level.

The storage area floor is approx. 2,150 ft below the ground surface. The final level of the excavations shall be as determined by the contracting officer. All excavations shall be parallel to the existing bedding planes within allowable tolerances. To the extent practical, a marker bed in the excavation rib will be defined as the reference plane from which the excavation shall be continued. In addition, holes shall be drilled into the floor and roof of the excavation for determination of the location of Marker Bed - 139 and the clay seams above the roof. Coring of these holes shall begin before the continuous miner advances more than 250 feet from the location.

Based on the existing, the average dip of the sedimentary beds in the underground areas will be approximately 2 percent to the south east.

3.2.2 Salt Composition and Density

The halite is relatively free of impurities with the exception of occasional thin but separate layers of lightly interspersed argillaceous materials (up to 4%) and of polyhalite (less than 1%). Halite is also widely interbedded with layers of anhydrite ranging from a few inches to several feet in thickness. The overall moisture content is 0.4%.

For purposes of excavation calculations, the salt in place is assumed to have a density of 135 lb /cu ft (1.8225 tons/cu yd).

3.2.3 Creep Allowance

Excavation dimensions shall include an allowance for salt creep of 1 ft in the vertical dimension and nine inches in the required width of all rooms.

TITLE			PAGE
FACTOR OF SAFETY – BOLT TENDON FAILURE			1 OF 2
PROJECT	AUTHOR C. FRANCKE DATE 9/5/91	CHK'D BY JR Tyler DATE 9/6/91	CHK'D BY
SO	CALC NO	FILE NO	GROUP

PROBLEM: DETERMINE THE FACTOR OF SAFETY (FofS) OF ROCKBOLTS AGAINST TENDON FAILURE.

ASSUMPTIONS:

1) THE TENDON IS EXPECTED TO BE GRADE 60 STEEL WHICH MEETS ASTM STANDARD A615 (REF. 2).
2) THE MAXIMUM WORKING LOAD ON THE TENDON IS 18.9 kip (84.1 KN).
3) THE MINIMUM (GUARANTEED) ULTIMATE TENSILE STRENGTH OF THE TENDON IS 90,000 psi (REF. 2).
4) THE TENDON IS 1" DIAMETER. Value we verifie

REFERENCES:

1) PTI (Post-Tensioning Institute), 1986, Recommendations for Prestressing Rock and Soil Anchors.
2) ASTM Standard A615.

METHOD:

THE WORKING LOAD ON THE TENDON IS CALCULATED.

CALCULATIONS:

THE MAXIMUM LOAD THAT THE TENDON CAN SUPPORT IS DETERMINED BY MULTIPLYING THE ULTIMATE TENSILE STRENGTH OF THE TENDON BY THE CROSS-SECTIONAL AREA OF THE TENDON.

REV NO	REV DATE --	AUTHOR	DATE	CHK'D BY	DATE	CHK'D BY	DATE

TITLE			PAGE
FACTOR OF SAFETY - BOLT TENDON FAILURE			2 of 2
PROJECT	AUTHOR C. FRANKE 9/5/91	CHK'D BY J.E. Tyburski 9/9/91	CHK'D BY DATE
W.O.	CALC NO	FILE NO	GROUP

CALCULATIONS (CONT'D)

$$P_t = T_t \pi d_t^2/4$$

WHERE: P_t = MAXIMUM ALLOWED WORKING LOAD
T_t = ULTIMATE TENSILE STRENGTH OF TENDON
d_t = DIAMETER OF TENDON

$$P_t = (90\ \text{kip/in}^2)\,\pi\,(1\ \text{in})^2/4$$
$$P_t = 70.7\ \text{kip}$$

FACTOR OF SAFETY

$$F_{of}S = \frac{\text{MAXIMUM ALLOWED TENSILE STRESS}}{\text{ACTUAL WORKING LOAD}}$$

$$F_{of}S = 70.7\ \text{kip}/18.9\ \text{kip}$$

$$F_{of}S = 3.7$$

DISCUSSION:

ACCORDING TO THE PTI RECOMMENDATIONS (REF 1): "The tendon size is determined such that the design load for the anchor does not exceed 60% of the guaranteed ultimate strength of the tendon." THIS WOULD BE EQUIVALENT TO A $F_{of}S$ OF 1.7 (i.e. 1/0.6 = 1.7). ~~NORMALLY,~~ IN OTHER WORDS, THE WORKING LOAD SHOULD NOT EXCEED $0.6 * P_t$ = 42.4 kip, WHICH IT DOES NOT. NORMALLY, ONE ONE DETERMINE A DESIRED SAFETY FACTOR, SUCH AS 1.7, AND DETERMINE THE REQUIRED BOLT DIAMETER. IN THIS CALCULATION, THE SAFETY FACTOR WAS NOT CALCULATED UNTIL THE END SINCE BOLT DIAMETER AND LOAD WERE KNOW

Checker Note: Agree, however when evaluating the FofS we should use 60% of Ultimate or Max Allowed Tensile Stress 42.4/18.9 or 2.2 which is still greater than 1.7 i.e. is conservative

REV NO	REV DATE	AUTHOR	DATE	CHK'D BY	DATE	CHK'D BY	DATE

Designation: A 615 – 90

Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement[1]

This standard is issued under the fixed designation A 615; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers deformed and plain billet-steel concrete-reinforcement bars in cut lengths or coils. A deformed bar is defined as a bar that is intended for use as reinforcement in reinforced concrete construction. The surface of the bar is provided with lugs or protrusions (hereinafter called *deformations*) which inhibit longitudinal movement of the bar relative to the concrete which surrounds the bar in such construction and conform to the provisions of this specification. The standard sizes and dimensions of deformed bars and their number designations shall be those listed in Table 1.

NOTE 1—For coils of deformed bars, the capacity of industrial straightening units limits the maximum bar size that can be straightened.

1.2 Bars are of three minimum yield levels: namely, 40 000, 60 000, and 75 000 psi, designated as Grade 40, Grade 60, and Grade 75, respectively.

1.3 Hot-rolled plain rounds, in sizes up to and including 2 in. in diameter in coils or cut lengths, when specified for ties, spirals and structural ties or supports shall be furnished under this specification in Grade 40, Grade 60, and Grade 75 (Note 2). For bending properties, test provisions of the nearest nominal diameter deformed bar size shall apply. These requirements providing for deformations and marking shall not be applicable.

1.4 The weldability of the steel is not part of this specification.

NOTE 2—The weight for plain rounds smaller than ¼ in. in diameter shall be computed on the basis of the size in Specification A 510.

NOTE 3—A complete metric conversion to Specification A 615 has not been developed—A 615M; therefore, no metric equivalents are presented in this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Methods and Definitions for Mechanical Testing of Steel Products[2]

A 510 Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel[2]

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[3]

2.2 *U.S. Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[4]

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[4]

2.3 *U.S. Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[4]

3. Ordering Information

3.1 Orders for material under this specification should include the following information:

3.1.1 Quantity (weight).

3.1.2 Name of material (deformed and plain billet-steel bars for concrete reinforcement).

3.1.3 Size.

3.1.4 Cut lengths or coils.

3.1.5 Deformed or plain.

3.1.6 Grade.

3.1.7 Packaging (see Section 19).

3.1.8 ASTM designation and year of issue, and

3.1.9 Certified mill test reports (if desired).

NOTE 4—A typical ordering description is as follows: 20 tons deformed and plain billet-steel bars for concrete reinforcement, No. 3 (9.5 mm), deformed, Grade 40, in secured lots, to ASTM A 615 – ___. Certified mill test reports are required.

4. Material and Manufacture

4.1 The bars shall be rolled from properly identified heats of mold cast or strand cast steel using the open-hearth, basic-oxygen, or electric-furnace process.

5. Chemical Composition

5.1 An analysis of each heat of steel shall be made by the manufacturer from test samples taken preferably during the pouring of the heats. The percentages of carbon, manganese, phosphorus, and sulfur shall be determined. The phosphorus content thus determined shall not exceed 0.06 %.

5.2 The chemical composition thus determined shall be reported on request to the purchaser or his representative.

---

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.05 on Steel Reinforcement.

[2] Current edition approved Apr. 27, 1990. Published June 1990. Originally approved as A 615 – 44. Last previous edition A 615 – 89.

[3] Annual Book of ASTM Standards, Vol 14.02.

[4] Annual Book of ASTM Standards, Vol 14.01.

[5] Available from Naval Publications and Forms Center, NPFC, Tiger Hall, Philadelphia, PA 19120.

TABLE 1 Deformed Bar Designation Numbers, Nominal Weights, Nominal Dimensions, and Deformation Requirements

Bar Designation No.[A]	Nominal Weight, lb/ft	Nominal Dimensions[B]			Deformation Requirements		
		Diameter, in.	Cross-Sectional Area, in.²	Perimeter, in.	Maximum Average Spacing, in.	Minimum Average Height, in.	Maximum Gap (Chord of Arc), in.
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	2.356	[illegible]	[illegible]	[illegible]
7	2.044	[illegible]	[illegible]	[illegible]	3.612	[illegible]	[illegible]
8	2.670	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	3.400	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	4.303	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	2.25	9.32	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[A] The nominal dimensions of a deformed bar are equivalent to those of a plain round bar having the same weight per foot as the deformed bar.
[B] Bar numbers are based on the number of eighths of an inch included in the nominal diameter of the bars.

5.3 An analysis may be made by the purchaser from finished bars. The phosphorus content thus determined shall not exceed that specified in 5.1 by more than 25 %.

6. Requirements for Deformations

6.1 Deformations shall be spaced along the bar at substantially uniform distances. The deformations on opposite sides of the bar shall be similar in size and shape.

6.2 The deformations shall be placed with respect to the axis of the bar so that the included angle is not less than 45°. Where the line of deformations forms an included angle with the axis of the bar of from 45 to 70° inclusive, the deformations shall alternately reverse in direction on each side, or those on one side shall be reversed in direction from those on the opposite side. Where the line of deformation is over 70°, a reversal in direction is not required.

6.3 The average spacing or distance between deformations on each side of the bar shall not exceed seven tenths of the nominal diameter of the bar.

6.4 The overall length of deformations shall be such that the gap between the ends of the deformations on opposite sides of the bar shall not exceed 12½ % of the nominal perimeter of the bar. Where the ends terminate in a longitudinal rib, the width of the longitudinal rib shall be considered the gap. Where more than two longitudinal ribs are involved, the total width of all longitudinal ribs shall not exceed 25 % of the nominal perimeter of the bar; furthermore, the summation of gaps shall not exceed 25 % of the nominal perimeter of the bar. The nominal perimeter of the bar shall be 3.14 times the nominal diameter.

TABLE 2 Tensile Requirements

	Grade 40[A]	Grade 60	Grade 75[B]
Tensile strength, min, psi	70 000	90 000	100 000
Yield strength, min, psi	40 000	60 000	75 000
Elongation in 8 in., min, %, Bar No.			
3	[illegible]	[illegible]	
4, 5, 6	[illegible]	[illegible]	
7, 8		[illegible]	
9, 10		[illegible]	
11, 14, 18		[illegible]	[illegible]

[A] Grade 40 bars are furnished only in sizes 3 through 6.
[B] Grade 75 bars are furnished only in sizes 11, 14, and 18.

6.5 The spacing, height, and gap of deformations shall conform to the requirements prescribed in Table 1.

7. Measurements of Deformations

7.1 The average spacing of deformations shall be determined by dividing a measured length of the bar specimen by the number of individual deformations and fractional parts of deformations on any one side of the bar specimen. A measured length of the bar specimen shall be considered the distance from a point on a deformation to a corresponding point on any other deformation on the same side of the bar. Spacing measurements shall not be made over a bar area containing bar marking symbols involving letters or numbers.

7.2 The average height of deformations shall be determined from measurements made on not less than two typical deformations. Determinations shall be based on three measurements per deformation, one at the center of the overall length and the other two at the quarter points of the overall length.

7.3 Insufficient height, insufficient circumferential coverage, or excessive spacing of deformations shall not constitute cause for rejection unless it has been clearly established by determinations on each lot (Note 5) tested that typical deformation height, gap, or spacing do not conform to the minimum requirements prescribed in Section 6. No rejection may be made on the basis of measurements if fewer than ten adjacent deformations on each side of the bar are measured.

NOTE 5—A lot is defined as all the bars of one bar number and pattern of deformation contained in an individual shipping release or shipping order.

8. Tensile Requirements

8.1 The material, as represented by the test specimens, shall conform to the requirements for tensile properties prescribed in Table 2.

8.2 The yield point or yield strength shall be determined by one of the following methods:

8.2.1 The yield point shall be determined by drop of the beam or halt in the gage of the testing machine.

8.2.2 Where the steel tested does not have a well defined yield point, the yield strength shall be determined at extension under load using an autographic diagram method or an

TABLE 3 Bend-Test Requirements

Bar Designation No.	Bend Test Mandrel Diameter[1]		
	Grade 40	Grade 60	Grade 75
3, 4, 5	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]
7		[illegible]	[illegible]
8		[illegible]	[illegible]
9, 10		[illegible]	[illegible]
11		[illegible]	[illegible]
14, 18		[illegible]	[illegible]

[1] Test mandrel 90° bend unless otherwise specified.
[2] d = nominal diameter of specimen.

extensometer as described in 13.1.2 and 13.1.3 of Methods and Definitions A 370. The extension under load shall be 0.005 in./in. of gage length (0.5 %) for Grade 40 and Grade 60 and shall be 0.0035 in./in. of gage length (0.35 %) for Grade 75. When material is furnished in coils, the test sample must be straightened prior to placing it in the jaws of the tensile machine (see Note 6).

8.3 The percentage of elongation shall be as prescribed in Table 2.

NOTE 6—Straightening should be done carefully to avoid the formation of local sharp bends and to minimize cold work. Insufficient straightening prior to attaching the extensometer can result in lower-than-actual yield strength readings.

9. Bending Requirements

9.1 The bend-test specimen shall withstand being bent around a pin without cracking on the outside of the bent portion. The requirements for degree of bending and sizes of pins are prescribed in Table 3.

9.2 The bend test shall be made on specimens of sufficient length to ensure free bending and with apparatus which provides:

9.2.1 Continuous and uniform application of force throughout the duration of the bending operation.

9.2.2 Unrestricted movement of the specimen at points of contact with the apparatus and bending around a pin free to rotate.

9.2.3 Close wrapping of the specimen around the pin during the bending operation.

9.3 Other acceptable more severe methods of bend testing, such as placing a specimen across two pins free to rotate and applying the bending force with a fixed pin, may be used. When failures occur under more severe methods, retests shall be permitted under the bend test method prescribed in 9.2.

10. Permissible Variation in Weight

10.1 The permissible variation shall not exceed 6 % under nominal weight, except for bars smaller than ⅜ in. plain round, the permissible variation in weight shall be computed upon the basis of the permissible variation in diameter in Specification A 510. Reinforcing bars are evaluated on the basis of nominal weights. In no case shall the overweight of any bar be the cause for rejection.

10.2 The specified limit of variation shall be evaluated in accordance with Practice E 29 (rounding method).

11. Finish

11.1 The bars shall be free of detrimental surface imperfections.

11.2 Rust, scale, surface imperfections or mill scale shall not be cause for rejection, provided the weight, length, cross-sectional area, and tensile properties of a bend specimen are not less than the requirements specified in this specification.

Surface imperfections that meet the requirements of 11.1 shall be considered detrimental when specimens containing such imperfections fail to conform to minimum tensile or bending requirements.

12. Test Specimens

12.1 Tension test specimens shall be the full section of the bar as rolled. The unit stress determination shall be based on the nominal bar area.

12.2 The bend test specimens shall be the full section of the bar as rolled.

13. Number of Tests

13.1 For bar sizes No. 3 to 11, inclusive, one tension test and one bend test shall be made of the largest size rolled from each heat. If, however, material from one heat differs by three or more designation numbers, one tension and one bend test shall be made from both the highest and lowest designation number of the deformed bars rolled.

13.2 In the case of Nos. 14 and 18 bars, one tension test and one bend test shall be made of each size rolled from each heat.

14. Retests

14.1 If any tensile property of any tension test specimen is less than that specified, and any part of the fracture is outside the middle third of the gage length, as indicated by some scratches marked on the specimen before testing, a retest shall be allowed.

14.2 If the results of an original tension specimen fail to meet the specified minimum requirements and are within 2000 psi of the required tensile strength, within 1000 psi of the required yield point, or within two percentage units of the required elongation, a retest shall be permitted on two random specimens for each original tension specimen failure from the lot. If all results of these retest specimens meet the specified requirements, the lot shall be accepted.

14.3 If a bend test fails for reasons other than mechanical reasons or flaws in the specimen as described in 14.4 and 14.5, a retest shall be permitted on two random specimens from the same lot. If the results of both test specimens meet the specified requirements, the lot shall be accepted. The retest shall be performed on test specimens that are at an temperature but not less than 60°F.

14.4 If any test specimen fails because of mechanical reasons such as failure of testing equipment or improper specimen preparation, it may be discarded and another specimen taken.

14.5 If any test specimen develops flaws, it may be discarded and another specimen of the same size bar from the same heat substituted.

15. Inspection

15.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's

er's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection, shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

15.2 *For Government Procurement Only*—Except as otherwise specified in the contract, the contractor is responsible for the performance of all inspection and test requirements specified herein and may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser at the time of purchase. The purchaser shall have the right to perform any of the inspections and tests at the same frequency as set forth in this specification, where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

16. Rejection

16.1 Unless otherwise specified, any rejection based on tests made in accordance with 5.3, shall be reported to the manufacturer within 5 working days from the receipt of samples by the purchaser.

16.2 Material that shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

17. Rehearing

17.1 Samples tested in accordance with 5.3 that represent rejected material shall be preserved for 2 weeks from the date rejection is reported to the manufacturer. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

18. Marking

18.1 When loaded for mill shipment, bars shall be properly separated and tagged with the manufacturer's heat or test identification number.

18.2 Each producer shall identify the symbols of his marking system.

18.3 All bars produced to this specification, except plain round bars which shall be tagged for grade, shall be identified by a distinguishing set of marks legibly rolled into the surface of one side of the bar to denote in the following order:

18.3.1 *Point of Origin*—Letter or symbol established as the producer's mill designation.

18.3.2 *Size Designation*—Arabic number corresponding to bar designation number of Table 1.

18.3.3 *Type of Steel*—Letter *S* indicating that the bar was produced to this specification.

18.3.4 *Minimum Yield Designation*—For Grade 60 bars, either the number 60 or a single continuous longitudinal line through at least 5 spaces offset from the center of the bar side. For Grade 75 bars, either the number 75 or two continuous longitudinal lines through at least 5 spaces offset each direction from the center of the bar. (No marking designation for Grade 40 bars.)

19. Packaging

19.1 When specified in the purchase order, packaging shall be in accordance with the procedures in Practices A 700.

19.2 *For Government Procurement Only*—When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are explicitly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103.

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SO	CALC NO	FILE NO	GROUP

PROBLEM: DETERMINE FACTOR OF SAFETY (F of S) FOR A RESIN ANCHOR BOND TO SALT VS. WORKING LOAD ON THE ANCHOR.

ASSUMPTIONS:

1.) MAXIMUM WORKING LOAD ON THE ANCHOR IS 18.9 kip (84.1 kN).
2.) FIXED ANCHOR LENGTH IS 3' (0.91 m).
3.) AVERAGE HOLE (AND ANCHOR) DIAMETER IS 1 3/8" (0.035 m).
4.) UNCONFINED COMPRESSIVE STRENGTH (UCS) OF WIPP SALT IS TAKEN AS 25 MPa. (SEE DISCUSSION).
See below

REFERENCES:

1.) G.S. Littlejohn and D.A. Bruce, "Rock Anchors - State of the Art - Part 1: Design", Ground Engineering, May 1975.
2.) PTI (Post-Tensioning Institute), Recommendations for Prestressed Rock and Soil Anchors, 1986.
3.) BSI (British Standards Institute), BSI 8081, "British Standard Code of Practice for Ground Anchorages", 1989.
4.) SAND 78-1596, Geologic Characterization Report, Powers et al.

METHOD: THE ULTIMATE ANCHOR LOAD IS CALCULATED BASED ON THE SIZE OF THE ANCHOR AND THE ANCHOR BOND STRENGTH.

For most elastic rocks using the higher UCS value from lab testing may be appropriate, however, because the strength of salt is time dependent, I'm not certain this is a conservative approach. The original checker comment (using 1 N/mm²) was to use a lower value. This needs to be discussed. A reasonable field test to evaluate time dependent slippage might need be developed for confirmation.

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CALCULATIONS:

ACCORDING TO REF 1., THE ULTIMATE ANCHOR LOAD IS CALCULATED AS FOLLOWS:

$$P_a = \pi d_a L_a \tau$$

WHERE: P_a = LOAD TO CAUSE BOND FAILURE
d_a = EFFECTIVE ANCHOR DIAMETER
L_a = FIXED ANCHOR LENGTH
τ = WORKING BOND STRENGTH

REF 1 FURTHER STATES THAT, IN THE ABSENCE OF PULL TEST DATA ON BOND STRENGTH, τ CAN BE ESTIMATED AS 1/10 OF THE UCS OF THE ROCK. THEREFORE:

$$\tau = 0.1\,(UCS)$$
$$= 0.1\,(25\,MPa)$$
$$\tau = 2.5\,MPa = 2500\,kN/m^2$$

This does not address the lack of relevant data, as suggested by Littlejohn & Bruce.

τ IS OFTEN REDUCED TO 1/3 τ TO ADD A SAFETY FACTOR. THIS WILL NOT BE DONE HERE BECAUSE THE 1/3 τ VALUE IS USED TO DETERMINE (DESIGN) ANCHOR LENGTH OR DIAMETER. SINCE ANCHOR LENGTH & DIAMETER ARE PRE-DETERMINED, THE FULL VALUE OF τ IS USED SO THAT THE REAL SAFETY FACTOR CAN BE DETERMINED.

THE LOAD TO CAUSE BOND FAILURE IS THEN:

$$P_a = \pi(0.05m)(0.91m)(2500\,kN/m^2)$$
$$P_a = 250\,kN = 56\,kip$$

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S.O.	CALC NO.	FILE NO.	GROUP

CALCULATIONS (CONT'D)

FACTOR OF SAFETY - ANCHOR BOND

$$FofS = \frac{\text{LOAD CAUSING FAILURE}}{\text{WORKING LOAD}}$$

$$FofS = 56\,kip / 18.9\,kip = 3.0$$

DISCUSSION

RECOMMENDED SAFETY FACTORS FOR ANCHOR BOND RANGE FROM 1.5 TO 4, DEPENDING ON ROCK TYPE AND APPLICATION (REF 1,2,3). SAFETY FACTOR IS NORMALLY INTRODUCED INTO THE CALCULATION BY REDUCING τ, WORKING BOND STRENGTH, TO 25% TO 50% OF THE ULTIMATE BOND STRENGTH (REF. 2). THIS WOULD BE EQUIVALENT TO A SAFETY FACTOR OF 2 TO 4. AS IS EXPLAINED ON PAGE 2 OF THIS CALC, τ WAS NOT REDUCED SO THAT THE TRUE FACTOR OF SAFETY COULD BE DETERMINED.

See Comment pg 1 of 3

THE VALUE USED FOR UNCONFINED COMPRESSIVE STRENGTH (UCS) IS BASED ON LABORATORY TESTING (REF. 4) AND ENGINEERING JUDGEMENT. BECAUSE UCS VALUES FROM LAB TESTING USUALLY UNDERESTIMATE THE IN SITU STRENGTH, THE HIGHEST VALUE FROM REF 4 WAS USED.

THE 3' FIXED ANCHOR LENGTH PROVIDES AN ACCEPTABLE FACTOR OF SAFETY AGAINST FAILURE OF THE ANCHOR BOND.

THE ABOVE ASSUMPTIONS WILL BE VERIFIED BY FIELD TESTING.

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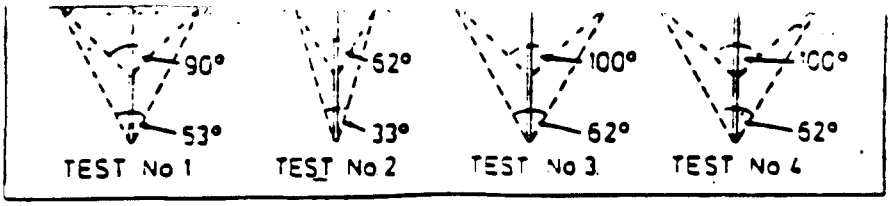

Fig 3 Possible failure modes based on test results at Trinity Cleur Creek
(after Saliman and Schaefer 1968)

plex by Littlejohn and Thomas-Davies (1973), where 2,000kN anchors were spaced at 1m centres. Another method to dissipate load within the rock mass is simply to install anchors at different inclinations as in the design by Soletanche (1968) for the Zarcesas Dam, Algeria. In some other countries a minimum distance between anchors is stipulated. Broms (1968), reviewing Swedish practice, confirmed a minimum spacing of 2.5m whilst the Czech Standard (1974) recommends 1.5m, one consideration being to reduce "interhole grouting", although this phenomenon is not necessarily a disadvantage in practice.

It is noteworthy that these guide rules or approaches are based on experience and engineering judgement, and not on an intimate knowledge of stress distribution around the anchor.

Remarks

With regard to uplift capacity no experimental or practical evidence and only very little theoretical data substantiate the methods currently used (Table I) to calculate the ultimate resistance to pull-out of individual, or groups of anchors. Indeed, there would appear to be results (Saliman and Schaefer (1968) and Brown (1970)) which indicate that failure in a rock mass does not generally occur in the form of an inverted 90 deg cone or wedge. However it is reassuring to know that most designs are likely to be conservative in adopting a cone method with no allowance for the shear strength of the rock mass.

Nevertheless, some standardisation on safety factors for temporary and permanent anchors is desirable together with agreement on what allowances should be made for surcharge due to unconsolidated overburden and the effect of upper layers of weathered rock.

In general effort should now be expended, in the form of field testing in a wide range of rock materials and masses which have been carefully classified, in order to study the shape and position of the rock zones mobilised at failure. Such programmes should accommodate single anchors and groups tested over a range of inclinations. Only in this way can anchor design in relation to overall stability be optimised both technically and economically.

BOND BETWEEN CEMENT GROUT AND ROCK

Introduction

Most designs to date concerning straight shaft fixed anchors have been successfully based on the assumption of uniform bond distribution over the fixed anchor surface area. In other words it has been generally accepted that the bond developed is merely a function of fixed anchor dimensions and applied load.

However, recent experimental and theoretical analyses have indicated that the character of the bond to the rock is more complex, and reflects additional parameters which often give rise to a markedly non-uniform stress distribution. Thus, in many cases the assumed mechanism of load transfer in the fixed anchor zone may be grossly inaccurate. For example, the situation could well arise where, for a high capacity anchor, the level of bond stress at the loaded (or proximal) end may be extremely high, possibly approaching failure, whereas the more distal parts of the fixed anchor may in effect be redundant. Clearly, such a situation will have a bearing on overall stability analyses, the interpretation of anchor extensions, and long-term creep behaviour.

Design criteria are reviewed relating to the magnitude and distribution of bond, fixed anchor dimensions, and factors of safety. For comparison, the results of relevant theoretical and experimental investigations are presented.

described by Littlejohn (1972) it is usu in Britain to assume an equivalent uniform distribution of bond stress along the fixe anchor. Thus the anchor load P is relate to the fixed anchor design by the equatio

$$P = \pi d L \tau \qquad (1$$

where L = fixed anchor length
d = effective anchor diameter
τ = working bond stress

This approach is used in many countr e.g. France (Fargeot 1972), Italy (Ca card 1973), Canada (Coates 1970), USA (White 1973).

The rule is based on the follow simple assumptions

(i) Transfer of the load from the fixe anchor to the rock occurs by a uniform distributed stress acting over the whole the curved surface of the fixed anchor.
(ii) The diameter of the borehole and th fixed anchor are identical.
(iii) Failure takes place by sliding at th rock/grout interface (smooth borehole) by shearing adjacent to the rock/grout terface in weaker medium (rough bore hole).
(iv) There are no discontinuities or inhe ent weakness planes along which failu can be induced, and
(v) There is no local debonding at th grout/rock interface.

Where shear strength tests are carri out on representative samples of the roc mass, the maximum average working bon stress at the rock/grout interface shou not exceed the minimum shear strengt divided by the relevant safety factor (no mally not less than 2). This approach ap plies primarily to soft rocks where the un axial compressive strength (UCS) is es than 7N/mm², and in which the holes ha been drilled using a rotary percussive tec nique. In the absence of shear strengt data or field pull-out tests, Littlejo (1972) states that the ultimate bond stre is often taken as one-tenth of the un ax compressive strength of massive roc (100 per cent core recovery) up to a ma mum value of 4.2N/mm², assum that the crushing strength of the cem grout is equal to or greater than 42N/mm Applying an apparent safety factor of 3 more, which is conservative bearing mind the lack of relevant data, the wor

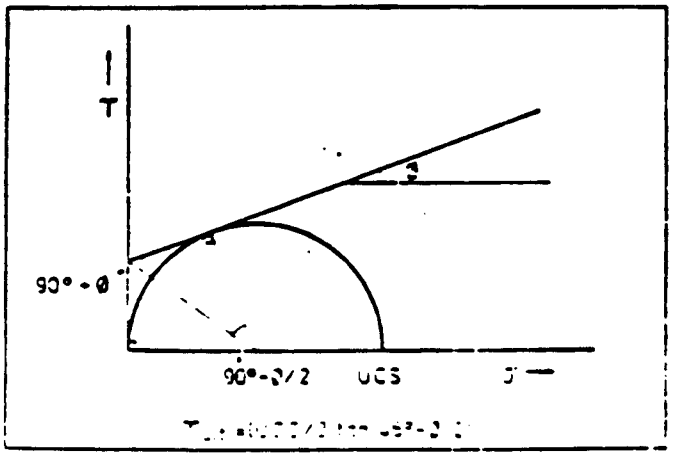

Fig 4 Relationship between shear strength and uniaxial compressive strength

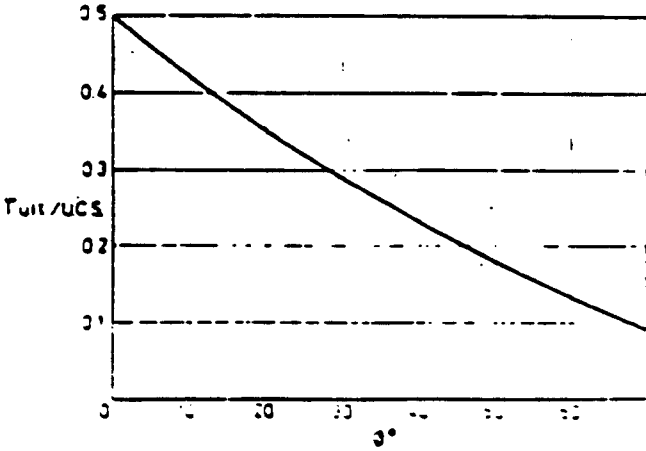

Fig 5 Effect of Ø on Tult/UCS ratio

Coates (1970) allows a maximum working bond of 2.45N/mm² but with a safety factor of 1.75 which indicates a value of τ_{ult} of 4.3N/mm². In some rocks, particularly granular weathered varieties with a relatively low UCS value, the assumption that τ_{ult} equals 10 per cent rock UCS may lead to an artificially low estimate of shear strength (Figs 4 and 5). In such cases the assumption that τ_{ult} equals 20-35 per cent UCS may be justified.

As a guide to specialists, bond values, as recommended throughout the world for a wide range of igneous, metamorphic and sedimentary rocks, are presented in Table III. Where included, the factor of safety relates to the ultimate and working bond values calculated assuming uniform bond distribution. It is common to find that the magnitude of bond is simply assessed by experienced engineers; the value adopted for working bond stress often lies in the range 0.35 to 1.4N/mm². Koch (1972) suggests bond stresses in this range for weak, medium and strong rock (Table III), and the Australian Code CA 33—1973 states that a value of 1.05N/mm² has been used in a wide range of igneous and sedimentary rocks, but confirms that site testing has permitted bond values of up to 2.1 N/mm² to be employed.

In this connection the draft Czech Standard (1974) concludes that since the estimation of bond magnitude and distribution is a complex problem, field anchor tests should always be conducted to confirm bond values in design, as there is no efficient or reliable alternative. Certainly, a common procedure amongst anchor designers is to arrive at estimates of permissible working bond values by factoring the value of the average ultimate bond calculated from test anchors, when available. Usually the recommended safety factor ranges from 2 to 3, but is frequently lower in very competent rocks, and higher in weaker, fissured, or weathered varieties.

The degree of weathering of the rock is

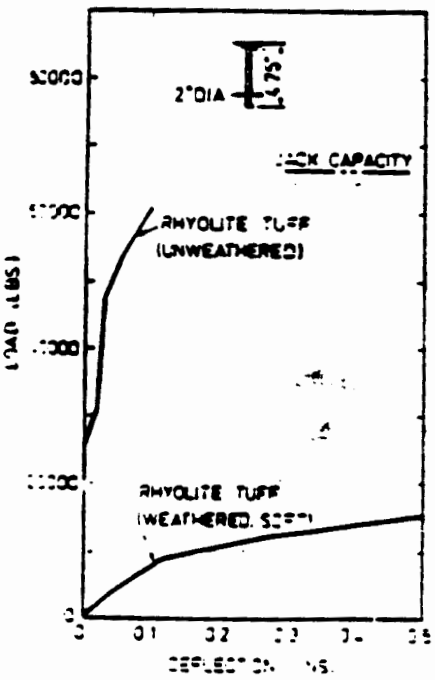

Fig. 5. Effect of weathering at Curreca'ti Motorway Transmission Line

(after Salman and Schaefer, 1968)

Rock type	Working bond (N/mm²)	Ultimate bond (N/mm²)	Factor of safety	Source
Igneous				
Medium hard basalt		5.73	3.4	[illegible]—Rae (1964)
Weathered granite		1.50-2.50		[illegible]—[illegible]
Basalt	1.21-1.38	3.44	[illegible]	[illegible]
Granite	1.38-1.55	4.83	[illegible]	[illegible]
Serpentine	0.45-0.55	1.55	[illegible]	[illegible]
Granite & basalt		1.72-3.10	[illegible]	[illegible]
Metamorphic				
Metamorphic schist	0.70	2.93	4.2	[illegible]
Slate & hard shale		1.93-2.28	[illegible]	[illegible]
Calcareous sediments				
Limestone	1.00	2.93	[illegible]	[illegible]
Chalk—Grades I-III	0.01N (Satur. Grades 0.3m)	[illegible]	[illegible] (Temporary) [illegible] (Permanent)	[illegible]
Tertiary limestone	0.83-0.97	2.76	[illegible]	[illegible]
Chalk limestone	0.46-1.00	2.76	[illegible]	[illegible]
Soft limestone		1.03-1.52	[illegible]	[illegible]
Chalk limestone		1.38-2.07	2.5	USA—PCI (1974)
Arenaceous sediments				
Hard coarse-grained sandstone	2.46		1.75	Canada—Coates (1970)
Weathered sandstone		0.69-0.85	3.0	New Zealand—[illegible]
Well cemented mudstones		0.69	2.0-2.5	New Zealand—[illegible]
Softer sandstone	0.40		3.0	Britain—[illegible] (1973)
Softer sandstone (UCS > 2.0N/mm²)	0.60		3.0	Britain—[illegible] (1973)
Hard fine sandstone	0.69-0.83	2.24	2.7-3.3	Britain—Wedding-Jones
Sandstone		0.83-1.73	2.5	USA—PCI (1974)
Argillaceous sediments				
Keuper marl		0.17-0.28 (0.46 C_u)	3.0	Britain—[illegible] (1970) (C_u = undrained cohesion)
Weak shale		0.38		Canada—Golder Brawner
Soft sandstone & shale	0.10-0.14	0.37	2.7-3.7	Britain—Wedding-Jones
Soft shale		0.21-0.83	1.5-2.5	USA—PCI (1974)
General				
Competent rock (where UCS > 20N/mm²)	Uniaxial compressive strength—30 up to a maximum value of 1.4N/mm²	Uniaxial compressive strength—70 up to a maximum value of (4.2N/mm²)	3	Britain—[illegible] (1972)
Weak rock	0.35-0.70			Australia—Koch (1972)
Medium rock	0.70-1.05			
Strong rock	1.05-1.40			
Wide variety of igneous and metamorphic rocks	1.05		2	Australia—Standard CA33
Wide variety of rocks	0.98			France—Fargeot (1972)
	0.50			Switzerland—Walther (1[illegible]
	0.70			Switzerland—Cornie (1[illegible]
		1.20-2.50		Switzerland—Cornie (1971)
	0.70		2.5 (Temporary) 3 (Permanent)	Italy—Mascardi (1972)
	0.69	2.76	4	Canada—Golder Brawner
	1.4	4.2	3	USA—White (1973)
		15-20 per cent of grout crushing strength	3	Australia—Langworth (197[illegible]
Concrete		1.38-2.70	2.5	USA—PCI (1974)

TABLE IV—ROCK/GROUT BOND VALUES WHICH HAVE BEEN EMPLOYED IN PRACTICE

Rock type	Working bond (N/mm²)	Test bond (N/mm²)	Ultimate bond (N/mm²)	[illegible] (test)	[illegible] (ultimate)	Source
Igneous						
Basalt	1.93		6.27		3.3	Britain—Parker (1958)
Basalt	1.10	3.60				USA—Eberhart & Vollman (1[illegible]
Tuff	0.88					France—Cambefort (1966)
Basalt	0.83	0.72				Britain—Cementation (1962)
Granite	1.55	1.72				Britain—Cementation (1962)
Dolerite	1.55	1.72				Britain—Cementation (1962)
Very fissured felsite	1.55	1.72				Britain—Cementation (1962)
Very hard dolerite	1.55	1.72				Britain—Cementation (1962)
Hard granite	1.55	1.72				Britain—Cementation (1962)
Basalt & tuff	1.55	1.72				Britain—Cementation (1962)
Granodiorite	1.08					Britain—Cementation (1962)
Shattered basalt		1.01				USA—Salman & Schaefer (1[illegible]
Decomposed granite		1.24				USA—Salman & Schaefer (1[illegible]
Flow breccia		0.93				USA—Salman & Schaefer (1[illegible]
Mylonitised porphyrite	0.32-0.97					Switzerland—Descoeudres (1[illegible]
Fractured diorite	0.98					Switzerland—Descoeudres (1[illegible]
Granite	0.83	0.81				Canada—Barton et al. (1971)
Metamorphic						
Schist	0.31					Switzerland—[illegible]
All types	1.20					[illegible]
Weathered fractured quartzite	1.55	1.72		1.1		Britain—Cementation (1962)
Blue schist	1.32	1.67		1.1		Britain—Cementation (1962)
Mica meta sediments	1.10	1.23		1.1		Britain—Cementation (1962)
Slate	0.43					Britain—Cementation (1962)
Chlorite meta greywacke	1.57	1.73		1.1		Britain—Cementation (1962)
[illegible]	0.35-0.59					[illegible]
Altered quartzite	0.51					[illegible]
Weathered meta tuff		0.20				[illegible]
Greywacke	0.34					[illegible]
Quartzite	0.93-1.20	1.32-1.72		1.1		[illegible]
Microgneiss	0.58					[illegible]

Rock	Bond (N/mm²)	Bond (N/mm²)	Bond (N/mm²)	(test)	(with meter)	Source
Metamorphic—contd.						
Sericite schist	0.05					Italy—Berardi (1972)
Quartzite schist	0.10					Italy—Berardi (1972)
Argillaceous & calcareous schist	0.63					Italy—Berardi (1972)
Slate	0.95	1.24		1.3		Switzerland—Meschler & Meir (1972)
Hights metasediments	0.81	1.08		1.3		USA—Bure (1972)
Slate & greywacke	1.08	— 1.40		1.3		Germany—Ahen (1972)
Various metasediments			57			Germany—Abraham & Pertig (1973)
Metamorphic slightly gneiss	0.53	0.83		1.5		USA—Nicholson Anchorage Co. Ltd (1973)
Slate	0.50	0.90	1.80	1.5	3.0	Britain—Littlejohn & Truman Davies (1974)
Sound Micaschist	1.74	2.15				USA—Feld & White (1974)
Micaschist	0.83-0.74	–		1.24		USA—Feld & White (1974)
Very poor gneiss & mud band	0.07					USA—Feld & White (1974)
Carbonate sediments						
Loamy limestone		0.63				Italy—Berardi (1980)
Fissured limestone & intercalations	1.08	1.19		1.1		Britain—Cementation Co. Ltd (1982)
Limestone	0.65					Switzerland—Muller (1986)
Poor limestone	0.32					France—Henneguin & Camberfort (1968)
Massive limestone	0.39-0.78					France—Henneguin & Camberfort (1968)
Karstic limestone	0.54					France—Henneguin & Camberfort (1968)
Tertiary limestone	1.00		2.63		2.8	Switzerland—Losinger & Co. Ltd (1966)
Limestone			4.55-4.85			Switzerland—Ruttner (1986)
Marly limestone	0.03-0.07 (average) 0.21-0.38 (measured)					Italy—Berardi (1987)
Limestone			0.27			USA—Salmon & Schaefer (1968)
Limestone	0.28					Italy—Berardi (1989)
Dolomitic limestone			1.80			Canada—Brown (1970)
Marly limestone	0.39-0.94					Italy—Berardi (1972)
Limestone	0.28					Italy—Berardi (1972)
Limestone puddingstone	0.44					France—Solétanche Co. Ltd (1988)
Limestone	1.18	1.42		1.2		USA—Bure (1972)
Chalk			0.70			Britain—Associated Tunnelling Co. Ltd (1973)
Dolomite		1.66				Canada—Golder Brawner (1973)
Dolomitic siltstone	0.43					USA—White (1973)
Limestone & marly bands	0.37	0.58		1.5		Italy—Mongiardi (1972)
Arenaceous sediments						
Sandstone	1.44	1.58		1.1		Britain—Morris & Garrett (1956)
Hard sandstone	1.42	1.56		1.1		Britain—Cementation Co. Ltd (1982)
Bunter sandstone	0.95	0.98		1.03		Britain—Cementation Co. Ltd (1982)
Sandstone	0.76	0.84		1.1		Britain—Cementation Co. Ltd (1982)
Sandstone	0.74					Czechoslovakia—Hobst (1963)
Sandstone	0.31	0.40	1.73	1.29	5.8	USA—Drosser (1970)
Sandstone	0.80					USA—Thomson (1970)
Poor sandstone	0.40					Germany—Brunner (1970)
Good sandstone	1.14					Germany—Brunner (1970)
Sandstone & breccia	0.38					France—Solétanche (1988)
Sandstone		0.95				Australia—Williams et al. (1972)
Bunter sandstone	0.60	1.20		2.0		Britain—Littlejohn (1973)
Sandstone	1.17					Australia—McLeod & Headley (1974)
Argillaceous sediments						
Shale	0.62					Canada—Juergens (1965)
Marl	0.10	0.28		2.8		Italy—Berardi (1967)
Shale	0.30		0.63		2.1	Canada—Hanna & Seaton (1987)
Very weathered shale			0.38			USA—Salmon & Schaefer (1968)
Shale	0.13-0.24					USA—Kerisel (1970)
Grey siltstone	0.62					Britain—Universal Anchorage Co. Ltd (1972)
Clay marl	0.14-0.24	0.21-0.38		1.5		Germany—Schwarz (1972)
Shale	0.42					Canada—McRae et al. (1972)
Argillite	0.82					Canada—Golder Brawner (1973)
Mudstone	0.63	0.88		1.4		Australia—McLeod & Headley (1974)
Miscellaneous						
Bedded sandstone & shale	0.25-0.90					Italy—Beomonte (1981)
Porous, sound gossamer	1.57	1.72		1.1		Britain—Cementation Co. Ltd (1982)
Shale & sandstone	0.07	0.10		1.5		USA—Reb (1984)
Soft rocks	0.75					Sweden—Nordin (1986)
Sandstone & shale	1.82					Poland—Bulas et al. (1987)
Siltstone & mudstone	1.65					Australia—Maddess et al. (1987)
Fractured rock (75 per cent shale)						
Poor			0.24			USA—Salmon & Schaefer (1968)
Average			0.38			USA—Salmon & Schaefer (1968)
Good			0.75			USA—Salmon & Schaefer (1968)
Limestone & clay breccia	0.20-0.25					Italy—Berardi (1972)

a major factor which affects not only the ultimate bond but also the load-deflection characteristics. Fig. 6 shows the results produced by test anchors in rhyolite tuff, of both sound and weathered varieties. No data are provided on grout or rock strengths but it is significant that the equivalent uniform bond stress at maximum jack capacity is scarcely 0.01N mm⁻². For design in soft or weathered rocks there are signs that the standard penetration test is being further exploited. For example, Suzuki et al. (1972) state that for weathered granite the magnitude of the bond can be determined from the equation

$$\tau_{ult} = 0.007N - 0.12 \text{ (N/mm}^2\text{)}$$

where N = number of blows per 0.3m ..... (2)

Similarly, Littlejohn (1970) illustrates a correlation between N and ultimate bond $\tau_{ult} = 0.01N$ (N/mm²).

In grades III, II and I of chalk he served a range of τ_{ult} of 0.21—1.07N, based on test anchors pulled to failure.

Although it would appear from evide presented in subsequent sections that assumptions made in relation to unifo bond distribution are not strictly accur it is noteworthy that few failures are countered at the rock grout interface new designs are often based on the s cessful completion of former proje that is former working bond values re-employed or slightly modified deli ng on the judgement of the designer.

Table IV contains data abstracted reports of rock anchor contracts throu out the world. In addition to the work test, and ultimate bond values, the m sured and designed safety factors are p vided where available. In certain cases fixed anchor diameter has been inferred facilitate analysis of the data, as publi

It will be noted that, even for one ro type, the magnitude of bond used in pr tice is extremely variable. There are ma reasons for this, the most important which are:

(*i*) Different designers use different bo values and safety factors, which may related to type of anchor and extent of anchor testing programme.

(*ii*) "Standard" values for a certain ro type have often been modified to refl local peculiarities or irregularities of geology.

(*iii*) Factors related to the construct techniques e.g. drilling method, flush procedure, and grout pressure will inf ence the results obtained. (The effect these aspects will be discussed in Part 2 Construction.)

On the whole however, it would acce that the bond values employed are to a d gree consistent with rock type and co petency.

Fixed anchor dimensions

The recommendations made by vario engineers with respect to length of fi anchor are presented in Table V. Under c tain conditions it is recognised that mu shorter lengths would suffice, even a the application of a generous factor safety. However, for a very short anch the effect of any sudden drop in to quality along the anchorage zone, and constructional errors or inefficienc could induce a serious decrease in th anchor's capacity.

With regard to the choice of anchor d meter several considerations may be tak into account:

(*i*) Type and size of tendon.

(*ii*) The relation of diameter to perme area of fixed anchor and hence t anchor capacity, assuming uniform bond.

(*iii*) Ratio of steel area to cross-sect of area of borehole for efficient bond d tribution and corrosion protection.

(*iv*) Drilling method and rig to be use and

(*v*) Nature of rock in the anchor zone a presence of unconsolidated ove burden, if any.

The authors find from a survey of se eral hundred commercial anchor tes that no direct relationship may be ob ved bearing in mind the range of ro types, but that most anchors conf the trend indicated in Table VI.

RECOMMENDATIONS	COMMENTARY
3.2.3 Factors of Safety	
The design load P for the anchor equals the maximum anticipated load applied to the anchor times the factor of safety used in the design of the anchored structure. The value of the factor of safety depends upon the type of application, the degree of uncertainty in the design of the structure and the risk.	The engineer should not compound various factors of safety when designing an anchored structure. The uncertainty and risk associated with the work should be in the [illegible] determining the design capacity of the anchor and then add a separate factor of safety to the added loads, the design capacity of the anchor and the anchor test load. The actual factor of safety for the anchor will have been compounded resulting in an overly conservative design.
3.2.4 Anchor Tendon Design	
The tendon size is determined such that the design load for the anchor does not exceed 60 percent of the guaranteed ultimate tensile strength (GUTS) of the tendon. The lock off load, which shall be determined by the design engineer, may be larger or smaller than the design load. The recommendations for corrosion protection given in Section 6.0 "Corrosion Protection" shall be considered.	The load in an anchor tendon may either increase or decrease with time depending on the behavior of the structure.
3.2.5 Free Stressing Length	
The free stressing length should not be less than 15 feet (4.572m).	The minimum stressing length recommended is to prevent significant reductions in transfer load due to stressing anchorage losses or movement.
3.2.6 Bond Length	
The bond length can be estimated by the following equation: $$L_b = \frac{P}{\pi \cdot d \cdot \tau_w}$$ Where: L_b = bond length; P = design load for the anchor; π = 3.14; d = diameter of the drill hole; τ_w = working bond stress in the interface between rock and grout.	The bond length normally is not less than 10 feet. For normal applications the bond between the tendon and anchor grout is not critical. Pull-out tests may be used to determine the ultimate ns to bond stress between the rock and the anchor grout. Pull-out tests usually reduce that the tendon capacity be increased or the bond length reduced in order to fail the anchor. Pull-out tests should not be required if the anchors are tested as described in Section 3.7.
The working bond stress used to determine the bond length is normally 25 to 50 percent of the ultimate bond stress.	When selecting the working bond stress the engineer should consider the critical nature of the anchor application, variations in the rock properties and the installation procedures.
The ultimate bond stress depends on the: 1. Shear strength of the rock; 2. Discontinuities in the rock mass.	

British Standard Code of practice for Ground Anchorages" British Standards Institute, 1989

Table 25. Rock/grout bond values which have been recommended for design (after [illegible])

Rock type	Working bond	Ultimate bond	Load factor of safety	Source
	N/mm²	N/mm²		
Igneous				
Medium hard basalt		5.73	3.4	India (Rao, 1964)
Weathered granite		1.50 to 2.50		Japan (Sugawara et al., 1972)
Basalt	1.21 to 1.39	3.88	2.9 to 3.2	Britain (Wycliffe-Jones, 1974)
Granite	1.28 to 1.55	4.83	3.1 to 3.5	Britain (Wycliffe-Jones, 1974)
Serpentine	0.45 to 0.59	1.55	2.6 to 3.5	Britain (Wycliffe-Jones, 1974)
Granite and basalt		1.72 to 3.10	1.5 to 2.5	USA (PCI, 1974)
Metamorphic				
Manhattan schist	0.70	2.80	4.0	USA (White, 1973)
Slate and hard shale		2.83 to 1.38	1.5 to 2.5	USA (PCI, 1974)
Calcareous sediments				
Limestone	1.00	2.83	2.8	Switzerland (Lesinger, 1968)
Chalk – Grades I–III	0.21 N (N = SPT blows/0.3 m)	0.22 to 1.27	1.5 to 2.0 (Temporary) 3.0 to 4.0 (Permanent)	Britain (Littlejohn, 1970)
Tertiary limestone	0.83 to 0.97	2.76	2.9 to 3.3	Britain (Wycliffe-Jones, 1974)
Chalk limestone	0.86 to 1.00	2.76	2.8 to 3.2	Britain (Wycliffe-Jones, 1974)
Soft limestone		1.03 to 1.52	1.5 to 2.5	USA (PCI, 1974)
Dolomitic limestone		1.38 to 2.07	1.5 to 2.5	USA (PCI, 1974)
Arenaceous sediments				
Hard coarse-grained sandstone	2.45		1.75	Canada (Coates, 1970)
Weathered sandstone		0.69 to 0.85	3.0	New Zealand (Irwin, 1971)
Well-cemented mudstones		0.69	2.0 to 2.5	New Zealand (Irwin, 1971)
Bunter sandstone	0.40		3.0	Britain (Littlejohn, 1973)
Bunter sandstone (ultimate compressive stress > 20 N/mm²)	0.60		3.0	Britain (Littlejohn, 1972)
Hard fine sandstone	0.89 to 0.83	2.24	2.7 to 3.3	Britain (Wycliffe-Jones, 1974)
Sandstone		0.83 to 1.73	1.5 to 2.5	USA (PCI, 1974)
Argillaceous sediments				
Keuper marl		0.17 to 0.25 (0.45 C_u)	3.0	Britain (Littlejohn, 1970) (C_u = undrained cohesion)
Weak shale		0.35		Canada (Golder Brawner, 1970)
Soft sandstone and shale	0.10 to 0.11	0.37	[illegible] to 2.7	Britain (Wycliffe-Jones, 1974)
Soft shale		0.21 to 0.83	1.5 to 2.5	USA (PCI, 1974)
General				
Competent rocks (where ultimate compressive stress > 20 N/mm²)	Unrealistic compressive strength – 30 [illegible] to 0.8 maximum value of 1.4 N/mm²	Unrealistic compressive strength – 10 [illegible] to 0.8 maximum value of 4.2 N/mm²	3	Britain (Littlejohn, 1972)
Weak rock	0.35 to 0.70	–	–	Australia (Kaye, 1972)
Medium rock	0.70 to 1.05			
Strong rock	1.05 to 1.40			
Wide variety of igneous and metamorphic rocks	1.05		2	Australia Standard CA35 (1972)

Table 25. (continued)

Rock type	Working bond	Ultimate bond	Load factor of safety	Source
	N/mm²	N/mm²		
Wide variety of rocks	0.98			France (Forgeot 1972)
	0.50			Switzerland (Weiner 1969)
	0.70			Switzerland (Gamma 1965)
		1.00 to 2.50		Switzerland (Gamma 1971)
	1.0		2.5 to 2.5 (Temporary) 3 (Permanent)	Italy (Mascardi 1970)
	0.69	2.76	4	Canada (Golder Brawner 1970)
	1.4	4.2	3	USA (White (1973))
		15 % to 20 % of grout crushing strength	3	Australia (Langworth 1971)
Concrete		1.38 to 2.76	1.5 to 2.5	USA (PCI (1974))

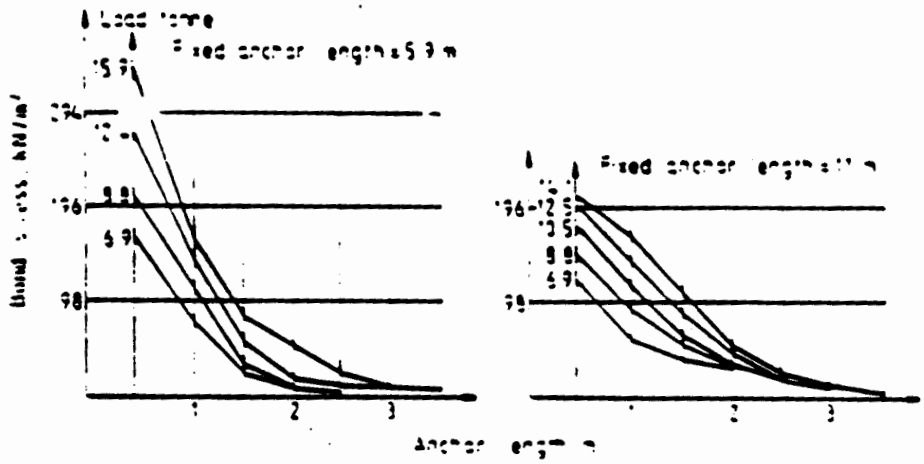

Figure 56. Distribution of bond along fixed anchor length (after Berardi (1967))

For compact sandy gravel ($\phi' = 40°$) at Vauxhall Bridge, London and compact dune sand ($\phi' = 35°$) at Ardeer, Scotland values of β equal to 101 and 31 have been measured in the field (Littlejohn 1970) which are in good agreement with respective values of 99 and 35 estimated from Figure 5.

The value of β depends to a large extent on construction technique and for the type B anchorage relevant to equation (3) value of 1.7 and 1.4 have been recorded in compact sandy gravel ($\phi' = 40°$) and compact dune sand ($\phi' = 35°$) respectively (Littlejohn 1970).

Littlejohn (1970) estimated for equation (3) that β lay in the range of 1 to 2 but that if the soil was not compacted or displaced during the casing installation and no residual grout pressure was left at the fixed anchor grout/soil interface on completion of the injection stage β might reduce to a value approximating to K_0. In the light of experience, this reduction is now considered unduly pessimistic since even with tremie grouting the full hydrostatic head of the grout is applied at the anchor interface which creates a contact pressure greater than $K_0 \gamma z$ in normally consolidated ground.

As a consequence, even for the tremie grouting method it is difficult to envisage a value of β less than 1 for design purposes.

TITLE			PAGE
FACTOR OF SAFETY - WEDGE PULLOUT			1 OF 4
PROJECT	AUTHOR / DATE: C. FRANKE 9/5/91	CHK'D BY / DATE: JR Tyler 9/9/91	CHK'D BY / DATE
SO	CALC NO	FILE NO	GROUP

PROBLEM: DETERMINE THE FACTOR OF SAFETY (F.S.) AGAINST PULLOUT OF A ROCK WEDGE BY A ROCKBOLT.

ASSUMPTIONS:

1.) THE GEOMETRY OF THE WEDGE IS AS SHOWN ON THE SKETCH ON PAGE 2.
2.) COHESION OF SALT IS $C = 1000 psi = 6.89 MPa$ (REF 1)
3.) DENSITY OF WIPP SALT, $\rho = 135 lb/ft^3$ (REF 2)

REFERENCES:

1.) SAND 78-1596, "Geological Characterization Report", Powers, et al, 1978.
2.) D-51-W-01, "Design Basis - Underground Excavations" Bechtel

METHOD: THE SHEAR RESISTANCE OF THE WEDGE ABOVE CLAY G AND THE WEIGHT OF THE WEDGE ARE COMPARED.

THE SHEAR STRENGTH OF SALT WILL BE TAKEN AS EQUAL TO THE COHESION. THIS IS A VERY CONSERVATIVE VALUE SINCE

$$T = C + \sigma \tan\phi \qquad \text{(REF 1)}$$

WHERE T IS THE SHEAR STRENGTH, σ IS NORMAL FORCE (i.e. UCS for MAXIMUM) AND ϕ IS THE FRICTION ANGLE.

General Comment: I don't know that this calculation is significant to a bolt in salt.

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TITLE: FACTOR OF SAFETY - WEDGE PULLOUT

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	C. FRANCKE	7/26/91	JR Tyler	9/4/91		

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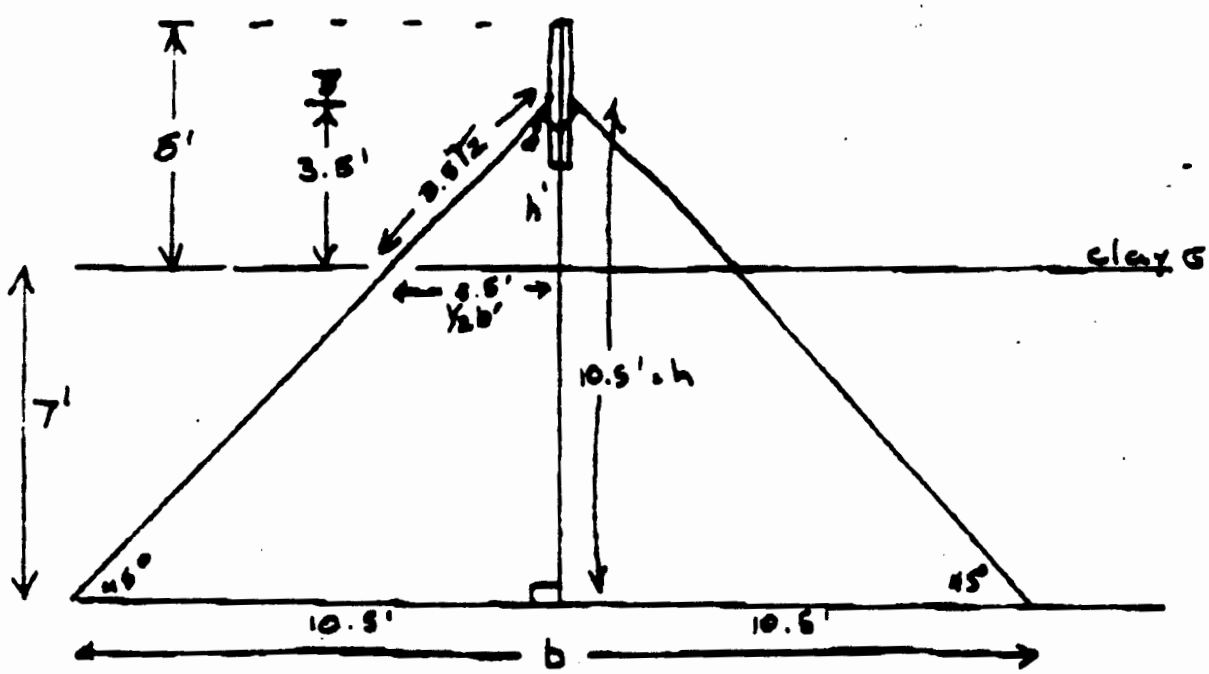

FIG. 1

W = WIDTH = 33'

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TITLE			PAGE
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CALCULATIONS: (CONT'D)

SHEAR RESISTANCE OF WEDGE (CONT'D)

$$S = [\tfrac{1}{2}(7')(3.5')(2) + (2)(\tfrac{1}{2})(3.5')(33')](T\cos\theta)$$

$$S = (351\ ft^2)\left(\frac{144\ in^2}{1\ ft^2}\right)(1000\ psi)\cos\theta$$

$$S = (50{,}544\ kip)\cos\theta$$

$$\tan\theta = \frac{7'}{\frac{1}{2}(33')}$$

$$\theta = 23°$$

$$S = (50{,}544\ kip)\cos 23°$$

$$S = 46{,}530\ kip$$

FACTOR OF SAFETY

$$F_{of}S = \frac{46{,}530\ kip}{491\ kip} = 95$$

DISCUSSION:

THE CALCULATED F of S IS QUITE ADEQUATE

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"Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico" Sand78-1 1978 Rogers, S

stress space (σ,T) where σ and T denote normal and shear stresses, and an envelope is drawn tangent to the circles representing the ultimate shear stress of any value of confining pressure.

When the data from Tables 9.2.4-1 and 9.2.4-2 are plotted, three Mohr's circles which are normal for SENM rock salt are obtained in Figure 9.2.4-2A in stress space (σ,T) . The ultimate stresses can be approximated by a straight line (Coulomb) envelope of the form $T = C + \sigma \tan \phi$. In conventional engineering terminology, C is called the cohesion and ϕ , the angle of internal friction. In this case, at ambient temperatures, rock salt from the 2,700 foot level has an apparent cohesion of approximately 1,000 psi and an angle of internal friction of 33°. Similar data for other rocks are being used for mine pillar design. However, it should be recognized that the validity of these ultimate stress analyses rests on two assumptions: (1) failure is independent of the intermediate principal stress, and (2) failure is defined solely in terms of stresses and independent of strain, strain rate and time. Both of these assumptions are currently being evaluated for rock salt.

In contrast to other rocks, it is important to remember that rock salt undergoes large deformations long before the ultimate stress is reached. Since these deformations can exceed 15% even at ambient temperature, it is conceivable that a practial failure condition might incorporate a maximum deformation criterion. To illustrate this case, a Coulomb envelope was constructed (Figure 9.2.4-2B) which defines the stress magnitudes at an arbitrarily chosen constant value of strain (ε_1 = 2.5%). This value is the average strain at the ultimate stress of samples tested in uniaxial compression at ambient temperature and a loading rate of 30 psi/min. It can be seen that Figure 9.2.4-2B is different from the ultimate stress envelope in Figure 9.2.4-2A. Clearly, the shapes of the Mohr envelopes are highly dependent on failure criteria. The values obtained also depend on the manner in which the Mohr's envelope is drawn. In Figure 9.2.4-2A, a "best fit" straight line tangent to the circles was drawn; while in B, a parabola was drawn tangent to the circles.

APPENDIX C - CHANNEL SUPPORT DESIGN

The final design of the steel beam support system was the result of an evolutionary process that started by considering an I beam. The original concept called for an I beam that would be held in place by eight rock anchors and four yieldable steel posts. This design had several difficulties with it:

- Each I beam would weigh about 2,000 pounds, making the installation process difficult and potentially dangerous.
- The supporting rock anchors could not be attached to the centerline of the I beam. Instead, the rock anchors would have to be attached by means of a separate plate to the flanges of the I beam. This would have generated excess moments in the beam as well as introducing torque forces, which would have been difficult to calculate.
- The yieldable posts would have been difficult to test, and as they were not performing any function that the rock anchors could not provide, they were eliminated from the design.

The final design calls for a 15 x 40 channel with 11 rock anchors that are fastened through the centerline of the channel.

The channel will be made of three 9 foot sections bolted together with four 7.5 inch by 3 inch splice plates which allow for greater ease in the handling and placement of the channel.

The beam has been designed to accommodate the unequal distribution of the rock load, and the rock anchors will be tensioned to account for the fact that most of the detached load is in the middle of the room.

The support channel design calculations are given below.

WESTINGHOUSE WASTE ISOLATION DIVISION
CALCULATION COVER SHEET

System: AU00	Design Class: III-A.
PWR: N/A	Sheet No.: 1 of 9
	Ref. EDT: N/A

FSAR Checked: ✓ FSAR Change Required: yes

DOE Order 6430.1A Checked: ✓

Source of Data:
1. Geotech. Expert Report - WIPP, June 1991.
2. —
3. —

Source of Formulas and References: AISC - Manual of Steel Construction
Blodget - Design of Weldments

Type of Calculation: Prelim.: _____ Final: ✓

References:	P&ID/Dwg. No./Rev.:	Entitled:
Westinghouse Drawings	54-D003-W1, -W2, -W3, -W4, -W5	Supplementary Roof Support, Room 1, Panel 1 General Arrangement, Sections and Details

RECORD OF ISSUES

Rev.	Description	By	Date	Chk'd	Date	App'd	Date
0	Issued for external review	JMK	9/5/91	HG	9/6/91	JWP	9/6/91

4918:0230

TITLE U/G. Room 1 - Roof Supp. System			PAGE 2 OF 7
PROJECT	AUTHOR JMK 8/29/91	CHK'D. BY HS 9/6/91	CHK'D. BY DATE
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Data and assumptions for the below calculations:

1. Density of salt material is 135 lb/ft as per Design Basis - U/G Excavations, D-51-W-01, page 6.
2. The total load overburden is based on 10 ft spacing of the rows of Rock Bolts in the longitudinal direction of the room.
3. Triangular distribution of the load is assumed across the width of the room (33'-0).
4. Material of the Rock Bolts is as per ASTM A 615 - Grade 60. Yield stress Fy = 60 000 psi, allowable working

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stress in tension $F_t = 0.60 F_y$ =

= 36.0 ksi. (See PTI-1986)

5. Allowable load on the Rock Bolt is

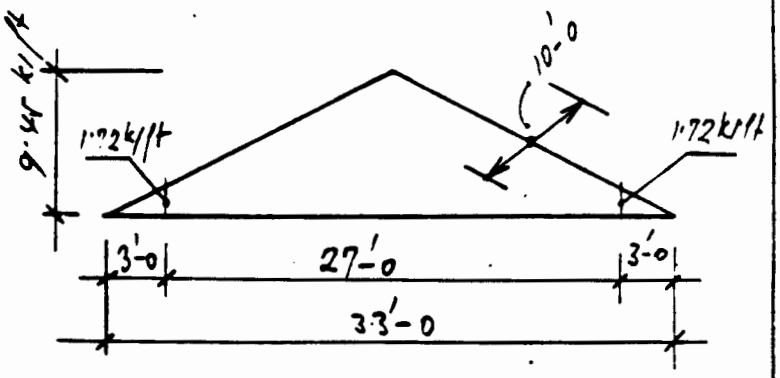
$$P_W = A \times F_t = 0.79 \times 36.0 = \underline{28.4^k}$$

Triangular Load:

Weight of the overburden

$$w = \left(\tfrac{1}{2}\, 10.0 \times 33.0 \times 7.0\right) \times 135\ \text{lb/ft}^3 = \underline{156\,000\ \text{lb}}$$

Load per linear foot across the room $q = \dfrac{2 \times 156.0}{33.0} = \underline{9.45\ \text{k/ft}}$



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TITLE U/G Room 1 - Roof Support System			PAGE 4 OF 7
PROJECT	AUTHOR JMK DATE 08/29/91	CHK'D. BY HS DATE 9/6/91	CHK'D. BY DATE
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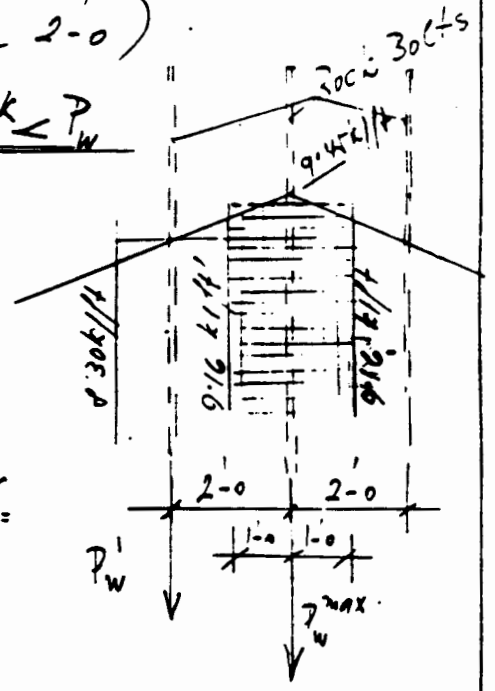
Load on the critical Rock Bolt @ center of the room: (spacing @ 2'-0)

$P_W^{max} = 2'0 \times 9.16 = \underline{18.33^k < P_W}$



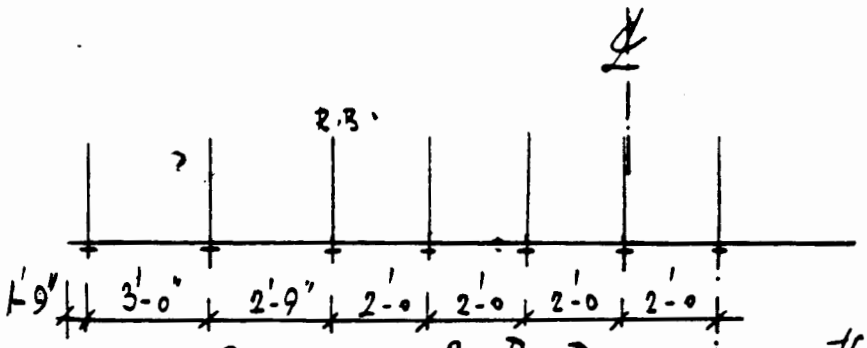
Adjacent Rock Bolt:

$P_W' = 2'0 \times 8.30 = \underline{16.6^k}$

In case the center R.B. fails half of the load i.e. $\frac{1}{2}$ 18.33^k = 9.16^k will be taken by the adjacent R.B.

$^2P_W = 16.6 + 9.16 = \underline{25.76^k < P_W = 28.4^k}$ - see page 3

$\Rightarrow$ no overloading occurs.



Spacing of R.Bs. across the room

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PROJECT	AUTHOR JMK 8/29/91	CHK'D. BY HS 9/6/91 DATE	CHK'D. BY DATE
S.O.	CALC. NO. G-91-[illegible]	FILE NO.	GROUP [illegible]

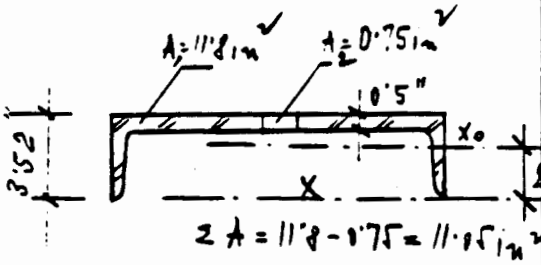
Check of stress in the channel from bending. ([15x40; $S = 3.37 in^3$)

Assume conservatively $M = 1/10\, w l^2$

$M_{\ell} = 1/10\ 8.9 \times 2.0^2 = 3.56$ k/ft ~ @ center of the room

$$\sigma = \frac{3560 \times 12}{3.37} = 12676 \text{ psi} < \sigma_{allow}$$

<u>Section modulus "S" of</u> the [15x40 with a ϕ1.5" hole.



Static moment M_x:

11.8×2.74 . . . . . $32.33 in^3$

$- 0.75 \times 3.27$ . . . $- 2.45$

$M_x = 29.88 in^3$

$$x_0 = \frac{M_x}{A_0} = \frac{29.88}{11.05} = 2.70 \text{ in}$$

$$I = I_0 + A_1 x_1 - I_\phi - A_2 x_2 = 9.23 + 11.8 \times 0.043^2 -$$

$$- 1/12 \times 1.5 \times 0.5^3 - 0.75 \times 0.82^2 = \underline{\underline{8.71 \text{ in}^4}}$$

$$S = \frac{I}{C} = \frac{8.71}{2.70} = \underline{\underline{3.21 in^3}}$$

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TITLE U/G, Room 1 - Roof Supporting System			PAGE 6 OF ?
PROJECT	AUTHOR JMK DATE 08/30/91	CHK'D BY HS DATE 9/6/91	CHK'D BY DATE
S.O.	CALC. NO. 6-91-JMK	FILE NO.	GROUP M. & S.E.

Check new stress in the [15 (see page 5)

$M = 3.56$ k/ft $\Rightarrow \sigma = \frac{3560 \times 12}{3.21} = 13308$ psi $< \sigma_{all}$

Shear in the web:

$P_w^{max} = 18.33^k$

$A_{req.} = \frac{18330}{14000} = 1.31 \text{ in}^2$

$r_{req} = \frac{1.31}{0.5 \times 2\pi} = 0.42$ in $\Rightarrow r_{used} \sim 1.00 > 0.42$ in

Use $\phi 2''$ washer under the rock bolt (see below) $2\ 5\frac{1}{2} \times 5\frac{1}{2}$

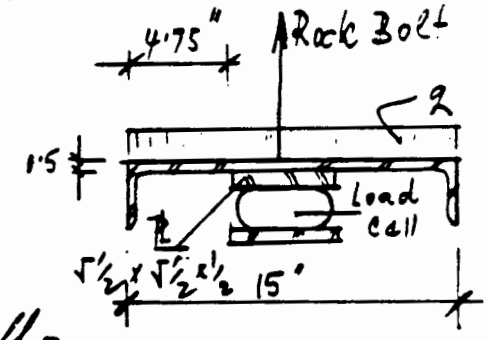
Bending of the [15 perpendicular to the length of the beam @ suppo

$q = \frac{2P_w}{15.0 \times 24''} = \frac{28400}{15 \times 24} =$

$\doteq 78.9$ psi

$M = \frac{1}{2} 78.9 \times 4.75^2 = 890$ lb. in

$\sigma = \frac{890}{0.042} = 21192$ psi $\doteq \sigma_{allow.}$



$S = \frac{1}{6} 1.0 \times 0.5^2 = 0.042$ in

REV. NO.	REV. DATE	AUTHOR	DATE	CHK'D. BY	DATE	CHK'D. BY	DATE

TITLE U/G. Room 1 – Roof Supporting System			PAGE 7 OF 2
PROJECT	AUTHOR VVX – 08/30/91	CHK'D. BY HS DATE 9/6/91	CHK'D. BY DATE
S.O.	CALC. NO. 6-91-JMK	FILE NO.	GROUP H.&C.E

Shear (in the 1/4" web) (along the ⅜ perimeter)

$A = 4 \times 5.5 \times 0.5 = 11 \text{ in}^2$

$\tau = \frac{28400.0}{11.0} = \underline{2582 \text{ psi}} < \sigma_{allow} = 14000 \text{ psi}$

Combined stress: (bending + shear)

$$\left(\frac{f_b}{F_{cr}}\right)^2 + \left(\frac{\tau}{\tau_{cr}}\right)^2 \leq 1$$

$$\left(\frac{21.19}{23.76}\right)^2 + \left(\frac{2.58}{14.0}\right)^2 = \underline{0.725 + 1.033 = 0.828 < 1.0}$$

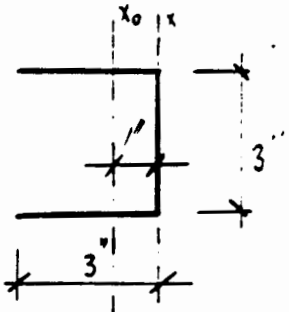
REV. NO.	REV. DATE	AUTHOR DATE	CHK'D. BY DATE	CHK'D. BY DATE

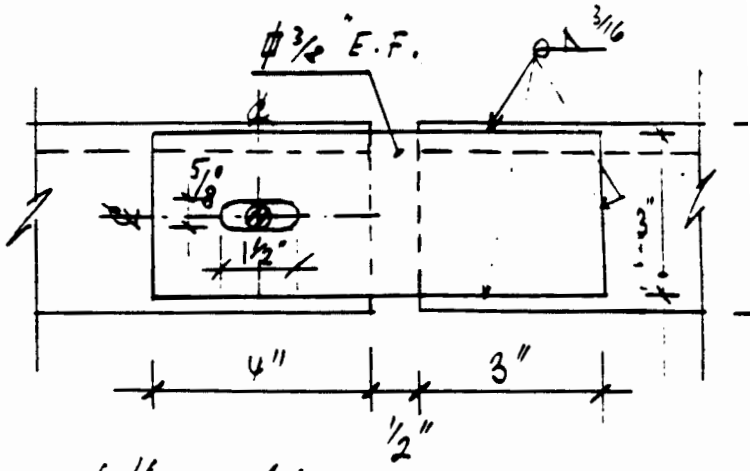
TITLE U/G Room - 1; Panel - 1; Roof Supp. System			PAGE 8 OF
PROJECT	AUTHOR [illegible] DATE 8/30/91	CHK'D. BY HS DATE 9/6/91	CHK'D. BY DATE
S.O. -	CALC NO. 6-91-[illegible]	FILE NO	GROUP [illegible]

Design of splice:

- assumed as a flexible joint, allowing small horizontal movement

C.G. of the weld:





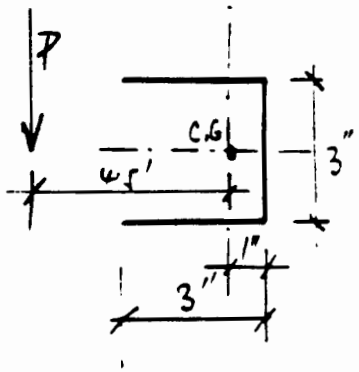
$S_{M_x} = 2(3 \times 1.5) = 9.u$

$L = 3 \times 3 = 9.u$

$X_0 = \frac{9.0}{9.0} = 1''$

Design of the weld:

See table XXIII, page 4-90 AISC.



$k = 1.0 \quad a = 1.5$

$l = 3'' \quad P = 5.66^k$

$C = 0.775$

$$D = \frac{P}{C\,C_1\,l} = \frac{5.66^k}{0.775 \times 1.0 \times 3.0} = 2.43$$

Use 3/16 weld

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TITLE U/G Room 1, Panel-1; Rail Supp. System			PAGE 9 OF 2
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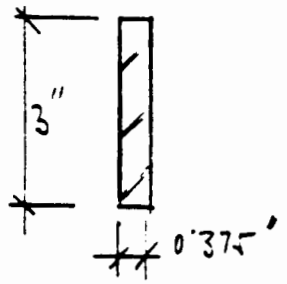
S.O.	CALC. NO. 6-91-[illegible]	FILE NO	GROUP M. & C.E.

Splice plate - stresses from bending and shear

Assume ≥ 3/8" thick



Moment:

$M = \frac{1}{2} \times 5.66 \times 2.5 = 7075$ in-lb

$\sigma = \frac{7075}{0.562} = 12589$ psi => OK

$S = \frac{1}{6} 0.375 \times 3.0^2 = 0.562 \text{ in}^3$

Shear

$\tau = \frac{\frac{1}{2} 5660}{3 \times 0.375} = 2515$ psi < 14000

Combined stress:

$\left(\frac{12589}{23760}\right)^2 + \left(\frac{2515}{14000}\right)^2 = 0.28 + 0.03 = 0.31 < 1.0 \Rightarrow$ OK

Bolt at the sliding end.

$\tau = \frac{\frac{1}{2} 5.66}{0.306} = 9.25$ ksi

Assume $\phi \frac{5}{8}''$

$A = 3.14 \times 0.31^2 = 0.306 \text{ in}^2$

Use Bolts A 325 ($F_v = 17.5$ ksi)

Finger tight.

REV. NO.	REV. DATE	AUTHOR	DATE	CHK'D. BY	DATE	CHK'D. BY	DATE

APPENDIX D

DRAFT 09/10/91

WASTE ISOLATION PILOT PLANT
SUPPLEMENTARY ROOF SUPPORT SYSTEM

APPENDIX D

Geomechanical Monitoring Program

Westinghouse Electric Corporation
Waste Isolation Division
Carlsbad, New Mexico
August 1991

GEOTECHNICAL MONITORING PROGRAM

1.0 INTRODUCTION

A system to support the roof in Room 1, Panel 1 has been designed on the basis of the rock mechanics data that is given in the Geotechnical Design Summary Report (Westinghouse, 1991a). The design itself, is presented in the Design Report for the Supplementary Roof Support System, Underground Storage Area, Panel 1, Room 1 (Westinghouse, 1991b). The support system accommodates a controlled yield of the roof rock as the creep of the salt takes place. The success of the planned system relies heavily on a monitoring program that will determine not only the geomechanical performance of the room but will also assess the structural performance of the support system.

The support system is designed to carry the dead weight of a rock wedge that is forming in the roof of Room 1. The development of this wedge has been established from the rock fall that occurred in SPDV Test Room 1 and from observations of fracture development in other parts of the underground facility. The wedge is not yet fully formed but experience in Room 1, Panel 1 would indicate that it will form within the next 7 years unless fracture development in the roof can be controlled. The support system in Room 1 has two purposes. It is design to minimize the development and propagation of roof fractures thereby, ensuring that the rock remains self supporting for as long as possible, and secondly the system must have an capacity to carry the dead weight of the rock wedge once it forms in the roof while accommodating both vertical and lateral displacements due to far field creep effects.

The geotechnical monitoring program will establish the loads that are developing in the support and the deformations of the rock that are taking place around the room. The geotechnical data will be used to ensure that the support system is performing in a controlled manner and to establish the load adjustments required to the support system in order to accommodate the creep movements of the salt, and to confirm that room performance remains within satisfactory bounds.

This plan describes the geotechnical monitoring program that will be implemented to evaluate both the room performance and the performance of the support system. The plan describes the instrumentation that will be installed in the room, and it discusses the criteria that will be applied to ensure that the support system is adjusted in a controlled manner and that room performance remains satisfactory. It should be noted that as more data becomes available, especially on the interaction of the support with the room, then the criteria that are the basis for adjusting the loads on the support may require modification.

The plan has been developed and will be implemented in accordance with the general requirements for the control of test activities as described in the Geotechnical Engineering Program Plan (Westinghouse, 1991c). They cover the eighteen criteria that are defined in the Quality Assurance Program for Nuclear Facilities (ANSI/ASME NQA-1-1986). The Geotechnical Engineering Program Plan supports the Quality Assurance Program implemented at the site (Westinghouse, 1990).

The geomechanical monitoring of a room can give indications of its deterioration. Monitoring of the performance of excavations at the WIPP has already provided early identification of such conditions. SPDV Test Room 1 showed evidence of worsening conditions at least 3 years prior to the roof failure in that room. In addition, the Geotechnical Expert Panel has expressed confidence that instrumentation in Panel 1 can give adequate notification of deteriorating conditions (US DOE, 1991).

2.0 MONITORING OF ROOM PERFORMANCE

The program for monitoring room performance has already been developed and implemented in Room 1, Panel 1. The basis for the monitoring is that the measurements and observations are simple to make; That minimal maintenance of instrumentation is required, that instrumentation is easily replaced if it malfunctions; and that conditions throughout the room are known. The data should also provide data on geomechanical performance features that have been identified elsewhere in the underground facility, especially in the SPDV Test Rooms as features that should be to give good comparison with other data collected at the site. Room performance is being characterized from the following:

- the development of bed separations and lateral shifts at the interfaces of the salt and the clays underlying the anhydrites "a" and "b".
- the establishment of the room closure rates and determine if they are accelerating with time or exceeding expected rates.
- the assessment of the behavior of the pillars.
- the assessment of fracture development in the roof and floor.

The instrumentation in Room 1, Panel 1, was upgraded during the summer of 1991 from the original monitoring program established for the panel in 1988. At that time, limitations were imposed on penetrations through the anhydrite "b" in the roof. These limitations were in effect for waste storage considerations and no longer apply to the use of the room as the location for the bin scale tests. Roof conditions are now assessed from observation boreholes and from extensometer measurements. Measurements of room closure, rock displacements and observations of fracture development in the immediate roof beam can now be made and used to evaluate the performance of the room. The upgraded monitoring program was presented to the Geotechnical Expert Panel who considered that it was adequate to determine deterioration within the room and could provide early warning of deteriorating conditions in the room (US DOE, 1991).

The location of the instrumentation monitoring room performance is shown in Figure 2.1. The specifications for the instruments are given in Table 2.1. A summary of the installation requirements including tolerances, workmanship and national codes and standards that the instrumentation must meet are given in Appendix A. Figures 2.2 and 2.3 provided the instrumentation cabling layout for the convergence meters and extensometers respectively.

2.1 ROOM CONVERGENCE MEASUREMENTS

Vertical and horizontal convergence stations will be installed at seven cross sections throughout the room to monitor roof/floor and wall/wall room closure. The locations for the instruments are provided in Figure 2.1. At each cross section, roof/floor convergence will be measured at mid span and at room quarter points and wall/wall convergence will be measured at mid room height. The convergence measurements will establish the rates of room closure for comparison with predicted rates and will be evaluated to determine assymmetric roof/floor closure of the room.

Each convergence station will consist of a mechanical anchor fixed about 150 mm below the rock surface. Details of a typical convergence anchor installation are given in Figure 2.4. An extensometer consisting of a wire or tape stretched under a constant tension and with an accurate distance measuring device is attached between the anchors . Changes in length between the anchors will be monitored periodically to determine room closure. The convergence measurements can be made manually or remotely. For manual measurements the the extensometer is put in place only for a reading and is subsequently removed. For the remote readings, the extensometer remains in position and the manual extensometer measuring device is replaced by a electronic length measuring device. In our application in Room 1, a potentiometer readout with a range of 36 inches will be used where remote readings can be obtained. Remote readings cannot be made at all locations because the permanent installation of wires across the room will interfere with access into the room.

2.2 EXTENSOMETER MEASUREMENTS

Borehole extensometers will be installed in the roof and the walls of Room 1. Roof extensometers will monitor bed separations at anhydrites "a" and "b", and dilation and creep movements within the immediate roof beam of salt. Wall extensometers will monitor the lateral deformations within the pillars.

Within each borehole, five measuring points will be anchored to the rock to monitor rock movements towards the room. Details of a typical borehole extensometer installation are shown in Figure 2.5. In the roof holes the anchors are nominally fixed at depths into the hole of 0, 6.5, 7.5, 13, and 14 feet, for the purpose of monitoring bed separation across the anhydrites "a" and "b". In the wall holes, the anchors are fixed at depths of 0, 5, 10, 15, 25 and 50 feet. The specifications for the drilling of boreholes, the installation of extensometers and for the instruments are given in Table 2.2.

Calibration of the measuring device for the multiple point extensometers will be carried out either by the manufacturer or by the Site Calibration Laboratory. Calibration will be traceable to N.I.S.T.

Readings will either be taken manually with a readout device provided by the manufacturer or will be performed remotely through the automatic data acquisition system that is maintained by the Manager and Operating Contractor in the underground. Measuring frequency, once the room is in use as a laboratory for the bin scale tests will be carried out every week. This frequency may be adjusted to meet any changes that develop.

2.3 SURVEY MEASUREMENTS

Survey measurements will be made in the room by the surveyors from Mine Engineering. These measurements will be used to separate roof and floor deformations. The measurements will be taken on a routine basis, probably at intervals of about 3 months.

2.4 FRACTURE MAPPING OF OBSERVATION BOREHOLES

Three observation boreholes have been drilled into the roof of Room 1, Panel 1. Observations of bed separation and lateral strata shifts will be made on a routine basis at intervals of about 3 months. The boreholes will be monitored using a scratch probe that has been used for the Excavation Effect Program (U.S. DOE, 1987). The holes can also be viewed with a borehole camera if the fractures require visual observation.

In addition, the boreholes for the rock anchors will be observed from fractures immediately following their drilling. This will be carried out using the scratch probe.

2.5 DATA ACQUISITION

The instrumentation monitoring room performance, is currently read manually. Conversion to remote reading of instrumentation is planned. This conversion will take place when the data acquisition system for the monitoring of the support system is installed in the room. It may not be practical to convert all the instrumentation to remote readings. The roof extensometers will be converted to remote reading. The ancillary equipment to allow remote reading of the quarter point convergence stations will be installed but a final decision on installation of the wires will depend on establishing that they will not be damaged by personnel maintaining or sampling the bins. The roof/floor convergence stations at midspan i.e. down the middle of the central access way and the wall/wall convergence stations will not be monitored remotely as they would interfere with access.

The instrumentation will be monitored from a data logger located in an alcove in S1950 of Panel 1 between Rooms 4 and 5. The data logger is part of the Geomechanical Instrumentation System installed in the underground. The system is controlled from a computer located on the surface. The data logger that will be used to remotely read the instrumentation monitoring room performance in Room 1 is already in place. The specifications to which the datalogger is manufactured are provided in Appendix A.

The results from the instrumentation in the room will be evaluated on a continuous basis. Documentation of the results will be provided annually in the Geotechnical Field Data and Analysis Reports.

3.0 MONITORING OF SUPPORT SYSTEM PERFORMANCE

The monitoring of the support system performance provides an assessment of the manner in which the support is controlling roof movements including the breakup of the immediate roof. The monitoring program in Room 1, Panel 1 will evaluate the following:

- the performance of the structural system that supports the roof.
- the load that develops in each rock anchor for the purpose of adjusting loads so that the build up is controlled in a consistent manner.

The basis for the instrumentation must be that the measurements are simple; that instrumentation is easily replaced if it malfunctions; and that the performance of each anchor can be continuously monitored and readily compared with performance of other anchors. The instrumentation layout for monitoring the support system performance is provided in Figure 2.6. Cabling layouts are provided in Figures 2.7, 2.8, and 2.9.

The most important of these measurements are those that determine the anchor loads. These measurements will be used to adjust the anchors to ensure that the anchors are not stressed beyond the allowable working stresses and that the roof is lowered in a controlled manner that accommodates the continued creep of the solid salt.

The measurements of cable elongation and pressures developing on the sheeting are taken to determine how these components of the support system are performing. No adjustments are planned on the basis of these measurements. However, if they show load buildup additional actions may be considered. It is not expected that breakup of the roof rock will be excessive, it appears more likely that the rock will remain primarily self supporting until the detached wedge in the roof fully forms. It is not expected that this will occur within the next two years based on the experience obtained from SPDV Test Room 1 Therefore, it is not believed that loads approaching the full weight of the detached wedge will develop on the expanded metal sheeting and the cables.

3.1 ROCKBOLT LOAD CELLS

The rockbolt load cells monitor the axial loading on the rock anchors. The measurements will be made on each anchor and will be the basis for adjusting the load on each anchor should an adjustment become necessary.

Each load cell consists of a cylindrical body with a central annulus for the rock anchor. The load measuring element is a spool of high strength steel or aluminum on which electrical resistance strain gauges are bonded in a full bridge configuration that provides temperature stability and compenstation for off center loading. A steel outer cover and O ring seals protect the strain gauges from mechanical damage and water penetration.

The load cells shall have sufficient capacity to measure up to 50 kips with a sensitivity of 0.02 kips. In order to maximize the vertical adjustment on the tendons, the height of the load cells shall not exceed 75 mm. The typical load cell installation is shown in Figure 2.10.

3.2 PRESSURE CELLS

Pressure Cells that will monitor the pressures that develop between the expanded metal sheeting and the salt roof. The measurements will be made in selected areas within the room that are expected to have the greatest roof movements and hence, be more susceptible to the development of loads due to the breakup of the immediate roof rock. Typical pressure cell installation is shown in Figure 2.11.

The pressure cell is manufactured from two steel plates welded together. The space between the two plates is filled with de-aired antifreeze solution or hydraulic fluid and is connected via a high-pressure stainless steel tube to a pressure gage and/or pressure transducer. A pump is used to inflate the pressure cell and press the cell against the rock. A change in load on the the cell will cause a deflection of the diaphragm which results in a change in the fluid pressure. The pressure cells, in Room 1, will be installed between the rock and the mesh to monitor the pressure distribution on the cable lacing and mesh.

The pressure cells should be constructed from corrosion resistant materials such as stainless steel. Each pressure cell will have pressure gage. The pressure cell can be modified for remote monitoring by replacing the pressure gage with or adding a pressure transducer.

The most important factor to take into consideration when installing pressure cells is to ensure a good contact with the surrounding material and to avoid localized or point loading of the cell. To avoid point loading, the pressure cells will be encapsulated with a concrete based grout. After the grout has set up, the pressure cells are placed between the rock surface and support mesh. The pressure cells are pumped up so that the cell is completely filled with fluid.

Pressure in the cells will be monitored using pressure gages. Monitoring of the pressure cells can be change from manually read to remotely read with the addition of a pressure transducer to the cell.

3.3 CABLE ELONGATION

Crack meters will monitor the elongation of the cables that support the mesh and expanded metal sheeting. The measurements will be made on selected sections within the room that are expected to have the largest deformations and be more susceptible to breakup of the surficial rock. Typical crack meter installation is shown in Figure 2.12.

3.4 DATA ACQUISITION SYSTEM

The data acquisition system shall provide for remote multiplexing of the load cells at locations within the room. The data acquisition system shall be capable of handling the required number of multiplexers. The data acquisition system shall be configured to monitor 33 rows of load cells, each row containing 11 loads cells.

The data logger will consist of a programmable controller, switching units, and a readout device. To prevent thermal deterioration, the switching units must multiplex all signal functions for each instrument. Continuous connection to a constant-voltage power bus is not allowed.

The data logger will include a Racal-Vadic Model VA1251G/K modem for data link connection to the surface data logging computer.

To facilitate compatibility with existing GIS equipment, existing communication parameters, protocol, and programming must be incorporated into the data logging components.

A Racal-Vadic Modem Model VA1251G/K will exchange ASCII character data over the datalink cable via the following parameters:

- Baud Rate - 300
- Parity - Even
- Stop Bits - One
- Word Length - Seven Bits

The two panel switches on the Racal Vadic Modem are to be set as follows:

- o Analog/Digital Loopback - OFF
- o Transmit Reversal - OFF

The modem's RS-232 interface will connect with the supplier-provided control units to ensure proper data communications.

The surface datalogging computer has been programmed to communicate with all underground control units through an exchange of ASCII character data. The computer sends a two character address sequence down the datalink cable through the surface modem. Each control unit then demodulates the character sequence through its modem. Each control unit is uniquely programmed (via a PROM chip) to respond to its own address sequence. Upon receipt of its address sequence, each control unit will poll its instruments, perform any necessary data reduction, and send instrument readings through the modem as a string of ASCII characters.

4.0 ADJUSTMENT OF SUPPORT SYSTEM

The most important part of the support system performance involves the controlled yield of the roof. It is expected that the interaction of the support system with the roof will pass through several stages.

The anchors will be set to a nominal load of 1000 lb after proof testing to 1.33 times their working load. The purpose of the preload is to ensure that the lacing and meshing under the channel is secured firmly in position. As the loads change they will be compared with an estimate of conditions. There are two cases to be considered. These are the control of load during the detachment of the wedge when the full loads have not developed and the case when the wedge has detached and the working loads have been reached and any continued build up would be dependent on the creep of the solid salt onto the wedge that creates a stress build up in the support system that must be relieved by the controlled yield of the support.

Initially, the roof will be self supporting as the fractures will not have developed sufficiently to define a detached wedge. It is likely that this condition will be maintained for a period of years, especially if the bolting systems are able to reduce the widening and propagation of the fractures that do develop. However, for worst case conditions, it must be assumed that fractures will propagate and that gradually the degree of self support of the roof will be lost. As this occurs, the rock anchors will provide increasing roof support and loads will build up in the anchors. Once the roof wedge becomes detached, then the rock anchors will be fully supporting the wedge and will have reached their working loads. Control of anchor loads must consider the adjustments needed during load build up when the wedge is not fully detached and load distributions may not be as expected, and those required once the wedge has detached and is subject to both vertical and lateral movements due to the creep of the solid salt.

In addition, the wedge shape must be taken into account when estimating the adjustments that must be made to the anchor loads. Two possible geometric shapes have been proposed to define the wedge that develops in the roof of excavations. A triangular distribution identified from visual observation of the roof fall in SPDV Test Room 1, and a parabolic distribution based on survey data of the roof of the room after the fall. For the purpose of assessing the adjustments to the anchors in Room 1, both distributions will be compared with the field data to determine which is more appropriate. The comparison will be carried out on a row by row basis and also over time since the geometry of the wedge may depend on location within the room and load distribution within a row of anchors may change with time as fractures develop.

4.1 CRITERIA FOR LOAD ADJUSTMENT

The criteria for adjusting the loads in the anchors are as follows for the two cases that have been identified:

CASE 1: Load distribution below Maximum Working Load

This case will occur as the load develops from the nominally applied loads due to the increasing support provided to the wedge as the fractures develop. During this stage it is not obvious exactly how the loads will build up, but it is expected that they will develop slowly because the rock is still self supporting. Based on these assumptions, the following criteria will be applied to load adjustments for a row during the build up to maximum working loads:

- No adjustments will be considered necessary to a row of anchors until the load in one anchor exceeds 4 kips.

- If the load distribution within a row of anchors is consistent with a triangular or a parabolic load distribution, then no adjustment is necessary. Consistent is taken to mean, variations from the load distribution of less than 20 percent for all anchors in the row.

- If the loading for a row of anchors is consistent with a triangular or a parabolic distribution but with a variation from 20 to 25 percent for an individual anchor, then no adjustment is necessary, but an analysis shall be made to establish the rate of load increase for all anchors within the row and to estimate whether the variation is increasing and the time that it will take to reach a value of 25 percent above the remainder of the distribution.

- If the load distribution for a row of anchors is consistent with a triangular or a parabolic load distribution but with a variation of 25 percent for an individual anchor, then an adjustment to that anchor will be carried out. The load on the anchor will be reduced by not more than 50%.

- If the load in one anchor exceeds 4 kips and the load distribution within the row is not consistent with either a triangular or a parabolic distribution, then a study will be carried out to establish whether an alternative plausible load distribution can be established. If this is possible, then this distribution will be used to determine the adjustment to the anchor load.

For example, if the loads develop on one side of the room due to assymmetric room closure, then an assymmetric load distribution may be found to be a more appropriate basis for load redistribution.

CASE 2: Load Distribution at Maximum Working Loads

Load distribution at maximum working load is considered to have developed when controlled adjustment of a row of bolts cannot reduce the anchor loads below levels that are consistent with the weight of a detached rock wedge. Once this stage has been reached, then the following criteria will be used to adjust the anchors in each row:

- If the measured load in an anchor is 10 percent or more over the allowable working load for that anchor, an adjustment to the load will be made. The load on the anchor will be reduced by not more than 50% of its allowable working load.

- o If the load distribution does not conform with a triangular or parabolic distribution, a study will be carried out to determine whether the measured distribution is reasonable and can be explained in terms of a geometric wedge shape that is appropriate.

These criteria are based on our expectation of the performance of the roof rock and of the support system and their interaction. A mock up demonstration is planned in another room in Panel 1. During the demonstration, loads in the anchors will be adjusted to establish the effects of changing loads by a controlled amount on the loads that develop on nearby bolts. Should the data from the demonstration indicate that the criteria do not provide adequate control for support system adjustments, then alternative criteria will be developed. The application of the modified criteria to the adjustment of the support system in Room 1 will require the approval of the Manager of Engineering for the Managing and Operating Contractor for the WIPP with concurrence from the Managers of Operations, Safety, and Quality Assurance.

4.2 ANALYTICAL EVALUATION FOR LOAD ADJUSTMENTS

In parallel with the monitoring of actual loads in the rock anchors, a study will be carried out to determine the load transfer that can occur between anchors. The study will include field tests and analytical computations. The field tests will investigate how load changes in one bolt affect adjacent bolts. Computational analyses will look at load transfer effects between bolts. These studies will be completed before adjustments to anchor loads are required in Room 1, Panel 1.

Computer simulations will assess the effects of adjusting the loads within the tendons . This will be done on a row basis, since the available software codes are based on two dimensional modelling and it is assumed that in eraction effects between rows spaced nominally 10 feet apart will not be significant. The codes that will be used are VISCOT, a finite element code and FLAC, a finite difference code. Both codes were developed for the structural analysis of geologic media. The VISCOT code which is a version of a publicly available code originally developed by Hinton and Owen (1982) was modified for used in the Salt Repository Program for the disposal of high level radioactive wastes. The FLAC code is a propietary code developed with funding from the Nuclear Regulatory Commission for application to repository projects.

The codes will be used to determine interaction effects between bolts supporting the isolated rock wedge. They will establish if adjusting the load in one anchor within a row will change the loads in other bolts within the row and by how much. They will also assess whether assymmetric load distributions can develop due to lateral or differential vertical displacements of the salt and how these effects can be compensated for or minimized by adjusting the anchor loads.

A preliminary assessment of load redistribution has been carried our using VISCOT. For the case of the fully detached wedge reduction is bolt loading of will be redistributed among the other bolts in a row without overloading of any bolt. The redistributions for a number of cases are shown in Figures 4.1. It should be noted that the study of bolt load adjustment will be an ongoing activity and that field data will be assessed to determine the effectiveness of the analytical evaluations for load adjustments.

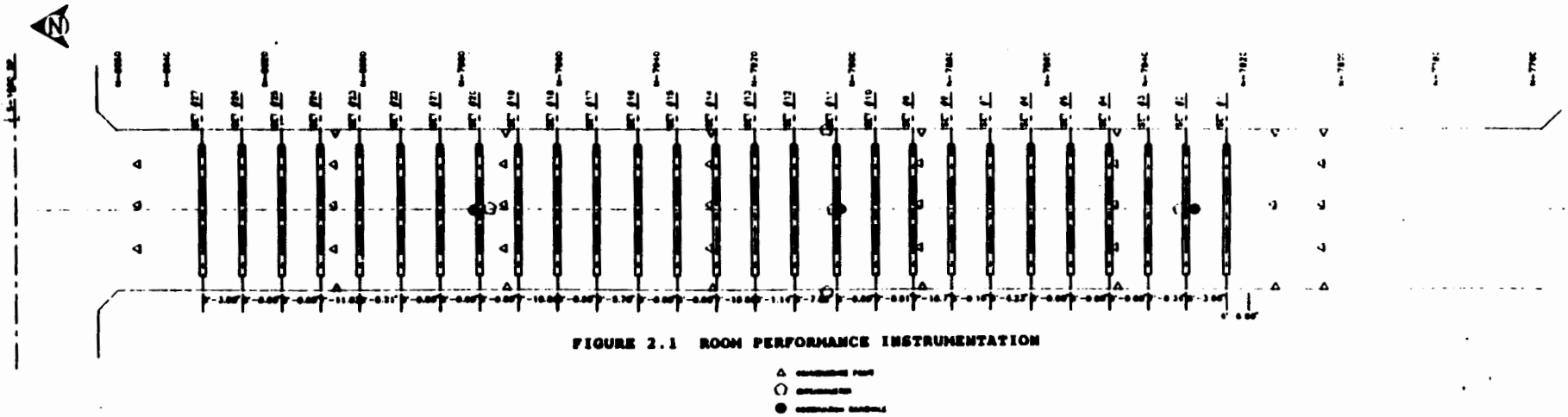


FIGURE 2.1 ROOM PERFORMANCE INSTRUMENTATION

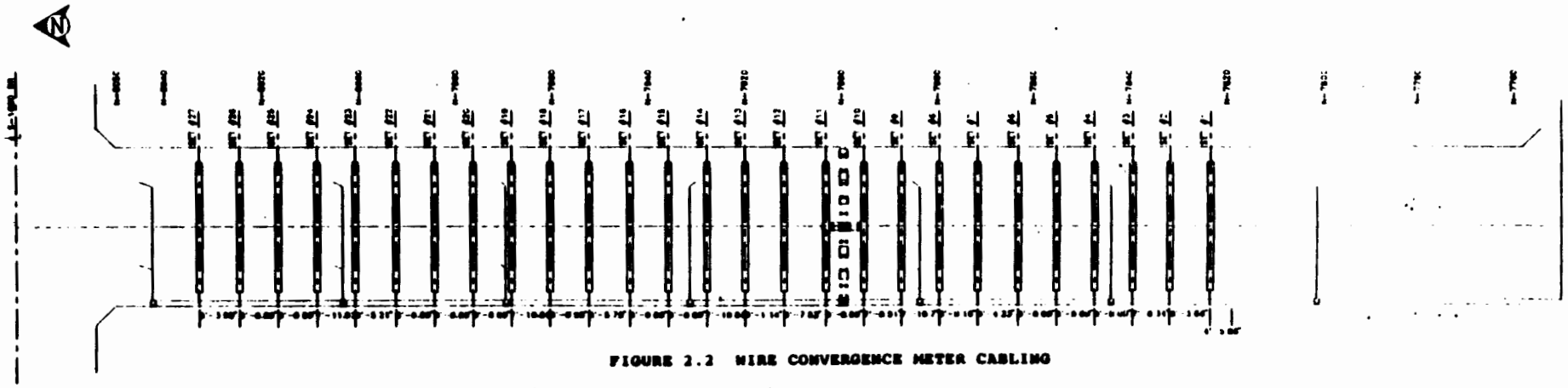


FIGURE 2.2 WIRE CONVERGENCE METER CABLING

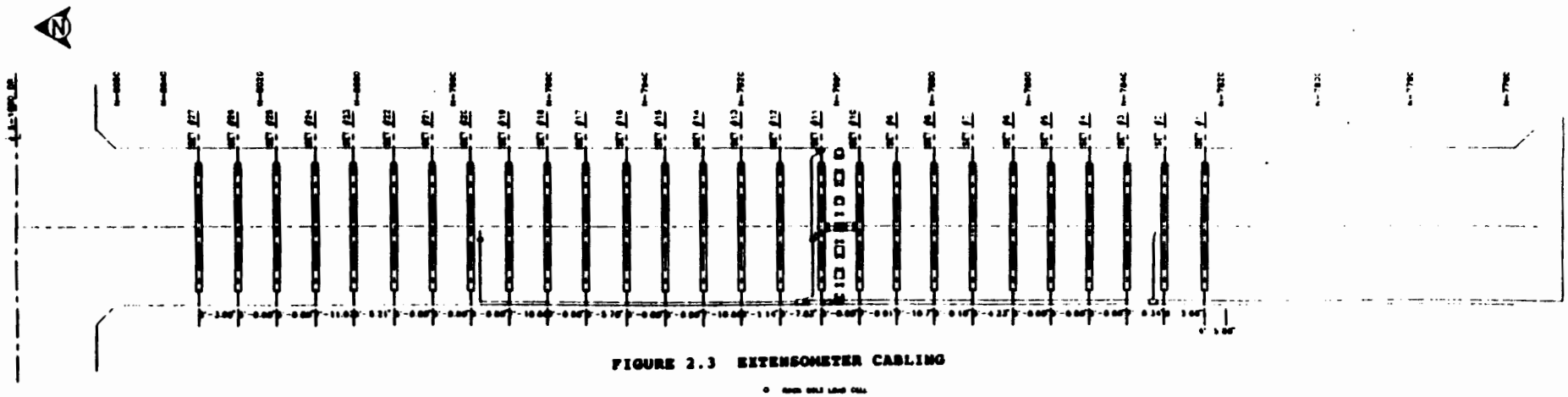
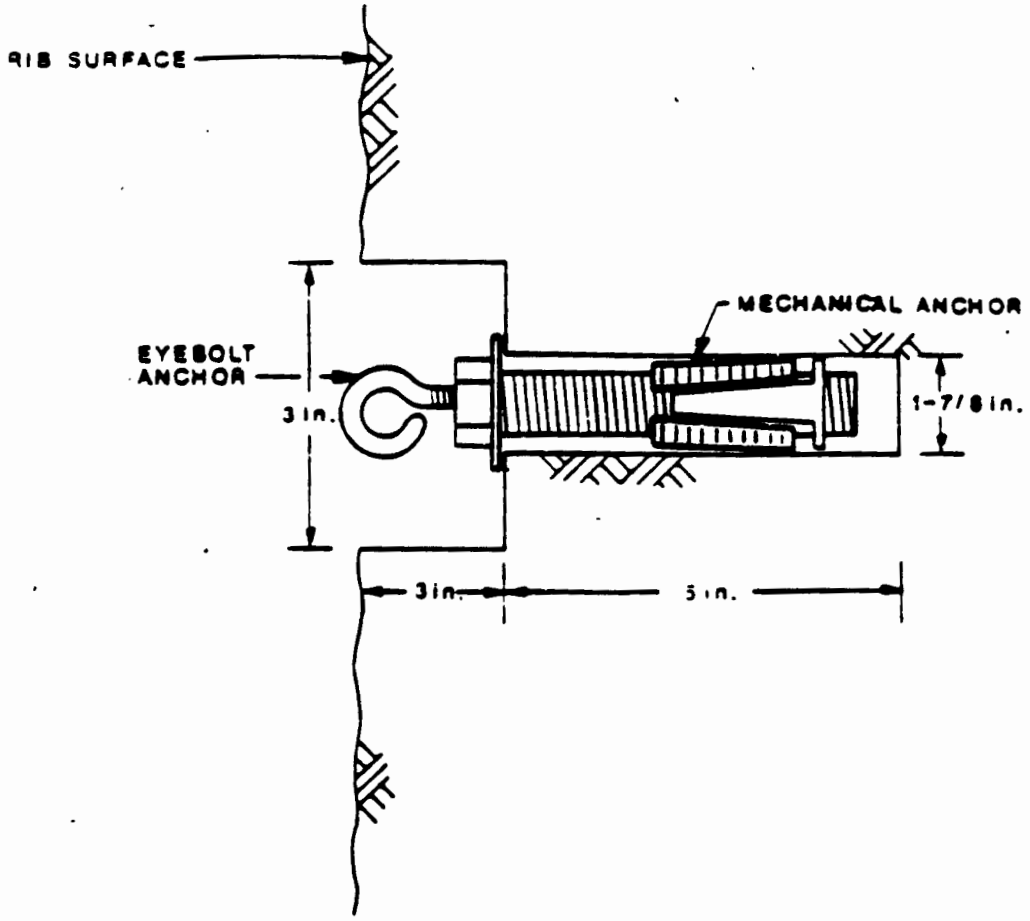


FIGURE 2.3 EXTENSOMETER CABLING

301001 88 84 08-A6



Note: • *Floor installations may be recessed greater than 3 in. and protected with coverplate.*

• *Dimensions approximate*

FIGURE 2.4 TYPICAL RADIAL CONVERGENCE POINT

301001 89 13 01 A4

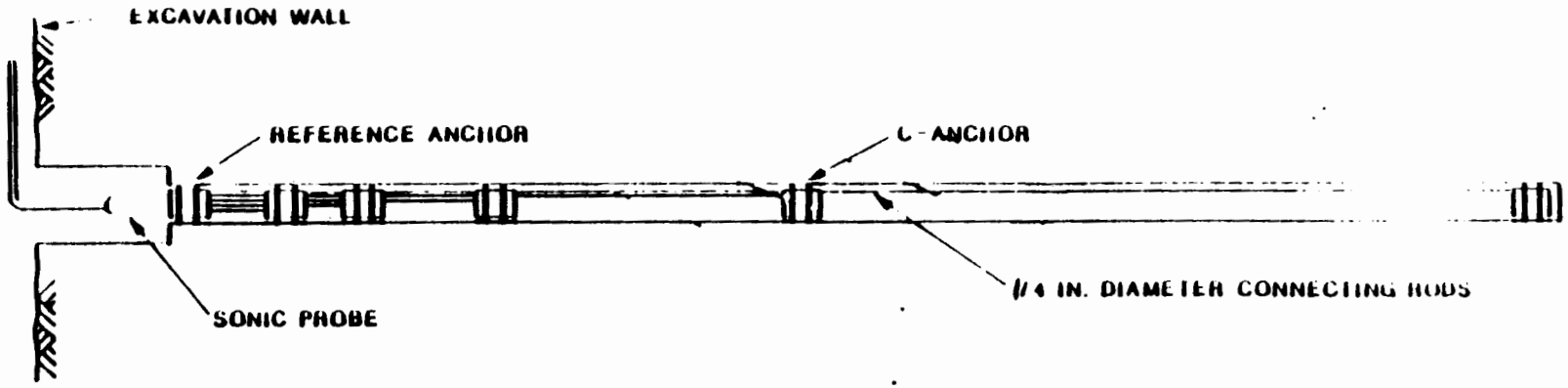


FIGURE 2.5 TYPICAL ROD-TYPE EXTENSOMETER INSTALLATION

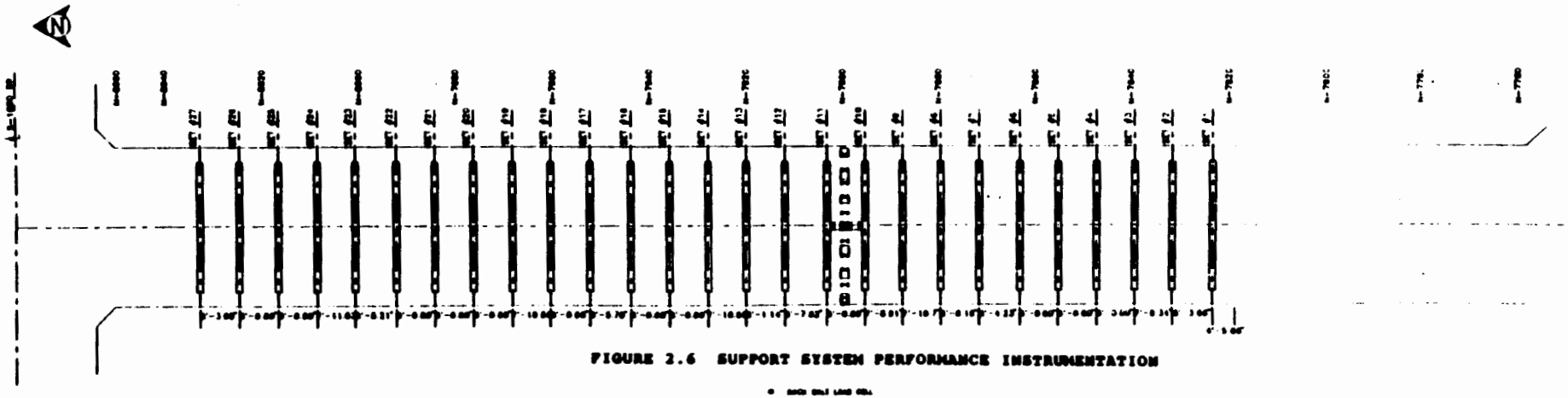


FIGURE 2.6 SUPPORT SYSTEM PERFORMANCE INSTRUMENTATION

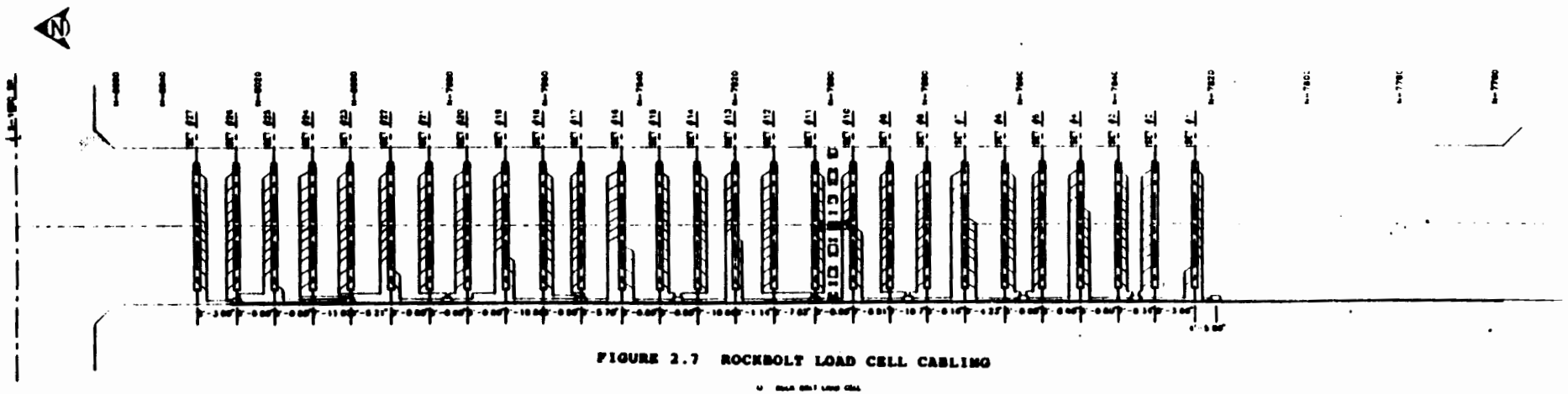


FIGURE 2.7 ROCKBOLT LOAD CELL CABLING

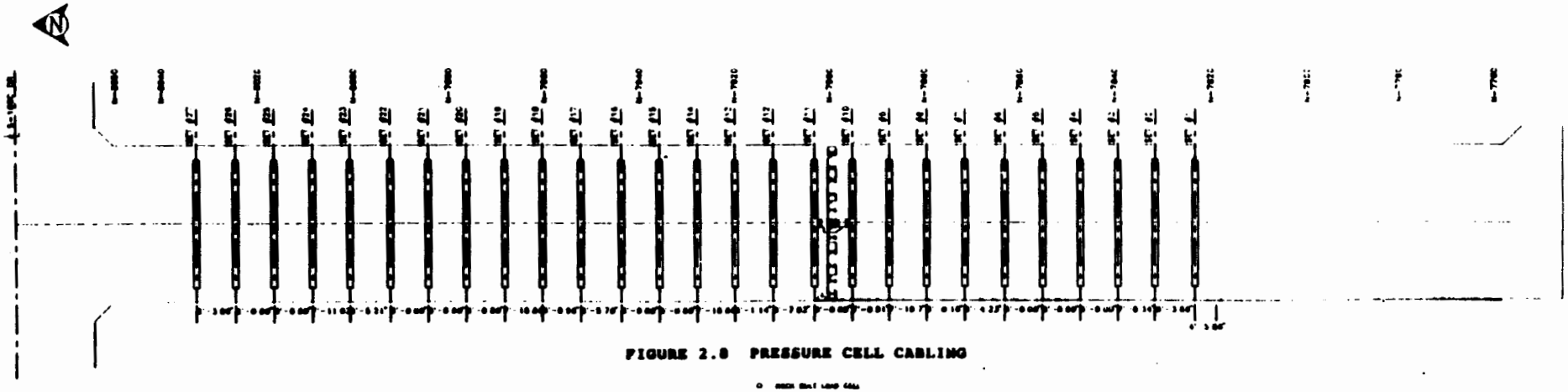


FIGURE 2.8 PRESSURE CELL CABLING

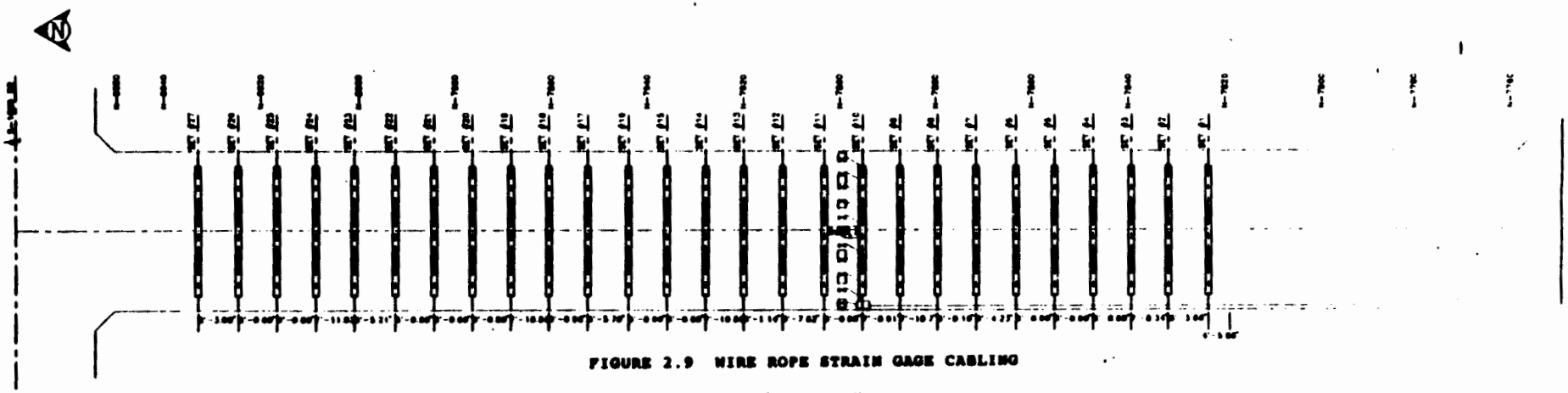


FIGURE 2.9 WIRE ROPE STRAIN GAGE CABLING

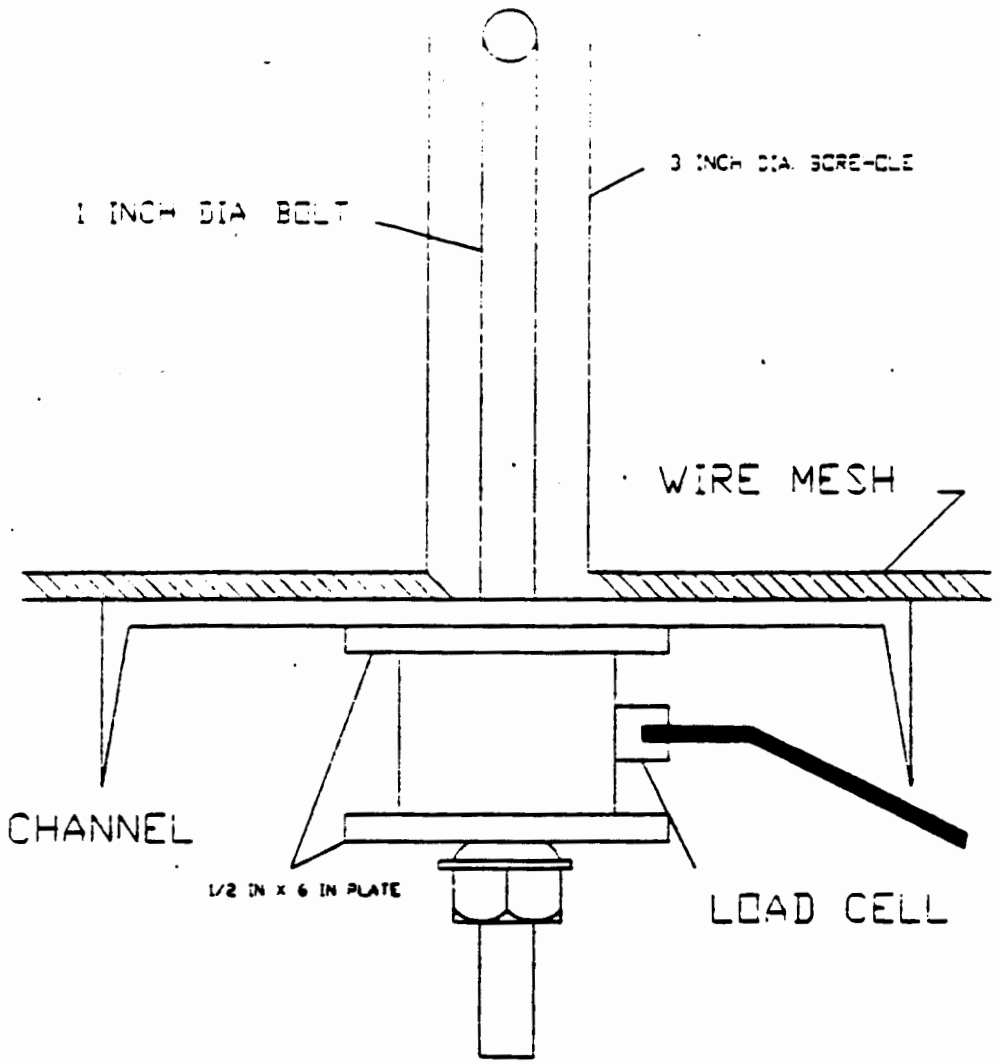


FIGURE 2.10 TYPICAL LOAD CELL INSTALLATION

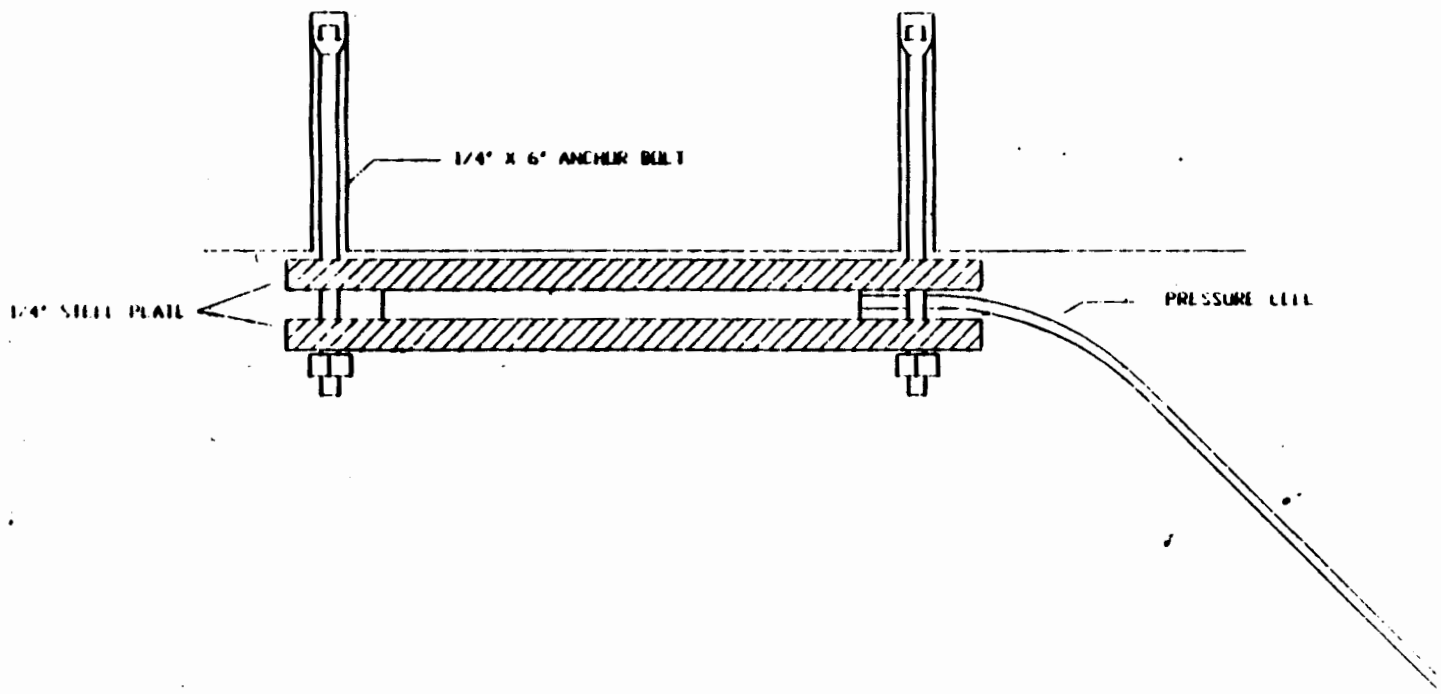


FIGURE 2.11 TYPICAL PRESSURE CELL INSTALLATION

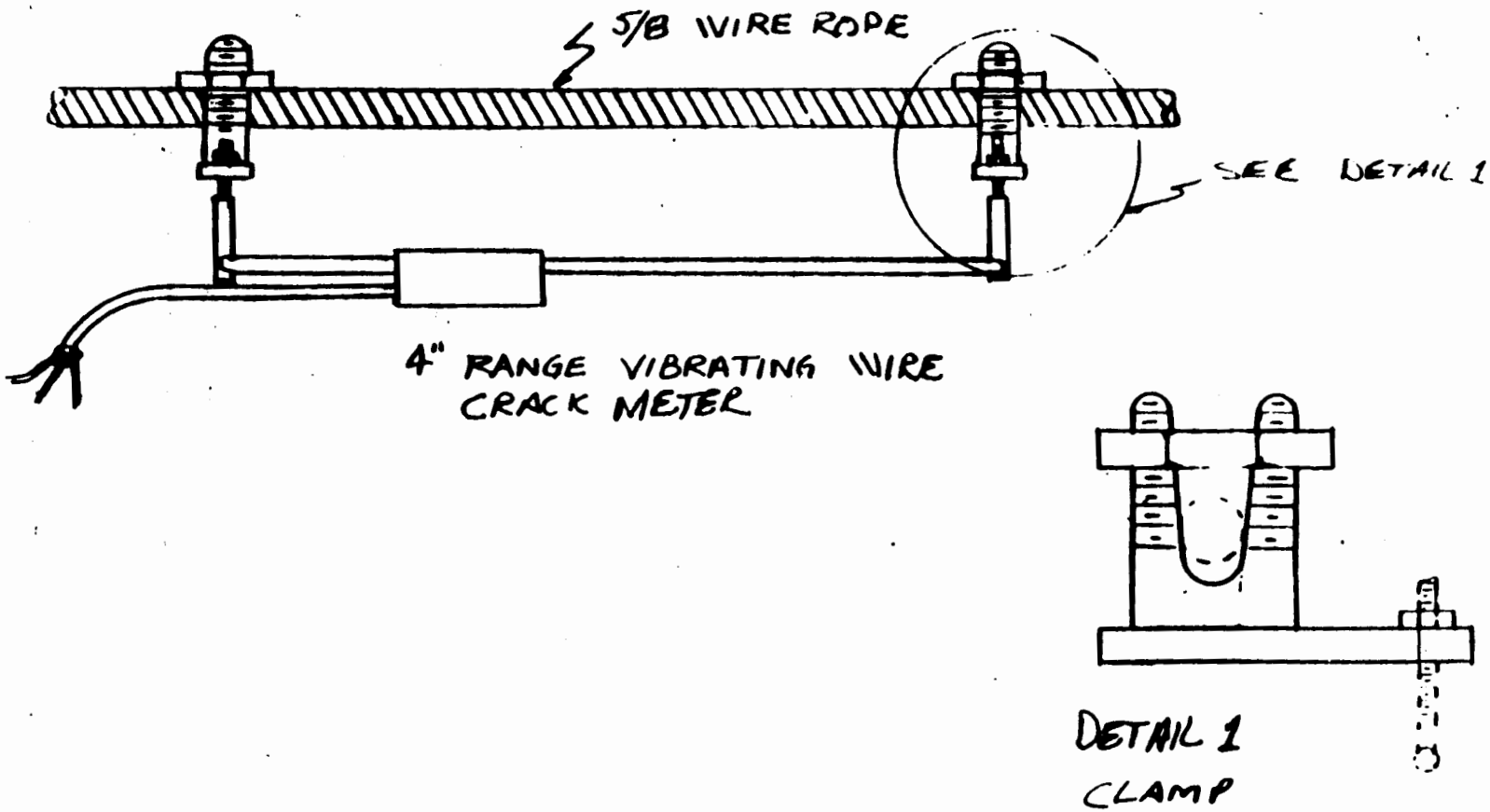


FIGURE 2.12 TYPICAL CRACKMETER INSTALLATION

FIGURE 4.1 ROCK BOLT LOADING REDISTRIBUTION

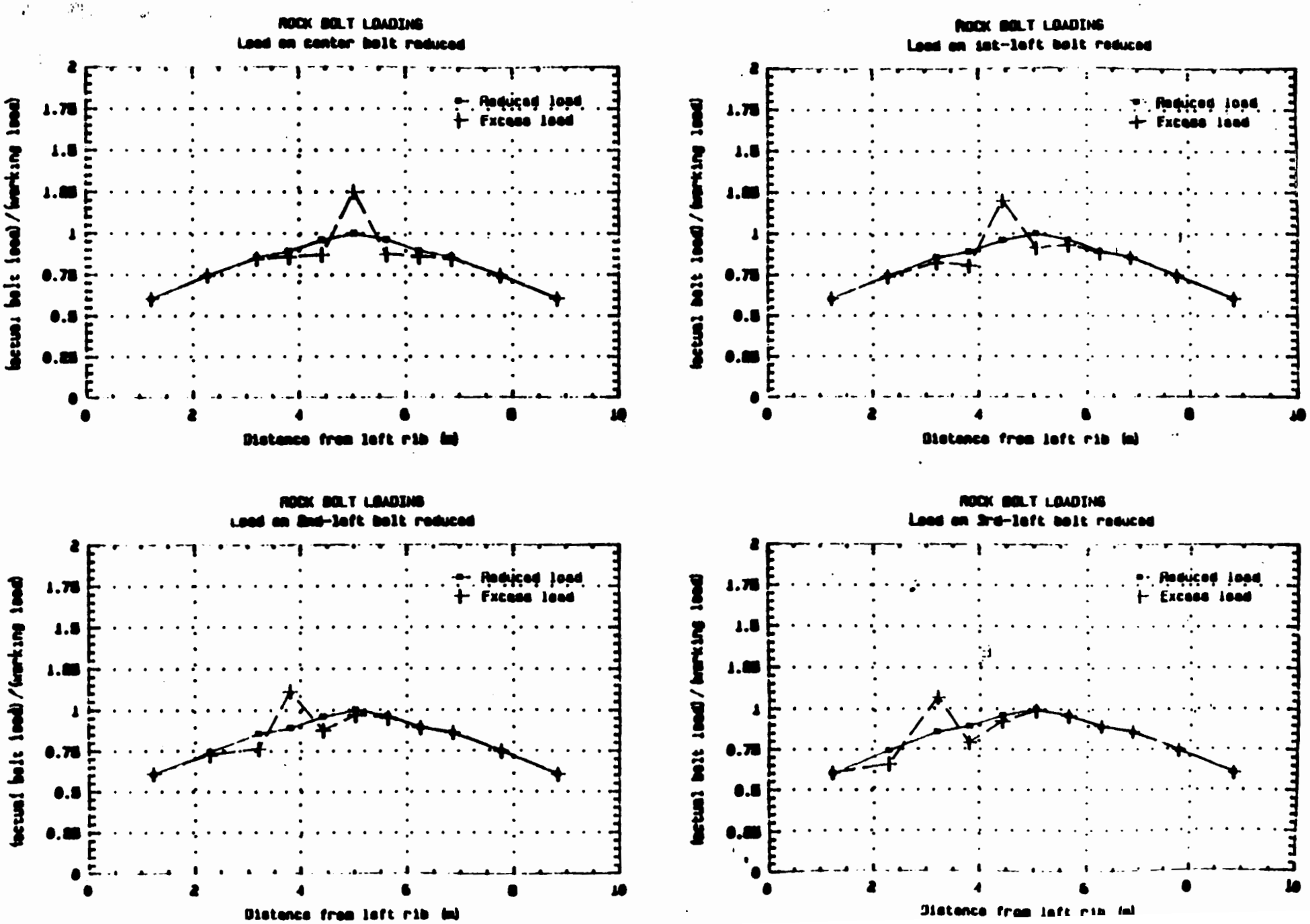


EXHIBIT C

ROOM 1, PANEL 1, SUPPLEMENTARY ROOF SUPPORT

EXTERNAL DESIGN REVIEW

1. INTRODUCTION.

At the invitation of Westinghouse Electric Corporation, Waste Isolation Division, an external design review panel has been assembled with personnel who are representatives from industry, government, research and safety, academia, and independent design firms, and who have a rock mechanics background.

This design review panel, consisting of Messrs. Byrne, Iannacchione, Mottahed, Petersen, Stahl, and Wilson (chairman), convened in Carlsbad, New Mexico, between September 16 and 20, 1991, with the purpose of completing a design review of the Room 1, Panel 1, Supplementary Roof Support System to fulfill the requirements of WIPP procedure WP09-018, Design Verification.

This report states the scope of the design review presented to the panel, describes the committee's review design checklist, highlights observations that have been identified from this review process, and provides recommendations to Westinghouse, Waste Isolation Division.

2. SCOPE.

The scope of this external design review was to comment on the supplementary roof support system for Panel 1, Room 1, in meeting its design function according to all requirements established in the Design Specification No. D-0087. Since the review panel was not a design team, their focus was directed to assessing the design presented by the members of the Engineering Department of Westinghouse Waste Isolation Division.

3. REVIEW DESIGN CHECKLIST.

The panel reviewed the Design Spec Document (WP09-018) and Design Spec D-0087 (Supplementary Roof Support for Room 1, Panel 1), to familiarize itself with the design verification requirements. It was generally agreed by the panel that the suggested Design Review Checklist, although comprehensive, was not appropriate for the design review at hand. Consequently, a new checklist was developed by the panel members and was used for assessing the design of the supplementary roof support for Room 1, Panel 1.

The Review Design Checklist used for this project is given in Appendix 1.

4. OBSERVATIONS AND RECOMMENDATIONS.

After the review of the design material presented by members of the WIPP design team, the following observations have been made by the panel.

4.1 Anchor Design Loads

There is an indication throughout the design report that the rock anchors have been designed to support the weight of a wedge of rock with a geometry defined by the shape of the SPDV Room #1 roof fall. This appears to be indicated by the eighth bullet of Section 3.3.2 (Design Requirements - Rock Mechanics) and by the fact that the layout of anchors shows a spacing of two feet in the central region of the room and a spacing of three feet towards the ribs. There would appear to be some difficulties with justifying this type of a design criterion. First, the current roof profile of SPDV Room #1 may not persist for time periods relevant to the Room 1 Panel 1 design. By the time SPDV Room #1 is 12 years old (i.e., in four years time), the existing cantilevered wedges in the corners of the roof might have deteriorated significantly, particularly as the adjacent pillars continue to expand laterally and drive the wedges inwards. Hence the detached roof profile, requiring support after 12 years of room life, could look significantly different from its present configuration. Second, the staged method of development of Room 1, Panel 1 (see enclosed figure) might result in the development of a smaller central roof wedge (i.e. initial roof shears determined by the initial room geometry) and associated larger cantilevered roof beams, with the latter being less stable than the small SPDV Room #1 cantilevered sections. This could result in the roof beam of Room 1 Panel 1 breaking to a very different profile than has been observed in the SPDV roof failure (see figure).

It would appear somewhat difficult to defend the use of the SPDV Room #1 detailed profile, therefore, as the design basis for Room 1, Panel 1. A more defensible assumption would be to design the rock anchors to support the dead weight of the full seven-foot-thick roof beam across the entire width of the room. In fact the current design appears to achieve this, since the dead weight of a roof beam section of three-foot width (i.e., anchor spacing near the ribs), seven-foot depth, and eight-foot length (i.e., average spacing of channel sections), is about 23 kips, assuming a salt specific weight of 135 pcf. It is recommended that it be explicitly stated in the design report that the roof anchor design will support a full width 7-foot thick salt beam, without exceeding the anchor design loading.

4.2 Anchor Shear/Bending Effects

Bullet 12 of Section 3.3.2 (Design Requirements - Rock Mechanics) defines the design condition for shear displacement at the Anhydrite "b" horizon as being 0.5 inches per year. This implies a total design shear displacement of 3.5 inches over the seven year life of

the room. Bullet 10 of the same section states that a 3-inch diameter hole will be reamed to provide adequate clearance and prevent shearing of the anchors. It is suggested that for the design condition, a minimum hole size of 4.5-inch diameter will be required to accommodate the shear displacements without imposing shear and bending effects on the one-inch diameter anchor. It is also recommended that additional observation holes be installed, particularly in the vicinity of the ribs where shear offsets are expected to be greatest. These holes would be used to verify that the hole size is adequate to avoid shear and bending of the anchor.

An alternative approach could be to accept the possibility of shear and bending at the Anhydrite "b" level within some of the anchors. While this would not necessarily result in unacceptable anchor performance, it would probably result in some yielding of the anchor at this location and would therefore violate the design intent which is to keep the anchors substantially below yield. If this latter option is adopted, it is recommended that a set of test anchors be installed and loaded at appropriate locations in an adjacent room. Observation holes would also be installed (particularly near ribs) in both the Room 1 and the adjacent room, and periodic proof testing of the test anchors would be conducted when observations indicate that shearing and bending of the anchors is taking place. This approach would provide either a validation of the design or an indication that replacement anchors need to be installed.

In either case, the design note should explicitly recommend that the reamed section of the anchor hole extend above the Anhydrite "b" horizon rather than reaming to a fixed depth ,for example, based on the estimated location of the Anhydrite. The procedure for field determination of the location of the Anhydrite in each anchor hole should also be provided.

4.3 Anchor Installation Quality Control

The design report states that each installed anchor will be tested to 1.33 time the design load, as part of the installation quality control procedure. It is recommended that consideration be given to including quality control testing of the resin/rocksalt bond, during bolt installation. This testing could be conducted in an adjacent room, using the same materials and installation techniques, during installation of the support in Room 1, Panel 1. One bond test for every 30 to 50 installed anchors could be performed. The bond length of the test anchors would be established so as to permit loading to typically twice the design bond stress, without yielding the test bolt. This would provide additional assurance that the anchors will perform satisfactorily since uncertainties related to the bond strength are usually considered higher than would be suggested by a load test to 1.33 times the

design load. In order to ensure that creep of the anchor is not an issue, the design load should be less than typically half the ultimate bond capacity. This should be demonstrated by a supplementary installation quality control program of the type suggested above.

4.4 Testing and Monitoring

The proposed testing and monitoring program is considered generally adequate. As noted elsewhere, however, it is recommended that additional visual observation holes be installed to monitor the development of shear offsets within the immediate roof, particularly in relation to the potential impacts of such shearing on the rock anchor performance. It is also anticipated that such shearing within the roof will result in the destruction of several instruments installed in this area. Since it is considered that such instrumentation is necessary to monitor the performance and safety of the facility (e.g., potential separations along the Anhydrite "a" horizon), it is suggested that a commitment be made to replace that instrumentation which is periodically destroyed during the operation of the test room.

4.5 Status of Existing Reinforcement in Room 1, Panel 1

The existing reinforcement in the test room consists of mechanically-anchored bolts, 10-feet long, on a 4-foot by 5-foot pattern. The bolts have been installed for about three years, and the installed instrumentation within the facility at large suggests that the extension of the bolted zone will be on the order of 1 inch per year. Testing needs to be performed to indicate the average extension of a 10 foot long bolt prior to failure. This will provide an indication of the elapsed time between bolt installation and the occurrence of failure. Such failures would be expected to occur explosively and pose a significant safety hazard.

There are several potential approaches for dealing with this problem. One method would be to design a restraining mat that can be demonstrated to absorb the impact of a failing rock bolt, and retain the bolt from ejecting explosively from its hole. Information to demonstrate that the proposed expanded metal/wire mesh system will adequately fulfill this function, has not been presented. A second method would be to unload the existing bolts concurrent with installation of the new support system. This could be safely achieved by remotely jacking the bolt to induce sufficient permanent set to remove the bolt load, and subsequently removing the nut and face-plate from the unloaded bolt. Since there is the potential for failing the bolt during the jacking operation, this phase of the process would be conducted remotely, eliminating the potential for injury. The bolt itself would remain in the hole but would develop no further loading. A third method would be to inject

a cementitious or resin grout so that failure of the bonded bolt would not occur explosively. This last alternative might not be viable within the test room as it is understood that the hole annulus has been filled with a silicone sealant.

4.6 POSSIBLE FLOOR HEAVE AND PILLAR SLABBING

The supplemental support design for Room 1, Panel 1 has basically dealt with the weakest link contributing to the room instability. In addition to the roof problem, there are other contributing elements, which admittedly with less impact, nevertheless could have repercussions in the operation of the test facilities.

It is the opinion of the panel that, at this stage of the design, it is prudent to initiate some measures to counteract the undesirable effect of two additional possible hazards, namely, floor heave and the slab detachment from the base of the pillar.

a. Floor heave.

Although the bins will be situated on pedestals capable of adjustment to accommodate 12 inches of the floor movement, no provisions beyond this magnitude of floor heave have been incorporated in the supplemental support design. The previous experience from other areas of the mine suggest the floor buckling which has necessitated the utilization of the floor machining. Although such an operation is prohibitive after the bin emplacement, other measures prior to bin placement (for example, the floor slotting and filling the slots with an expandable material) would counteract the eventuality of the floor heave (however remote it might be).

b. Possibility of slab detachment.

The presence of argillacious salt about one to two feet above the floor, might tend to enhance slabbing in this area. The provisions for counteracting this effect at the top of the pillar has been made by extending the wire meshing to the seven feet above the floor. In order to minimize such nuisance effects from possible side slabbing, it is recommended that the wire meshing be extended to the floor of the opening. It must be noted that the cost and the completion of such a task requires minimum time and effort.

4.7 NEED TO DEVELOP CRITERIA FOR UTILIZING GEOTECHNICAL INFORMATION IN THE SUPPLEMENTARY SUPPORT DESIGN.

Repeated statements are made concerning the utilization of geotechnical information [illegible] monitoring the performance of the design during a seven-year period. However, no indications are given as to how this information will be analyzed and reported. Also, the criteria for determining the success or failure of the support system has not been addressed. We believe these criteria either already exist or will be developed during the execution of the design. Therefore, why not identify these criteria as part of the design statement, so that clear, well defined action points will be known to all phases of the operation.

4.8 POSSIBLE MIGRATION OF DETACHED WEDGE ABOVE THE ANHYDRITE 'B' HORIZON.

In the unlikely event that the detached wedge may migrate above the Anhydrite "b" horizon, alternative supplemental support systems may be needed to assure Room 1, Panel 1 stability. It is therefore critical that the Anhydrite "a" horizon be continuously monitored to assure the stability of this unit.

4.9 MOCK-UP TESTING.

The proposal to establish a mock-up testing program is commendable and will play an important part in testing support technique to be adapted as well as assisting in the development of installation procedures to be used in Room 1, Panel 1. It should be ensured that mock-up tests take place before the actual implementation of the supplemental support techniques proposed for Room 1, Panel 1.

5. CONCLUSIONS AND RECOMMENDATIONS.

The design review panel has followed the design criteria established to evaluate the supplemental support system proposed for Room 1, Panel 1. The panel has concluded that the design meets the requirements presented, that is, Room 1, Panel 1, can be expected to provide a useful life of at least seven years from the time at which the proposed ground support design is installed. Moreover, the design is acceptable and meets the requirements established in the WIPP Design Spec document WP00-09018, Design Verification. It is considered, however, that the recommendations offered by the panel will enhance the overall design.

The Westinghouse, Waste Isolation Division, can be congratulated for their thorough design of the support system. The review panel would like to thank the WIPP for their cooperation and demonstrated professionalism.

Panel Members

Dr. John Wilson, Chairman

Dr. John Byrne

Mr. Anthony Iannacchione

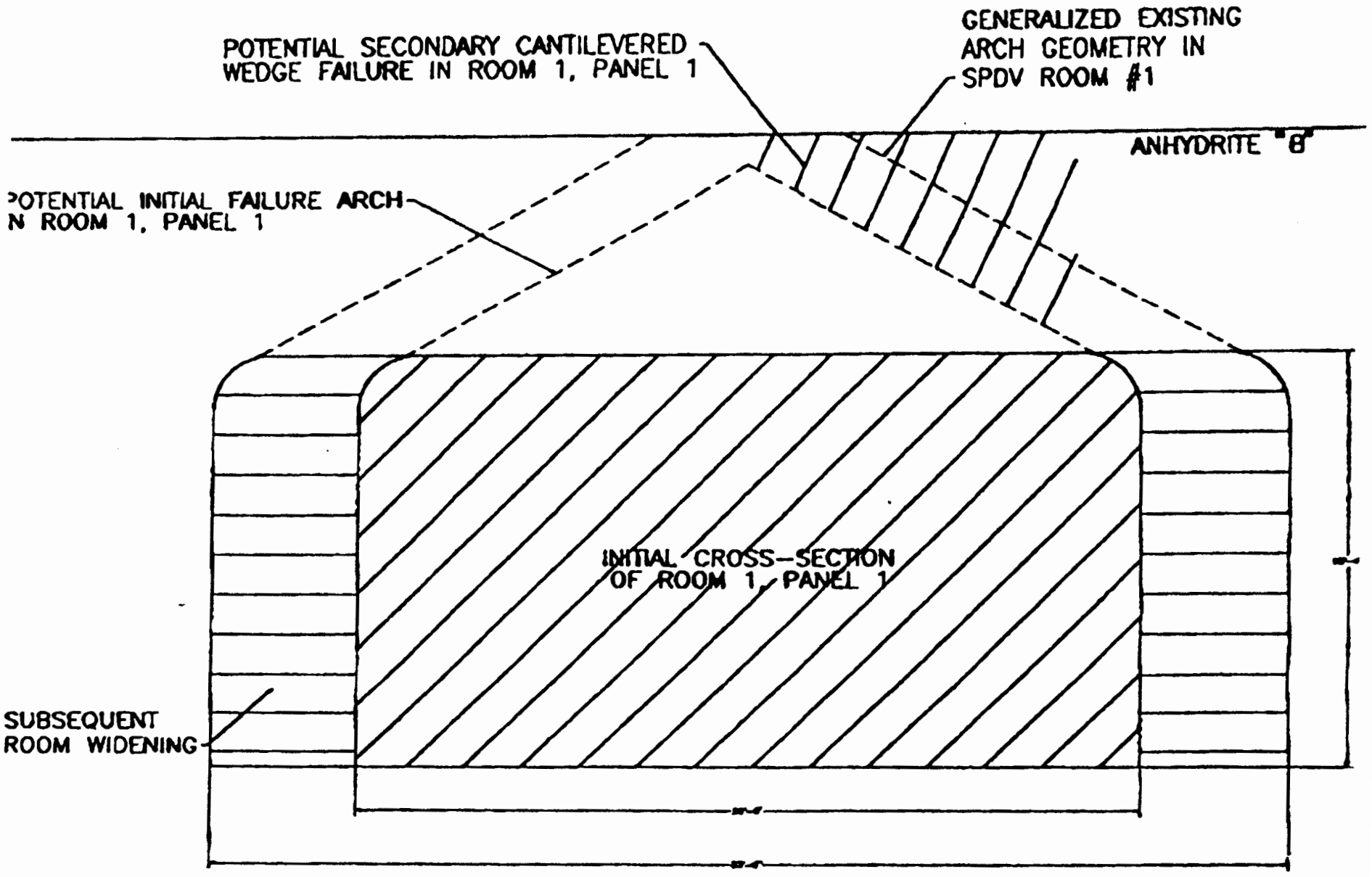
Dr. Parviz Mottahed

Mr. Gary Petersen

Mr. Robert Stahl

Respectfully submitted,

Dr. John Wilson, Chairman
September 19, 1991



TYPICAL CROSS-SECTION

APPENDIX 1
PANEL REVIEW CHECKLIST

ITEM	REVIEW CONSIDERATION	YES	NO	REMARKS
1	Has the history of the mine stability at WIPP to date been adequately studied so that experiences have been properly utilized in the design of supplementary support for Room 1, Panel 1?	X		
2	Are the objectives and design requirements for Room 1, Panel 1, clearly defined and consistent?	X		
3	Are the assumptions made in the support system design acceptable?	X		
4	Is the design presented consistent in meeting the objectives given earlier?	X		See Sections 4.1, 4.2, 4.3, 4.5
5	Have the geotechnical considerations been covered in the Rock Mechanics design to meet the objectives of the program?	X		
6	Are the calculations regarding the design of the support founded upon reasonable assumptions?	X		
7	Is the proposed instrumentation for the measurement of displacements of bolt loads sufficient, both in number and according to installation procedures?	X		See Section 4.4, 4.7, 4.8
8	Is the accuracy of support installation/and instrumentation monitoring, consistent with the requirements for this supplemental support program for Room 1, Panel 1?	X		

SUMMARY OF SUPPLEMENTAL AFFIDAVIT OF
LOKESH CHATURVEDI, PH.D.

Lokesh Chaturvedi has been the Deputy Director of the Environmental Evaluation Group ("EEG") in Albuquerque, New Mexico since March 1988 and has been employed at EEG since 1982. (¶ 2).

Dr. Chaturvedi discusses his assessment of the effect of a roof-fall in an underground WIPP room with bins containing transuranic waste. (¶ 7) DOE has failed to thoroughly analyze the consequences of a severe roof-fall, despite the fact that EEG has told DOE that such a fall should be analyzed. (¶ 8)

A severe collapse has a high probability of producing: (1) release of radioactivity, (2) an explosion which will disperse radioactive matter, and (3) contamination of the underground facility. (¶ 9). It will be extremely difficult and expensive to clean up the contamination caused by such an accident and will prevent the WIPP from being used as planned for an indefinite period. (¶ 10)

STATE OF NEW MEXICO)
) ss.
COUNTY OF BERNALILLO)

AFFIDAVIT OF LOKESH CHATURVEDI, Ph.D.

I, Lokesh Chaturvedi, Ph.D., do hereby depose upon my oath and state as follows:

1. My name is Lokesh Chaturvedi and I reside in the City of Albuquerque, County of Bernalillo, State of New Mexico.

2. I am employed as the Deputy Director of the Environmental Evaluation Group ("EEG") and have been so employed since March 1988. From June 1982 to March 1988 I was employed by EEG as Senior Engineering Geologist. Before joining EEG in 1982, I was a tenured Associate Professor of Geological Engineering at New Mexico State University in Las Cruces, New Mexico.

3. As detailed in my resume, a copy of which is attached hereto as Exhibit A-1, I received a Ph.D. in Geological Sciences from Cornell University in 1969, a M.S. in Civil Engineering from Purdue University in 1965, a M.Sc. in Applied Geology from University of Roorkee in Roorkee, India in 1963 and a B.Sc.in Geology, Physics and Mathematics from Maharaja's College in Jaipur, India in 1960. I have taught courses in Introductory Geology, Physical Geology, Geology for Engineers, Introduction to Geological Engineering, Site Investigation, Engineering Geology, Subsurface Exploration, Environmental Geology, Hydrogeology, Soil Mechanics, Rock Mechanics, Geomorphology and

Geological Oceanography at both undergraduate and graduate levels. Since 1968, I have authored or coauthored 56 published research papers on the subjects of Radioactive Waste Disposal, Remote Sensing, Geothermal Hydrology and Mechanical Properties of Rocks. I have performed several funded research projects in site evaluation, geothermal hydrology and multispectral remote sensing and I have performed several professional consulting projects in the areas of hydrogeology, subsurface exploration, engineering materials and nuclear waste disposal site investigation. I am a member of the Geological Society of America, American Geophysical Union, American Society of Civil Engineers and International Association of Engineering Geologists and have chaired a number of technical sessions at national and international professional society meetings.

4. The State of New Mexico established EEG in 1978 to provide independent technical evaluation of the Waste Isolation Pilot Plant ("WIPP") located near Carlsbad, New Mexico. The United States Congress provides 100% federal funding for EEG through appropriations to the U.S. Department of Energy ("DOE"). EEG has offices in both Albuquerque and Carlsbad. In addition to multi-disciplinary technical evaluation of the project, EEG performs independent environmental monitoring of air, water and soil, both on-site at WIPP and in surrounding communities.

5. Since 1978, EEC has published 48 EEG Reports and many other papers dealing with scientific and technical aspects of

WIPP. I have read and am generally familiar with the contents of all of these published EEG Reports.

6. I personally have visited the WIPP site on about 50 occasions including about 40 underground inspections.

7. I provided an affidavit to the Attorney General of the State of New Mexico on September 21, 1991 that contained my assessment of various scientific and technical aspects of the WIPP Project. The Attorney General has requested that I provide this additional affidavit in order to reflect my assessment of the effect of a roof-fall in an underground WIPP room with bins containing transuranic waste for experiments. I have been informed by the Attorney General that my opinion will be used to respond to the assertion in the brief filed by the federal government that the State has failed to describe how it would be injured if the roof of a WIPP test room collapsed. (Defendants' Memorandum in Opposition to Plaintiffs' Motion for Preliminary Injunction, at 32).

8. The EEG has criticized the DOE for failure to analyze the consequences of a severe roof fall in the Final Safety Analysis Report Addendum addressed to the dry bin-tests. The matter has still not been resolved to our satisfaction. The EEG has told the DOE that a roof fall involving multiple bins is a credible accident and must be analyzed. (See EEG letter to DOE, August 9, 1991). DOE has not generated the data necessary to precisely calculate the effect of such an accident. In the

absence of specific information, such as the impact resistance of the bins and the attachments, I am providing my best judgement as to what may be the outcome of such an accident.

9. At its full capacity, Room 1, Panel 1 at the WIPP will contain 78 bins, emplaced for experimental purposes and containing transuranic radioactive waste, and if the room were to experience a roof fall similar to the one which took place on February 4, 1991, in SPDV Test Room 1, when a block of rock salt weighing in excess of 1000 tons fell, the following consequences are highly probable:

a. Release of radioactivity. The test bins are mild steel containers and are not designed to withstand significant impact such as might be imparted by a major roof-fall. The occurrence of a roof fall is almost certain to rupture many bins and cause the dispersion of the contents. The contents of WIPP waste containers, in accordance with WIPP Waste Acceptance Criteria, may be as much as 1% free liquids and 1% respirable matter. Thus, a bin may contain significant quantities of radioactive liquids and dust particles, some of which would probably be expelled when a bin breaks open.

b. Explosion. The gases generated by corrosion and microbial action in reaction with transuranic waste are hydrogen and methane, which are explosive. The EEG has specifically studied the flammability of waste-generated gases. If the bins cannot be actively monitored and purged, the violent breakage of

one or more waste bins in an area surrounded by electrical apparatus may cause fire or explosion, further dispersing radioactive matter.

c. Contamination of the underground facility. The entire underground WIPP facility is ventilated to the surface by large fans capable of moving 400,000 cubic feet per minute of air. When continuous air monitors (CAM's) detect radiation, ventilation is not stopped but, instead, shifted to a filter system, which is designed to trap radionuclides. However, the entire underground facility and exhaust shaft "downstream" of the room with roof-fall and "upstream" of the filters would become contaminated by radioactivity released by a roof fall.

10. It would be extremely difficult and expensive to clean up the gross contamination of the underground WIPP facility caused by such an accident. The result of a large roof fall on a bin-filled room that has not been closed off for permanent storage would create a situation where the WIPP facilities have been contaminated with radioactivity but cannot be used as planned, for an indefinite period.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge.

Executed: 12 November, 1991.

Lokesh Chaturvedi

LOKESH CHATURVEDI, Ph.D.

LOKESH CHATURVEDI
5401 Vista Lejana N.E.
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PRESENT POSITION: Deputy Director
Environmental Evaluation Group
7007 Wyoming Blvd. N.E., Suite F-2
Albuquerque, New Mexico 87109

Responsible for an independent technical evaluation of the Waste Isolation Pilot Plant (WIPP) - the first planned deep geological repository for radioactive waste in the US - as part of an interdisciplinary team of scientists and engineers.

SUMMARY OF PROFESSIONAL EXPERIENCE

Teaching: Have taught courses in Introductory Geology, Physical Geology, Geology for Engineers, Introduction to Geological Engineering, Site Investigation, Engineering Geology, Subsurface Exploration, Environmental Geology, Hydrogeology, Soil Mechanics, Rock Mechanics, Geomorphology and Geological Oceanography at both undergraduate and graduate levels.
Research: Have published research papers in Radioactive Waste Disposal, Remote Sensing, Geothermal Hydrology and Mechanical Properties of Rocks. Have performed several funded research projects in site evaluation for radioactive waste disposal, geothermal hydrology and multispectral remote sensing.
Consulting: Have performed several professional consulting projects in the areas of hydrogeology, subsurface exploration, engineering materials and nuclear waste disposal site investigation.

EDUCATION

Ph.D., Geological Sciences, 1969, Cornell University, Ithaca, NY.
M.S., Civil Engineering, 1965, Purdue University, Lafayette, IN.
M.Sc., Applied Geology, 1963, University of Roorkee, Roorkee, India.
B.Sc., Geology, Physics, Mathematics, 1960, Maharaja's College, Jaipur, India.

PROFESSIONAL EXPERIENCE

Deputy Director, Environmental Evaluation Group, Albuquerque, NM, March, 1988 to present.

Senior Engineering Geologist, Environmental Evaluation Group, Santa Fe, NM, June 1982 to March 1988.

PROFESSIONAL EXPERIENCE (Cont.)

Associate Professor in Geological Engineering, Departments of Earth Science and Civil Engineering, New Mexico State University, Las Cruces, NM, September 1976 - May 1982.

Assistant Professor in Geology, City University of New York, Hunter College, New York, NY, September 1974 - June 1976.

Senior Lecturer in Engineering Geology, Department of Civil Engineering, Indian Institute of Technology, New Delhi, India, September 1969 -June 1974.

Visiting Assistant Professor in Geological Engineering, Michigan Technological University, Houghton, MI, January 1969 - June 1969.

Research Assistant, Water Resources Research Institute and the Department of Geological Sciences, Cornell University, Ithaca, NY, January 1968 - December 1968.

Visiting Research Scientist, National Energy Authority of Iceland (Orkustofnun), Department of Natural Heat (Jardhitadeld), Reykjavik, Iceland, June 1967 - December 1967.

Teaching Assistant, Department of Geological Sciences, Cornell University, Ithaca, NY, September 1965 - June 1967.

Research Assistant, Multispectral Remote Sensing Research Project, Department of Soil Science, Purdue University, Lafayette, IN, January 1965 - May 1965.

Teaching Assistant, Department of Engineering Geology, Purdue University, Lafayette, IN, September 1963 - December 1965.

PROFESSIONAL SOCIETY AFFILIATIONS

Memberships:
- Geological Society of America
- American Geophysical Union
- American Society of Civil Engineers
- Association of Engineering Geologists
- Assoc. of Groundwater Scientists and Engineers
- New Mexico Geological Society

Committees:
- Corresponding Member, Committee on Groundwater, American Society of Civil Engineers, 1982 - present.
- GSA Representative, Joint ASCE-GSA-AEG Committee on Engineering Geology, 1984 - present.
- Member, International Association of Engineering Geology (IAEG) Panel on Engineering Geology Research In USA, 1984 - 1985.

PROFESSIONAL SOCIETY AFFILIATIONS (Cont.)

Convenor and Chairman, GSA Symposium on Geologic Disposal of Radioactive Wastes, Geological Society of America 96th Annual Meeting, Indianapolis, IN, November 1983.

Member, Technical Program Committee, International Association of Engineering Geology (I.A.E.G.) Symposium on Hazardous Waste Disposal, Winston-Salem, NC, October 1985.

Co-chairman, Session on Environmental Geology, Geological Society ofAmerica, 100th Annual Meeting, Phoenix, AZ, October 26 - 29, 1987.

Member, Program Committee, International Conferences on High-Level Radioactive Waste Management (ASCE/ANS), 1988.

Co-Chairman, Symposium on "Site Characterization for Radioactive Waste Remediation and Disposal," 28th International Geological Congress, Washington, D.C., July, 1989.

U.S. Delegate, INTRAVAL (International Validation of Hydrologic Models) Workshop, Cologne, Germany, October 15-19, 1990.

U.S. Delegate, Organization for Economic Cooperation and Development/Nuclear Energy Authority (OECD/NEA) Workshop on Site Evaluation and Design of Experiments (SEDE '90), Paris, France, October 22-24, 1990.

SELECTED PRESENTATIONS

Several invited presentations at the Radioactive and Hazardous Material Committee of New Mexico Legislature, Governor's Radioactive Waste Consultation Task Force, Universities, National Academy of Sciences, and Public Forums plus the following Congressional Hearings:

Testimony at the Joint Hearing on WIPP before the Subcommittees of the Committee on Energy and Commerce and the Committee on Interior and Insular Affairs of U.S. House of Representatives, May 8, 1990.

Testimony at the Hearing on WIPP before the Environment, Energy, and Natural Resources Subcommittee of the Committee on Government Operations of U.S. House of Representatives, June 12, 1989.

Testimony at the Hearing on WIPP before a Subcommittee of the Committee on Government Operations of U.S. House of Representatives, September 13, 1988.

PUBLICATIONS

Chaturvedi, L. and J. K. Channell, Issues in Evaluating Long-Term Risks from a Nuclear Waste Repository - The Experience of WIPP, accepted for publication in the Proceedings, 1991 Joint International Waste Management Conference, ASME/ANS.

Channell, J. K., Lokesh Chaturvedi and R.H. Neill, 1991 Human Intrusion Scenarios in Nuclear Waste Repository Evaluations, invited paper, Proc., International High Level Radioactive Waste Management Conference. (ANS/ASCE), vol. I, pp. 308-312.

Neill, R.H. and Lokesh Chaturvedi, Status of the WIPP Project, accepted for publication in Proceedings, Waste Management '91, University of Arizona.

Chaturvedi, L., 1989, Evaluation of the DOE Plans for Radioactive Experiments and Operational Demonstration at WIPP (EEG-42), DOE/AL/10752-42, September 1989, 44 p.+ App.

Neill, R. H. and L. Chaturvedi, 1989, Technical and Programmatic Evaluation of WIPP, in R. G. Post and M. E. Wacks (eds.), Waste Management '89, Vol. 1, pp. 253-259.

Chaturvedi, L., J. K. Channell and J. B. Chapman, 1988, Potential Problems Resulting From the Plans for the First Five Years of the WIPP Project, in R. G. Post and M. E. Wacks (eds.), Waste Management '88, Vol. 2, pp. 355-364.

Chapman, Jenny B. and L. Chaturvedi, 1988, Lithologic Control on the Hydrology and Water-chemistry of the Permian Rustler Formation in the Vicinity of the WIPP Site, Southeastern New Mexico, (abs.), Geol. Soc. of America 1988 Centennial Abstracts With Programs, p. A365.

Chaturvedi, L. (ed.), 1987, The Rustler Formation at the WIPP Site, Environmental Evaluation Group Report (EEG-34), DOE/AL/10752-34, January 1987, 70 p.

Channell, J. K., L. Chaturvedi and J. B. Chapman, 1987, Modeling of Radionuclide Transport in the Rustler Formation, Southeastern New Mexico, (abs.), EOS, Vol. 68. No. 16, p. 318.

Chaturvedi, L., et. al., 1987, Performance Assessment for a Nuclear Waste Repository--The WIPP Experience, in R. G. Post and M. E. Wacks (eds.), Waste Management '87, Vol. 3, pp. 141-145.

Chaturvedi, L. and J. B. Chapman, 1986, Geological issues in the siting and construction of a nuclear waste repository, Geol. Soc. of America, 96th Annual Meeting, Abstracts Vol., p. 563.

PUBLICATIONS (Cont.)

Chaturvedi, L., C. G. Keyes, Jr., C. A. Swanberg and Y. P. Gupta, 1978, Potential for Geothermal Desalination in New Mexico, Transactions, Geothermal Resources Council, Vol. 2, pp. 91-94.

Lovelace, A., K. White and L. Chaturvedi, 1977, Landslides in New Mexico, Proceedings, 15th Annual Engineering Geology and Soils Engineering Symposium, pp. 341-351.

Chaturvedi, L., 1977, Shallow Thermal Survey as a Tool for Geothermal Site Selection (abs.), Proceedings, Association of Engineering Geologists, 20th Annual Meeting, Seattle, WA.

Chaturvedi, L. and B. C. Raymahashay, 195, Geological Setting and Geochemical Characteristics of the Parbati Valley Geothermal Field, India, Proceedings, 2nd U.N. Symposium on the Development and Uses of Geothermal Energy, Vol. I, pp. 329-338.

Chaturvedi, L., B. Lal and S. Chockalingam, 1974, Arid Zone Terrain Evaluation for Engineering Purposes, Report of Research Defense R&D Organization, Government of India, New Delhi, 150 p.

Raymahashay, B. C., and L.Chaturvedi, 1974, Regional Geology and Geochemistry of the Manikaran-Kasol Geothermal Area, India, Proceedings, International Symposium of Water-Rock Interaction, Praque, Czechoslovakia, pp. 223-229.

Chaturvedi, L. and R. Puri, 1973, Assessment of Dynamic Stability of Some Quartzites and Sandstones, Proceedings, Symposium on Rock Mechanics and Tunnelling, Silver Jubilee Session, Indian Geothechnical Society, pp. 191-199.

Chaturvedi, L., 1972, Structural Interpretation of Shallow Thermal Surveys in Iceland, Proceedings, 24th International Geological Congress, Section 9, pp. 174-196.

Chaturvedi, L., 1971, Geothermal Power, Science Today, pp. 13-17, November 1971.

Chaturvedi, L., 1969, Geological Structure and its Effect on the Geothermal Hydrology of Southwestern Hreppar, Iceland, Ph.D. Thesis, Cornell University, Ithaca, NY. 160 p.

Chaturvedi, L. and G. Palmason, 1968, Interpretation of Infrared Imagery of Myvatn Area, Iceland, Bulletin, National Energy Authority, Reykjavik, Iceland, 22 p.

SUMMARY OF AFFIDAVIT OF
EUGENE P. COYLE, Ph.D.

Dr. Coyle is an economist who concentrates on energy and resource economics. (¶ 1). Dr. Coyle is familiar with many of the economic issues surrounding the WIPP and served as an economic expert in a prior suit involving the WIPP. In that case, Dr. Coyle stated that both the direct and indirect costs of a delay in the WIPP project, as estimated by the WIPP Project Manager, were "overstated, speculative and inconsistent." (¶ 8-9).

Dr. Coyle concludes that the present claimed cost of the WIPP for construction of $1.1 billion total and $13 million per month for operations cannot be supported on the basis of Admin. Rec. IV V, as asserted by the Defendants in their Memorandum in Opposition. (¶ 11). The actual cost of operating the WIPP per month is much less than the Defendants' estimate. (¶ 16).

Further, a July 1990 report by the Inspector General of the Department of Energy concerning the DOE's Response to Delays in the Opening of the WIPP reveals that as early as April 1989 the WIPP facility was being operated as if radioactive waste was being stored when in fact there was no waste on site. The DOE has developed no plans to minimize the cost of operating the WIPP during delays. The DOE has not reduced operational expenditures during the period of delay but has, in fact, increased the number of positions. (¶¶ 17, 19, 22).

UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF COLUMBIA

STATE OF NEW MEXICO EX. REL.
TOM UDALL, ATTORNEY GENERAL

Plaintiffs

v. CIV No. 91-2527 (JGP)

JAMES WATKINS, SECRETARY OF
THE DEPARTMENT OF ENERGY, MANUAL
LUJAN, Jr., SECRETARY OF THE
DEPARTMENT OF INTERIOR,
DAVE O'NEAL, ASSISTANT SECRETARY
OF THE DEPARTMENT OF THE INTERIOR,
CY JAMISON, DIRECTOR OF THE
BUREAU OF LAND MANAGEMENT,
UNITED STATES DEPARTMENT OF ENERGY
AND UNITED STATES DEPARTMENT OF
THE INTERIOR,

Defendants.

County of Marin)
) ss.
State of California)

AFFIDAVIT OF EUGENE P. COYLE

I, Eugene P. Coyle, under penalty of perjury, state as follows:

1. Since 1974 I have been a consulting economist with a focus on energy and resource economics. My present business address is 433 Town Center, Suite 702, Corte Madera, California 94925.

2. In the course of my practice, I regularly study problems with construction programs and projects under consideration for investment. I analyze accounting reports such as balance sheets, budgets, cash flow projections and income statements.

3. In this affidavit I provide my opinion regarding the cost of the WIPP and its monthly budget.

4. As detailed in my Statement of Qualifications, a copy of which is attached hereto as Exhibit A, I earned a B. A. in Economics from Providence College in 1954 and a Ph. D. in Economics from Boston College in 1969. I also took graduate courses at New York University, including a course in Financial Accounting.

5. From 1962 to 1964 I was employed as an analyst by a private bank on Wall Street, Brown Brothers Harriman & Company.

6. From 1966 to 1974 I taught Economics and Finance full time at Emmanuel College, Boston, the University of Miami, Florida, and St. Mary's College of California. Since then I have taught part time. In 1989 I taught both graduate and undergraduate courses at the University of La Verne in Naples, Italy. My teaching includes courses in Economic theory, Money and Banking, Finance and Advanced Corporate Finance.

7. I have testified as an expert witness before Utility Commissions or Administrative agencies in 22 states and 1 U. S. territory. I have also testified before the U. S. House of Representatives, and the legislatures or agencies of California, Kentucky, Nevada, Rhode Island, North Carolina, and Oklahoma. I have previously testified as an expert witness for the U. S. Department of Justice, in U. S. DISTRICT COURT, Sacramento California, U. S. vs 566.08 acres et. al., Civ S-80-305 PCW, August 1986.

8. I am familiar with many of the economics issues surrounding the WIPP because I filed Affidavits as an economic expert for the plaintiffs in Southwest Research and Information Center, Inc. et. al. v. The United States Department of Energy et. al. (D. C. N. M. No. 81-537-JB)

9. In that case I stated in an Affidavit that both the direct and indirect costs of a delay in the WIPP project, as claimed by the Project Manager, WIPP Project Office, were overstated, speculative, and inconsistent.

10. The views and opinions set forth in this affidavit are my own, based on the following material made available to me:

a. Memorandum in Opposition to Plaintiff's Motion For Preliminary Injunction.

b. Department of Energy, Office of the Inspector General, The Department's Response to Delays in the Opening of the Waste Isolation Pilot Plant, (Release date: July 17, 1990.) This is attached to this Affidavit as Exhibit B.

c. Department of Energy, Office of the Inspector General, The Potential for Cost Reduction in the Waste Isolation Pilot Plant (WIPP) Project, (Release date: June 18, 1984.) This is attached to this Affidavit as Exhibit C.

d. Department of Energy, Office of the Inspector General, Memorandum on Survey of Transuranic Waste Shipments to the Waste Isolation Pilot Plant During the Test Phase; Report No. WR-L-90-3, Feb 13, 1990. This is attached to this Affidavit as Exhibit D.

e. A portion of the WIPP FY 1989 budget. (Attached as Appendix A to The Department's Response to Delays in the Opening of the Waste Isolation Pilot Plant).

f. Department of Energy, Statement of Leo P. Duffy, June 13, 1991. Admin. Rec. IV VV.

g. Department of Energy, Memorandum for Director, Office of Environmental Restoration and Waste Management on Approval of Key Decision (KD)-4, Start of Cold Operations of the Waste Isolation Pilot Plant (WIPP) Facility. Admin. Rec. IV Y.

h. Department of Energy FY 1984 Congressional Budget Request. This is attached to this Affidavit as Exhibit E.

11. The claimed cost of WIPP, for construction and on-going operation, of $1.1 billion total and $13 million per month cannot be supported on the basis of Admin. Rec. IV Y.

12. I have carefully reviewed Admin. Rec. IV. Y. and found no support there whatever for the Department of Energy claim of having spent 1.1 billion dollars. Admin. Rec. IV. Y. shows, rather, total spending on WIPP through Fiscal Year 1991 of $693 million dollars.

13. I have carefully reviewed Admin. Rec. IV. Y. and found no support there whatever for the Department of Energy claim of costs of approximately 13 million dollars per month. Admin. Rec. IV. Y. appears to be a paper print-out of a slide presentation. It contains only three pages with any dollar figures at all. It contains no figure of $13 million dollars per month, nor does it have figures which would sum to $13 million dollars per month. The document provides little detail of past budgets and no detail at all on operations.

14. The absence of any support in the document that the Department of Energy cited for its claim regarding operating costs led me to examine additional documents.

15. The Inspector General of the Department of Energy did an audit of WIPP titled Response to Delays in the Opening of the Waste Isolation Pilot Plant. (Release date: July 17, 1990.) This Report is attached as Exhibit B. The audit's Appendix A is titled "WIPP FY 1989 Budget". The cost per day shown on this page is $220,000, or approximately $6.6 million per month.

16. Inflation since FY 1989 might suggest a small upward adjustment in costs. An inflation adjustment, however, could explain only a small fraction of the spread between $6.6 million and $13 million.

17. The budget in the audit's Appendix A reflects operations during a period of rehearsal of full test phase operations. On page 6, under the heading WIPP Operations, DOE's Inspector General's audit states:

> When visiting the WIPP site in April 1989, we observed that the facility was operating as if radioactive waste was being stored, when in fact there was no waste on site. For example, we were badged; security staff inspected our brief cases; we had to pass through a metal detector; employees wore dosimetry badges; we required radiation screening to exit from the underground area; waste handlers wore protective clothing; workers controlled access to the waste handling building to prevent radiation escape; and employees rehearsed the procedures for moving waste containers. On-site officials explained that the staff had begun to follow these procedures within the preceding six months as part of the operational

readiness demonstration. They expected the practices to be a permanent condition at the site, regardless of how long the delay in opening might be.

It appears, then, the FY 1989 budget represents what the cost would be if WIPP were in full Test Phase operation.

18. Although the total budget appears to be about $6.6 million a month, close examination suggests that the operations actually cost significantly less. The budget contains the following items:

a.	Off-site activity (Sandia National Labs)	$21,400,000
b.	Management Reserve	$ 988,000
c.	Undistributed Budget	$ 5,133,000
d.	Tax and Fee	$ 4,378,000
e.	Capital Funds	$ 5,272,000.

It appears that the first three items should be subtracted from the total Operating budget. In addition, it is probably appropriate to subtract some portion of the fourth item as well, but it is impossible to determine what portion of that figure can be attributed to operations. Therefore, I have not subtracted it. Finally, a portion of the Capital Funds should also be subtracted, but the detail of how it is spread through the budget is not available, so this adjustment will not be made either. By subtracting the off-site activities, the Management Reserve and the Undistributed Budget figures from Auditor's figure of $80,273,000 we reach $57,995,000. This results in a cost per month of about $4.8 million.

19. The Department of Energy's Inspector General's audit, Response to Delays in the Opening of the Waste Isolation Pilot Plant suggests that significant savings may be available during a delay. In the section headed RESULTS OF AUDIT, on page 3, the auditors state:

> Sound business practice requires the Department to understand the cost implications of delays in opening WIPP and to develop plans to minimize the cost of these delays. Although an increasing number of obstacles has prevented WIPP from opening, the Department has not done such planning. Rather, the Department has continued to incur operating costs as if WIPP were about to open for the test phase. Contingency plans were not formulated because AL [Albuquerque Operations Office] project management instructions did not require such plans. Thus, the Department,

without knowing the cost-saving potential of alternative plans, may be spending funds unnecessarily.

On page 4, the auditors continue:

> The Department has faced a growing number of obstacles which have delayed the opening of WIPP. The Project Office, however, has not developed any plans to minimize the impact of these delays on the cost of the overall project. The Department has continued supporting a level of spending as if WIPP were about to open and receive waste.

20. Following the passage quoted above, the audit listed obstacles to the opening of WIPP to receive waste. Among five unresolved items which would prevent WIPP from receiving waste was item number 2.:

"2. The Congress had not passed land withdrawal legislation."

21. The Memorandum in Opposition To Plaintiff's Motion for Preliminary Injunction states at page 43 "... an additional 13 million dollars will continue to be spent every month, whether or not the Test Phase goes forward. (Admin. Rec. IV. Y.)" (emphasis added.) This suggests that the Department has no intention to reduce operations during a delay to save on expenditures.

22. The DOE Inspector General, addressing earlier delays in Response to Delays in the Opening of the Waste Isolation Pilot Plant, noted on page 6 that, "The Department has not reduced operations expenditures during the period of delay, and, in fact, has increased the number of positions."

The audit continued, on page 7, to assert that

> Although WIPP Project Office contingency planning to minimize the cost of delay is, in our view, a logical implication of Department Order 4700.1, "Project Management System," AL [Albuquerque Operations Office] did not require such planning.

In the section headed Cost Saving Unknown, the auditors state as follows:

> The Department, without knowing the net cost-saving potential of suspending or reducing certain operations, may be

> spending funds unnecessarily. Since the Department has not prepared plans for alternatives to maintaining the current state of operational readiness, we cannot estimate the possible excess cost. Should there be further delays in the initiation of WIPP waste operations, the need for effective contingency planning, as recommended in this report, becomes even more important.

23. The audit noted that the AL [Albuquerque Operations Office] stated that the WIPP Project Office will develop contingency plans for program reduction and plant shutdown/mothball. "Estimated completion date for the plans is October 31, 1990." (page 9.) I have not seen any contingency plans as of this date. If such plans have been completed they may provide lower projected monthly costs during a delay.

24. The auditors from the DOE Inspector General's Office examined previous WIPP responses to delay. In a section headed Responses to Delay on page 5 of the previously cited audit, they note as follows:

> The Department has responded to issues causing delay without analyzing their economic consequences and without developing contingency plans to minimize costs. ...
>
> One AL official explained that, as a matter of policy, the Department was committed to move forward aggressively toward opening. ... The official admitted that the Project Office had not developed contingency plans if one or more issues were not resolved in a timely manner. His comments were to the effect that opponents of the project might see the preparation of such plans as a weakening of Department resolve and use it to further impede progress.

If contingency plans have not yet been developed, monthly operating expenses during a delay will be larger than those incurred by a more prudent management.

25. I have also reviewed "Statement of Leo P. Duffy," Director of Environmental Restoration and Waste Management, U. S. Department of Energy, before the Subcommittee on Environment, Energy, and Natural Resources, Committee on Government Operations, U. S. House of Representatives, June 13, 1991. (Admin.

Rec. Exhibit IV VV.) In supporting the conduct of tests at the WIPP facility Mr. Duffy asserts, on page 3, that

> In particular, the conduct of both bin-scale and alcove tests at WIPP would avoid establishment of comparable facilities at other locations. The establishment of another facility is estimated to cost between $10 and $20 million, requiring 12 to 18 months for completion and would still not establish the actual facility capability.

26. I found no support in any of the documents I examined for the estimated cost asserted by Mr. Duffy.

Eugene P. Coyle

EUGENE P. COYLE

SUBSCRIBED AND SWORN to me before me this 9th day of November, 1991.

OFFICIAL SEAL
JUNE M. FRANCIS
NOTARY PUBLIC - CALIFORNIA
MARIN COUNTY
My Comm. Expires Nov. 30, 1993

June M. Francis

Notary Public

My Commission Expires:

Nov. 30, 1993

Exhibit A

STATEMENT OF QUALIFICATIONS

EUGENE P. COYLE
Consulting Economist

Suite 702, 433 Town Center
Corte Madera, Ca. 94925
(415) 461-9006

My consulting practice has focused principally on regulatory and resource economics, with assignments ranging from pricing and cost allocation, through valuation of resources, including park lands, to negotiation of contracts between resource owners and developers. As part of my responsibilities I have testified as an expert witness in Federal and State Courts and before public utility commissions in 22 states and one territory.

A chronology of my education and professional activities follows:

I received a BA degree with a major in economics from Providence College. Following military service as an Aviation Cadet, jet pilot, and helicopter pilot in the U.S. Air Force, I was employed as a commercial pilot in Colombia and Ecuador before beginning graduate school to further study economics.

In 1960 and 1961 I was a graduate student in economics at Boston College. For the academic year 1960-1961 I was awarded an Assistantship at Boston College .

From 1962 through 1964 I was employed as an analyst at Brown Brothers Harriman and Company, a private bank at 59 Wall Street, New York, N.Y. At Brown Brothers I was responsible for recommending investments in the common stock of utility companies. As part of my duties I traveled throughout the country to familiarize myself with growth prospects of utility service territories, to interview and evaluate utility management (generally seeing the Chief Executive Officer and/or the Chief Financial Officer) and, in short, to make a judgement about the future prospects of the company.

I was also responsible for appraising all corporate bond offerings as investment vehicles for the bank's clients. I evaluated the suitability of each offering for various classes of investors and forecast the yields at which the offering would be made.

In the fall of 1964 I was awarded a Teaching Fellowship at Boston College and returned there to complete my graduate studies. I was a Teaching Fellow for two years and earned my Ph.D. in economics from Boston College in 1969. My graduate work included numerous courses in Economics and Statistics. In addition to the full graduate program leading to the Ph.D. I also took courses in accounting and public utility investment at New York University's Graduate School of Business Administration.

In 1969 I was invited to participate in a conference on financial aspects of utility regulation at Stanford University, co-sponsored by American Telephone and Telegraph and in 1972 I received a National Science Foundation grant to participate in a six week conference on applied price theory at Brown University. A major portion of our time was spent on discussion of public utility price theory.

My **graduate and undergraduate teaching** has covered a wide spectrum of economics and finance courses, including Economic Principles, Price Theory, Corporate Finance, Statistics, Money and Banking, Economic History, History of Economic Thought, and Macro Economics.

I taught at Emmanuel College during 1966-1968. As Assistant Professor of Finance at the University of Miami, Florida, 1968-1970, I taught the Advanced Corporate Finance course in the MBA program. During 1971- May 1974, I was an Assistant Professor, St. Mary's College in California. I have occasionally taught evening courses at the undergraduate level and spent the Spring semester of 1989 teaching full-time in the MBA program of the University of La Verne in Naples, Italy.

As a **consulting economist,** I have lectured and spoken widely at conferences and conventions, including at The Third National Seminar for Consumer Representatives in State and Local Government, University of Wisconsin, Milwaukee, in 1975; at the National Conference of the American Public Power Association, Anaheim, California, June 1976; at the ERDA Conference on Energy Technologies for the West, San Francisco, California, 1976; at the Edison Electric Institute Rate Fundamentals Course, Indiana University, 1979; and at the 5th Miami International Conference on Alternative Energy Sources, 1982. I have also lectured at colleges and universities and have made numerous radio and television appearances.

In addition to the appearances mentioned, I have also **given testimony on utility and energy issues** before the following Legislative Bodies and Public Authorities:

United States House of Representatives, Committee on Interstate and Foreign Commerce, Subcommittee on energy and power, April 1976;

California Assembly, Committee on Energy and Diminishing Materials, March 1975;

California Energy Conservation and Development Commission, September 1975;

Kentucky, Governor's Special Advisory Commission, October 1975;

Legislative Subcommittee on Utility Rates and Public Utility Commission, Las Vegas, Nevada, April 1976;

Rhode Island, Special Hearing, State Capitol, December 1975;

North Carolina, Utility Commission Conference Lifeline Utility Rates, June 1978;

Oklahoma, Oklahoma Legislature,Committee on Oil, Gas and Energy, October 13, 1977; Oklahoma, Oklahoma Legislature, Special Committee on Public Utilities, September 25, 1978.

Recent publications include a review of Public Regulation in the ***Journal of Economic Issues***, September, 1988; "An Historical Perspective on Time Necessary To Develop Geothermal Power in the U. S.", Geothermal Resource Council ***Bulletin*** (with M. E. Erskine), 1988; and "An Active Regulatory Approach to Cost of Capital", ***Proceedings***, NARUC biennial conference, 1986. I have also published articles, book reviews, and studies related to utility rates, energy economics, alternative technology, cost of capital and regulatory theory.

Exhibit B

REPORT NO.

WR-OC-90-7

U.S. Department of Energy
Office of Inspector General

Release Date:

July 17, 1990

THE DEPARTMENT'S RESPONSE TO DELAYS IN THE OPENING OF THE WASTE ISOLATION PILOT PLANT

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U.S. DEPARTMENT OF ENERGY
OFFICE OF INSPECTOR GENERAL

THE DEPARTMENT'S RESPONSE TO DELAYS IN THE OPENING OF THE WASTE ISOLATION PILOT PLANT

Report No.: WR-OC-90-7
Date of Issue: July 17, 1990

Western Regional Office
Albuquerque, NM 87115

THE DEPARTMENT'S RESPONSE TO DELAYS IN THE OPENING OF THE WASTE ISOLATION PILOT PLANT

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OFFICE OF INSPECTOR GENERAL
WESTERN REGIONAL OFFICE
ALBUQUERQUE, NEW MEXICO 87115

THE DEPARTMENT'S RESPONSE TO DELAYS IN THE OPENING OF THE WASTE ISOLATION PILOT PLANT

Audit Report No.: WR-OC-90-7 Date: July 17, 1990

PURPOSE AND SCOPE OF AUDIT

This report concerns the Department of Energy's (Department) response to delays in opening the Waste Isolation Pilot Plant (WIPP) at Carlsbad, New Mexico, and evaluates the Department's efforts to minimize the financial effects of these delays.

Our review was made from April to October 1989 at Carlsbad and Albuquerque, New Mexico. During the audit we:

- Reviewed Department policies, practices, and guidelines for anticipating and resolving delays in the acquisition of major systems;
- Interviewed WIPP Project Office and Westinghouse Electric Corporation's Waste Isolation Division (Westinghouse) officials;
- Analyzed financial and project management records for data relating to the chronology of delays and Department responses to delays; and,
- Toured the underground and surface facilities at the WIPP project.

We followed generally accepted Government auditing standards for performance audits, including tests of internal control and compliance with laws and regulations as necessary to satisfy the audit's objective. Since our review was limited, it would not necessarily have disclosed all material internal control weaknesses. However, our finding relating to contingency planning should be considered when the Albuquerque Operations Office (AL) prepares the year-end assurance memorandum on internal control.

The firm of KPMG Peat Marwick participated with the Office of Inspector General in the conduct of this audit.

We held an exit conference with AL officials on May 21, 1990.

BACKGROUND

WIPP is a research and development facility intended to demonstrate the safe disposal, in deep geologic formations, of radioactive wastes generated by the Government's defense activities. WIPP is located on a 10,240 acre site 26 miles east of Carlsbad, New Mexico, and is designed to hold 6.3 million cubic feet of waste. Based on data in the 1989 Supplemental Environmental Impact Statement, WIPP has the designed capacity to receive all retrievably stored waste which the Department estimated existed in 1987 as well as all newly generated waste through the year 2013. Westinghouse is the management and operating contractor for WIPP.

The completed surface facilities include a 69,000 square foot administrative support and waste handling building, technical support and maintenance facilities, security and visitor facilities, and administrative offices. Westinghouse has mined approximately 10 miles of underground tunnels on a single level 2,150 feet below the surface.

There were about 675 full-time employees at the site, including 585 Westinghouse employees. These workers had assignments to continue the maintenance of mechanical equipment, support ongoing experiments, complete construction/mining of underground storage and maintenance areas, preserve site security and safety, and generate information to answer concerns which critics of WIPP had raised.

When operational, WIPP will contain contact handled, transuranic (CH TRU) waste. This waste is defined as:

> Without regard to source or form, waste that is contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years and concentrations greater than 100 nanocuries/gram at the time of assay....CH TRU waste has a surface dose rate of no greater than 200 mRem/hr. No shielding is required when handling this type of waste.

The Department's organization structure shows the various management responsibilities for WIPP. The Assistant Secretary for Defense Programs is responsible for directing the project. The Manager, AL, has field management responsibility. The Assistant Manager for Energy and Special Programs (AMESP) at AL heads a dedicated Project Office which oversees Westinghouse's activity and coordinates AL's specialized support resources. The WIPP Program Manager, Office of Defense Waste and Byproducts, at Headquarters is responsible for management of the programmatic activities. A project manager who reports to the AL AMESP is responsible for day-to-day execution of the project.

When approved in Fiscal Year 1977, the Department estimated WIPP would open in April 1989 at a cost of $948 million. As a result of cost reduction programs conducted through 1983, the Department lowered the estimated cost from $948 to $693 million and moved up the opening date to October 1988. Later, the Department projected that annual operating costs would average about $79.7 million (in 1986 dollars).

The Department divided the WIPP project into three phases - construction, test, and permanent waste disposal. The construction phase was completed within the revised cost estimate, but not within the expected time frame. Work extended six months beyond the estimated completion date because of problems encountered in boring an air intake shaft. The Department is unable to begin the test phase because a number of conditions necessary to receive waste have not been met. A decision on permanent waste disposal cannot be made until the test phase is successfully completed.

RESULTS OF AUDIT

Sound business practice requires the Department to understand the cost implications of delays in opening WIPP and to develop plans to minimize the cost of these delays. Although an increasing number of obstacles has prevented WIPP from opening, the Department has not done such planning. Rather, the Department has continued to incur operating costs as if WIPP were about to open for the test phase. Contingency plans were not formulated because AL project management instructions did not require such plans. Thus, the Department, without knowing the cost-saving potential of alternative plans, may be spending funds unnecessarily.

Need for Contingency Analysis and Planning

Since analyses of costs and expected benefits commonly precede decisions to invest in new facilities, private sector managers are aware of the economic consequences of delay in the timely completion of a major capital project. Delays change the relationships between costs and benefits by (1) extending the period of time over which costs are incurred, (2) adding new expenses to address the causes of delay, (3) pushing the start of the benefits stream further into the future, and (4) possibly reducing the benefits stream over the life of the project.

Armed with knowledge of the economic consequences of delay, private sector management develops plans for minimizing costs during various possible periods of delay. Managers compare, for varying periods of delay, the costs saved by suspending or reducing certain operations against the costs incurred when reactivating or increasing those operations at a later date. Any analysis showing positive cost savings by suspending or reducing operations leads to a plan for minimizing cost for that period of delay.

Extended Delays

The Department has faced a growing number of obstacles which have delayed the opening of WIPP. The Project Office, however, has not developed any plans to minimize the impact of these delays on the cost of the overall project. The Department has continued supporting a level of spending as if WIPP were about to open and receive waste.

Obstacles

As of October 1989, the Department faced a larger number of issues to resolve than it did in October 1988 when it conceded that WIPP would not be able to open as scheduled. Moreover, the estimated time for resolving these issues has extended beyond management's initial projections.

In a September 1988 Project Manager's Monthly Progress Report, the Department identified five unresolved items, shown below, which would prevent WIPP from receiving waste.

1. The air intake shaft was incomplete.

2. The Congress had not passed land withdrawal legislation.

3. The regulatory authority having jurisdiction for Resource Conservation and Recovery Act (RCRA) matters was undetermined.

APPENDIX A

WIPP FY 1989 Budget
(Dollars in Thousands)

Operations			
Administrative Services	$ 2,274		
Construction	478		
Controller	1,183		
Engineering	20,021		
Project Planning and Control	733		
Public Affairs	1,614		
Quality Assurance	1,104		
Safety, Security, Environment	8,738		
TRU Waste Integration	3,725		
Waste Operations	13,747		
Total Operations		$53,617	
Management Reserve		988	
Undistributed Budget		5,133	
Tax and Fee		4,378	
Total Westinghouse			$64,116
Sandia National Laboratories			21,429
Total WIPP Project			$85,545
Total Project			$85,545
Less: Capital Funds			(5,272)
Continuing Costs			$80,273
$80,273/365 = Cost per day			$ 220

Exhibit C

DOE/IG-0207

U.S. Department of Energy
Office of Inspector General

Release Date:
June 18, 1984

Report on

The Potential for Cost Reduction in the Waste Isolation Pilot Plant (WIPP) Project

IG

U.S. DEPARTMENT OF ENERGY

OFFICE OF INSPECTOR GENERAL

THE POTENTIAL FOR COST REDUCTION IN THE WASTE ISOLATION PILOT PLANT (WIPP) PROJECT

REPORT NO. DOE/IG-0207
DATE OF ISSUE: May 31, 1984

OFFICE OF INSPECTIONS
WASHINGTON, D.C.

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APPENDIXES:

A. Technical Notes (Available on request)

B. Management Reaction

C. Detailed Legislative History

D. Acronyms

I. SUMMARY

During the First Quarter of Fiscal Year 1984, we conducted a review of the Waste Isolation Pilot Plant (WIPP) project managed by the Assistant Secretary for Defense Programs. Although a commendable effort to reduce project costs had been initiated by program officials in December 1981, we found additional cost reduction opportunities.

For example, we found that the research and development program had not received the same degree of scrutiny during cost reduction activities as had the area of capital costs, and we identified several experiments that could be reduced in scope or eliminated. Although we did not identify cost reduction opportunities during our review of land and siting issues, we found that the Department may be vulnerable to additional costs amounting to millions of dollars. More importantly, we found that capital costs of the project could be further reduced by decreasing the size and shielding of the hot cell facility, or by eliminating it completely, and by adopting a less costly, but adequate, alternative for dining area/visitor center facilities. Although it is difficult to quantify the cost savings associated with these cost reduction opportunities, we estimate possible savings of tens of millions of dollars.

II. PURPOSE AND SCOPE

The purpose of this inspection was to assess the technical rationale for certain decisions regarding the siting and design of the WIPP facility, to determine if the planned research and development activities were needed and would be accomplished cost-effectively, and to identify potential cost reduction opportunities that could be realized before construction of the WIPP facility.

In conducting our inspection, we interviewed the Department's program management staff at Headquarters and, during the field portion of our inspection from September 26 to October 7, 1983, interviewed the WIPP Project Office personnel and contractor personnel located at Albuquerque, New Mexico, and the project site at Carlsbad, New Mexico. The project and contractor personnel who were interviewed included representatives from the Albuquerque Operations Office, Sandia National Laboratories (Sandia), the Westinghouse Electric Corporation, Bechtel National, Incorporated, and the U.S. Army Corps of Engineers. Discussions were also held with personnel from the Department's Civilian Radioactive Waste Management Office and Office of Nuclear Waste Isolation (ONWI), as well as individuals from the Tennessee Valley Authority who were pursuing nuclear waste management activities. In addition, we reviewed documentation associated with the project and studies and reports on related technical issues.

III. SYNOPSIS OF FINDINGS

Land and Siting Issues

o The Department's conclusion that there would be minimal impact on WIPP operations and public health and safety from the existence of a pressurized brine reservoir in the Castile Formation underlying the WIPP underground facility was adequately supported. (See page 13.)

o The total cost of the WIPP project could be increased by several million dollars if it becomes necessary to condemn existing potash leases at the WIPP site. (See page 13.)

o The Department is committed to construction of the WIPP facility at a cost of $409 million[1] with no guarantee that it will receive authority to emplace radioactive waste in the facility when it is completed in 1987. (See page 13.)

Research and Development

o Experiments at the WIPP with actual defense high-level waste (HLW) are not needed to support future repository design efforts. (See page 16.)

o The WIPP research and development program includes several experiments that are not needed or could be reduced in scope with minimal impact to the project's stated mission. (See page 21.)

Cost of Facilities

o The design of the waste handling facility provided for a larger facility and greater shielding for radioactivity than necessary to handle the type and amounts of remote-handled (RH) radioactive transuranic (TRU) waste and defense HLW planned for the WIPP. We estimated potential cost savings of at least $1.2 million in this area. (See page 27.)

o Eliminating the WIPP experiments with actual defense HLW could result in a further reduction in the size and shielding of the hot cell, and allow consideration of less costly alternatives that could eliminate the requirement for a hot cell completely. Potential savings are on the order of tens of millions of dollars. (See page 30.)

o Present plans to add a dining area/visitor center to the WIPP Guard and Security building would add unnecessarily to the cost of the WIPP project. Adoption of a less costly alternative could result in a cost savings of at least $800,000. (See page 32.)

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[1] U.S. Department of Energy Fiscal Year 1985 Congressional Budget Request, February 1984.

IV. RECOMMENDATIONS

A. For the Assistant Secretary for Defense Programs:

1. Develop and publish a strategy and major milestones for obtaining legislation by the Congress to withdraw the WIPP site from public lands.

2. Conduct a cost/benefit review of the experiments currently planned for the WIPP research and development program to determine those that could be reduced in scope or eliminated, with emphasis on those experiments that may be impacted by the Nuclear Waste Policy Act of 1982.

3. Reexamine the design of the Waste Handling and Support building to identify areas of overdesign as targets for cost reduction efforts.

4. Defer construction of the hot cell and related facilities until a decision is made concerning commingling defense and civilian HLW.

5. Review the justification for the dining area/visitor center presently proposed for the Guard and Security building in view of less costly, but adequate, alternatives.

B. For the Assistant Secretary for Management and Administration, ensure that an Independent Cost Estimate (ICE) is conducted of the WIPP project immediately following the "bottoms-up" estimate to be completed by program officials in early 1984.

V. MANAGEMENT REACTION

The Acting Assistant Secretary for Defense Programs (ASDP) provided extensive comments on our draft report. The full text of his comments is in Appendix B. The basic position taken by the ASDP and his reactions to our recommendations are summarized below. Some of his specific comments on the findings and our responses are included in Section VII, DETAILED FINDINGS. Although the ASDP generally disagreed with the findings of the draft report, there was some agreement with the recommendations. His comments clearly indicated, however, that our major recommendations are not likely to be implemented.

Regarding the mission of the WIPP, the ASDP stated that experiments with actual defense HLW were mandated by the authorizing legislation. On the land and siting issues identified, the ASDP stated that the depressed condition of the domestic potash industry obviated the need to condemn leases at the WIPP site; therefore, $17 million for that purpose was deleted from the budget. Also, the present lack of authority to emplace radioactive waste at the WIPP site was not viewed as a problem, since draft land withdrawal legislation providing the necessary emplacement authority will be submitted soon to the Congress.

Commenting on the research and development experimental program, the ASDP stated that the WIPP research and development mission cannot be accomplished without the use of actual defense HLW, that there are technical issues for which resolution will never be satisfactorily demonstrated without using actual defense HLW waste forms, and that credibility of the demonstration is a must. He said that experiments and demonstrations planned for the WIPP are only those needed to demonstrate that the technical concerns are tractable and that large-scale waste handling operations may be safely conducted.

Regarding the cost of facilities, the ASDP did not agree that reduction of hot cell shielding would be cost effective. Neither did he agree that the guard/security center, which includes visitor reception facilities, would add unnecessarily to the cost of the WIPP project. The ASDP's comments on our recommendations are summarized below:

Recommendation 1: Drafts of proposed legislation to withdraw the WIPP site lands have been prepared and a strategy for obtaining a legislative land withdrawal has been determined. This will include the authority to emplace radioactive wastes.

Recommendation 2: There was no objection to a cost/benefit review of the WIPP research and development program by knowledgeable people. The National Academy of Sciences would be available for such a review once their existing contract [to provide technical oversight of the WIPP research and development program] is extended.

Recommendation 3: The Waste Handling and Support building is designed to provide important operational and safety flexibilities. There is no viable opportunity to reduce shielding at this time since the design package is out for bid.

Recommendation 4: (Added in final report)

Recommendation 5: The Guard and Security building will be reviewed to assure cost effectiveness. However, only minor changes are anticipated.

VI. BACKGROUND

A. Introduction

The Waste Isolation Pilot Plant (WIPP), located near Carlsbad, New Mexico, is being developed by the Department of Energy as a defense research and development activity. As authorized by Congress in 1979, the mission of the WIPP project is:

> "... for the express 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."[2]

The rather broad congressional authorization has allowed the Department to design the WIPP facilities to support a comprehensive and extensive program of research and development experiments and demonstration activities. As currently designed, the WIPP provides for demonstration of the receipt, inspection, and emplacement of defense-generated TRU waste in a retrievable mode in salt. Studies will also evaluate the disposal of actual defense-generated HLW. The Department's Fiscal Year 1984 Congressional Budget Request estimated completion of construction of WIPP facilities in Fiscal Year 1988, and estimated the total cost of the project at $748 million in year of expenditure dollars. By the end of 1983, the Department had expended $217.9[3] million for the WIPP project.

The Nuclear Waste Policy Act of 1982, which was signed into law in January 1983, contained provisions that will significantly impact the research and development program planned for the WIPP. Specifically, the Act contains a provision that requires the President to conduct an evaluation by January 1985, of the feasibility of disposing of defense-generated HLW in a licensed, commercial repository containing HLW generated by civilian nuclear reactors.

Also, the Department's "Defense Waste Management Plan" (June 1983) stated that it was the Department's intent to "commingle" defense HLW and civilian HLW in a commercial repository unless there were unacceptable adverse impacts on defense programs. There are no apparent significant adverse impacts that preclude a decision to commingle defense and civilian HLW in a licensed, commercial repository.[4] Therefore, there is no need to pursue activities at the WIPP to support development of a geologic repository for only defense HLW.

In the project's early years, from 1976 to 1981, a number of events occurred that contributed to increased costs and schedule delays. In 1979, a joint House/Senate conference committee concluded

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[2] Public Law 96-164, Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980, December 29, 1979.

[3] Year of expenditure dollars.

[4] Draft Report, An Evaluation of Defense High-Level Waste Disposal in Geologic Repositories, Assistant Secretary for Defense Programs, January 1984.

that frequent changes had driven up costs, delayed design and construction, and confused management, the public and the Congress. As a result, the committee felt that the project was unmanageable and served only to delay ultimate decisions and solutions necessary for the long term storage of nuclear waste. Many of these events, as reflected in the following legislative history, were the result of differing views between the former Administration and the Congress over the mission for the WIPP.[5]

Other events, such as the decision to modify the initial design of WIPP's underground facilities from two, mined levels for waste disposal to one level, also impacted the project's cost and schedule. These events are described in the following discussion of the project's design history. Finally, the impact of these events on the total cost of the project is illustrated in the following cost history. This history details the increase in the total cost of the project to almost $948 million, before efforts initiated in December 1981 led to cost reduction activities that reduced the project cost in April 1983 to an estimated $693 million.

B. Legislative History

Briefly, in 1974, the Atomic Energy Commission (AEC), a predecessor of the Department, initiated efforts to locate a site and construct a radioactive waste disposal pilot plant (RWDPP). Under the AEC's concept, the RWDPP would be limited to disposal of defense-generated TRU waste and include provisions for experiments with HLW, both defense and civilian. That same year, Congress passed the Energy Reorganization Act of 1974, which did not require facilities for disposal of defense-generated TRU waste to be licensed by the Nuclear Regulatory Commission (NRC), but did require the NRC to license facilities for disposal of defense HLW and civilian HLW.

In 1976, site activities were initiated for a RWDPP at the present WIPP site by the Energy Research and Development Administration (ERDA), also a predecessor of the Department. Legislative documents indicated that this project, which subsequently became the WIPP project, was specifically authorized by Congress in 1976 as a research, development, and demonstration project for the storage of defense wastes. Line item funds for the project were requested in ERDA's budget request for Fiscal Year 1977. However, funding was delayed until November 1977 as a result of Congress passing a continuing appropriation in lieu of a Federal budget.

During 1978, an Interagency Review Group (IRG) conducted a review of the Federal nuclear waste management program. The view by the IRG, that a repository for disposal of TRU wastes should be

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[5] A detailed discussion of the early legislative history is at Appendix C.

licensed, contributed to considerable debate during congressional hearings in 1978 on the Department's budget request for Fiscal Year 1979 line item funds for the WIPP project.

Both the House and Senate Committees on Armed Services were particularly concerned with the views of the IRG pertaining to licensing facilities for disposal of TRU wastes. They were also concerned that the Department might have developed a different view of the WIPP project than was originally authorized, i.e. including a role for the NRC during the construction and operation of the facility. Attempts were made to limit the scope of the WIPP project through language in the congressional appropriations. Subsequently, the continuing appropriation passed by Congress for Fiscal Year 1979 funding included a provision that prohibited the Department from expending funds on activities to license the WIPP facility or store spent fuel from commercial sources.

In July 1979, the Department's Acting Under Secretary advised the House Committee on Armed Services that the Department was considering two significant changes to the WIPP project:

(1) Amending the WIPP mission to include the disposal, in a retrievable mode, of up to 1000 commercial spent fuel assemblies, and

(2) Obtaining an NRC license for the WIPP facility.

He also indicated that the Administration might wish to broaden WIPP's mission with licensing by NRC and advised that the Department was exploring the possibility of tranferring jurisdiction for the WIPP project to a non-defense committee because of the apparent impasse between the Department and Congress with respect to the project.

Subsequently, the Administration attempted to cancel the WIPP project and include the project site as one of the alternative sites to be considered for a licensed repository under the commercial nuclear waste management program. This approach was rejected by Congress in December 1979 with passage of Public Law 96-164, which provided a statutory definition of the WIPP project. The Administration attempted to terminate the project by not requesting funds for Fiscal Year 1981. However, Congress appropriated funds to continue the project. A final attempt to terminate the WIPP project occurred in March 1980, when the President requested Congress to rescind the budget authority for the project. This request was not supported by Congress.

Finally, the Nuclear Waste Policy Act of 1982 was signed into law in January 1983. The Act provided that not later than January 1985, the President would evaluate whether storage capacity in

one or more of the repositories established under the Act could be used for disposal of defense HLW. The Act further stated that unless the President found that a separate repository was required for disposal of defense HLW, the Secretary of Energy should proceed promptly to arrange for disposal of defense HLW in one or more of the repositories established by the Act.

C. Design History

The earlier concept of a RWDPP was the basis for the WIPP conceptual design completed by Sandia in June 1977. The principal objectives of the WIPP facility, as designed by Sandia, were to:

(1) Demonstrate the adequacy of bedded-salt formations for isolating contact-handled and remote-handled radioactive wastes generated by ERDA in support of national defense programs, and

(2) Provide a facility for experiments (some involving HLW) to extend the understanding of the behavior of other waste types in a salt medium.

The project described in Sandia's conceptual design seemed more ambitious and broader in scope than the congressional authorization for a research, development and demonstration project for the storage of defense waste. For example, Sandia described the WIPP as a facility to gather data and demonstrate on a large scale the feasibility of disposal of radioactive waste in bedded salt. Sandia did not consider the WIPP facility to be a pilot plant in the usual meaning, i.e., a small scale, limited use facility to be followed by construction of a main plant. Instead, the WIPP was intended to be full-scale, with the capability for expansion to full repository operations with few modifications.

Sandia also intended the WIPP facilities to be stringently designed as though a license from NRC were required. The conceptual design included surface facilities to receive and handle radioactive wastes, both TRU and HLW, and underground facilities consisting of two, mined working levels; an upper level for storage of contact-handled TRU waste and a deeper level for storage of remote-handled, heat producing waste and for experiments with HLW. Based on the conceptual design, Sandia's estimate of the capital cost of the WIPP project was $330 million.

Although the principal mission of the WIPP project was to dispose of defense-generated TRU waste, the AEC/ERDA wished to maintain a capability for HLW disposal at the selected site. This was reflected by the two, mined working levels[6] and the facilities designed to the characteristics of commercial HLW.

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[6] Summary of the Results of the Evaluation of the WIPP Site and Preliminary Design Validation Program, WIPP-DOE-161, March 28, 1983 Page 8.

The concept of the WIPP project as a potential repository for HLW was pursued by the Department during the former Administration. The Department proposed to greatly expand the scope of the project by including experiments with up to 1000 canisters of commercial spent fuel and obtaining a license for the facility from NRC. However, as previously discussed, the Congress passed legislation to prohibit the Department from expending WIPP funds for licensing activities and from storing spent fuel at the facility. The Congress also redefined the WIPP as a research and development facility exempted from licensing by NRC. This legislation removed the possibility of HLW disposal from the WIPP mission. Therefore, a separate underground level for eventual storage of HLW was no longer needed. As a result, the WIPP design was modified to include only one underground working level, primarily to demonstrate storage of defense-generated, contact-handled and remote-handled TRU waste.

Although the congressional authorization required the Department to delete activities related to permanent disposal of HLW from WIPP's mission, the present design of the WIPP facilities does not rule out this option in the future. For example, the WIPP in-situ test program includes a number of experiments with actual HLW from defense activities to determine the effects of heat-producing waste in the less pure salt beds selected for TRU emplacement. In addition, the underground facilities include a large area dedicated to handling and emplacement activities with defense HLW and in-situ experiments with defense HLW "spiked" with additional radioactivity to allow accelerated testing. Thus, the ability of surface facilities to receive and handle both defense and civilian HLW canisters has not been impacted by the congressional authorization for the WIPP, since these facilities will be used to support defense HLW experiments and were designed to the characteristics of commercial HLW.

D. Cost History

In 1976, Congress authorized $6 million to begin land acquisition and preliminary architect/engineer design work for the WIPP project. The Total Estimated Cost (TEC)[7] of the project was to be developed as part of an additional conceptual design engineering effort. At the start of the conceptual design effort, the preliminary estimate of the project's cost was $100 million. By 1977, after 50 percent completion of Title I (conceptual) design, the preliminary estimate had increased to $140 million. Since 1978, two major, "bottoms-up" cost estimates have been generated

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[7] Total Estimated Cost (TEC) represents all capital costs necessary to construct the facility, including architect/engineer services and construction management. Total Project Cost (TPC) is the sum of the TEC and Operating Costs, which includes the cost of research and development and the cost to operate the facility.

for the project. Subsequently, the second bottoms-up estimate has been adjusted twice by cost reduction programs.

The first comprehensive cost estimate for the project was completed in June 1979. The Total Project Cost (TPC) was estimated at $737 million, which included a TEC of $441 million and operating costs (including research and development costs)[8] of $296 million. A key assumption was that the WIPP facility would not be licensed.

A new cost estimate was completed in October 1981 to reflect not so much the technical changes as the disruptions to the project schedule by legislative and budgetary actions. The TPC was estimated at $948 million, which included a TEC of $652 million and operating costs of $296 million. The major design change during this period was primarily the result of congressional passage of Public Law 96-164. This change involved substitution of a single-level repository plan in place of the previous dual-level plan.

The October 1981 revised cost estimate reflected the following changes that occurred after the June 1979 estimate:

- Design evolution and reestimating changes
- Revision of mission and design to comply with Public Law 96-164
- Insertion of site and preliminary design validation activities into the project schedule
- Unexpected increases in inflation rates
- Revised schedules resulting from budget constraints
- Costs of compliance with the Stipulated Agreement signed by the Department with the State of New Mexico for the WIPP project.

The Under Secretary approved the project's revised cost, schedule and technical baseline in December 1981.[9] The approval was granted with the condition that the Assistant Secretary for Defense Programs conduct a review of the cost elements of the project to reduce the total cost where possible. An extensive cost reduction effort undertaken by the WIPP Project Office was substantially completed in March 1982, and the TPC estimate was

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[8] For this discussion, operating costs will include costs for research and development activities.

[9] Memorandum to the Record, Subject: ESAAB Memorandum 1-82: Energy System Acquisition Advisory Board Meeting: Waste Isolation Pilot Plant, December 2, 1981, Under Secretary, December 29, 1981.

reduced to $748 million. This estimate included a TEC of $504 million and operating costs of $244 million.

An ongoing effort to identify additional areas for cost reductions led to a revised cost estimate in April 1983. The TPC was estimated at $693 million, which included a TEC of $459 million and operating costs of $234 million. The more significant changes in the cost estimate were primarily the result of reductions in escalation rates and contingency factors.

The WIPP Project Office is continuing efforts to identify possible cost reductions through the use of cost trending techniques. When the WIPP project's Title II (preliminary) design is completed in early 1984, the project's principal contractors will generate a new, bottoms-up estimate. In addition, the Department's Office of Project and Facilities Management is expected to initiate an Independent Cost Estimate (ICE) review of the project.

E. The WIPP Research and Development Program

Public Law 96-164 authorized the WIPP facility as 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 licensing by the NRC. The Department's interpretation of the congressional authorization is reflected in the current scope of the WIPP project, which includes an extensive research and development program to be performed by Sandia. Of approximately $214 million in operating funds budgeted for the WIPP project through Fiscal Year 1988, over half will be paid to Sandia, principally for support of WIPP's research and development program.

According to Sandia, the planned research and development program provides the technical basis for systems design and safety and environmental assessments for future repositories for defense-related radioactive wastes. It also applies those design methods and safety and environmental assessments for defense wastes to the development of the WIPP facility. Thus, the WIPP research and development program will provide and demonstrate the technology needed to develop a future defense repository in bedded salt.

The WIPP research and development program is divided into three general phases: Technical Development, In-Situ Tests Without Radioactivity, and In-Situ Tests With Radioactivity. The Technical Development phase includes computer model development and application, laboratory studies, and field tests. The In-Situ Tests Without Radioactivity include the SPDV[10] program, technology

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[10] The WIPP Site and Preliminary Design Validation (SPDV) program was developed and implemented to permit in-situ observation of geologic conditions at the proposed waste storage horizon and to allow determination of the geomechanical reaction of the salt beds after excavation of underground rooms.

experiments and demonstration of repository operations, such as waste handling procedures and retrieval methods. The In-Situ Tests With Radioactivity primarily address waste package interactions, including Radiation Source Experiments (RSEs), defense HLW tests, and demonstrations with actual TRU wastes and defense HLW. The RSEs are optional and no plans exist to exercise this option at the present time.

According to Sandia, the WIPP project, although devoted entirely to defense wastes, will serve as a source of technical information for subsequent development of commercial waste repositories. In addition, the WIPP research and development program will constitute a significant body of information about the generic development of repositories in salt. The program incorporates Sandia's philosophy of establishing reference cases on which to base experiments and analysis. In many cases, experiments will replicate conditions expected in an actual repository. Also, overtests (using canisters "spiked" with additional radiation) will enable a comparison to be made with a reference case and provide experimental data simulating long-term effects in a relatively shorter time.

Several reference cases for the research and development program were developed by WIPP project personnel for direct application to the WIPP mission, while other reference cases were developed outside the WIPP project for use elsewhere. For example, the concept for emplacement of RH TRU waste was based on WIPP studies to define the most effective concept for storage and subsequent permanent disposal of RH TRU in the WIPP. In contrast, the reference case for defense HLW experiments reflects repository conditions that were determined outside the WIPP project[11] by the National Waste Terminal Storage (NWTS) program[12] for commercial waste disposal.

Sandia's Experimental Programs Division has established near-term and long-term objectives for each experiment planned for the WIPP research and development program. The near-term objectives

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[11] The reference conditions used as a basis for defense HLW experiments were developed by the Reference Repository Conditions Interface Working Group. Their work is reported in "Interim Reference Repository Conditions for Commercial and Defense High-Level Nuclear Waste and Spent Fuel Repositories in Salt," NWTS-3, Office of NWTS Integration, 1981.

[12] Responsibility for the NWTS program was given to the Department's Civilian Radioactive Waste Management Office by Public Law 97-425, the Nuclear Waste Policy Act of 1982. The Act included provisions for eventual commingling of defense and commercial HLW in a licensed repository.

provide information directly applicable to the WIPP project. However, the long-term objectives are oriented principally toward increasing confidence in computer models and codes that will be used to design a future nuclear waste repository, although some of this data may be useful to the WIPP project. Sandia estimated that a majority of the technology experiments and waste package interaction experiments will be in support of efforts related to a future repository.

In 1978, the National Research Council established the Panel on the Waste Isolation Pilot Plant (the WIPP Panel) to review various aspects of the WIPP project for the Department.[13] The WIPP Panel has been under contract with the Department since its inception in the summer of 1978. Efforts are currently underway to continue the WIPP Panel's involvement in the review of the project through the start of waste receiving operations in October 1988.

The WIPP Panel review addressed the scientific and technical adequacy of certain aspects of the WIPP project, e.g. the research and development program developed by Sandia. However, the WIPP Panel did not consider the cost aspects of the project. For example, the WIPP Panel did not consider the cost versus benefits of the various experiments proposed by Sandia, nor did they consider whether the experiments could be conducted in a cheaper or more cost-effective manner. Our review of the WIPP research and development program focused primarily on whether certain experiments were needed and, if so, whether they could be accomplished more cost-effectively.

VII. DETAILED FINDINGS

A. Land and Siting Issues

Although our review of land and siting issues failed to identify cost reduction opportunities, several noteworthy points emerged. For example, we found that the Department's conclusion that there would be minimal impact on WIPP operations and public health and safety from a pressurized brine reservoir underlying the WIPP underground facilities was adequately supported. We also found that the need to condemn existing potash leases could add significantly to the total cost of the WIPP project. Finally, we found that the Department is committed to construction of the WIPP facilities at a cost of $409 million with no guarantee that it will receive authorization to emplace radioactive wastes at the WIPP site.

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[13] In March 1978, the Department asked the National Research Council of the National Academy of Sciences to review the scientific and technical criteria and guidelines for designing, constructing and operating the WIPP facility. The Panel on the Waste Isolation Pilot Plant was formed to conduct this review.

The discovery of brine pockets during WIPP site characterization activities led the Department to initiate an extensive effort to determine the potential impact on WIPP operations from pressurized brine pockets in the Castile Formation underlying the proposed WIPP facility. Our review of these efforts concluded that the studies conducted by the Department were adequate to reach a conclusion. Also, our review supported the Department's conclusion that if a pressurized brine reservoir did exist in the Castile Formation below the WIPP underground facility, it would have minimal impact on WIPP operations and the public health and safety.

Also, we reviewed the Department's efforts to condemn various mining and hydrocarbon leases that existed on lands required for WIPP operations. Several companies presently hold leases on lands designated for the WIPP site that allow them to mine for potash. The WIPP Program Office does not see a need to condemn these leases at the present time because of the depressed state of the potash industry and the unlikelihood that mining operations would be initiated in the near future. Condemnation of these leases, however, would be a costly and timely process in the unlikely event that the potash industry experienced a recovery. Therefore, the WIPP project could realize additional costs on the order of several million dollars if condemnation of existing potash leases becomes necessary.

In comments on the draft report, the ASDP stated that condemnation of potash leases was seen as an extremely unlikely event. Based on that assessment, the program office deleted the $17 million allowance in the budget for condemnation payments. While the short term assessment by the program office may appear valid, however, uncertainties of predicting future events dictate that management should be aware of the potential for additional costs to the project if it becomes necessary in the future to condemn the leases.

Finally, we reviewed the Department's efforts to withdraw the lands required for the WIPP facility from the operation of public land laws. On June 29, 1983, the Department was granted use of lands at the site for construction of facilities for the WIPP project by an administrative land withdrawal by the Department of Interior (DOI). The DOI order withdrew 8,960 acres of land from the operation of the public land laws for a period of eight years for the limited use of construction of WIPP facilities. The order prohibited the Department from placing radioactive waste at the WIPP site during the eight years of the administrative withdrawal. However, the order envisioned eventual legislation by Congress that would permanently withdraw the land for the purpose of conducting a research, development and demonstration program using radioactive wastes and, eventually, designating the WIPP facility as a permanent repository for TRU wastes.

According to the Department's Fiscal Year 1984 Congressional Budget Request, construction of the WIPP facilities will be completed in the First Quarter of Fiscal Year 1988 at a cost of $409 million. At the present time, however, the Department lacks the authority to place radioactive wastes at the WIPP site. Without this authority, the Department could have a facility costing $409 million that is unable to perform its stated mission.

The Department could be granted the necessary authority to place radioactive wastes at the WIPP site by one of two means, neither of which is under the control of the Department. One approach would require the Secretary of Interior to reverse an earlier decision by his predecessor that prohibited the Department from placing radioactive waste at the WIPP site during the period covered by the administrative land withdrawal. However, reversal is unlikely since both Interior and the Department have left the final determination to the Congress.[14]

The other approach involves passage of legislation by the Congress to permanently withdraw the WIPP site from public lands and to authorize deposition or experimental use of nuclear wastes at the WIPP facility. WIPP program officials indicated that the Department intends to start the legislative process of submitting a proposed legislative land withdrawal to the Congress in January 1985. As a practical matter, WIPP program officials expect the Congress to favorably resolve the land withdrawal issue. Nevertheless, the fact remains that the Department will have committed $409 million in construction funds for WIPP facilities in the absence of a guarantee that it will receive authority to emplace radioactive waste at the WIPP site when the facility is completed in 1987.

B. Research and Development

We found that the planned research and development program had not received the same attention during cost reduction reviews as the design and construction activities. Based on our review, we concluded that there is a potential for significant reductions in the cost of the research and development program. For example, the planned experiments with actual defense HLW could be eliminated. Also, the extensive effort planned by Sandia to develop computer codes and models could be reduced in scope. Furthermore, the planned experiments involving vertical and horizontal emplacement of radioactive wastes underground could be limited to only horizontal emplacement tests. Finally, the TRU Waste Drum Durability experiment is not needed. All of these reductions could be accomplished without adversely affecting the legislated mission of the WIPP.

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[14] Letter, with Attachment, from the Acting Assistant Secretary for Interior to the Chairman, Senate Committee on Energy and Natural Resources, June 29, 1983.

1. Experiments at the WIPP Using Actual Defense HLW are not Needed To Support Future Repository Design Efforts.

Public Law 96-164 defined the WIPP project as a research and development facility to demonstrate the safe disposal of radioactive wastes from defense activities and programs. The program office interpreted this broad legislative guidance by establishing specific objectives for a research and development program. The principal objectives of that program are to develop technology for the design and operation of the WIPP facility and for future repositories for defense wastes.

We concluded that these objectives could be achieved, and substantial, unnecessary costs could be avoided, by using mock and simulated HLW instead of actual defense HLW in the experimental program. Savings in the WIPP research and development program are estimated at $5.2 million, less the cost of some additional experiments with simulated radioactive wastes. There would be substantial savings in facility costs as well (see p. 30). Moreover, there is no apparent need for a repository solely for defense HLW.

Present Plans To Use Actual DHLW are Limited in Scope and Emphasize Thermal Effects

The WIPP research and development program includes only six series of tests involving defense HLW related experiments. Three series of tests do not involve radioactive material. Of these, one test series will use HLW canisters of mock waste (non-radioactive waste) to develop safety and handling procedures and build confidence for handling actual defense HLW. These experiments involve little in the way of new techniques, since the Department's defense programs have been handling HLW for years. The other two series of tests will obtain data on the thermal (heat) effects of nuclear waste on the host salt. The thermal effects of defense HLW will be simulated using electric heaters.

Two of the remaining three series of tests will evaluate waste package performance and interaction in the host rock environment under in-situ thermal and radiation conditions. These Radiation Source Experiments (RSEs) would use cesium capsules to duplicate the thermal and gamma radiation effects of actual defense HLW.[15] Cesium capsules provide an advantage over actual HLW in that they can closely simulate the thermal and gamma radiation effects, but do not require the extensive and costly handling facilities, such as a protective "hot cell."

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[15] According to SAND 81-2628, dated June 1983, the RSEs are optional. In addition, Sandia personnel advised us that there are no present plans to exercise this option.

The final series of tests, the only series that involves experiments with canisters of actual defense HLW, includes some experiments[16] that cannot be effectively replicated without using some form of actual waste. These experiments involve only five defense HLW canisters of actual waste that have been penetrated or breached in order to measure the leaching/release characteristics of the waste form and the near field migration of radionuclides into the backfill material and the first meter of salt host rock. Although defense HLW must be used to obtain the desired data, less costly alternatives are available.

For example, the WIPP In-Situ Testing Plan developed by Sandia indicated that data on the leaching and migration of radionuclides have been evaluated in the laboratory under simulated environmental and geochemical conditions. In addition, ONWI has reported that computer codes are being developed by the NWTS program that will predict the leaching and migration processes. While it is generally desirable to validate computer models and codes with field tests at different locations, we believe that an additional validation at the WIPP site is not essential. This view is reinforced by the likelihood that, in accordance with the Nuclear Waste Policy Act of 1982,[17] defense HLW will be commingled with civilian HLW in a commercial repository.

According to Sandia scientists, the thermal effect on the repository from heat generated by radioactive decay is the primary concern in disposing of radioactive wastes. Based on previous work at Project Salt Vault at Lyons, Kansas, radiation effects per se are considered of lesser importance. By performing experiments underground with mock and simulated wastes, it is possible to achieve the desired combinations of temperature, stress, radiation and repository geometry to obtain the data necessary to support WIPP operations and future repository design activities. In addition, the experiments with mock wastes alone will provide the data required to develop the equipment and procedures needed for safe handling and emplacement of defense HLW.

Findings of Research and Development are Largely Site-Specific

In the unlikely event that a decision is made to design a future repository for only defense HLW, there still is insufficient justification for conducting an experimental program with actual defense HLW at the WIPP. Since the models and codes appear highly site-specific, some validation of the WIPP-generated

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[16] The final series of tests involve only 40 DHLW canisters. RSEs can be used, in place of actual defense HLW, in tests involving 35 of these canisters.

[17] The Act mandates commingling of wastes unless an unacceptable, adverse impact to defense programs is identified.

models and codes would be required for the specific repository site.

According to Sandia, in-situ tests must be done at candidate repository locations to validate design concepts and performance-assessment models. Therefore, there is a strong possibility that to some degree many, if not all, the WIPP experiments with actual defense HLW would have to be repeated at the future repository site.

Overall geotechnical testing at the WIPP to develop and verify accurate computer codes was considered unnecessary and impractical by WIPP's Technical Support Contractor (TSC).[18] The TSC agreed that a computer program that used detailed geologic input at a given location may produce accurate results in that location. However, the TSC also believed that results may not be any good at other locations within the WIPP facility and would not be any good in another repository.

The site-dependent nature of models and codes also was emphasized by ONWI, which is responsible for determining the feasibility of a commercial repository in salt.[19] ONWI considered salt site-specific applications of the computer codes as the major activity of the performance assessment task. In addition, ONWI stated that the cause and effect relationship for major components of each subsystem would need to be developed for a given site and its associated parameters.

Defense HLW Experiments Might Duplicate Work in the Commercial Waste Program

The Nuclear Waste Policy Act of 1982 required the President, by January 1985, to evaluate the feasibility of disposing of defense HLW in a licensed, commercial repository. The Department has clearly stated its intention to dispose of defense HLW by "commingling" with civilian HLW in a commercial repository unless there would be a significant adverse impact. No significant adverse impact on defense programs has been identified by the program office. Therefore, it is unlikely that experiments at the WIPP in support of design efforts for a future repository devoted exclusively to defense HLW will be needed. If the experiments are not needed for a future repository, the experiments certainly are not needed for WIPP itself, since HLW will not be permanently stored there. Finally, the designers of commercial repositories have their own testing program; they are not depending on the availability of experimental data from WIPP.

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[18] Summary Minutes of Meeting Held at DOE/WPO on February 18, 1982, to Resolve Comments on SAND 81-2628 WIPP R&D Program: In-Situ Testing Plan, January 1982.

[19] Preliminary Performance Assessment for a Nuclear Waste Repository in Salt, ONWI, March 1983.

The Department's Defense Waste Management Plan, issued in June 1983, stated that defense HLW would be placed in a commercial repository unless there would be unacceptable adverse impacts to defense programs. Although there has been no decision on this issue, one is expected shortly. In accordance with the Nuclear Waste Policy Act of 1982, an evaluation of this issue must be completed by January 1985. The Assistant Secretary for Defense Programs is conducting this evaluation for the Department.[20] Since no significa adverse impact has been identified, we expect that defense HLW will be commingled with civilian HLW in a commercial repository.

Although the WIPP experiments with actual defense HLW were justified by the belief that the data generated would be applicable to a future repository, there is no indication that the data will be used by the commercial waste program. We compared the WIPP research and development program schedule with ONWI's published milestones for developing a repository in salt and found no indication that results from WIPP's experimental program would play a significant role or represent a milestone in ONWI's plans. In fact, ONWI officials advised us that the WIPP project will not impact development of the commercial repository facilities. The NWTS program will select its sites and designs and construct its facilities independent of the WIPP effort. The WIPP project is not on the NWTS program critical path and no part of the NWTS experimental program is dependent upon a deliverable from the WIPP project. Even if the NWTS program schedule was to slip several years, there was no indication of plans by ONWI to utilize data generated by WIPP experiments with defense HLW in the design of a commercial repository.

Finally, a licensed, commercial repository containing commingled HLW would be designed for the more severe conditions associated with commercial HLW. Several studies have indicated that commercial HLW packages will emit some 20 times more the thermal and radioactive output of the reference defense HLW package.[21] In view of the public concern over nuclear waste disposal, it is doubtful that the NRC would issue a license for a commercial repository designed on the basis of data extrapolated from the results of defense HLW experiments. Furthermore, according to ONWI personnel, the

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[20] Draft Report, An Evaluation of Defense High-Level Waste Disposal in Geologic Repositories, Assistant Secretary for Defense Programs, January 1984.

[21] Comparison of the commercial HLW packages described in "Waste Package Reference Conceptual Designs For A Repository In Salt" draft, WTSD-TME-001, Westinghouse Electric Corporation, August 1983, with the reference defense HLW packages described in "Description of Defense Waste Processing Facility Reference Waste Form and Canister," DP 1606.-Rev. 1, E.I. du Pont de Nemours & Co., August 1983.

civilian nuclear waste management program is planning a single test program for commercial HLW that will cover a broad range of conditions, with the lower range approximating defense HLW conditions.

Conclusion

Based on our review of the WIPP research and development program and the experimental program by ONWI in support of their commercial repository design efforts, we concluded that less costly methods could be used to obtain data equivalent to that expected from experiments at the WIPP using actual defense HLW. Experiments with mock and simulated defense HLW could provide much of the data that might be applicable to a future repository while reducing the cost of the WIPP research and development program. In addition, computer codes being developed by ONWI, as well as laboratory and field tests, will provide much of the leaching and migration data that might be expected from experiments with breached or penetrated canisters of actual defense HLW.

In comments regarding the mission of the WIPP, the ASDP stated that experiments at the WIPP with actual defense HLW were mandated by the authorizing legislation. However, a review of the legislative history failed to disclose this specific mandate.

Also, the ASDP disagreed with the finding that experiments at the WIPP with actual defense HLW were not needed. The ASDP stated that certain effects, such as the combined effects of stress, heat, radiation, chemistry and scale cannot be demonstrated in the laboratory. He said that simulated experiments would only provide a small amount of the data required and merely would form the base to determine what actual defense HLW experiments would be required. Moreover, he said that since radiation is the public fear, any experiments that do not use actual defense HLW would not be addressing the real concern.

We agree that, in the unlikely event that a separate repository is required for disposal of defense HLW, it may be desirable to conduct a demonstration at the WIPP with canisters of actual defense HLW. While such a demonstration is not justifiable on technical grounds, and it would be extremely expensive, the public perception regarding the safety of disposal of nuclear waste from defense activities may make such a demonstration necessary. But, while the legislation provides for research and development efforts with "defense wastes," it is not clear that the Congress would object to obtaining equivalent data on HLW by using mock and simulated wastes if significant cost savings were achieved, especially if defense HLW will be commingled with civilian waste in a commercial repository.

2. The WIPP Research and Development Program Includes Experiments That are not Needed or Could Be Reduced in Scope With Minimal Impact to the Project's Stated Mission.

In early 1982, WIPP project participants reexamined all aspects of the project to identify potential areas for cost reductions to reduce the overall project cost. Although a number of areas were identified, Sandia was unable to identify specific cost reduction opportunities in the WIPP research and development program. As an alternative, Sandia agreed to reduce its research and development program by $16.4 million, or roughly 20 percent. However, there appear to be some additional cost reduction opportunities. A limited review of Sandia's experimental program identified two experiments that could be reduced in scope, and one that could be cancelled, without adversely affecting the overall mission of the WIPP project.

Computer Codes and Models

One experiment that could be reduced in scope involves efforts to develop and validate computer codes and models for use in a future repository. Although computer codes and models directly applicable to requirements of the 5-year WIPP demonstration tests are necessary, the extensive effort planned by Sandia to develop codes and models for the design of future repositories is not needed.

As discussed previously, it now appears doubtful that the models and codes generated at the WIPP site would be used in the design of a future defense repository. The WIPP design itself used little data from prior experimental work at actual salt sites. For instance, Project Salt Vault, which was conducted at Lyons, Kansas, from 1965 to 1971, generated considerable data on bedded salt. These data were not, however, used to develop the WIPP design. There were several reasons for this. First, the error band of the measurements was too wide. Second, there was poor agreement between the laboratory test results and the field test data. Finally, computer advances required collection of better quality data. We believe that until these types of issues are fully resolved, there will be a reluctance by designers of future repositories to utilize models and codes that were generated at the WIPP site.

In addition, computer codes and models developed and validated at the WIPP site may have some application in the design of a future repository in bedded salt, but would have little application if the future repository were located in a different host rock. Although a decision to commingle defense HLW and civilian HLW in a licensed repository has not been made, there are strong indications that the decision will favor commingling HLW in the first commercial repository, which may not be located in bedded salt.

There are several geologic media being studied as potential sites for the first commercial repository. In addition to bedded salt, the alternatives include domed salt, basalt, and tuff. In accordance with the Nuclear Waste Policy Act of 1982, the President will recommend a site for the first commercial repository to the Congress in 1987.[22] Therefore, if a decision on the geologic media for the first repository is not expected until 1987 at the earliest, it is difficult to justify an extensive computer modeling effort at WIPP.

Finally, as previously stated in an earlier finding, the principal drawback to computer models and codes is that their performance is highly dependent on the specific characteristics found at any given site. This point was continually emphasized by ONWI officials. In addition, the properties of salt are influenced by the type and amount of impurities, the presence of inclusions and clay seams and the specific host media geometry. Although some of the WIPP modeling and code work would have some application at other bedded salt sites, additional work would be needed to refine and validate the models and codes for the specific site under study.

In comments to the draft report, the ASDP stated that salt appears to be the leading contender among various host rocks for a future repository. Also, he said that the codes and models being developed for the WIPP will be applicable to any future salt repository with only modest "calibration."

Nonetheless, at this time, the host rock for the future repository has not been selected. According to Sandia estimates, approximately $20 million[23] has been allocated for long-term efforts to develop salt-specific computer codes and models, some of which may have application to the WIPP if activities are extended beyond the 5-year demonstration period. In the worst case, much of the $20 million will be lost if salt is not selected as the host rock for a repository. At best, an additional 25 percent of the cost to develop the salt-specific codes and models would be required to calibrate them for a future salt site, provided that the deficiencies experienced with the codes and models developed for Project Salt Vault have been resolved. In view of these uncertainties, an extensive and costly effort to develop codes and models at the WIPP for a future salt repository is unwarranted.

Vertical and Horizontal Emplacement Experiments

Other WIPP experiments that could be reduced in scope without adversely affecting the project's mission include experiments to demonstrate the safe handling, emplacement and retrieval of RH radioactive wastes. Sandia plans to emplace RH defense waste canisters underground in both the vertical and horizontal direction.

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[22] Current indications suggest that this decision may be delayed until 1991.

[23] Constant 1982 dollars.

The rationale for vertical emplacement of defense HLW canisters is that this mode represents the reference design case.[24] The argument for horizontal emplacement of defense HLW canisters is that, from a technical perspective, there appears to be little difference in the effect on the geologic media between the emplacement modes, but there may be a cost advantage over the vertical emplacement mode. Elimination of vertical emplacement experiments from the planned research and development program could save at least $3.2 million in equipment fabrication costs and an additional several millions of dollars of design and engineering costs.

The concept of vertical emplacement of defense HLW canisters for WIPP experiments was based on the reference repository conditions established by the NWTS program for disposal of HLW in a licensed, commercial repository. The reference conditions for disposal of HLW canisters included vertical emplacement in unlined boreholes drilled into the repository floor. The concept developed for WIPP experiments will use an emplacement machine and a facility cask to vertically emplace defense HLW canisters into unlined boreholes in the floor of the WIPP facility. Several additional pieces of equipment, e.g., a drilling machine, would be required to retrieve the canisters. Project officials estimated the cost to fabricate the necessary equipment at $3.2 million. However, several million dollars would also be needed for design and engineering work.

The concept of horizontal emplacement of WIPP RH TRU waste canisters evolved from studies by the WIPP program to define the most effective concept for storage and subsequent disposal of the RH TRU waste. The concept utilizes a waste handling machine in conjunction with a facility cask and push/pull cylinder to emplace a RH TRU waste canister into a horizontal borehole ~~in~~ the wall of the WIPP facility. Project officials estimated the cost to fabricate the necessary equipment at $1.2 million, plus an additional several million dollars for design and engineering work.

The rationale for eliminating the vertical emplacement experiments is based on three considerations. First, it is highly unlikely that the data generated by these experiments will be utilized. For example, Sandia viewed the planned WIPP research and development program as a significant body of information about the generic development of repositories in salt. However, at the time of our review, we found no indication that ONWI, which is responsible for the design of a commercial repository in salt, planned to use data generated by WIPP experiments to support their repository design efforts. Also, it appears that the NWTS program will need to conduct its own experiments to develop and demonstrate handling and safety procedures for emplacement of

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[24] The reference repository conditions for disposal of HLW canisters were developed by the NWTS program.

civilian HLW, since it is likely that defense HLW will be commingled with civilian HLW in a licensed, commercial repository. The more severe characteristics of civilian HLW, i.e., almost 20 times the radioactivity and thermal content of defense HLW, would dictate that most, if not all of the WIPP vertical emplacement experiments be repeated by the NWTS program with civilian HLW.

Second, the decision by program officials to vertically emplace defense HLW was based on reference conditions developed by the NWTS program for a commercial repository. Since the WIPP vertical emplacement work very likely would be repeated by the NWTS program, and several studies indicated that there may be little difference between the effects on the geologic media from vertical or horizontal emplacement, a study at the WIPP limited to horizontal emplacement of defense HLW could provide generic data useful to radioactive waste management programs and allow further cost reductions in the WIPP project.

For example, several studies indicated that the thermal effects from horizontal emplacement of waste are similar to the effects from vertical emplacement. Futhermore, the studies indicated that concerns over differences in the rates of salt creep and impediments to retrieval of horizontally emplaced waste from excessive sleeve sag may be unfounded.

A recent study by Sandia involved a thermal analysis of the WIPP repository media by modeling the effects of horizontal and vertical emplacement of waste canisters. In each case, the room and heater (to simulate thermal effects of radioactive waste) configuration was modeled as closely as possible to "real-life" situation. Although the horizontally emplaced heater was not buried to the same depth as the vertically emplaced heater (1.83 meters versus 2.5 meters), Sandia noted that the difference between temperature fields and creep rates for each case was not overwhelmingly great. The study concluded that, if the heaters were emplaced to the same depth, more than likely the discrepancies in temperature and salt creep would diminish.

Also, in a report on the 12 W/m^2 Mockup for Defense High Level Waste experiment planned for the WIPP, Sandia considered the thermal effects from vertical versus horizontal emplacement of defense HLW canisters. The study noted that temperatures on the room surface for horizontal emplacement were very close to those for the room with heaters located in the floor. Therefore, Sandia felt that a structural response for horizontal emplacement might be expected to be the same as that for vertical emplacement. Although the study emphasized that the horizontal emplacement configuration was purely hypothetical and probably not realistic, Sandia concluded that the room responses for vertical and horizontal emplacements were similar enough to warrant further study.

Moreover, an ONWI report on the preliminary results of the thermomechanical response of nuclear waste canisters in rock salt concluded that, from a thermomechanical point of view, horizontal emplacement seemed to offer no additional geotechnical complexities over vertical emplacement. The report also concluded that horizontal emplacement in salt appeared no more problematic than the equivalent vertical case.

Also, studies by both Sandia and ONWI indicated little difference in the salt creep rate for vertical versus horizontal emplacement. Specifically, a Sandia study of the thermal analysis of the WIPP indicated that, in most instances, there was not an overwhelming difference in the creep rates observed from horizontal and vertical emplacement. In addition, an investigation by ONWI of the sleeve sag problem associated with unbalanced buoyancy and salt creep for horizontal emplacement found that the creep strains and associated sleeve sags were negligible throughout the wide spectrum of scoping creep models that were used.

Third, in addition to the technical considerations that indicate little, if any, difference in the effect on the geologic media from emplacing waste either vertically or horizontally, there are certain cost benefits that could result from conducting only horizontal emplacement studies at the WIPP. For example, the configuration and weight of the reference RH TRU waste canister and the defense HLW canister are similar. Horizontal emplacement of similar canisters would obviate the need to design and fabricate different pieces of equipment to support separate emplacement strategies. Since the same equipment, possibly with minor modification, could be used to emplace both types of wastes, several million dollars in design, engineering and fabrication costs could be saved.

Finally, it appears that the horizontal emplacement concept might provide an overall cost benefit over vertical emplacement for disposal of HLW in a repository. A recent ONWI study that addressed a thermomechanical analysis of nuclear waste repositories with horizontal emplacement concluded that not only did horizontal emplacement appear no more troublesome than vertical emplacement, but economically, the horizontal case may be desirable.

In comments to the draft report, the ASDP stated that a strong argument could be made to conduct both vertical and horizontal simulated HLW experiments at the WIPP to acquire the data base to allow the future repository to select the most appropriate design. However, according to the Mission Plan recently released by the Office of Civilian Radioactive Waste Management, engineering trade-off studies are presently underway in the civilian program to analyze key design concepts, among them horizontal versus vertical

emplacement of waste.[25] Therefore, the experiments proposed for the WIPP appear to duplicate efforts already underway in the Department.

TRU Waste Drum Durability Experiment

We concluded that the TRU Waste Drum Durability experiment was not needed and could be cancelled with a savings to the project of at least $300,000.

According to Sandia, the TRU Waste Drum Durability experiment would study the corrosion experienced by TRU waste drums under "credible and overtest conditions of handling, emplacement, and short term storage in a salt waste repository." The TRU waste drum was not intended as a long-term physical barrier, but need only resist extensive corrosion long enough so as not to hinder retrieval, if necessary. The retrievability period for TRU waste drums at the WIPP is 5 years after emplacement.

The experiment proposed by Sandia will be conducted in-situ, in two, mined rooms of the WIPP facility. A total of 42 TRU waste drums filled with non-radioactive material will be subjected to conditions ranging from emplacement in dry air to immersion in a brine pool. Sandia officials estimated the cost of these experiments to be at least $300,000.

We found that information concerning the durability of TRU waste drums for longer periods, and under more adverse conditions than will be experienced during the WIPP experiment, was already available from other sources. For example, according to Sandia reports, corrosion rates for the material used for TRU waste storage drums have already been reported. The lifetime before uniform corrosion of a bare, unpainted drum was determined to be 25 years, if immersed in an aerated brine pool. The lifetime associated with this "worst case" is over 10 years longer than the maximum 5-15 year retrievability period for TRU waste drums established for a geologic repository.

Data are also available for measured corrosion rates of 1018 steel, used for construction of 210L (55-gallon) TRU waste drums, at 25°C inundated with aerated and deaerated brine as a function of humidity, and in contact with dry and moist salt. In addition, corrosion rates for bare, unpainted drums have been determined for various environments. The lifetimes before uniform corrosion of all metal were found to be:

- 635 years in crushed salt with 0.5 percent water
- 254 years in 100 percent relative humidity in crushed salt
- 25 years in an aerated brine pool

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[25] Mission Plan for the Civilian Radioactive Waste Management Program, DOE/RW-0005 DRAFT, Volumes I and II, Department of Energy, April 1984.

Finally, we found that the WIPP TSC[26] was skeptical of the need for experiments of TRU waste drum durability. The TSC felt that overtests of humidity, temperature, and brine for TRU waste drum experiments were excessive based on the environments that were expected at the WIPP and because existing data on corrosion had indicated no problems. The TSC also felt that the experimental conditions of humidity, brine pool, etc., were not representative of credible storage conditions. Also, laboratory tests indicated that bare metal had a lifetime of 254 years in crushed salt at 100 percent relative humidity, an order of magnitude greater than the retrievability period established for the WIPP. Furthermore, the TSC believed that investigations of coatings to extend drum lifetime, if required, could best be accomplished via simple and inexpensive laboratory materials tests. Therefore, the TSC concluded that full-size, in-situ tests were not warranted.

In comments to the draft report, the ASDP stated that although the TRU Waste Drum Durability experiment was needed to determine the effects of the "worst case" scenario envisioned for the WIPP, program officials have recently concluded that these experiments could be made an integral part of the required retrievability demonstration at the WIPP, thus substantially reducing the cost. This integration of the TRU waste drum tests as described by the ASDP is an indication of potential economies that could result from a comprehensive review of the research and development program developed by Sandia for the WIPP project.

C. Cost of Facilities

In addition to the cost reduction opportunities identifed in the WIPP research and development program, we identified several WIPP facilities that could be reduced in size or possibly eliminated without adversely effecting the project's mission. These included the hot cell and related facilities and the proposed visitor center.

1. The Waste Handling Facility is Overdesigned in View of the Stated Mission of the WIPP Project

The stated mission for the WIPP is for a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from defense activities and programs of the United States. In view of WIPP's mission, we concluded that the "hot cell" area of the waste handling facility was overshielded and oversized for activities devoted to defense wastes. The potential savings in this area are estimated to be in excess of $1 million.

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26 The WIPP Technical Support Contractor (TSC) is the Westinghouse Electric Corporation.

For example, the design criteria for the hot cell specified shielding to limit radiation exposure of workers to one rem per year. The shielding criterion was based on surface radiation up to 400,000 rems per hour. This criterion far exceeds the radiation level that would reasonably be expected under WIPP's presently stated mission and research and development program.

Full-sized canisters of reference composition defense HLW would emit surface radiation up to 5,500 rems per hour. For planned "overtest" experiments, in which 20 of the 40 defense HLW canisters will be "spiked" with additional radioactive material, the surface radiation would be increased to 25,000 rems per hour. A criterion of 400,000 rems per hour establishes a safety factor of almost 16 times the expected "overtest" conditions of 25,000 rems per hour.

Furthermore, in addition to the defense HLW, the hot cell facility will handle RH TRU waste. The maximum surface radiation for RH TRU waste canisters is 100 rems per hour. Because of the relatively low levels of radiation associated with the three classes[27] of RH wastes to be processed by the hot cell facility, we believe that shielding the hot cell to withstand radiation levels up to 400,000 rems per hour is overly conservative and not needed.

Also, the present plan is to process no more than one or two canisters per day of RH TRU waste (surface radiation at 100 rems per hour). Moreover, handling of the 40 canisters of defense HLW, including the 20 "spiked" to 25,000 rems per hour, will occur within the 5-year demonstration period. Thus, relatively little time will be spent handling either the 25,000 rem per hour material or the lower radioactivity RH TRU waste. We believe that the hot cell facility should be shielded in accordance with the expected radiation levels and time of handling.

Finally, not only does it appear that the hot cell facility is shielded far in excess of what is necessary to support WIPP's stated mission, but there are strong indications that the hot cell may be oversized. For example, in the cost reduction effort initiated in December 1981, WIPP's contractors examined the waste handling facility for possible cost reduction opportunities. Reductions in both the headroom and volume of the hot cell were considered high priority study items.

Both the WIPP TSC (Westinghouse) and the WIPP architect/engineer (A/E) (Bechtel) concluded that the primary impact from a reduction in the hot cell head room and volume would be the loss of some flexibility for future operations. Specifically, Westinghouse

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[27] RH TRU canisters with surface radiation at 100 rems per hour, defense HLW canisters at 5,500 rems per hour, and spiked defense HLW at 25,000 rems per hour.

reported that the only negative impact in reducing the hot cell's headroom would be the "loss of future flexibility." Regarding the reduction in the hot cell's volume, they stated that "new rail and truck casks must be developed. Deletion of [the] bridge mounted manipulator will limit flexibility for handling off-design conditions."[28]

Bechtel reported[29] that a reduction in the facility's headroom would impact the hot cell, transfer cell, cask unloading room, conveyance and elsewhere. Whereas such a change would result in a "slight decrease in operational flexibility," it would, on the other hand, result in "significant cost savings without affecting criteria or current mission." Using rough order of magnitude data, Bechtel calculated that a change could save about $700,000. Regarding the volume of the hot cell, Bechtel stated that a reduction would result in "further limitations on operating flexibility and, perhaps, canister throughput," but calculated (roughly) that such a reduction in volume would result in savings of some $500,000.

In the end, the WIPP Project Office decided not to adopt either of these two changes, stating that: "the RH waste handling area changes and associated RH waste hot cell changes were rejected because these options would prohibit flexibility for handling larger than normal packages or packages having unusual shapes."[30]

Since the Department has adopted a specific package for defense HLW canisters, and since the RH TRU waste canister is of similar size and shape,[31] overhead clearances far in excess of the dimensions of these packages are not needed. In summary, the WIPP RH waste handling facility appears to be overdesigned in relation to its present mission and experimental program. Significant savings may be achieved by resizing the facility and reducing its shielding.

The ASDP did not comment on the fact that the WIPP hot cell is shielded to a safety factor of almost 16 times the expected "overtest" conditions of 25,000 rems per hour. However, in the comments provided, the ASDP reaffirmed the position of the program office that excess head room and additional shielding is necessary to retain flexibility. In addition, he said that since the

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[28] Westinghouse Letter to WIPP Project Manager, January 19, 1982.

[29] Bechtel Letter to WIPP Project Manager, December 24, 1981.

[30] Environmental Analysis - Cost Reduction Proposals, WIPP-DOE-136, July 1982, page 34.

[31] The WIPP Waste Acceptance Criteria for RH TRU wastes specifies that the waste package size shall be nominally 26 inches in diameter with a maximum length of 10 feet, 1 inch.

construction contract for the waste handling facility is expected to be awarded in April 1984,[32] any savings from reductions in the size and shielding of the facility would be offset by the cost of reengineering and delays in contract placement.

2. The Legislated Mission for the WIPP Project Would Be Unaffected if the Hot Cell Included in the Waste Handling Facility Was Substantially Reduced in Size or Eliminated.

By eliminating the tests with actual defense HLW, and restricting the experimental program to mock (non-radioactive) waste and simulated high-level wastes, which do not require a hot cell facility, it would become possible to further reduce the present, stringent design requirements of the waste handling areas, e.g., a further reduction in the shielding requirements.

Moreover, as previously discussed, defense HLW will presumably be commingled with civilian HLW for disposal in a licensed, commercial repository. This occurrence would significantly impact the need for conducting experiments at the WIPP for defense HLW, since the principal justification for the experiments was to generate data for use in designing a future repository for defense wastes.

At this point, consideration should be given to other options for the disposal of the relatively small quantities of RH TRU wastes. Such options could lead to the complete elimination of the costly hot cell facility and related areas at the WIPP. These options include, for example, the use of an all purpose cask for transportation and permanent disposal of RH TRU waste at the WIPP, or immobilization of RH TRU waste with defense HLW at another facility, e.g., the Defense Waste Processing Facility (DWPF) under construction at the Savannah River Plant in South Carolina.

As discussed in a previous finding on the research and development program, demonstrations with mock RH wastes and experiments with radiation sources can provide essentially the same data as the demonstrations with actual RH wastes. In particular, the experiments with mock defense HLW could provide confirmation of equipment and procedures for emplacing the waste packages, surveying and marking emplacement locations, retrieving by use of remote-handling equipment, and demonstrating safe field operations associated with emplacement, marking and retrieval. We believe that it is not necessary to validate these activities with canisters of actual defense HLW.

Also, Radiation Source Experiments (RSEs) can be used to evaluate waste package performance and interaction in the host rock environment under in-situ thermal and radiation conditions. As an option, the WIPP experimental program includes tests with canisters filled with radioactive cesium capsules to simulate actual defense

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32 Award of the contract is now expected in June 1984.

HLW conditions. The use of cesium capsules in the waste canisters can adequately duplicate the thermal output and gamma radiation of defense HLW, and adding additional capsules can intensify conditions, when desired, for accelerated test purposes. Sandia had initially planned to begin experiments with radiation sources prior to the completion of the WIPP waste handling facilities and without the use of a hot cell.

The only tests that could not be effectively replicated without the use of actual defense HLW are those where canisters have been deliberately penetrated or breached in order to measure the leaching/release characteristics of the waste form, and the near field migration of radionuclides into the backfill material and the first meter of salt host rock. Studies indicate, however, that the process of leaching and migration is currently being addressed elsewhere, and that computer codes to predict these processes have been developed by the NWTS program for disposal of HLW in a commercial repository.

Furthermore, since defense HLW will presumably be commingled with civilian HLW for disposal in a licensed, commercial repository, we believe that most, if not all the experiments at the WIPP with defense HLW would need to be repeated or, at a minimum, revalidated for a future repository.

Elimination of WIPP experiments with actual defense HLW provides options that obviate the need for the hot cell and related areas. This results from a change in the primary operational considerations at the WIPP for safe handling of radioactive material, i.e., a reduction in the levels of radiation from in excess of 5,500 rems per hour for defense HLW to 100 rems per hour for RH TRU waste.

These options include, for example, the use of an all purpose cask for permanent disposal of RH TRU waste at the WIPP. Also, immobilization of RH TRU waste with defense HLW at a defense facility, e.g., the DWPF, and subsequent disposal in a HLW repository.[33] We found no indication that these options had been considered.

In comments to the draft report, the ASDP did not agree that a reduction in hot cell shielding through elimination of (actual) defense HLW experiments would be cost effective. The ASDP stated

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[33] The RH TRU waste inventory is roughly 2.5 percent of the total TRU waste inventory projected by 1986. This relatively small amount of RH TRU waste could be processed, e.g., incinerated, and then immobilized with defense HLW in a defense waste immobilization facility, such as the DWPF, for subsequent disposal as HLW in a commercial repository.

that it would defer, for more than a decade, a viable demonstration that high-level waste can be safely disposed of and would exacerbate the widespread public view that the problem is too difficult to solve.

Public Law 96-164, however, enabled the Department to define and implement an appropriate research and development program for the WIPP. Selected tasks of the research and development program, and the facilities planned to support these tasks, have been reviewed. Further reductions in the proposed experimental program and the associated facilities are possible by modifying certain activities, especially those that would be impacted by the Nuclear Waste Policy Act. For example, the hot cell and related areas, which constitute a major facility cost, can be eliminated by deferring to the repository site those few experiments involving actual high-level wastes. These experiments, the results of which are strongly site-specific, are not necessary to satisfy the legislated mandate for the WIPP project.

3. Present Plans to Add a Dining Area/Visitor Center to the WIPP Guard and Security Building Would Add Unnecessarily to the Cost of the WIPP Project.

Sufficient facilities will be available at the WIPP to provide for adequate dining and visitor areas without constructing the elaborate dining area/visitor center currently planned for the Guard and Security building.

The initial design of the WIPP administration building included a cafeteria to provide hot food service to WIPP personnel. Plans for a separate administration facility were subsequently cancelled as part of the cost reduction effort initiated in December 1981, and many of the administrative functions were accommodated in a multi-purpose facility, the Waste Handling and Support building. Plans for a cafeteria were not dropped completely, since the design of a smaller lunchroom, without a hot food service area, was included in the Waste Handling and Support building design. The building design also included two conference rooms that could hold 30 and 50 people respectively.

At the request of the WIPP Project Office, in April 1983, the WIPP A/E developed three alternative designs for a guard and security building that would include provisions for a visitor center. The alternatives varied from the design of a building costing $129,000 that included a small area to meet visitors and a small display area, to a building costing $182,000 that included an auditorium with a three-screen visual display capability.

Subsequently, the WIPP Project Office suggested a more sophisticated design that included dining facilities for 150 people and an additional dining room with food preparation facilities for 20 people. The design was to include the capability to convert

the larger dining area into a visitor orientation area. In September 1983, the A/E submitted the requested design, which included an estimated cost of $970,000 for construction and $62,500 for design.

The number of visitors to the WIPP site currently averages from 10 to 15 people. Present plans are to set aside a portion of an almost completed warehouse as a visitor briefing area. In addition, project officials indicated that briefing rooms already designed into the Waste Handling and Support building could be used for briefings for site visitors. These briefing rooms are more than adequate to provide almost all of the visiting groups a briefing area. Arguments that visitors might disturb the work routine are not valid, since visitors will normally receive tours of work areas.

Moreover, approximately half of the WIPP personnel will normally be located underground, and would, in all probability, take their meals underground, as is common practice in mines. The above ground dining facilities in the Waste Handling and Support building would be used by the support building personnel and probably by the waste handling personnel as well.

We concluded that the initial design alternatives for the Guard and Security building submitted by the WIPP A/E in April 1983, included adequate provisions for a visitor area. If one of these alternatives were adopted in lieu of the elaborate design presently planned for the WIPP, a cost savings of at least $800,000 could be realized.

In comments to the draft report, the ASDP indicated that occasionally the requirements for conference facilities at the WIPP site will exceed the capacity of existing conference rooms. No nearby facilities are available to augment the WIPP facilities due to the remoteness of the site. Also, cafeteria facilities would be utilized by up to 135 WIPP personnel on the day shift, in addition to visitors to the WIPP facility. The ASDP also stated that adopting a less costly alternative for the dining area/visitor center would result in a savings of only $460,000. Nonetheless, the planned facility would be needed to support the expected numbers of dignitaries and visitors with the "highest degree of professionalism and courtesy."

The justification for a dining facility to accommodate up to 135 day workers and occasional visitors is weak. For example, lunch periods could be staggered to limit the number of personnel that would utilize the facilities at one time. Also, it is unlikely that all of the personnel would take advantage of the dining facilities. Therefore, the lunchroom presently planned for the support building should be adequate. Furthermore, on the rare occasion that large

groups of visitors are on site, accommodations could be made available in the various facilities, such as the conference rooms, training rooms, and warehouse and other large working areas, that are planned for the WIPP site. Food services for large groups could be provided in several ways, such as through the use of a food catering service on an as needed basis.

APPENDIXES

A - Technical Notes

B - Comments from the Acting Assistant Secretary for Defense Programs

C - Legislative History

D - Acronyms

TECHNICAL NOTES[1]

TN 83-04/A	Concerns Raised to the Inspector General Related to Storage of Certain Transuranic Wastes at the Waste Isolation Pilot Plant
TN 83-04/1	Requirement for a Dining Area/Visitor Center at WIPP
TN 83-04/2	Necessity for a Water Pipeline from Carlsbad to the WIPP Site
TN 83-04/3	The WIPP Quality Assurance and Safety Programs
TN 83-04/4	Impact of Underlying Brine Pockets on the Waste Isolation Pilot Plant (WIPP) Project
TN 83-04/5	Technology Transfer for the WIPP Project
TN 83-04/6	Requirement for a WIPP Airstrip
TN 83-04/7	The WIPP Research and Development and Experimental Programs
TN 83-04/8	Duplication of Construction Management Responsibilities Among the Architect/Engineer (A/E), Technical Support Contractor (TSC), and the Construction Manager (CM)
TN 83-04/9	Potential Cost Reductions in the WIPP R&D Program
TN 83-04/10	Administrative Land Withdrawal for WIPP Site
TN 83-04/11	Adequacy of the Waste Isolation Pilot Plant (WIPP) Project
TN 83-04/12	The Appropriateness of WIPP's R&D Program
TN 83-04/13	The Disposal of Immobilized RH-Defense Wastes
TN 83-04/14	WIPP's Cost Estimates
TN 83-04/15	Design of WIPP's RH Waste Handling Facility
TN 83-04/16	WIPP Lease Issues
TN 83-04/17	WIPP Land Withdrawal and Deposition of Nuclear Waste

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[1] These Technical Notes are available on appropriate request from the Office of Inspector General, U.S. Department of Energy, Washington, D.C., 20585.

Appendix B

MANAGEMENT REACTION

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Appendix B

United States Government

Department of Energ

memorandum

DATE: APR 20 1984

REPLY TO ATTN OF: DP-12.1

SUBJECT: Comments on Draft Inspection Report on the Waste Isolation Pilot Plant

TO: James R. Richards, IG-1

We have reviewed your draft inspection report on the Waste Isolation Pilot Plant Project (WIPP). Our detailed comments are attached.

The Department of Energy (DOE), the Administration, and the Congress are committed to reversing the open-ended "interim" storage approach to radioactive waste which has been in effect for decades. This commitment is clearly articulated in the Defense Waste Management Plan and is fully supported by Congress and the Administration. WIPP is the cornerstone of Defense Program's activities to demonstrate conclusively that waste disposal is technically, institutionally, and politically achievable. Our progress on WIPP in the last 3 years has been significant in furthering the interest of the Department and the Nation in this regard.

The mission of WIPP is clearly set forth in Public Law 96-164 and its legislative history. The DOE implementation of that statute has been reviewed in detail with each budget cycle and on many special occasions. There has been no challenge to our implementation of the mission--disposal of transuranic waste and important experiments with high-level waste.

Our progress in design, construction, and controlling cost has been recognized as unique for a project of this size and importance. The design is sound and workable and construction progress is excellent. The total project cost has been reduced $255 million with additional savings currently being examined. With these savings, the schedule has been improved by 18 months. We must not lose this opportunity to show the public what can be done with clear direction, timely funding, and aggressive attack on an important national problem perceived by many to be without solution.

The Project's progress on the institutional relations front is a model for future repository development. The relationship with the State of New Mexico is improving steadily. The institutional and political problems are the most difficult to solve--the technical problems are easier. It is difficult for anyone outside the program to appreciate the complexities of the nontechnical issues and the painful progress that typically comes in small steps. In the WIPP Project, meaningful progress is being made on all fronts.

The Department's approach to the experimental program is sound and well accepted in the technical community. Experimental results are being shared with the Office of Civilian Radioactive Waste Management (OCRWM) programs. WIPP is having an impact on those programs, and we believe that in the future the contribution will be seen to have increasing significance. In view of what may be a lack of understanding of WIPP's importance to civilian programs, we have solicited the views of OCRWM. A copy of our memorandum to them is attached. You may want to consider their response before issuing your final report.

We believe very strongly that WIPP, as it is being implemented has widespread support and interest in the technical community. This support and interest includes both United States and international waste management activities. Your draft report questions the importance of WIPP to the future of transuranic and high-level waste disposal in the civilian arena. The National Academy of Sciences panel on WIPP has provided conclusions and recommendations supporting our decisions concerning WIPP. We take very seriously their advice and counsel. In response to your expressed concerns, we have again sought the Academy's views on these issues. Our letter to the Academy is attached. Again, you may want to consider their response in a final report.

Specific actions that we are taking to address the report's findings and recommendations are contained in the detailed comments. We would appreciate an opportunity to review the report after your consideration of these comments.

R L Morgan

Robert L. Morgan
Deputy Assistant Secretary
for Defense Programs

3 Attachments

Comments on IG-40, dated March 7, 1984

General Comments

The Department of Energy (DOE) and Defense Programs are committed to reversing the open-ended "interim" storage approach to radioactive waste which has been in effect for decades. This commitment is clearly articulated in the Defense Waste Management Plan and is fully supported by Congress and the Administration. WIPP is the cornerstone of our program to demonstrate conclusively that waste disposal is technically, institutionally, and politically achievable. Our progress on WIPP over the last 3 years has been exemplary in furthering the interest of the Department and the Nation in this regard.

The mission of WIPP is clearly set forth in Public Law 96-164 and its legislative history. The DOE implementation of that statute has been reviewed in detail with each budget cycle and at other critical points as required by DOE's procedures for major systems aquisition. There has been no question about DOE implementation of the mission--disposal of transuranic waste and important experiments with high-level waste. The intent of Congress is crystal clear, and support by this Administration is unswerving.

The draft Inspector General's (IG) report does not reflect the clear congressional mandate expressed in the legislative history to take positive action to demonstrate that radioactive waste could be isolated in a safe and timely manner. The timeliness was to be attained by not accepting high-level waste (HLW) for disposal at WIPP (avoiding the licensing process) and verifying that the high-level waste isolation issues were tractable by demonstrating, in a realistic way, that no unrecognized technical or operational problems exist. The research and demonstration program of WIPP is a program designed to accomplish that legislative mandate.

The major thrust of the draft IG report is:

1) to challenge the timeliness, usefulness, and transferability of WIPP data and demonstrations to other waste management programs,

2) to conclude that WIPP's thermal structural interaction (TSI) program to develop rock mechanics codes cannot be applied to other programs, and,

3) to conclude that alternative experiments and research (such as more laboratory work or mock waste testing) are available to eliminate the in situ defense high level waste (DHLW) program.

Transferability

The report questions whether data from WIPP would be of value to other repository programs and particularily other salt programs. Both timeliness and usefulness are questioned. WIPP is at least a decade ahead of other programs in addressing the relevant issues with in situ tests and demonstrations. This project will provide conclusive proof to both the technical critics and the skeptical public that radioactive waste management issues can be handled.

There are, in fact, significant opportunities for commercial program management to incorporate the experiences and research results of WIPP. Discussions are now taking place on how to do this better. All WIPP plans and research reports are publicly available and distributed to the Office of Nuclear Waste Isolation (ONWI) and their contractors. We are already beginning to see evidence that the Office of Civilian Radioactive Waste Management (OCRWM) exploratory programs are being patterned after the WIPP Site and Preliminary Design Validation Program. We fully expect DP/OCRWM interaction to increase significantly as the WIPP research program accelerates.

In view of the report's position on the utility of WIPP to civilian waste repository efforts, we have solicited a management position from OCRWM. That memo is attached to these comments. You may want to consider their response in your final report.

The National Academy of Sciences (NAS) has been reviewing the WIPP Project. A panel on WIPP was established in 1978 under the Academy's Board on Radioactive Waste Management. The essence of the panel's role is to insure that WIPP proceeds on a sound technical basis.

The NAS was chartered by the Congress during the Lincoln Administration to conduct scientific research for the Government. Executive Order 2859 (August 11, 1918) established the role for NAS to seek to establish cooperative links between Government and non-Government research activities. Executive Order 10668 (May 12, 1956) established further objectives for the NAS for the promotion of research and efforts to avoid duplication in research. This later executive order also established a role for bringing foreign and United States research efforts together and gathering scientific data from public and private sources. This Executive Order specifies the process by which the Government is represented on the National Research Council.

NAS, therefore, has a unique responsibility and capability to reach consensus positions in the scientific community. This is recognized by the scientific community on a worldwide basis. In light of the unique capability and expertise of the NAS, the Project takes very seriously their advice and conclusions. The issue of transferability of WIPP program data has been addressed by the Academy, and their conclusion in July 1983:

> "Consequently, the opportunity to carry out R&D on emplacement and retrieval of a variety of waste forms, particularly high-level waste, in a real underground salt repository at depth, is an important aspect of the Waste Isolation Pilot Plant (WIPP) program.
>
> "Much of the information from the investigation of the Carlsbad site and all of the technology being developed by this project are applicable to any repository located in domed or bedded salt and licensed for high-level and transuranic defense and commercial wastes."

A procurement action is now underway to extend the NAS contract through the start of waste receiving operations. Their essential charge remains unchanged--insure that WIPP proceeds on a sound technical basis. A major part of the NAS work will be an independent scientific and technical review of the experimental program.

It is the Department's position that WIPP data is useful and timely for design and construction of civilian waste repositories. Most importantly, it will address the technical concerns about isolation of heat-producing wastes in salt long before a commercial in situ test facility is available. The ONWI statements to the contrary should be viewed as a nontechnical position (unapproved by management) which they may feel required to take in view of the differences between programs. We believe ONWI concerns are not related to the technical value of the data and the evaluations but whether the information gained could be used in a licensing action. For these reasons the WIPP program documentation and quality programs are designed to comprehensively meet licensing standards. (See NAS conclusion.)

Computer Code Development

A second major point raised in the IG report is WIPP's development of rock mechanic codes. The conclusions reached in the report may result from an incomplete understanding of the concepts behind the development and use of modeling codes. A conclusion is reached that numerical analysis codes are useful only for the location where they are validated. This is not the case. The codes, once verified, have wide application to other salt sites. To apply them with confidence simply requires that the values for the constitutive parameters and stratigraphic model for the specific site be determined for input to the code. Modest data acquisition for confidence in code calibration is necessary, but an extended period of data acquisition solely for code validation will not be required. To support this position, it should be noted that just recently the WIPP program received a request from ONWI for access to the rock mechanics code under development by Sandia National Laboratories (SNL). This request will be supported. The IG report should note that the WIPP thermal-structural interaction (TSI) program is designed to substantially improve and validate a code for use at WIPP and transfer to ONWI. The report's conclusion with regard to code development is incorrect.

Alternative Experiments

Finally, the report's position that an adequate early demonstration of the ability to dispose of DHLW could be attained without using DHLW would not withstand scrutiny from the scientific, political, and public communities. Simulated DHLW experiments and configurations would not address their concern over whether realistic tests and demonstrations with actual waste had "proven" its safety. In fact, the actual in situ and potential in situ environments under which DHLW must be tested (pressure, temperature, radiation, and scale effects) cannot be simulated in the laboratory and must be done underground. Again, the NAS position is a clear indication that the Department's strategy with regard to WIPP experiments is correct.

A major institutional concern in disposing of nuclear waste is the development of credibility in the public mind. This cannot be accomplished with simulated waste. Again, the National Academy of Sciences has addressed the in situ experimental program and concluded:

> "The WIPP facility offers an opportunity for professionally executed emplacement experiments, using present waste form concepts and equipment, in an actual repository operation. This will be possible years before any comparable repository is available. Results of experiments with high-level waste in WIPP can bring decisive experience to the design of future repositories."

In summary, it is our judgement, considering the relatively small cost of conducting high-level waste experiments in WIPP compared to the total cost of WIPP or another salt repository, that the Department would be negligent in not conducting these high-level waste experiments of significance to future salt repositories.

Conclusions

Although most of the individual points and details addressing the IG concerns regarding the benefits of the technical R&D program were addressed by the WIPP Project Office (WPO) in early comments on the technical notes prepared by the

IG staff, we do not believe that these comments were adequately considered and we suggest that a final report fully respond to these comments.

The IG report did not recognize the major accomplishments of WIPP. Progress in design, construction, and controlling cost is unique for projects of this size and importance. The design is sound and workable, and construction progress has been excellent. The total project cost has been reduced $255 million with additional savings currently being implemented. With these savings the schedule has been improved by 18 months. We must not lose this opportunity to show the world what can be done with clear direction, timely funding, and aggressive attack on an important national problem which is perceived by many to be without solution.

The Department's progress on the institutional front is a model for future repository development. The relationship with the State of New Mexico is improving steadily. The institutional and political problems are the most difficult to solve--the technical problems are easier. We appreciate that it is difficult for those outside the program to fully understand the complexities of the nontechnical issues and the painful progress that typically comes in small steps. In the WIPP Project, meaningful progress is being made on all fronts.

WIPP has received widespread review and support in the technical community from both United States and international waste management programs. The National Academy of Sciences panel on WIPP has provided conclusions and recommendations important to decisions concerning WIPP. We take very seriously their advice and counsel. In response to your expressed concerns, we have again sought the Academy's views on these issues. Our letter is attached to these comments. Again, you may want to consider their response in a final report. It is imperative to the credibility of the Department and the final report that the most competent views on this important issue be included.

The WIPP Project is cost effective as it is planned, designed, and constructed. We believe that its impact on civilian waste repository efforts will be significant. The civilian program is complex and costly and a

repository may not be available until the next century. We believe that even small improvements in civilian repository schedules, due to WIPP influence, will reap generous cost savings in addition to solving an important defense waste disposal problem.

Other issues raised in the draft report are addressed in the specific comments that follow.

Specific Comments

Pg. 3, Land and Siting Issues

As stated in the Final Environmental Impact Statement (FEIS), acquisition of potash leases which predate initiation of the WIPP project has been planned since the inception of WIPP. Because of the depressed state of the potash industry in the Carlsbad area and the competition from foreign sources of potash, the potash leases within the WIPP site may never be developed. Presently, potash obtained from the Dead Sea in Israel can be delivered to the principal Mississippi port at a lower cost than potash mined in the Carlsbad Potash District. Thus, development of these leases may not be economically feasible in the forseeable future, and lease acquisition by DOE should be delayed as long as possible.

Improvements in extraction technology may eventually permit mining of the potash, which is 400-700 feet above the repository horizon, without any impact upon the WIPP facility. Further, because the existing leases are small (one section) it is not at all cost effective to extract these minerals given the facts cited above and the large capital investment required for extraction. Therefore, the need to condemn potash leases is viewed as an extremely unlikely event. We have deleted the $17 million allowance in the budget for condemnation payments and do not view this situation as a problem.

The conclusion that WIPP could be completed without any guarantee of being able to emplace waste is strictly speaking correct. The Department intends to submit land withdrawal legislation to address this issue in January 1985. The intended approach was coordinated with appropriate congressional committees and the Bureau of Land Management (BLM) in mid-1983.

This "problem" is not unique to WIPP; it is faced by every project and program. There is no guarantee that Congress will continue any project from one year to the next. There is also no guarantee that Congress will provide operating funds for any project, once constructed.

Although the existing administrative land withdrawal does not allow emplacement of radioactive waste, that provision could be administratively changed by the BLM. The statement is incorrect that a legislative withdrawal is required before emplacement of waste. No provision of the Federal Land Policy and Management Act (FLPMA) would prevent emplacement of waste under an appropriately worded administrative land withdrawal. The Department of the Interior (DOI) has simply made a policy call in the current withdrawal not permitting waste emplacement which is always subject to change.

Pg. 3, Research & Development

The facts do not support the IG findings that the WIPP R&D program with actual DHLW can be eliminated or reduced in scope with "minimal impact to the project's stated mission." The WIPP R&D mission cannot be accomplished without the use of actual DHLW. While some elements of the concern for disposal of DHLW in salt may be addressed with electric heaters and some may be explored with other waste forms, such as cesium capsules, there are other technical issues for which resolution will never be satisfactorily demonstrated without employing actual DHLW waste forms. The combined effects of stress, heat, radiation, chemistry, and scale cannot now be demonstrated in the laboratory. It is imperative that knowledge be acquired as to how the waste and environment interact in order to fully address relevant concerns about potential waste form leaching in the backfill. Also, credibility of the demonstration is a must in these programs; anything less than realistic test environments will be taken by the public and critics as an admission that a "real" demonstration was too difficult or unsafe.

Pg. 4, Cost of Facilities

We do not agree that savings which might accrue from reduction of hot-cell shielding through elimination of DHLW experiments would be cost effective. This would, in fact, inhibit important waste management goals. Elimination of DHLW tests and demonstration programs would be a major setback for DOE's waste management program. It would defer, for more than a decade, a viable demonstration that high-level waste can be safely disposed of and would exacerbate the widespread public view that the problem is too difficult to solve. The capability to achieve meaningful waste disposal demonstrations has taken decades to accomplish. It would be a major setback and simply unwise to eliminate what has taken years to establish for a rather insignificant saving.

We also do not agree that the guard/security center which also includes visitor reception facilities adds unnecessarily to the cost of WIPP. The inability of DOE to accommodate large groups and important high ranking local, State, Federal, industry and foreign officials would seriously detract from the credibility of the program. A value engineering study has been initiated to assure that only cost effective facilities are constructed. Some cost savings have already been identified.

Pg. 5, Item 1

This recommendation has been completed. Drafts of proposed legislation to withdraw the WIPP site lands have been prepared, and a strategy for obtaining a legislative withdrawal has been determined. The report simply does not recognize that a viable strategy exists and that it has the full concurrence of the congressional committees involved and the New Mexico Congressional Delegation. Legislation will be submitted in January 1985 to permanently withdraw the WIPP site for exclusive DOE use. This will include the authority to emplace radioactive waste.

Pg. 5, Item 2

We have no objection to a cost/benefit review of the WIPP R&D program by knowledgeable people. The National Academy of Sciences will be available for such a review once their existing contract is extended. It should be noted that we have completed extensive peer reviews of the experimental program. These reviews have resulted in modifications of the program. The report's conclusion that the Nuclear Waste Policy Act (NWPA) impacts the experimental program does not follow logically. The high level waste (HLW) experiments at WIPP are designed to demonstrate the disposal of defense HLW within the context of the basic mission.

Pg. 5, Item 3

The waste handling and support building are designed to provide important operational and safety flexibilities. There is no viable opportunity to reduce shielding at this time since the design package is out for bid. Knowledgeable operations and design engineers have reviewed the cell sizes, shielding, and headroom. A conscious decision was made to retain the planned flexibility due to insignificant construction cost savings. Pilot plant and experimental facilities frequently turn out to be too small and have insufficient flexibility for future R&D. It is then too late and too costly to enlarge them. Reductions would be a serious error, and the potential savings are small.

Pg. 5, Item 4

The guard and security building will be reviewed to assure cost effectiveness. However, only minor changes are anticipated. There is good justification for its size and capabilities. WIPP will be the national and international center of attention for repository development.

Pg. 7, Para. 2

The NWPA requires a Presidential decision on commingling of defense and commercial waste. This, however, does not alter the fact that DHLW was never to be disposed of in WIPP, but in some other licensed facility. Salt was, and is still, a prime contender for the host rock for a licensed repository; and the need for early and rapid resolution of technical issues regarding disposal of radioactive wastes in salt is, therefore, not altered at all by this NWPA requirement.

Pg. 8, Para. 2

The congressional view of WIPP is misinterpreted by this report. The Armed Services Committees wanted WIPP to proceed with its R&D mission as rapidly as possible. They believed that the prior Administration's changes and objectives would not enable achieving the goals they wished to see WIPP accomplish, namely, to demonstrate as rapidly as practical that defense wastes could be isolated in a safe and acceptable manner. For this and other reasons, the Nuclear Regulatory Commission (NRC) licensing involvement was proscribed by Congress. Congress agreed that the WIPP Project was indeed manageable and in 1979 authorized another $22 million for its continuation.

Pg. 10, Para. 2, Line 7

The attempts by Congress to restrict the scope of WIPP to R&D on defense wastes was not directed at the DHLW experimental program but rather to what was then a program involving commercial waste and spent fuel from nuclear power plants.

Pg. 11

The entire legislative history, as outlined in this report, should be taken as a clear statement of congressional desire and intent to proceed with a defense-waste-only R&D facility, unhindered by encumbrances that would occur

if it were linked to the commercial program. The report's suggestions for change in the approach to the R&D mission at this late date are inconsistent with clear and continued congressional direction. Passage of NWPA does not change the need for early demonstration that isolation of HLW in salt is viable.

Pg. 12

The R&D concepts first conceived for WIPP in 1977 have been subject to DOE and congressional review annually. The statement that the project ". . . design seemed more ambitious and broader in scope than the Congressional authorization. . ." is not consistent with the legislative history. Successive authorizations and appropriations have affirmed the program objectives. Those experiments and demonstrations planned for WIPP are only those that are needed to demonstrate that the technical concerns are tractable and that large-scale waste handling operations may be safely conducted. These yearly reviews by the Department and the Congress are not acknowledged by the report.

Pg. 13, Para. 1

Even though an NRC license is not required for WIPP, the R&D is pursued and documented in a manner which will allow full use of the experimental data by other parties who must work in a licensing atmosphere.

Pg. 14, Para. 2, Lines 4-7

One of the values of WIPP is that it allows concepts that may be beneficial to be evaluated well ahead of implementation. It may prove to be desirable to place even HLW in salt beds with clay impurities so that sorption of leakage products could occur close to the waste containers. If no significant undesirable effects are noted on the WIPP experiments, then the requirement for "thick pure" salt could be deleted from the commercial waste program.

Pg. 18, Para. 1

This paragraph should also acknowledge that many of the WIPP experiments are required for the purpose of addressing the long-term behavior of the WIPP facility itself.

Pg. 20, Para. 2

The report is incorrect in assessing the purposes of the long-term experiments. Both the near-term and long-term objectives have application to the WIPP itself. For instance, the long-term experiment to understand and predict room closure and backfill recompaction is clearly required for WIPP. If there is a division of experimental worth to WIPP and to a future repository, then it is the reference case heated room (room A1, A2, and A3) and DHLW waste package tests that have less value to WIPP. The implication, that a majority of the "technology" experiments are of value only to a future repository is not correct. Most of the TSI experiments also provide data for evaluating the behavior of rooms and backfill under ambient conditions. The induced behavior may be accelerated by elevated temperatures, as in room B, to allow assessment of results in terms of long-term predictions in a more reasonable time frame.

Pg. 21, Para. 2

The TSI and waste package experiments originally proposed were reviewed by a peer group of technical experts. The peer review group modified some tests, but concurred that the experiments were examining the proper issues in the proper way. It is generally agreed that TSI and plugging and sealing issues can only be adequately examined in large-scale in situ tests. The factors for a realistic test (pressure, temperature, radiation, chemical environment) of waste package issues can only be achieved underground.

Pg. 23

Only two companies (Kerr-McGee and IMC) presently hold potash leases within the WIPP site boundary. As stated in the FEIS (Section 8.1.4), the DOE would take action to obtain the rights to a lease if the lessee files an application to develop a lease. DOE has considered the possible requirement to acquire the potash leases and views the event as unlikely. (See General Comments.)

Pg. 24

The findings correctly state that there are two possible means of obtaining the authority to emplace nuclear wastes in the WIPP facility, since action by the Secretary of the Interior to modify the existing administrative withdrawal to allow waste emplacement is not prohibited under the terms of FLPMA. Speculation with regard to possible DOI actions is not likely to resolve the situation. In any event, a fully coordinated strategy is in place. (See General Comments.)

Pg. 25

The R&D program did not provide the same detail for the cost-reduction program as did the design and construction segments because the program had not, at that time, been sufficiently detailed to define specifics. R&D is difficult to examine with a rigorous cost/benefit methodology since it is impossible to put a dollar value on the data. However, the initial estimates, which were based primarily on numbers of instrument channels required, were reduced significantly. These reductions have led to less redundance in instrumentation not always a desirable aspect when acquiring data in a difficult environment and over long periods of time. Various experiments were examined as to need; the present program has only those elements required to address issues of unresolved technical concern.

Pg. 26, Lines 9-10

These objectives cannot be achieved without the use of actual defense HLW. Some elements of the concern for disposal of DHLW in salt may be addressed with electric heaters and some may be explored with other waste forms, such as cesium capsules. However, there are other issues for which resolution will never be satisfactorily demonstrated without employing actual DHLW waste forms. There are technical issues that require conducting experiments with actual waste forms. The combined effects of stress, heat, radiation, chemistry, and scale cannot now be demonstrated in the laboratory. It is imperative that knowledge be acquired as to how the waste and environment interact in order to fully address relevant concerns for waste form leaching and transport in the backfill. Also, credibility of the demonstration is a must in these programs; anything less than realistic test environments will be taken by the public and critics as an admission that a "real" demonstration was too difficult or unsafe.

Pg. 26, Para. 2

Whether or not defense and commercial high-level wastes are commingled does not impact the conduct of the WIPP Project. This paragraph leads to no logical conclusion.

Pg. 27, Para. 1, Lines 3-7

We do not concur that the DHLW demonstration is without technical justification. The only way all the relevant conditions can be brought to bear is by in situ tests with actual waste forms. Also, the report generally is not sensitive to the importance of demonstrations to public confidence and acceptance of a waste disposal option. That may be as important to the program as the resolution of specific technical issues. We are pleased that the authors at this point acknowledge the importance of public perception. It is a fact that things are what they are perceived to be. The waste disposal issue is perceived by some to be without solution.

Pg. 27, Para. 2, Lines 6-9

We do not agree with the stated conclusion. Simulated experiments are a part of the WIPP R&D program, but they provide only a small fraction of the data required. They do form an essential base to allow determination of which DHLW experiments are required.

Pg. 27, Para. 2, Lines 9-13

It is not a credible position that computer codes, without actual in situ validation, will prove anything or provide convincing information to the technical community. Laboratory tests (which have been done for WIPP) will need the verification and synergism available from in situ tests before being fully accepted. And it should be emphasized that WIPP can perform these insitu tests at least a decade in advance of any ONWI program. ONWI has no site today for performance of radioactive field tests despite continuous effort to acquire such a test site.

It is interesting to note that in 1982 the Department wanted to conduct heater experiments in a salt mine near Cleveland, Ohio. The task became so highly politicized that it was eventually abandoned. The incident is mentioned to point out the difficulty in making technological progress without consideration of institutional issues.

Pg. 27, Footnote 2

This report uses different terminology than that used by WIPP. Apparently, the report uses the phrase "simulated waste" to mean radioactive sources whose radioactivity is supplied by cesium. WIPP uses the phrase to mean nonradioactive sources, ones where only the physical size and shape and the thermal output are simulated. The radiation source experiments use sources that we refer to as cesium-capsule sources. WIPP uses the phrase "mock waste" only when we are talking about nonradioactive canisters used in handling demonstrations.

Pg. 28, Para. 1, Lines 1-4

While mechanical performance of a repository in salt is most affected by the thermal component, the real long-term concern is how the radioactive waste behaves under the conditions imposed by the repository environment. Radiation, not heat, is the public fear. Consequently, any experiments or demonstrations which do not culminate with use of actual waste are not addressing the real concern.

Pg. 28, Para. 1, Lines 9-11

Mock waste demonstrations will not accomplish their purpose unless the radiation fields and all handling procedures are similar to those required for DHLW. (See earlier comments.)

Pg. 29, Para. 1

Radiation source experiments (RSE's) are not now an element of the WIPP R&D program. They were identified as a less desirable alternative if DHLW could not be acquired by 1989 since it was considered important to proceed with actual radioactive experiments. Even in that event, however, it would be necessary eventually to do some experiments with actual DHLW. Thus, RSE's were never considered to be a total replacement for DHLW.

Pg. 29, Para. 3, Lines 1-4

There have been no field tests with high-level radioactive wastes which address leaching and migration of radionuclides in host media. WIPP is the only facility available to do such tests and will be for the forseeable future.

Pg. 29, Para. 3, Lines 4-6

These codes, while valuable, are not credible until they have been validated by adequate tests such as those planned for WIPP.

Pg. 31, Paras. 1 & 2

This discussion indicates a possible misunderstanding of the utility and application of modeling and numerical code analyses. Codes are not specific to a given site. It is necessary to "calibrate" a code to specific sites and to use proper descriptions of the site stratigraphy and constitutive relationships. However, the validation of the physics of the model and code capability can be adequately demonstrated in WIPP for any salt site. Thus, similar model and code development need not be conducted by other programs--they need only to "calibrate" the code to their site by laboratory determination of constitutive properties and by modest in situ verification. The number of experiments required will be far fewer than if WIPP had not provided a sound base. Also, these paragraphs again seem to lose sight of the fact that all the structural modeling is required for WIPP itself. Even some of the thermal/structural work is necessary for WIPP to obtain accelerated mechanical behavior due to the slowness of phenomena at ambient conditions.

Pg. 31, Para. 3; Pg. 32, Para. 1

The comment attributed to Westinghouse is a proper quote but is incorrectly used in reaching the conclusion in the report. The comment was actually an early review comment related to a "DRAFT" test plan which was later finalized as SAND 81-2628. The final document was responsive to the comment by incorporating numerous minor changes that favorably affect the feasibility and usefulness of model and code development. The current in situ investigation program will provide the stratigraphic and rock behavior data in the detail necessary to develop codes and methods of geomechanical analysis that can be utilized elsewhere within the Salado salts or in other similar stratigraphies throughout the United States. Thus, the criticism leveled at the draft testing program plan concerning geomechanical computer codes is simply outdated. The final testing program plan should be used as a basis for questioning the appropriateness of portions of the planned insitu testing. Again, the final plan resolves the review comment.

Pg. 32, Para. 2

To imply that WIPP data has no utility to the ONWI program and that the WIPP program will not impact other salt repositories is incorrect. If this is the actual position of ONWI, it is a criticism of the commercial program, not WIPP. To refrain from conducting technically useful programs just because someone else may not use the information, even when apropos, is not sensible. Furthermore, current actions and indications of interest in the WIPP program by ONWI indicate this paragraph is not a proper statement of their position. ONWI may believe the acceptability of the WIPP results in a licensing action would be in doubt. This, however, is a different issue than whether the WIPP experiments and results are applicable in the technical sense. It is for just this reason, that is assuring that the results are useful to others, that WIPP is going to extremes to document all aspects of the R&D program. (See General Comments.)

Pg. 33, Para. 1

The statement that commercial high level waste (CHLW) has at least 22 times the thermal output of DHLW is not correct. The present reference DHLW is 470 W/canister--for CHLW the reference loading is 2200 W/canister, a ratio of about 4.7. The commercial program must "overtest" the reference condition so greater thermal powers are being evaluated; but they are not likely to be adopted, at least until considerable experience has been developed at more conservative loadings. Thus, the WIPP will provide a very important baseline from which the commercial program can make its required departure to somewhat higher thermal loading. In any new arena, but especially in one such as radioactive repository development, it is prudent to proceed in a conservative manner. WIPP is this conservative first step upon which the commercial program can build with enhanced confidence. The National Academy of Sciences concluded that WIPP will bring "decisive experience" to the OCRWM program.

Pg. 34

Virtually all of the code development is required to support WIPP and predictions of its behavior, as well as for addressing the reference DHLW rooms. Closure and backfill consolidation for WIPP demand that room closure be understood. Elevated temperature will allow pertinent observations on a shorter time scale. If the codes and models developed for WIPP are not used by a future salt repository, it is not because they are not applicable or inadequately documented--they are. The fact that WIPP itself did not use Project Salt Vault data in its design is because the scope of the experiment was insufficient and the data base inadequate. WIPP experiments are designed to avoid this problem. The codes now in use are believed adequate for repository design--but present codes reflect considerable improvement in the last few years. While it may be true that in a decade there will be a considerable advance in modeling techniques, it is a fallacy of the worst kind to adopt a philosophy of "do nothing for a decade because then we can do it better." If we do not evaluate the present capability against in situ data, we will not know whether improvements are needed and, if they are, which aspects of the modeling need further development. It would be a serious error to wait 10 years to find out what, if anything, is wrong with the models.

Pg. 35, Paras. 1 and 2

While a salt site may or may not be selected for the first repository, salt will remain a strong contender for a repository for the next decade. Many would say it is a leading contender. To defer model and code development until it is known whether salt is the host rock chosen would not be advisable since the critical issues are now defined and the sooner they are resolved the better it will be for the entire waste management program. The long observation times (years) required for many of these tests dictate beginning them as soon as possible. The national waste management policy was one of deferral. That policy has changed. The IG proposals to defer actions are out of step with national policy.

Pg. 35, Para. 3

This statement is incorrect as discussed in earlier comments. To predict the behavior of a given salt formation requires media data from that site, but the computer codes and models developed from WIPP can be utilized for the prediction. The codes would have to be "calibrated" to the new site, but refinement of the code and model should not be required.

Pg. 36, Para. 2, Lines 4-5

There are no plans to emplace remote handled transuranic waste (RH-TRU) waste in a vertical configuration. The discussion is confused by including TRU and DHLW together. The rationale for these emplacements comes from quite different sources, as indeed, the rest of the paragraph indicates. A stronger argument to be made is that both vertical and horizontal simulated high-level waste experiments should be conducted in WIPP to acquire the data base to allow the future repository to select the most appropriate design.

Pg. 38, Para. 1

Again, the transfer of information to the commercial program is questioned. But as before, the results should be technically applicable and the extensive documentation should also make it acceptable to NRC. If ONWI does not plan to use WIPP data, that should be a matter for the commercial waste program managers to address and not be considered an indictment of WIPP.

The NWTS repositories will need to conduct some experiments, but the baseline established by WIPP is a point from which they can develop tests to address their particular needs. Much of what WIPP is doing will not need to be redone for another salt site.

Pg. 38, Last Line

This statement is wrong; see comment for Pg. 33, line 4.

Pg. 39, Para. 2

The vertical emplacement was for high-level waste to model the design chosen by ONWI. They presumably had a rationale for this geometry, so it should not be concluded there is no technical basis unless confirmed by ONWI. There is no valid technical reason to repeat most of the WIPP DHLW experiments. Certain issues peculiar to a commercial salt repository may require testing, but WIPP tests need not be repeated.

Pg. 39, Para. 3

The first sentence seems to be a nonsequitur. The actual viability of horizontal emplacement, including retrievability, cannot be assured without in situ testing to validate the model predictions.

Pg. 42, Para. 2

Horizontal emplacement of high-level waste might be more desirable. But both vertical and horizontal tests would be required to achieve a scientific basis for a judgment. A decision of this magnitude should not be made on the basis of unvalidated model calculations.

Pg. 42, Para. 4

The report concludes there is no useful purpose for the TRU container durability tests. There are at least three aspects of this set of experiments that are not recognized by the report.

First, while it is true that the TRU containers were originally not relied upon to be a long-term physical barrier, the proposed Environmental Protection Agency (EPA) requirement for engineered barriers puts a new light on this issue. The laboratory tests cited in this report indicate the containers may retain their integrity for quite a long time. Furthermore, room closures are

now predicted to require many hundreds of years. As a consequence, it is now desirable to demonstrate that, even for worst case breaching scenarios, the container is an effective barrier for some period of time.

Second, there will need to be a logical and demonstrable argument for going to full-scale operations in the WIPP in about 1993. Nearly a decade of experience from these tests will be available and will, in fact, constitute the only TRU tests that can be utilized in this decision. The State EEG will certainly require this sort of evaluation at that time.

Third, the costs are misunderstood. The $300,000 includes the horizontal RH-TRU tests, which represents a large portion of the costs. Also, we have recently concluded that these contact handled transuranic waste (CH-TRU) durability tests can be conducted as an integral part of the required retrievability demonstration, thereby substantially reducing the cost of the experiment to a very low level.

Pg. 44, Para. 1

The overtests; i.e., inundation and high humidity, are exactly the conditions assumed to occur in WIPP's worst case analysis of the most probable breach scenario. The paragraph also notes that the experimental conditions do not model storage conditions. In fact, a portion of the experiments do represent anticipated storage environments. The others may be regarded either as overtests to accelerate effects, or as actual conditions for a potential future flooding of the rooms. Either way, this data must be acquired under realistic conditions, on packages subject to real handling and backfill operations. Laboratory tests are useful guides, but are not sufficient in themselves.

Pgs. 47-48

Personnel experienced with operating facilities with hot cells know that, historically, problems or new operations will tax available headroom, floor space, and shielding capability. In such cases, operations become very

difficult or impossible. New or modified facilities must then be constructed at greater expense, or complex equipment and complex methods must be used to work within the available space, again at greater expense. It was recommended, then, that the extra space be retained and that it was a reasonable amount to retain.

Since that time, it has been identified that the Sandia experiments with canisters having simulated defects will require that the defects be produced in the hot cell. Further, the hot cell will be used to overpack a DHLW canister into the "ONWI overpack canister" configuration for experiments. This configuration is larger in size and considerably larger in diameter and weight. These operations utilize some of the space and flexibiity built into the facility and are examples of why this flexibility is needed. Note that there will be future operations during possible retrieval of RH TRU, but especially in retrieval of DHLW and the DHLW defected canisters requiring hot cell operations for shipment of the waste off-site. Although no details have been worked out, the flexibility retained within the hot cell is expected to be utilized and to be adequate for these operations.

The report indicates that two separate reductions of $700,000 and $500,000 were possible. Presently the waste handling building (WHB) design is complete, and the construction contract is expected to be placed in April 1984. Reengineering the building at its present completed stage would be significantly more expensive now than in 1982 when it was in its partially complete stage. Thus, the $1.2 million total savings estimated would be reduced by approximately $650,000. Also, reengineering at this time would require 4 to 6 months and delay contract placement and construction by a minimum of 8 months, and thus, escalation would become a significant cost. With a $32 million total estimated cost, an 8-month delay (assuming 7 percent annual inflation costs) would produce a cost increase of approximately $1 million and delay project completion by 8 months since the WHB is on the critical path. Therefore, there are no savings which can be acquired, and we should not pursue a hot cell option which does not provide needed operational and safety flexibilities.

Pg. 53, Para. 2

The report questions the visitor orientation area of the Guard and Security Facility. The support building has three rooms which can be used for meetings, conferences, training, etc. Project experience indicates that the space for these purposes in the support building is reasonable and adequate only for normal business requirements. In Albuquerque, at 2501 Yale Blvd., there are two larger conference rooms and an additional small conference room. Both DOE and the technical support contractor use these conference rooms, and there are times when meetings must be rescheduled because of conflicts and nonavailable conference rooms. In Carlsbad, the total number of personnel on site will be larger; and, in addition, the New Mexico EEG, and Sandia will have personnel permanently onsite. The visitor briefing area in the warehouse is a temporary facility, and will later be converted back to warehouse use. There are also occasions when large meeting facilities are required; and in Albuquerque, a large room at a nearby hotel is then rented. At the WIPP Site, no such facilities are readily available. The visitor center in the Guard and Security Facility would fill this additional need.

Using the Guard and Security Facility for visitors provides access to models and displays. Audio-visual equipment would also be permanently available. The space will thus provide for both visitor reception and routine conference functions.

Pg. 53, Para. 3

The report states that approximately half of the WIPP personnel will normally be located underground, and in all probability take their meals underground. There apparently is some misunderstanding.

When WIPP is at full operation, as presently envisioned, the operating contractor will have the majority of personnel on first shift and will be storing waste on that shift. Site personnel for first shift will be approximately 160 total; and of these only about 25 are expected to be underground. Thus, about 135 people would be above ground to utilize cafeteria services.

ACRONYMS

AEC - Atomic Energy Commission

A/E - Architect/Engineer

ASDP - Assistant Secretary for Defense Programs

DOI - Department of Interior

ERDA - Energy Research and Development Administration

HLW - High-level Waste

IRG - Interagency Review Group

NWTS - National Waste Terminal Storage

ONWI - Office of Nuclear Waste Isolation

RH - Remote-handled

RWDPP - Radioactive Waste Disposal Pilot Plant

Sandia - Sandia National Laboratories

TRU - Transuranic Waste

TEC - Total Estimated Cost

TPC - Total Project Cost

TSC - Technical Support Contractor

WIPP - Waste Isolation Pilot Plant

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Exhibit D

United States Government

Department of Energ

memorandum

DATE: February 13, 1990

REPLY TO ATTN OF: IG-35

SUBJECT: Survey of Transuranic Waste Shipments to the Waste Isolation Pilot Plant During the Test Phase; Report No. WR-L-90-3

TO: Bruce G. Twining, Manager, Albuquerque Operations Office

PURPOSE AND SCOPE

We have completed an audit survey of the planned shipments of transuranic (TRU) waste to the Waste Isolation Pilot Plant (WIPP) during the test phase. The purpose of this survey was to determine whether the Albuquerque Operations Office (AL) could meet the test phase objectives and reduce proposed costs by (1) limiting the number of shipping sites, and (2) conducting the operations demonstration with fewer shipments.

We performed the survey field work at AL Headquarters (Albuquerque, New Mexico) and the WIPP Project Office (Carlsbad, New Mexico) between June 14 and August 3, 1989. During this time, we

- Analyzed the Department of Energy's (Department) April 1989 draft test plan for the WIPP test phase (including the June 16, 1989 addendum), and related laws and regulations;
- Examined planned shipping schedules, historical and planned acquisitions of waste transportation equipment and loading facilities at the waste generator storage sites, cost estimates, and contracts and purchase orders with Westinghouse Electric Corporation, Nuclear Packaging, Inc., and Dawn Trucking Company;
- Reviewed National Academy of Sciences and the State of New Mexico Environmental Evaluation Group (EEG) comments on the draft test plan, and
- Interviewed AL, Westinghouse, and EEG personnel.

During the survey, we followed generally accepted government auditing standards for performance audits.

BACKGROUND

Public Law 96-164 authorized WIPP for the purpose of demonstrating the safe disposal of the Department's defense program transuranic (TRU) waste.

With the construction phase of the WIPP facility complete, the Department plans to initiate the next phase of WIPP's development, the test phase. The purpose of the test phase is to collect the data needed to make a decision on whether to designate WIPP as a permanent repository of TRU waste.

The April 1989 test plan divided the testing into two major components: Performance Assessment, and Operations Demonstration. Both parts would be done simultaneously. The Performance Assessment will determine WIPP's compliance with EPA Standard, 40 CFR 191, Subpart B, Sections 13 and 15. To make this assessment, scientists will perform experiments using approximately .5 percent of the WIPP capacity. The Operations Demonstration will demonstrate the Department's ability to safely and effectively certify, transport, and emplace TRU waste at the WIPP facility, and will use approximately 2.2 percent of the WIPP capacity.

SURVEY RESULTS

We terminated this project at the survey phase for two reasons: (1) the Department had not completely defined the sites that would ship waste; and (2) the National Academy of Sciences (NAS) recommended that the Department delay the Operations Demonstration. The Department planned to ship all waste for the Performance Assessment, and the majority of waste for the Operations Demonstration, from the Rocky Flats Plant and the Idaho National Engineering Laboratory. There was the possibility that some waste for the Operations Demonstration would be shipped from other, unidentified sites. In addition, on July 19, 1989, the NAS recommended that the Department defer the Operations Demonstration until several important scientific and engineering issues concerning undergound emplacement of waste for permanent isolation at WIPP have been resolved. The Department's resolution of these issues could, in our opinion, cause major changes to the Operations Demonstration plans.

Although we require no formal response to this report, we will continue to monitor developments as they occur. We appreciate the cooperation and assistance provided by your staff during the course of the survey.

William J. Costello
Manager, Western Region
Office of Inspector General

cc: Harry N. Hill, Director,
MRD, AL
Richard G. Motley, Director,
Audit Liaison Division,
MA-322, Forrestal 4A-128

WIPP Library

UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF COLUMBIA

STATE OF NEW MEXICO, ex. rel. TOM UDALL, Attorney General, Plaintiffs. v. JAMES D. WATKINS, Secretary of the Department of Energy, et al., Defendants.	Civil Action No. 91-2527 JGP

PLAINTIFF'S REPLY AFFIDAVITS SUBMITTED IN OPPOSITION
TO DEFENDANTS' MOTION FOR SUMMARY JUDGMENT
AND IN SUPPORT OF PLAINTIFF'S MOTION FOR A
TEMPORARY RESTRAINING ORDER
AND PRELIMINARY INJUNCTION

VOLUME II

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SUMMARY OF AFFIDAVIT OF
DR. G. THEODORE DAVIS, M.D.

Dr. G. Theodore Davis is a licensed and practicing physician in New Mexico who is board certified in emergency medicine and a member of the State of New Mexico WIPP Medical Working Group. (¶ 1).

He testifies that the New Mexico Medical Society, a widely respected professional medical organization comprise of practicing physicians throughout New Mexico, recently stated that, "At present, the physicians of the State of New Mexico do not feel that they are prepared to take care of someone who is injured in an accident involving nuclear waste." (¶ 11). Dr. Davis took a survey of emergency department physicians in the hospitals along the north-south WIPP corridor conducted during the week of November 4, 1991. The survey results indicate that serious deficiencies still remain. (¶¶ 14, 15, 17-25).

Dr. Davis concludes:

1. The one-day seminars provided to New Mexico health care personnel did not constitute "training," but rather served as a beginner-level introduction to the issues. (¶ 10).

2. There is a lack of necessary radiation monitors. (¶ 19). DTPA, the major drug used to treat radiation accident victims, is also unavailable. (¶¶ 19, 34).

3. Special entrances and decontamination areas are essential for adequate response to radiation accidents. Many of the WIPP corridor hospitals are small, making it exceptionally difficult to maintain appropriate contamination control when there are several other non-radiologic patients that need to be managed. (¶ 18).

AFFIDAVIT

I, G. Theodore Davis, M.D., being duly sworn and deposed state as follows:

1. I am a licensed and practicing physician in the State of New Mexico. I am board certified in emergency medicine. I am also a member of the State of New Mexico WIPP Medical Working Group. Currently I am in the practice of occupational medicine, and have offices in Albuquerque, Santa Fe, Carlsbad, and other locations.

2. I make this affidavit to show the court that in general, physicians, nurses and other hospital personnel in New Mexico have received limited or no training and equipment for emergency management of radiation accidents and, specifically, concerning potential WIPP related transportation accidents.

3. I practiced emergency medicine from 1978 through 1985. During that period I was a staff physician in emergency departments at several New Mexico hospitals, including some in the WIPP transportation corridors.

4. My medical education and training, including the most recent post-graduate continuing medical education courses are further described in my Curriculum Vitae, which is attached to this affidavit as Exhibit 1. I would however, like to highlight the formal training

in the emergency management of radiation accidents through the Radiation Emergency Assistance Center/Training Site, (REAC/TS), in Oak Ridge Tennessee. It is affiliated with the Department of Energy. The courses that I have taken there include:

a. "Handling of Radiation Accidents by Emergency Personnel,", November 28 - 30, 1979;

b. "Medical Planning and Care in Radiation Accidents,", November 10 - 14, 1980; and

c. "Handling of Radiation Accidents by Emergency Personnel,", April 25 - 28, 1989.

The REAC/TS facility serves as both a treatment facility and as a central training and demonstration unit where physicians, nurses, and other medical personnel receive intensive training in medical management of radiation accidents.

5. I have presented lectures concerning the emergency management of radiation accidents and the health effects of radiation to accredited symposia and other continuing education programs of the American College of Emergency Physicians, the Nevada Academy of Family Practice, The Maricopa County Medical Center, The University of New Mexico Residency Program, Hospital Staff Meetings, and Volunteer Fire Departments.

6. My publications include a February 14, 1991 co-authored double book review of Radiation-Induced Cancer from Low-Dose Exposure and Health Effects of Exposure to Low-Levels of Ionizing Radiation: Beir V., which appeared in "The New England Journal of Medicine." My other publications are listed in my Curriculum Vitae, attached to this affidavit of Exhibit 1.

7. In September of 1991, I was invited by the U.S. Congress, House Interior Subcommittee on Energy and the Environment, to present testimony concerning radiation protection policies of the Nuclear Regulatory Commission.

8. I have read the Affidavits of Robert C. Ricks, M.S., Ph.D., and Marion Deming, R.N. Based on my personnel knowledge and experience, I am prepared to comment on portions of these affidavits. Further, I will present some additional information.

9. I attended the one day educational seminar at St. Vincent Hospital in Santa Fe on November 10, 1989 that was provided by REAC/TS for WIPP corridor health care providers in New Mexico concerning how to handle emergency radiation accidents. Participants were given written materials and one day of didactic presentations, which included lectures, visual materials, demonstrations, and a video presentation entitled "Hospital Emergency Department Response to Radiation Accidents." This material was well presented, but the course fell far short of training physicians, nurses, and other health care personnel in how to medically manage radiation related accidents. Basic topics in radiation biology and emergency management of radiation accidents were presented. However, there were no laboratory exercises for the participants and there was no radiation emergency drill exercise. Most course participants were unfamiliar with the basic principles that were discussed. These participants could not have mastered the information during this course, and could not have applied the information directly without significant additional study, practice, and drills. In my opinion, this course could not be construed as adequate medical training for how to handle emergency radiation accidents. Professor Ricks, in his affidavit, indicates that the

other courses that were given at the various hospitals were nearly identical to this one at St. Vincent Hospital.

10. I would like to contrast this one day seminar with the training program that I attended at REAC/TS in Oak Ridge Tennessee, from April 25 - 28 in 1989. A course schedule is attached to this affidavit as Exhibit 2. This course was three and a half days long, and included, in addition to didactic lectures, a laboratory exercise in radiation protection and radiation monitoring, a laboratory exercise in contamination control, a demonstration of a radiation accident drill and decontamination procedure, and actual emergency drills that lasted approximately two and a half hours. Following the drills there was a review of video tapes that were made during these exercises. Participants critiqued their own performance, and that of others. From a medical education perspective, I consider this a "training program." The courses, such as the one provided at St. Vincent and other "corridor hospitals" as described by Professor Ricks were appropriate beginner level introductions to the issues, but would not in my opinion constitute "training."

11. I am a member of the New Mexico Medical Society, a widely respected professional medical organization comprised of practicing physicians throughout New Mexico. On August 12, 1991, Barbara L. McAneny M.D., Chair of the Liaison Committee of New Mexico Medical Society to the Department of Energy wrote Senator Jeff Bingaman concerning the Society's opinion of the level of equipment and training to treat victims of radiation accidents in New Mexico. Dr. McAneny states in the letter:

> At present, the physicians of the State of New Mexico do not feel that they are prepared to take care of someone who is injured in an accident involving nuclear waste. We lack the training, despite the DOE's one day training session. We lack the necessary equipment in our emergency rooms and we do not have appropriate medical protocols available. We feel that training must not only include accident site training, but training to help physicians provide important care and long-term care to patients after their accident. We do not know what type of help we can expect from the Department of Energy in terms of caring for these patients and we do not know whether private insurers or the DOE would provide the funds for supplies and care of patients injured in a nuclear accident.

Dr. McAneny's letter is attached to this affidavit as Exhibit 3.

12. On August 28, 1991, I attended a meeting of the New Mexico Medical Society Liaison Committee to the State of New Mexico Environment Department. The minutes of this meeting are attached to this affidavit as Exhibit 4. Those minutes state that the Liaison Committee believes that "the medical community is not prepared to provide medical care to New Mexicans injured in/or contaminated in WIPP-related accidents." Therefore, they recommend that nuclear waste should not be transported until the proper medical procedures are prepared and personnel are adequately trained and the appropriate equipment is in place. In order to meet these requirements the Liaison Committee made the following suggestions, among others:

- Initial training in general aspects of accidents must occur at the hospitals, to include physicians, nurses, EMT's. It will be necessary to have drills at the hospitals and WIPP specific training and these will need to be repeated at least annually because of the turn-over in personnel;

- Procedure development will need to occur at hospitals. This must occur before drills can be done. Hospital administrators and other personnel will need to go to UNM for procedure development seminars. Then the procedures will have to be evaluated by the hospitals involved;

q. What drugs do you have available to treat internal contamination, and specifically do you have DTPA?

r. What type of radioactive waste would be transported in WIPP shipments?

s. Do you generally feel that you and your facility are prepared to manage WIPP related accidents?

t. Please provide any general comments that you would like.

17. None of the physicians contacted had participated in the REAC/TS courses given at New Mexico hospitals. None had specific training in emergency management of radiation accidents similar to that provided at the REAC/TS training courses in Oak Ridge. None of the physicians had ever managed an actual radiation accident.

18. Two physicians had participated in a WIPP accident related drill at their hospital. The physician in Carlsbad had been in a drill one week prior to my contact with him. This had involved one mock patient who had an open fracture and contaminated leg wound. The physician in Artesia had participated in a drill two months prior to my contact with him. This scenario involved two or three mock patients who were not contaminated. He had had no prior drills or training before this drill. The physician in Carlsbad felt that the hospital and staff were adequately prepared to manage WIPP site related accidents. He expressed desire to have additional emergency medical training, possibly through the REAC/TS facility.

19. Other physicians expressed concern that they and their facilities were not prepared to manage WIPP related accidents, and expressed a number of concerns which included:

a. there is a high turn-over of emergency room personnel including nurses and physicians, and new people rotating through the emergency room who may have little or no knowledge of WIPP or medical management of radiation accidents;

b. several of the emergency department physicians travel from out of town or out of state to work at the facility;

c. they may have little or no knowledge of WIPP, or the hospitals contingency plans;

d. there was a wide-spread lack of training concerning WIPP and radiation transportation accidents in general;

e. there was a lack of necessary equipment and drugs, including radiation monitors and DTPA;

f. a number of physicians who staff the emergency departments were actually local family practitioners who had not had specific training in radiation accidents or WIPP related emergencies;

g. two physicians stated that they felt ongoing training in emergency management of radiation accidents needed to take place at hospitals on a state-wide basis, and that this training should occur on a frequent basis because of the high turn-over of nursing and other emergency department staff personnel.

20. The Carlsbad and Roswell hospitals have designated radiation emergency areas and separate entrances. The other hospitals did not have either designated radiation emergency areas or separate emergency entrances. These hospitals had only a total of one to five rooms in the emergency department, and three to five beds. In these facilities there was no

specifically designated radiation emergency area, and a portion of the emergency room would have to be cordoned off for potentially or actually contaminated patients.

21. Only two physicians knew of materials that were available to cover floors, walls, and equipment.

22. Carlsbad and Artesia physicians believed that radiation detection monitors available, but were uncertain of the type. It was unknown whether the other hospital emergency departments had such equipment. The Carlsbad hospital had a decontamination table top with separate drains and holding tanks. The other facilities did not have this equipment.

23. None of the physicians thought that DTPA was available at their facility, but one had heard that it was available at the University of New Mexico Hospital.

24. Two physicians knew of a specific emergency department plan or protocol for their facility. The other physicians were uncertain of the existence of such a plan. The plan had been tested at Carlsbad and Artesia through recently conducted drills.

25. In summary, my survey reached conclusions similar to those obtained by Marion Deming. Like Ms. Deming, I wanted to interview hospital personnel who would be on the "front lines". It is these individuals who will have the ultimate responsibility for the medical assessment and care of persons involved in WIPP related mishaps.

26. In my opinion, the fact that one-day courses have been given at certain hospitals, or the fact that a drill has been conducted with the emergency personnel who happened to be working on a particular day, does not constitute emergency medical preparedness, and does not necessarily provide appropriate and valid verification of medical preparedness. The fact that hospitals in the WIPP corridor were given a REAC/TS one-day course and were given a copy of the 1984 AMA publication "A Guide to the Hospital Management of Injuries Arising from Exposure to or Involving Ionizing Radiation", does not ensure that those hospitals and their personnel are prepared to manage WIPP related accidents.

27. I concur with Professor Ricks that excellent and intensive training in the generic management of radiation medical emergencies would possibly include most of the information necessary to adequately manage victims of a WIPP transportation accident. However, some specific training related to detection of alpha-emitters, and decorporation of internal contamination with transuranic elements, like those contained in WIPP shipments, would also be necessary.

28. Professor Ricks states that REAC/TS courses in New Mexico correspond with AMA guidance which says that special entrance and decontamination areas may be desirable but are not essential for adequate response to radiation accidents. Ricks states that at the University of Florida's Shands Teaching Hospital, the hospital emergency room could be used as the admitting facility without compromising its continued function for non-radiation emergency by designating one of the trauma rooms as the patient handling area, and applying appropriate contamination control and traffic routing procedures. This may work in a large

urban area. However, in rural hospitals, like those in New Mexico, there is frequently only one trauma room, and sometimes only one available bed in that room. The Raton hospital emergency room, for example, consists of only room. It becomes exceptionally difficult to maintain appropriate contamination control when there are several other non-radiologic patients that need to be managed, under circumstances where there is only one physician available in an emergency situation. Also, where there is only one emergency entrance, one must assume that the entrance has become contaminated by virtue of radiation victims being brought in through that entryway. This is the conclusion that Professor Ricks reached in an article he co-authored entitled, "Emergency Department Radiation Accident Protocol" attached to this affidavit as Exhibit 6. Therefore, access for and treatment of non-radiological emergency patients could be severely compromised under certain circumstances, unless major safeguards, like separate entryways are in place well in advance. Emergency rooms in New Mexico Hospitals are already over-loaded with patients. See Rex Graham, "EMERGENCY: Treating New Mexico's Uninsured Clogs Emergency Rooms," Albuquerque Journal at p.1 (Oct. 27, 1991), attached to this affidavit as Exhibit 7. Also, in large urban areas, there are alternative hospitals where critical patients can be diverted if one hospital is contaminated. In rural New Mexico communities, there is only one emergency medical facility, and if it were contaminated due to a WIPP related accident, other vital emergency care could be compromised.

29. Professor Ricks states that "management of WIPP transportation accidents does not differ from management of the victims of an accident of a shipment of radio-pharmaceuticals. Although in principle this is correct, potential radiological contamination with plutonium and

americium poses specific problems. These isotopes are extremely long lived, and pose serious long term health problems from internal contamination. Radiopharmaceuticals tend to be short-lived isotopes, and would not require alpha-monitoring to detect them, nor the use of decorporation drugs.

30. Professor Ricks asserts that experience like "hands-on" training is desirable. He states, however, that REAC/TS training conducted for Westinghouse WID in 1989 and 1991 for WIPP corridor hospitals did not provide "hands-on" experience. Ricks explained that physicians and nurses already knew how to: put on caps, gowns, masks; triage based on medical problems; assess and treat medical problems; collect biological samples; cleanse skin and wounds; and manage isolation techniques. He further indicated that during the courses, the lectures, videos and slides presented and/or demonstrated the adaptations of routine procedures that are recommended for radiation accident management. At the REAC/TS training program in Oak Ridge, one of the most beneficial aspects of the training was the emergency medical radiation drills that were conducted. Although most of us who participated knew how to put on caps and gowns, triage, clean skin wounds, etc., we learned that there were some very special skills that complimented these basic techniques that needed to be understood and mastered. The only mechanism through which this could be appreciated was the actual drill. REAC/TS felt that this drill was important enough to film the exercise. Afterwards, instructors spent time with all participants critiquing their performance, and those of others. We noted many mistakes that had been made during this drill, that would have lead to radioactive contamination, or other problems, had it been an actual event.

31. Professor Ricks states that during the REAC/TS courses in corridor hospitals, radiation detection equipment was demonstrated and problems associated with alpha-monitoring was discussed. Based on the survey I did, it appears that many physicians in WIPP corridor hospitals are not familiar with the use of radiation detection equipment in general, and do not have alpha-monitors. Radioactive isotopes like plutonium and americium emit alpha particles primarily. These particles are not detectable by standard geiger counters, and a more sensitive instrument known as an alpha-detector is necessary to monitor these radiations.

32. Professor Ricks states that the use of DTPA as a chelator for internally deposited transuranics (ie, Pu) was discussed during the REAC/TS courses. He asserts that "the fact that WIPP shipments will contain high-fired oxides of plutonium and/or americium was discussed including the insoluble nature of the potential contaminants." He stresses that for these insoluble transuranics immediate chelation is not necessary and certainly not within one hour. He further states that REAC/TS training recommended administration of DTPA within three hours if possible, but for insoluble forms twelve to twenty four hours later would be satisfactory. There is no regulatory requirement that prohibits flammable or soluble forms of plutonium and americium from coming to WIPP. Furthermore, at this time, neither the DOE, other governmental agencies, nor individuals know exactly what chemical and physical forms of radioactive and chemical wastes would be shipped to WIPP. With this uncertainty in mind, the availability of DTPA for emergency administration in the emergency department setting at the WIPP corridor hospitals is medically indicated, and vitally important for appropriate care. The Informational Material Package Insert for Ca-DTPA from Oak Ridge

Associated Universities, Medical Sciences Division, revision May 24, 1991, states "The chelating efficacy (of DTPA) is greatest immediately, or within one hour of exposure when the radionuclide is circulating in or available to the tissue, fluids, and plasma." This insert is attached to this affidavit as Exhibit 8.

33. Once plutonium is taken into the blood stream it is taken up by organs and tissues in the body. Once these radioactive isotopes are incorporated into the body, they will remain there essentially for the rest of the person's life. If the chelating drug can be given while the radioactive substance is still in the blood stream, and before it is taken into the body cells and tissues, the drug can bond with the radioactive material and carry it out of the body through the urine. Because the plutonium and americium are quickly absorbed by the body organs and tissues, it is necessary for the drug to be administered as quickly as possible. In WIPP related radiation accidents with a waste container breach, there would be possibilities of inhalation exposure, wound exposure (burns, lacerations, and others), or ingestion (certain chemical forms of plutonium can be absorbed from the gut). In any of these exposure types, it would be medically indicated to administer intravenous or aerosolized DTPA to the victim within one hour.

34. Professor Ricks states that the mechanism of acquiring the DTPA drug was explained during the course, along with the opinion that DTPA was <u>not needed</u> in corridor hospitals in New Mexico (or elsewhere), but rather could be obtained from New Mexico co-investigator physicians identified by REAC/TS. Although there are six co-investigator physicians in New Mexico, one or more of them may not be available on an emergency

basis. Based on this fact, and the discussion above, I do not believe that, under these circumstances, the drug would be available within a necessary time frame to treat individuals who are potentially or actually internally contaminated during a WIPP accident.

35. Plutonium and americium are considered to be a highly dangerous and carcinogenic substances, even in microscopic amounts. In nuclear weapons facilities, research laboratories, and other facilities where these materials are handled, extreme safety precautions are taken, including different types of detectors and alarms to alert workers of possible releases of the substance. Also several different types of redundant safety systems are always in place. Plutonium and americium are considered to be a bone-seekers, and both bone and liver are considered to be target organs. The allowable body burden of plutonium and americium for an occupational worker, which may be accumulated over a life-time, is 40 nanocuries. The DOE has estimated that each 55 gallon drum of WIPP waste could contain up to 1 curie of Pu. This represents about 25 million maximum permissible occupational body burdens per drum.

36. The causation of different types of cancers in experimental animals by internal contamination with microscopic amounts of plutonium is well documented in scientific literature. A recent report, "A 42-y Medical Follow-up of Manhattan Project Plutonium Workers," by Drs. Voelz and Lawrence, Health Physics, August, 1991, documents the development of a rare bone tumor (osteogenic sarcoma) at an unusual anatomical site in a plutonium worker whose exposure was concidered to be very low. This report is attached to this affidavit as Exhibit 9.

37. In conclusion, in my opinion the health care personnel in the State of New Mexico are not adequately trained or equipped to manage WIPP related radiation accidents.

STATE OF NEW MEXICO

COUNTY OF BERNALILLO

G. Theodore Davis, M.D.

G. Theodore Davis, M.D.

Subscribed and sworn to before me this the 8th day of November, 1991

Notary Public

OFFICIAL SEAL
LARRY CHAVEZ
NOTARY PUBLIC
STATE OF NEW MEXICO
My Commission Expires April 9, 1995

My commission expires: April 9, 1995

EXHIBIT 1

G. THEODORE DAVIS MD
Encino Crescent Building
1010 Las Lomas N.E., Suite 1
Albuquerque, New Mexico 87102
Office (505) 242-8502
Home (505) 242-7822

CURRICULUM VITAE

Home Address: 515 Tulane Place, N.E., Albuquerque, N.M. 87106 (505) 268-7822

Present Position: Private Practice, Occupational and Musculoskeletal Medicine, Albuquerque, N.M. 1988 to present

Board Certification: Diplomate, American Board of Emergency Medicine

Fellowship: Fellow, American Academy of Disability Evaluating Physicians

Medical Education: M.D. 1976, Emory University School of Medicine, Atlanta, Georgia

Postgraduate Medical Training: 1976-77, L.S.U. Medical Center, Shreveport, La.

Medical Licensure: New Mexico #77-151 ; Arizona # 19833 ; Colorado # 30083

Hospital Staff Privileges: Presbyterian Hospitals, Albuquerque
St. Joseph Northeast and West Mesa Hospitals, Albuquerque

Previous Professional Positions Held:

Private Practice, Occupational Medicine, Center for Occupational Medicine and Orthopaedic Surgery, Albuquerque, N.M., 1985-88

Private Practice, Emergency Medicine, Emergency Physicians, Inc., St. Joseph Hospitals, Albuquerque, N.M. 1980-85

Private Practice, Emergency Medicine, and Director of "Emergency and Clinic Physician Services," Albuquerque, New Mexico, 1978-80

General Medical Officer, U.S. Public Health Service, Gallup Indian Medical Center, 1977-78

Current Professional, Academic, Teaching and Research Activities and Appointments:

Co-Chairman, Clinical Traning Committee, American Academy of Disability Evaluating physicians

Member, Medical Education Committee and Continuing Medical Education Committee, American Academy of Disability Evaluating Physicians

National Lecturer on Medical Evaluation of Impairment and Disability, American Academy of Disability Evaluating Physicians

Assistant Clinical Instructor, Department of Family, Community and Emergency Medicine, University of New Mexico School of Medicine, Albq. NM

Instructor, Advanced Cardiac Life Support, American Heart Association, 1978-present

Coinvestigator (with U.S. Department of Energy, Oak Ridge Associated Universities and The Radiation Emergency Assistance Center/Training Site) in the use of calcium and zinc diethylenetriaminepentaacetate (DTPA) for decorporation therapy of internally deposited actinide (radionuclide) contamination in humans, 1982 to present

Professional and Scientific Memberships and Positions:

New Mexico Medical Society
Greater Albuquerque Medical Association
Fellow, American Academy of Disability Evaluating Physicians
Instructor, American Heart Association
Clinical Faculty, University of New Mexico School of Medicine
American Occupational Medicine Association
Rocky Mountain Academy of Occupational Medicine
New Mexico Public Health Association
American Association of Orthopaedic Medicine
Institute and Society of Orthopaedic Medicine

Recent Postgraduate Continuing Medical Education Courses and Credits:

(Summary: Total credits achieved from Feb. 1987 to April '91 = 454 hours; of these, 239 hours pertain specifically to occupational or orthopaedic medicine, and the related subjects of medical assessment of impairment and disability, and the human biomechanics and ergonomics of work)

"Clinical Training Program," American Academy of Disability Evaluating Physicians, Chicago, IL, April 9-13, 1991 (37 credit hours) [*]

Publication of "Book Review" in New England Journal of Medicine, Feb. 14, 1991, Vol 324, # 7, pp.497-499 (10 credit hours) [*]

"The Medical Letter," Yale University School of Medicine, Exam # 21, January 21, 1991 (13 credit hours)

"State of Arizona Medical Licensing Examination," passed Dec. 6, 1990

"Fourth Annual Scientific Seminar and Symposium," American Academy of Disability Evaluating Physicians, Las Vegas, NV, Nov. 1-3, 1990 (18 credit hours)

"Advanced Workers' Compensation in New Mexico--Legal Symposium," Albq., Nov. 1990

"Clinical Training Program," American Academy of Disability Evaluating Physicians, Chicago, IL, Sept. 1990 (10 credit hours) [*]

"Occupational Ergonomics II," University of Michigan Public Health Consortium, Ann Arbor, MI, June 25-27, 1990 (20 credit hours)

"Occupational Ergonomics I," University of Michigan Public Health Consortium, Ann Arbor, MI, June 18-22, 1990 (33 credit hours)

"Advanced Cardiac Life Support," American Heart Association, Albuquerque, NM, March 22, 1990; Oct. 26, 1989; July 7, 1989 (12 credit hours) [*]

"Clinical Training Program," American Academy of Disabily Evaluating Physicians, Chicago, IL, March 1990 (24 credit hours) [*]

"Medical Management of Radiation Accidents," St. Vincent Hospital Education Department, Santa Fe, NM, Nov. 10, 1989 (7 credit hours)

"Third Annual Convention," American Academy of Disability Evaluating Physicians, Orlando, FL, Nov. 1-4, 1989 (9 credit hours)

"Clinical Training Program," American Academy of Disability Evaluating Physicians, Chicago, IL, Sept. 20-24, 1989 (24 credit hours)

"Overview Course in Disability Medicine," American Academy of Disability Evaluating Physicians, San Francisco, CA, August 18-19, 1989 (10.5 credit hours)

"Loss Control Seminar," New Mexico Medical Society, Albuquerque, NM, May 13, 1989 (4 credit hours)

"Handling of Radiation Accidents by Emergency Personnel," Radiation Emergency Assistance Center/Training Site, Oak Ridge, TN, April 25-28, 1989 (20 credit hours)

"Sixth Annual Meeting & Seminar of the American Association of Orthopaedic Medicine," San Diego, CA, Feb. 15-19, 1989 (30 credit hours)

"Emergency Medicine Intensive Home Study Seminar," Mentor Medical Network, Inc., 1988 (149 credit hours)

"4th Annual Office Based Sports Medicine Symposium," Univ. of Calif., San Francisco, Park City, UT, Feb 14-21, 1987 (24 credit hours)

[*] Dr. Davis was also an instructor or presentor in these programs

Accredited Professional Presentations:

"Physician's Workshop in Impairment and Disability Assessment" and "Assessment of Spinal Impairment and Inclinometry Measurement of the Spine," Clinical Training Program, Am. Acad. of Disab. Eval. Physicians, Chicago, IL, April 9-13, 1991

"Physician's Workshop in Impairment and Disability Assessment" and "Assessment of Spinal Impairment and Inclinometry Measurement of the Spine," Clinical Training Program, Am. Acad. of Disab. Eval. Physicians, Chicago, IL, Sept. 1990

"Emergency Management of Radiation Accidents," Grand Rounds, UNM School of Medicine, Dept. of Family & Community Medicine, May 2, 1990

"Inclinometer Techniques of Spinal Movement Measurement," and "Physician's Workshop in Impairment and Disability Assessment," Clinical Training Program, Am. Acad. of Disab. Eval. Physicians, Chicago, IL, March, 1990

"Evaluation of Neuro-musculoskeletal Disability,", Grand Rounds, UNM School of Medicine, Dept. of Family, Community and Emergency Medicine, May 31, 1989

"Assessment of Back Injuries and Back Pain," Current Concepts In Primary Care, University of New Mexico Office of Continuing Medical Education, Albuquerque, N.M., April 9, 1988

"A Practical Approach to Musculoskeletal Pain and Disorders," Southwest Associates In Manual Medicine, Albuquerque, N.M., March 21, 1987, and September 27, 1986

"Medical Effects of High Level Radiation Exposure," The Nevada Academy of Family Physicians Annual Meeting, Lake Tahoe, Nevada, January 24, 1984.

"Radiation: The Physics, Physiology and Treatment of Radiation Poisoning," Emergency Medicine Symposium, New Mexico Chapter, American College of Emergency Physicians, Taos, New Mexico, April 3, 1982

"Emergency Medical Response to Nuclear Waste Transportation Accidents," Cuba Health Center and Fire Department, Cuba, New Mexico, May 6, 1981

"Emergency Medical Management of Radioactive Waste Transportation Accidents," New Mexico Public Health Association, Albuquerque, New Mexico, May 23, 1981

Lecturer and Instructor in "Advanced Cardiac Life Support," New Mexico, American Heart Association, 1978 to present

Publications:

"Assessment of Spinal Related Impairments: An Historical Perspective and Current Guidelines," co-authored with Robert Morgan, RPT, JOURNAL OF DISABILITY (accepted, and in preparation for 1991 publication)

"Spinal Movement Assessment with Inclinometry and other Techniques," co-authored with Robert Morgan, RPT, JOURNAL OF DISABILITY (accepted, and in preparation for 1991 publication)

"Book Reviews of Radiation-Induced Cancer from Low-Dose Exposure and Health Effects of Exposure to Low Levels of Ionizing Radiation: BEIR V," co-authored with Andre Bruwer, M.D., NEW ENGLAND JOURNAL OF MEDICINE, Feb. 14, 1991, Vol. 324, # 7, pp 497-499

Evaluation and Treatment of Musculoskeletal Disorders in the Extremities, G. Montgomery, M.D., G.T. Davis, M.D., R. Morgan, G. Mazer, P.T., copyright by S.A.M.M., 1988

The Physics, Pathophysiology and Emergency Management of Radiation Accidents, copyright by G.T. Davis, M.D., 1982

The Medical Effects of a Nuclear Attack on Albuquerque, New Mexico, by H. Johnston, L.D. Weiss, Ph.D., G. T. Davis, M.D., Published by the University of New Mexico School of Medicine, 1981

(updated April 1991)

EXHIBIT 2

HANDLING OF RADIATION ACCIDENTS BY EMERGENCY PERSONNEL
April 25-28, 1989

COURSE SCHEDULE

DATE	TIME	TOPIC	LECTURER
Tuesday April 25	8:00-8:15 a.m.	Registration	Payne, Davis, Sipe
	8:15-9:00 a.m.	Introduction	Ricks
		Tour of REAC/TS	Staff
	9:00-10:15 a.m.	SCOPE OF THE PROBLEM	Lushbaugh
	10:15-10:30 a.m.	Coffee Break	
	10:30-12:00 noon	PRACTICAL RADIATION-PHYSICS FOR EMERGENCY PERSONNEL	Ricks
	12:00 noon	Photograph Session	
		Lunch	
	1:30-2:15 p.m.	MONITORING DEVICES AND THEIR USES	West
	2:15-2:30 p.m.	Coffee Break	
	2:30-4:30 p.m.	RADIATION PROTECTION AND RADIATION MONITORING (Laboratory Exercise)	West, Byrd, Berger
	6:30 p.m.	Social Hour and Dinner (Garden Plaza, Oak Ridge)	Hosted by REAC/TS

HANDLING OF RADIATION ACCIDENTS BY EMERGENCY PERSONNEL
April 25-28, 1989

COURSE SCHEDULE

DATE	TIME	TOPIC	LECTURER
Wednesday April 26	8:00-9:00 a.m.	RADIOBIOLOGY OF MAN	Adler
	9:00-10:00 a.m.	Laboratory Exercise: Contamination Control	West, Byrd
	10:00-10:15 a.m.	Coffee Break	
	10:15-11:15 a.m.	ADAPTING EMERGENCY CARE FOR RADIATION ACCIDENT VICTIMS	Berger
	11:15-12:00 noon	TREATMENT FOR INTERNAL CONTAMINATION	Garrett
	12:00 noon	Lunch	
	1:30-2:30 p.m.	RADIATION EMERGENCY SITUATIONS AND THEIR MANAGEMENT	Fry
	2:30-2:45 p.m.	Coffee Break	
	2:45-3:45 p.m.	PLANNING EMERGENCY DRILLS	Ricks
	3:45-4:30 p.m.	EMERGENCY TEAM ORGANIZATION	Ricks

HANDLING OF RADIATION ACCIDENTS BY EMERGENCY PERSONNEL
April 25-28, 1989

COURSE SCHEDULE

DATE	TIME	TOPIC	LECTURER
Thursday April 27	8:00-8:30 a.m.	RECOMMENDATIONS FOR EMERGENCY SUPPLIES & EQUIPMENT	Sipe
	8:30-9:00 a.m.	HOSPITAL EMERGENCY DEPARTMENT RESPONSE TO RADIATION ACCIDENTS	Videotape
	9:00-10:15 a.m.	LABORATORY/DEMONSTRATION: Drill Walk-Through and Decontamination	Poda, Sipe, West
	10:15-10:30 a.m.	Coffee Break	
	10:30-11:00 a.m.	PRE-HOSPITAL RESPONSE TO RADIATION ACCIDENTS	Videotape
	11:00 a.m.	Lunch	
	12:30 p.m.	Emergency Drill (Group A)	Participants
		(Museum) Reactor Operations and Safety (Group B)	Marsee
	3:00 p.m.	Emergency Drill (Group B)	Participants
		(Museum) Reactor Operations and Safety (Group A)	Marsee
	4:30 p.m.	End	
	6:30 p.m.	Dinner at REAC/TS. Review of Emergency Drill Videotapes.	Hosted by REAC/TS

HANDLING OF RADIATION ACCIDENTS BY EMERGENCY PERSONNEL
April 25-28, 1989

COURSE SCHEDULE

DATE	TIME	TOPIC	LECTURER
Friday April 28	8:00-8:45 a.m.	MULTICASUALTY INCIDENTS INVOLVING RADIATION: HISTORY AND IMPLICATIONS	Ricks
	8:45-9:45 a.m.	ADAPTING RESPONSE IN MULTI-CASUALTY INCIDENTS	Berger
	9:45-10:00 a.m.	Coffee Break	
	10:00-10:30 a.m.	PUBLIC INFORMATION IN RADIATION ACCIDENTS	Alexander/ Wyatt
	10:30-11:30 a.m.	DOE SPECIAL ASSISTANCE PLANS...	Davis
	11:30-12:15 p.m.	Question and Answer Session	Staff
		Written Examination	Staff
		Examination Grading	Staff
		Course Critique and Closing Remarks	Ricks

397/April 12, 1989

EXHIBIT 3

New Mexico Oncology Hematology Consultants, Ltd.

Clark E. Haskins, M.D.-Diplomate, Medical Oncology
Barbara L. McAneny, M.D.-Diplomate, Medical Oncology; Diplomate, Hematology
Richard O. Giudice, M.D.-Diplomate, Medical Oncology; Diplomate, Hematology

August 12, 1991

The Honorable Jeff Bingaman
United States Senator
Hart Senate Office Building Room 524
Washington, D.C. 20510

Dear Senator Bingaman:

I am writing this letter on behalf of the New Mexico Medical Society which passed a resolution concerning the Waste Isolation Pilot Project. The New Mexico Medical Society recognizes that long-term storage of nuclear waste is becoming an increasingly pressing problem in our society. We recognize that wastes are presently contained in inadequate above-ground storage facilities and shallow trenches at various sites. We realize that these sites are a health hazard in and of themselves, and cannot become a long-term solution. However, our first concern is for the health and safety of our patients, the citizens of New Mexico. At present, the physicians of the State of New Mexico do not feel that they are prepared to take care of someone who is injured in an accident involving nuclear waste. We lack the training, despite the DOE's one day training session. We lack the necessary equipment in our emergency rooms and we do not have appropriate medical protocols available. We feel that training must not only include accident site training, but training to help physicians provide inpatient care and long-term care to patients after their accident. We do not know what type of help we can expect from the Department of Energy in terms of caring for these patients and we do not know whether private insurers or the DOE would provide the funds for supplies and care of patients injured in a nuclear accident.

Finally, as physicians, our major concern is to protect the health of New Mexicans. We would prefer to prevent nuclear contamination than to treat it. We would therefore like to make sure that basic health and safety standards are followed. Because of this, on August 6, the New Mexico Medical Society Council passed the following resolutions:

RESOLVED: WIPP must meet EPA standards for nuclear waste repositories before any waste is brought to the site.

RESOLVED: Transport must be made as safe as possible by assuring that DOE complies with Federal and State laws for routing, driver qualifications, and packaging.

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RESOLVED: DOE must assure continuous training of personnel and must supply equipment for emergency response to the health care facilities which might be expected to provide primary or referral care to persons exposed along the route of transport or at the WIPP site.

RESOLVED: That the provision of health care and oversight of health and safety concerns should be the responsibility of an easily identified State Official, who has the authority to coordinate the medical response to an accident, as well as to impose regulations to prevent accidents.

We appreciate your concern on this matter of utmost importance and hope to work with you, the Department of Energy, the Department of Transportation and the New Mexico Department of Environment to assure the safety of the citizens of New Mexico.

Sincerely,

Barbara McAneny MD

Barbara L. McAneny, M.D.
Council, New Mexico Medical Society
Chair, Liaison Committee of New Mexico Medical Society to the Department of Energy

BLM:th

cc: Judy Espinosa
Secretary, Department of Environment

EXHIBIT 4

The Liaison Committee to Health and Environment Department met August 28, 1991 at 4:00 p.m. at the New Mexico Medical Society Headquarters. In attendance were:

Barbara McAneny, M.D., Chairman	Kenneth Bowman, M.D.
Kenneth Osgood, M.D.	Norah Walsh, M.D.
Calvin Dudley, M.D.	Fred Metler, M.D.
Kenneth Bull, M.D.	G. Theodore Davis, M.D.
John Koster, M.D.	Chuck Stutzman, M.D.

The Committee reviewed the meeting with Judy Espinosa, Secretary of the Department of Environment. As a result of this meeting, a letter was sent to our congressional delegation explaining the concerns of the Committee and inadequate organization of handling emergencies as a result of a WIPP accident. From the meeting and letter, the state and DOE have established a Task Force to begin discussions of preparedness in the event of an accident involving nuclear waste. The chairman has been appointed to this Task Force. As well, she has participated in a course teaching health care providers how to deal with hazardous accidents, taught by REAC/TS.

The Liaison Committee to the Department of Environment presently feels that the medical community is not prepared to provide medical care to New Mexicans injured and/or contaminated in WIPP-related accidents. Therefore, they recommend that nuclear waste should not be transported until the proper medical procedures are prepared and personnel is adequately trained and the appropriate equipment is in place. In order to meet these requirements, the following list of suggestions is proposed:

1) The route must be clearly defined so that training in hospitals along the route can be added as needed;

2) Initial training in general aspects of accidents must occur at the hospitals, to include physicians, nurses, EMT's. it will be necessary to have drills at the hospitals and WIPP specific training and these will need to be repeated at least annually because of the turnover in personnel;

3) Procedure development will need to occur at hospitals. This must occur before drills can be done. Hospital administrators and other personnel will need to go to UNM for procedure development seminars. Then the procedures will have to be evaluated by the hospitals involved;

4) Annual workshops and conferences will be needed to update protocols;

5) The costs incurred by hospitals, physicians, administrative time, supplies used, will need to be reimbursed ideally by WIPP and DOE;

6) DTPA needs to be available entirely along the route in each hospital so that it is readily available and can be used withing the first hour of a possible exposure;

7) Letters of intent need to be provided to hospital on the WIPP route for immediate care and UNM needs to be designated as a backup for transfer for definitive care of injured and contaminated patients. Other hospitals in the Albuquerque area will need to understand their role as possible back-up hospitals. Costs incurred for such treatment at local hospitals and at referral hospitals will need to be covered by DOE/WIPP. The accessibility and availability of Federal resources, such as FEMA, JNACC, DOE, DOD REBG/TS and NRC need to be set down in writing for the state. In particular, what costs will be covered and what responsibilities will be born for each organization;

8) A coordination center for response to an accident is needed with a key state official, perhaps the Governor, identified, with authority to mobilize the medical personnel and emergency teams and coordinate with other agencies;

9) There needs to be a coordination and oversight committee with the responsibility to assure the Governor and the state on a continuing basis that the preparation is adequate;

10) The system, docimeters, equipment, and training needs to be audited by non-DOE/WIPP officials;

11) Items such as blood samples, etc., to be tested for contamination must have a means for transport and a lab available and adequate for testing;

12) The costs incurred by the state in case of an accident in transport or off-site relief need to be covered by WIPP and DOE;

13) Alpha detection devices need to be provided for the hospitals and on all of the WIPP trucks, they need to be the same size, type, and calibrations should be done centrally rather than locally;

14) Determination of intervention levels for actions in case of accident and reclamation evacuation levels, etc., need to be defined and the ability to close roads, evacuate towns, needs to be determined;

15) The workers at the WIPP sitoc and transportation industries need to ensure that they have adequate insurance coverage which will not eliminate nuclear-related injuries or delayed nuclear-related illnesses;

The Committee felt that the Society's annual continuing medical education program should be structured to inform the membership on how to deal with a nuclear accident and how to form a plan for their hospital. This should include CME.

Furthermore, the Committee requested that information on the TRU-PAC II's be provided to the Committee for safety reasons. The concern of the Committee was that they are not tested to failure and therefore the dependability of the PACT's is questionable.

The Committee also requested that a meeting and site visit to scheduled at the WIPP site in Carlsbad.

The meeting was adjourned at 5:30 p.m.

Respectfully submitted,

Barbara L. McAneny, M.D.
Chairman

BLM:rs

EXHIBIT 5

NEW MEXICO CHAPTER

American College of Emergency Physicians

In Care Of:
Division of Emergency Medicine
University of New Mexico
School of Medicine
620 Camino de Salud NE
Albuquerque, NM 87131

July 26, 1991

Robert M. Lopez
Special Waste Bureau
Environmental Improvement Division
1190 St. Francis Drive
Harold Runnels Building
Santa Fe, NM 87503

Dear Bobby,

To follow up our discussion at the July 25th meeting, I wanted to restate the concerns we in the New Mexico Chapter of the American College of Emergency Physicians have regarding our present state of readiness for WIPP shipments.

Though our protocol for the emergency medical care of victims from a WIPP transportation accident is nearly complete, we presently do not have the ability to implement it.

Training of hospital staff in its use will be necessary to make such a detailed protocol work. The REAC/TS presentations provide an introduction to the elementary physics and medical implications of radioactive contamination but they do not provide any practical guidelines for treating a contaminated patient. More specific training of "what to do and how to do it" will have to be developed. Also, since a WIPP related accident is expected to be an infrequent event, retraining sessions and regular drills will be essential for maintaining readiness over the lifetime of the WIPP.

The selection and training of Radiation Safety Officers presents special problems. I know of no program which could provide them with the expertise they need to do the job of surveying for contamination and overseeing its containment; this is completely outside the experience and training of most healthcare workers. The DOE may have a course which would cover our requirements, but if not, we will have to develop our own and this may prove difficult.

Essential equipment needed to implement the protocol is lacking at most of our hospitals.

Funding for these educational programs and equipment purchases does not exist.

The issue of DTPA distribution needs further consideration. This drug should be available within an hour of contamination. It would seem most prudent, therefore, to have DTPA widely distributed, but this would require larger amounts of this drug in New Mexico and it is difficult to obtain. If it is to remain centralized to a few areas, as it is now, a reliable system of rapid disbursement will have to be developed.

Addressing these problems would clearly be facilitated by a single central state authority overseeing WIPP preparations. It could review and adopt standard protocols, with standardized equipment lists and training programs; costs could then be ascertained and funding applied for. It would also serve to coordinate the efforts of the various sectors involved in handling a WIPP transportation accident.

I am enclosing a first draft copy of the protocol we have been working on so that you have a better feel for the complexity of the issue as we see it, and a better understanding of our concerns about developing training programs. Also, on page 7 you will find a list of the equipment needed to implement this; you can see that, with the exception of the alpha detector, most of the items are inexpensive and "low tech"; many could be purchased at any hardware store, but hospitals do not usually have them on hand.

Thank you for the opportunity to express NMACEP's major concerns regarding this issue. The formation of this committee is an encouraging step towards our common goal of making New Mexico ready to accept WIPP shipments.

Sincerely,

David M. Wesselman, M.D., F.A.C.E.P.
President, NMACEP
1100 Central SE
Albuquerque, NM 87102
841-1125 (office)
828-2820 (home)

EHIBIT 6

Emergency Department Radiation Accident Protocol

*Ralph B. Leonard, MD, PhD**
Winston-Salem, North Carolina
Robert C. Ricks, PhD†
Oak Ridge, Tennessee

Every emergency department faces the potential problem of handling one or more victims of a radiation accident. While emergency departments near nuclear power plants or isotope production laboratories probably have a detailed protocol for such emergencies, a similar protocol is needed for the emergency department that may have to handle an isolated event, such as a vehicular accident that spills radioactive material and contaminates passengers or bystanders. This communication attempts to answer that need, presenting a step-by-step protocol for decontamination of a radiation victim, the rationale on which each step is based, a list of needed supplies, and a short summary of decorporation procedures that should be started in the emergency department. Leonard RB, Ricks RC: Emergency department radiation accident protocol. *Ann Emerg Med* 9:462-470, September 1980.
disaster management, radiation accident; emergency department protocol, radiation accidents; radiation accident, emergency department protocol

INTRODUCTION

The recent event at Three Mile Island in Harrisburg, Pennsylvania, made all emergency physicians acutely aware of their need to be prepared to handle contaminated victims of radiation accidents. Because very few people in emergency departments have had actual experience with such problems, it may be difficult for the departments to prepare a detailed protocol. Emergency departments near a nuclear power plant or isotope production plant probably have such a protocol. However, even those not so located must be ready for isolated events, such as vehicular accidents spilling radioactive material, or accidents in chemistry laboratories or in nuclear medicine departments. Thus, every emergency department should have a protocol for handling victims of a radiation accident.

In 1963, the *Journal of the American Medical Association* published an article by Saenger,[1] which discussed hospital planning for radiation accidents. We expand the data in Saenger's presentation by means of a detailed outline* that can be adapted easily by any emergency department. Obviously, for that adaptation, specific names and beeper numbers would be included, as would specific rooms or areas in which the specific actions would be carried out. Emergency departments near a nuclear power plant or isotope production plant would include the safety personnel and available equipment of that plant as part of the protocol.

* Derived from course: "Handling of Radiation Accidents by Emergency Personnel," Radiation Emergency Assistance Center/Training Site, Oak Ridge, Tennessee.

From the Section on Emergency Medical Services, Department of Surgery, Bowman Gray School of Medicine of Wake Forest University, Winston-Salem, North Carolina,* and the Radiation Emergency Assistance Center/Training Site, Oak Ridge Associated Universities, Oak Ridge, Tennessee †

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RADIATION PHYSICS

While it is not our purpose to discuss radiation physics in detail, a few basic concepts are needed to explain the steps taken in this protocol. A detailed discussion of radiation physics can be obtained from any college physics textbook, and an explanation of the various counters used in measuring radioactivity from any introductory nuclear medicine textbook.[2,3] For this discussion, the term "radioactivity" refers to the loss of either particles (alpha or beta) or energy (gamma rays) from a spontaneously decaying unstable atom.

Alpha particles are composed of two protons and two neutrons (the nucleus of a helium atom) and are heavy particles with a plus two electronic charge. They have a range of a few centimeters in air. In tissue, they have a range of only a few micrometers and, consequently, cannot penetrate skin. Thus alpha-emitting contamination is not a hazard to intact skin, but it is a hazard to open wounds or when inhaled or ingested.

Beta particles are emitted from the nucleus and are similar to electrons. They have a range of several meters in air and a few millimeters in tissue; consequently, they pose a biological threat both internally and externally.

Gamma rays are electromagnetic energy (like x-rays) emitted from the nucleus. They have a range of many meters in air and many centimeters in tissue and, like beta particles, constitute a biological hazard both internally and externally.

Beta and gamma emitters are most likely to be encountered by emergency medicine personnel. Alpha emitters are primarily transuranic isotopes and are generally found in nuclear chemistry laboratories and isotope production facilities. When checking a patient for radioactivity, however, one must monitor for alpha as well as beta and gamma radiation.

The radiation counter most commonly used by Civil Defense personnel and in emergency departments is the CDV-700 Geiger-Mueller (GM) counter. This is an excellent device for detecting beta and gamma radiation, but it must contain a special window for detecting alpha radiation because of the low penetrating power of alpha particles. The alpha window must be held close to the surface being monitored, but must not touch that surface or it will be contaminated.

When monitoring a possibly contaminated patient, one is primarily interested in determining whether the patient is contaminated and, if so, where. Secondarily, one needs a rough estimate of the amount of contamination. Because the flux of particles falls off as the inverse square of the distance of the probe from the radioactivity, the probe must be held at a constant distance from the surfaces being monitored.

All emergency physicians and those (other than the radiation safety officer) assigned in the protocol to monitor a contaminated patient should discuss the details of monitoring with the radiation safety officer or health physicists at their institutions in order to be familiar with both the equipment and the procedures before a radiation accident occurs.

Types of Accidents

In considering the medical problems of a victim of a radiation accident, one must keep in mind three situations. The first is *contamination*, in which a radioactive material, in the form of dust, solid particles or liquid, becomes physically attached to the victim's skin or clothes. This can be detected by proper monitoring of the patient and may consist of alpha, beta- or gamma emitters, depending on the type of isotope in the contaminant. This type of accident requires physical decontamination as outlined in the protocol (Appendix 1).

The second situation is *incorporation*, in which a radioactive material, in the form of dust, solid particles, or liquid, is inhaled or ingested or contaminates an open wound. This is a true emergency because the radioactive material will be able to irradiate internal tissues, causing much more extensive cellular damage. Many radioactive elements become biologically and essentially permanently incorporated into the body's molecules. In addition, elements such as uranium pose a toxic threat, as do nonradioactive heavy metals. Such a situation demands immediate decorporation (Appendix 2).

The third situation is *irradiation*, in which the patient has been subjected to a high flux of gamma rays or x-rays. As such, he is *not* radioactive and no radiation will be detected on his body or his clothes. Any tissue damage he has sustained happened instantaneously and will manifest itself in time. The irradiation may be local, such as exposure of a hand, or total body. The latter situation may give rise to the "radiation syndrome."[4-14] Although the details of the "radiation syndrome" are not relevant to emergency department care, emergency department personnel should be familiar with the early symptoms and note them on the patient's chart.

The gastrointestinal system represents a handy and reliable "dosimeter" which allows the emergency physician to gauge the dose of radiation received by the patient.[5] Low levels of radiation will produce anorexia and nausea. Vomiting, if it occurs, may be delayed for five or more hours. If vomiting begins within one to five hours, it is usually a sign of significant irradiation, with possible serious sequelae. If vomiting begins within one hour, it is indicative of a near lethal irradiation dose; if it begins within minutes of exposure, it is probably a sign of a lethal dose. Thus information on gastrointestinal signs and symptoms — from feelings of anorexia and nausea to vomiting — should be noted on the chart along with the time each began.

The lymphocyte count is a more sensitive "clinical dosimeter" wherever round-the-clock laboratory facilities are available. Consequently a complete blood cell and differential count should be obtained as soon as possible so that subsequent changes can be monitored.[5] Decreases in the absolute lymphocyte count, if they are to occur, are apparent within 24 hr. If the count does not decline below 1,200/cu mm within 24 hr, the patient will require no clinical support; if it falls below 500/cu mm, a severe course can be anticipated; if the lymphocytes disappear within six hours, the dose of radiation was fatal.

RADIATION ACCIDENT PROTOCOL

We present an emergency department radiation accident protocol for the handling of patients believed to be contaminated externally or internally by radioactive materials (Appendix 1). It should go without saying that the steps in the protocol must be practiced *before* a radiation emergency occurs, and that each person on the emergency staff should know his responsibilities and how to carry them out. All necessary equipment (Appendix 3) should be available before an accident occurs or be obtainable between the time the emergency department receives notification that a possibly contaminated victim is on the way and the time that victim arrives.

can be made with two sheets and a plastic sheet as described (Appendix 1).

In either event, several large containers are necessary for collection of the contaminated wash water. Most contamination can be removed by surprisingly small amounts of water, and three five-gallon containers should be adequate. In addition, several plastic-lined, lidded containers are needed for other contaminated materials, such as gauze and gloves.

Decontamination Team

The physician designated as being in charge *must* be familiar in advance with the protocol and all procedures.

The nurse assigned to the decontamination room is responsible for collecting all specimens and measuring vital signs, as well as for assisting the physician.

The radiation safety officer will monitor the patient to determine whether he is contaminated and, if so, to determine where he is contaminated and at what level of activity. He is also responsible for analysis of all swabs of radioactive areas.

A circulating nurse helps label specimens, receives equipment or supplies from the person standing outside the decontamination room, and records data on the patient's contamination and vital signs.

Decontamination Team Preparation

The decontamination team should be outfitted with protective clothes as outlined in the protocol. However, if the patient arrives before that is possible and has life-threatening injuries that must be attended to immediately, the team can treat him as soon as they have put on surgical gloves, gowns, and masks. Rarely is a patient so contaminated that the level of radioactivity is a threat to the medical team. The main goals of precautions taken during decontamination are to prevent the radioactive material from internally contaminating the patient through oral ingestion, inhalation, or open wounds, and to prevent spread of contamination throughout the emergency department and the hospital.

When time and the patient's condition permit it, the decontamination team should prepare as follows:

They should make use of restroom facilities, since they will not be allowed to leave the decontamination room once the patient arrives.

A film badge with the team member's name on it should be attached to the member's street clothes or uniform. Because the protective clothing goes on over street clothes, large or extra-large sizes of surgical trousers and pullover shirts should be available. Water-proof shoe covers should be put on and the cuffs of the trousers taped securely to them. A tab left at the end of the tape will make its removal easier. A surgical gown is then put on, followed by a pair of surgical gloves which are taped to the sleeves of the gown. A surgical hood and mask are adequate to protect the head, hair, and face from contamination: the decontamination procedure should never be so sloppy that goggles are necessary. The second pair of surgical gloves is not taped down because they must be changed during decontamination if they are torn or if the radiation safety officer finds they are badly contaminated.

Finally, a dosimeter with the wearer's name on it should be attached to the outside gown at the neck where it can be read easily but is not likely to be contaminated.

Patient Arrival

The emergency physician in charge and the radiation safety officer should meet the ambulance at the entrance to the emergency suite. The physician's primary task at this point is to determine whether the victim has injuries other than potential radiation injuries and, if he is so injured, how critical those injuries are. While the physician is doing that, the radiation safety officer can determine whether the victim is contaminated. The ambulance attendants should have removed the victim's clothes and left them at the accident site, for a major portion of the contamination is usually found on them. If that was not done, and the victim is contaminated, the physician must decide if the victim's condition permits removal of the clothes inside the ambulance because it, presumably, is already contaminated. If the victim needs immediate medical attention, he is taken, clothed, directly to the decontamination room. When a choice must be made, the care of life-threatening conditions must always take priority over containment of contamination.

While those decisions are being made, other members of the decontamination team should bring the prepared stretcher to the ambulance door. From this point on, we will assume that one victim only is involved, and that he is contaminated. He now becomes "the patient." He is transferred to the stretcher and taken to the decontamination room along the specially prepared route. The ambulance attendants are to remain with the ambulance until checked for contamination by a person designated by the radiation safety officer. If the attendants or the ambulance or both are contaminated, their decontamination is the responsibility of the radiation safety officer and his assistants.

Decontamination of Patient

It is essential that care of serious medical problems take precedence over any attempts to decontaminate the patient. The physician and nurse must do a complete physical examination and attend immediately to the basics of resuscitation and preliminary studies. Only when the patient's condition is stable should they turn to decontamination.

If the patient is still clothed, his clothes should be removed and sealed in a plastic bag. While the radiation safety officer begins to monitor the patient, team members use cotton-tipped applicators to swab the ear canals, nares, and oral cavity. These swabs should be placed in a glass tube, and the tube labeled (patient's name, the time, and the site), stoppered, and placed in a lead container (obtained from the Nuclear Medicine Department) for later monitoring and analysis. The circulating nurse records on a diagram of the body the areas found by the radiation safety officer to be contaminated, along with the meter readings from each site. The patient must be turned so that his back is monitored also. All contaminated areas should be swabbed with cotton-tipped applicators which are then stored as indicated.

The first priority in the decontamination procedure should be contaminated open wounds, for such areas allow for rapid incorporation of radioisotopes. Decorporation procedures should be started (see Appendix 2), and irrigation of the wound should begin with copious amounts of normal saline for at least three minutes. If monitoring shows persistent contamination, irrigation can be continued with normal saline, although substitution of 3% hydrogen peroxide may be more helpful. If repeated monitoring shows that contamination persists, gentle surgical debridement of the surface tissue of the

wound should be done. It need not be too radical, as most of the contaminants will adhere to the outer surface of the wound. Deep debridement and excision should be necessary only when particles or pieces of radioactive material have been imploded into the tissues. Any tissue removed should be placed in a stoppered container which is then placed in a lead container for later analysis.

If radiation material is found in the eyes, gentle irrigation should be undertaken with the stream diverted away from the medial canthus so that it does not force material into the lacrimal duct.

Contaminated nares and ear canals should be gently irrigated with frequent suction so that radioactive material is not forced deeper into those cavities. Radioactive material found in the oral cavity constitutes a medical emergency because, f it reaches the stomach, internal ontamination and incorporation will ccur. Gentle irrigation and suction hould be started promptly with the nouth turned sideways or down (as ne patient's condition allows) so that ne irrigation solution runs out of the nouth and is not swallowed. After ie mouth has been decontaminated, nasogastric tube should be inserted to the stomach in order to determine whether radioactive material is esent. If so, decorporation should started (see Appendix 2), and lave should be instigated with normal ine in small aliquots so that the mach contents are not forced ough the pyloric sphincter.

The skin is naturally the most mon area of the body to be coninated. However, gentle scrubg with soap and tepid water is ally all that is needed to remove contamination. Hot water should be used because it causes cutanevasodilatation, and this increases chances of incorporation. For the reason, a stiff brush should not sed and the area should not be bed to vigorously. If contamina- persists after two or three wash- Lava® soap or a mixture of half and half cornmeal can be used gentle ubrasive in place of the Clorox®, either full strength for areas or diluted for larger can then be used if the conation persists.

air can usually be decontami- with repeated shampooing oap and tepid water. If conition persists, the hair can be d with clippers, but the scalp not be shaved, for any breaking of the skin will allow incorporation.

Removal of Patient from Decontamination Room

After the patient has been medically treated and decontaminated, he should be discharged home or admitted to the hospital, depending on his clinical condition.

The patient's body should be dried thoroughly and all previously contaminated areas should be reswabbed with cotton-tipped applicators, which are then marked "post-decontamination" and stored for later analysis. If the radiation safety officer finds no contamination when he remonitors the patient, new floor coverings are placed from the clean line at the door to the stretcher on which the patient lies (and from the door to a clean stretcher outside the room unless the area outside the room has already been decontaminated). The clean stretcher is brought in; the patient is transferred to it by new attendants (those involved in the decontamination procedure may now be contaminated); and the stretcher and patient are wheeled to the door. After the radiation safety officer makes a final check of the patient and the stretcher (especially the wheels), the patient is wheeled from the room.

Each member of the decontamination team then goes to the clean line and begins to remove his protective clothes in the manner described (Appendix 1).

Radiation Safety Officer

The radiation safety officer and his assistants are responsible for monitoring, and decontaminating if needed, the ambulance and attendants, the route from the ambulance entrance to the decontamination room, and the decontamination room. He should set up procedures and choose an appropriate area in which the attendants can be decontaminated. If only their hands are contaminated, for example, they could enter the decontamination room and wash their hands there. Where possible, the radiation safety officer's assistants should be carrying out those decontamination procedures while the patient is being decontaminated.

The radiation safety officer oversees the disposal of any clothing, sheeting, refuse, and water found to be contaminated.

Finally, he must analyze or have analyzed all medical specimens and swabs in order to determine which radioactive isotopes are present. Such information is essential for the future medical care of the patient. He should also let the decontamination team know the results of analysis of their film badges and dosimeter readings.

24-Hr Advice and Assistance

Each state radiological health department has qualified staffpersons and should be contacted for assistance regarding radiation accidents. Also, the United States Department of Energy maintains regional offices, each with a radiological assistance plan to aid emergency service personnel during radiation accidents. Finally, the Radiation Emergency Assistance Center/Training Site (REAC/TS) provides a 24-hour consultation service to any person requesting advice in handling radiation accidents. REAC/TS can provide telephone advice, send a team of experts to assist at an accident site, or accept a badly contaminated/irradiated patient for transfer to its facilities after the on-site emergency team has provided initial treatment and decontamination. REAC/TS can be contacted 1) by calling (615) 576-3131 Monday through Friday (8:00 am to 4:30 pm); 2) by calling (615) 482-2441 (beeper 241), a 24-hour telephone that rings at the switchboard of the Oak Ridge Hospital; or 3) by writing REAC/TS, Box 117, Oak Ridge, Tennessee 37830. REAC/TS is also a major source of information on the biological effects of radiation, since it maintains a computerized data bank of world-wide reports on accidental, diagnostic, and therapeutic irradiation.

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Appendix 1. *Radiation accident protocol for emergency departments.*

I. Notification
- A. Director of emergency department
  1. Decides whether to implement radiation accident plan
  2. Notifies others (B-E)
  3. Takes charge of victim(s) or designates person to do so
- B. Director of nursing
- C. Radiation safety officer
- D. Security
- E. Informational services

II. Obtain On-Site Information
- A. Number and condition of victims — uncontaminated
- B. Number and condition of victims — contaminated
- C. Type of radioactive isotopes involved
- D. Type of radiation accident
  1. Irradiation
  2. Contamination
  3. Incorporation

III. Emergency Department Preparation
- A. Evacuation of emergency department
  1. All patients or others near route from ambulance entrance to decontamination room to be moved to other areas
     - a. Patients with noncritical problems to waiting rooms or other suitable areas
     - b. Patients with critical problems to another section of emergency department with continued medical supervision and care
     - c. All pregnant or possibly pregnant women to areas free of possible contamination
- B. Preparation for arrival of victim(s)
  1. Floor
     - a. Route from ambulance entrance to decontamination room to be covered with roll of plastic or paper or with sheets, the covering secured to floor with tape
     - b. Above route to be marked off with ropes and marked "radioactive" until cleared by radiation safety officer
  2. Decontamination room
     - a. Room should have separate ventilation system; if not, turn off ventilation (call hospital engineer)
     - b. Floor to be covered smoothly with plastic or paper floor covering (or sheets) secured to floor with tape
     - c. Strip of tape on floor at entrance to decontamination room to delineate contaminated side from noncontaminated side
     - d. Radiation safety officer to designate person with counter to stay at entrance to monitor all personnel, equipment, and samples leaving decontamination room
     - e. Nonessential equipment to be removed from room or covered with plastic
     - f. Light switches and handles on cabinets and doors to be covered with tape
     - g. Charge nurse to designate person to stand outside to obtain supplies for medical and decontamination teams
     - h. Place contamination tray on stretcher or make trough on decontamination table as follows:
       - i. Roll two sheets lengthwise and place along edge and head of table
       - ii. Place plastic sheeting over rolled sheets, tucking it under the sides and head
       - iii. Form ends of plastic sheet at the foot of table into a trough that empties into a large plastic container or wastebasket lined with a heavy plastic bag
       - iv. Elevate head of table or stretcher so that all water runs into container
     - i. Provide large plastic or metal containers with plastic bags to receive discarded contaminated clothes, gauze, supplies, etc
- C. Decontamination team
  1. Physician
     - a. Takes charge of medical problems of patient
     - b. Directs decontamination procedure
  2. Nurse
     - a. Assists physician
     - b. Is responsible for collecting all specimens
       - i. Laboratory (blood for complete blood cell count, typing and cross-matching; urine for analysis, etc)
       - ii. Swabs of contaminated areas (see below)
     - c. Monitors vital signs and records data
  3. Radiation safety officer
     - a. Monitors patient and decontamination team during care of patient
     - b. Responsible for analysis of all swabs of contaminated areas of patient
  4. Circulating nurse
     - a. Assists team as needed
     - b. Labels all specimens
     - c. Obtains all needed supplies from outside decontamination room from persons stationed at door

Appendix 3. *Supplies needed to prepare the emergency department for a contaminated patient.*

I. For Emergency Department Preparation
   A. Rolls of 4-foot-wide plastic sufficient to
      1. Cover floor from ambulance entrance to decontamination room (rolls of paper or sheets can be substituted)
      2. Cover the floor of the decontamination room (rolls of paper or sheets can be substituted)
      3. Prepare several stretchers for contaminated patients
   B. Rolls of 2-inch-wide masking tape to
      1. Secure floor covering
      2. Tape decontamination team's sleeves and cuffs
      3. Cover handles in decontamination room
      4. Make "clean line" at door to decontamination room
   C. Rope to delineate contaminated route from ambulance entrance to decontamination room
   D. "Radioactive" signs to place on rope and on door to decontamination room

II. For Decontamination Room
   A. Decontamination tray, or
   B. Plastic and cotton sheets to make decontamination trough on stretcher
   C. Three 5-gallon containers for wash water
   D. Three large waste containers
   E. Plastic bags to line waste containers
   F. Cotton-tipped applicators
   G. Stoppered glass containers for swabs of contaminated areas
   H. Lead storage containers for stoppered glass containers — obtain from Nuclear Medicine Department
   I. Chart with drawing of patient outline (front and back) for recording of contaminated areas
   J. Clorox®
   K. Lava® soap
   L. Soft scrub brushes
   M. Mixture of ½ Tide®, ½ cornmeal (keep airtight or refrigerate)
   N. 3% hydrogen peroxide

III. For Decontamination Team
   A. Large and extra-large surgical scrub suits
   B. Surgical gowns (waterproof)
   C. Surgical hoods
   D. Surgical masks
   E. Surgical gloves (various sizes)
   F. Waterproof shoe covers
   G. Film badges
   H. Dosimeters

IV. For Radiation Safety Officer
   A. Beta-gamma detector
   B. Alpha detector
   C. Extra batteries for detectors
   D. "Radioactive" tape-labels to mark containers holding contaminated specimens or swabs
   E. "Post-decontamination" tape-labels to mark containers holding relevant swabs

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EXHIBIT 7

ALBUQUERQUE JOURNAL
10/27/91

10/27/91

EMERGENCY

Treating New Mexico's Uninsured Clogs Emergency Rooms

By Rex Graham

JOURNAL STAFF WRITER

RESTAURANT workers, clerks and construction workers with no health insurance increasingly end up in hospital emergency rooms when they get sick or injured, clogging up waiting rooms and wearing down people like Vince Lopez in Española.

Lopez, head nurse in the Española Hospital emergency department, scrubbed blood from the bruised and swollen nose of a patient one recent weekday night. The man was thrown from his motorcycle when a car struck him from behind. He wasn't wearing a helmet. He had no insurance.

The motorcyclist's girlfriend, also uninsured, was motionless on a nearby bed with a broken pelvis.

"I'm double-shifting," Lopez said as he wrapped white gauze around a sutured six-inch cut on the motorcyclist's right leg.

The motorcyclist's ambulance ride, emergency treatment and six-day hospital stay cost $5,364. Neither the man nor his girlfriend have made any payment to Española Hospital for their combined $10,376 bill, said a spokeswoman for Presbyterian Healthcare Services, a non-profit corporation that owns and operates the hospital.

Hospitals across the state are writing off more bad debts due to surging emergency visits. For example, University Hospital in Albuquerque wrote off 82 percent of its emergency charges during its last fiscal year, said Dr. Paul Roth, acting chairman of the Department of Emergency Medicine.

New Mexicans with insurance ultimately end up footing part of the bill for the uninsured as hospitals raise prices to cover bad debts and

MORE: See UNINSURED on PAGE A6

AARON WILSON / JOURNAL

Emergency room residents Toni Genia, middle, and Linda Kelley, interpret the vital signs of a trauma patient during a hectic evening at University Hospital.

Uninsured Bleed Funds From State's Hospitals

CONTINUED FROM PAGE A1

insurance companies raise premiums.

The state's Medicaid system pays hospitalization and doctors' office charges for residents meeting poverty guidelines. But many people with low-paying jobs don't qualify for Medicaid and can't afford insurance. They are increasingly relying on emergency rooms for treatment.

Because of the cost, they're reluctant to go to the non-profit, primary-care clinics that charge a fee based on income, said Liz Baca, executive director of the Gallup-Thoreau-Grants Healthcare System, a non-profit group that receives state and federal grants and city and county funds. "They hesitate to come in, and when they do come in, the illness has gotten out of control and it costs more money to treat."

Busy emergency departments that have difficulty collecting charges from uninsured patients are common throughout the state. Although total hospital admissions plunged 12 percent from 1987 to 1990 due to government and insurance company cost-containment rules, emergency room visits soared.

The federal Consolidated Omnibus Budget Reconciliation Act of 1985 requires all hospital emergency departments and ambulances to treat or transport anyone who asks, regardless of how sick they are or their ability to pay.

The law has had a huge impact in New Mexico, which leads the nation in the number of uninsured at 26 percent of the population.

State statistics show the impact of the 1985 federal law: Lovelace Medical Center, the Albuquerque Presbyterian hospitals and St. Joseph hospitals have watched their emergency department visits jump anywhere from 13 to 28 percent between 1987 and this year, according to estimates by the New Mexico Hospital Association.

Emergency visits at hospitals in Clovis, Santa Rosa and Farmington have jumped 30 percent or more.

While emergency department visits statewide rose a total 14 percent since 1987, hospital admissions dropped almost 12 percent as insurance companies and the federal government discouraged admissions to reduce health costs.

Emergency department managers unanimously agree most of the increase is due to uninsured patients, although hospitals don't have a breakdown on the percentage of patients who lack insurance.

"They go to a doctor's office and they don't have insurance and the doctor says, 'Why don't you go to UNM?'" said Dr. Judith Brillman, clinical director of University Hospital's emergency department at the University of New Mexico.

EMERGENCY ROOM VISITS

Albuquerque hospitals	1987	1991*	Increase
Presbyterian hospitals	46,361	53,566	13 %
Lovelace Medical Center	20,418	28,239	28 %
St. Joseph hospitals	29,931	36,264	17 %
University Hospital	37,627	39,058	4 %
Other N.M. hospitals with 100 or more beds			
Clovis High Plains Hospital	8,995	11,738	30 %
Eastern N.M. Medical Center (Roswell)	19,072	20,534	8 %
Guadalupe Medical Center (Santa Rosa)	8,537	12,482	46 %
Memorial Medical Center (Las Cruces)	30,219	34,689	15 %
St. Vincent Hospital (Santa Fe)	31,344	33,059	5 %
San Juan Regional Medical Center (Farmington)	16,201	24,516	51 %
Total N.M. emergency room visits	380,411	441,987	14 %

* 1991 estimated

Source: New Mexico Hospital Association

CAROL COOPERRIDER / JOURNAL

Española Hospital's emergency visits increased from 8,784 in 1987 to an estimated 10,350 this year. Thirty percent of its emergency department charges are unpaid.

During one recent 3 to 11 p.m. shift, the hospital saw 21 emergency patients, 11 of whom had no insurance.

San Juan Regional Medical Center reported 42 percent of its emergency department charges were for uninsured patients, few of whom paid their bills.

"It's a big hit. Everything else in the hospital has to be priced to make up for it," said San Juan Regional Vice President Richard Kaser. "That means people who have insurance wind up paying a part of that cost."

Some uninsured New Mexicans come to emergency departments with colds and minor aches and pains that could be treated more cheaply at a doctor's office. They are sometimes turned away from doctors' offices if they can't immediately pay.

Others who are uninsured simply don't get care for minor illnesses, which can later fester into major problems.

Emergency doctors agree a growing number of uninsured show evidence of grossly inadequate primary care: rectal bleeding from advanced intestinal cancers, pneumonia, heart disease and other major problems.

Many uninsured women with breast cancer have never had a diagnostic mammogram, which can detect the disease in the early, more treatable stages.

"It's a symptom of a disjointed financing and delivery system," said Howard Shaver, president of the New Mexico Hospital Association. "It's a very expensive way for people to get primary care, and it's not very efficient because people aren't getting long-term care."

A study published last week in the Journal of the American Medical Association found that when low-income patients with no insurance finally do come to a hospital, they cost more to treat than insured patients with the same diagnosis.

The authors suggested care was more expensive because the uninsured often have no family doctor and little medical history to guide their care.

Many uninsured Bernalillo County residents know University

University Hospital emergency room nurse Eve Raily talks to Yvette Armijo, an uninsured patient. Armijo suffered a broken finger recently.

AARON WILSON / JOURNAL

Hospital does not turn away any county resident. And when University Hospital becomes crowded, there's a ripple effect that spreads to hospitals across the county.

The hospital is part of a medical center that receives $35 million a year from the state Legislature and $20 million a year from property taxpayers.

The state's only level-1 trauma center — which means it provides 24-hour-a-day care for multiple trauma patients — University Hospital specializes in patients wounded by gunfire, knifings or traffic accidents. But when those victims arrive, less severely injured or ill patients may be too uncomfortable to wait their turn.

"They get tired of the waits at University Hospital and come to my emergency room," said Dr. Scott Smith, director of the Lovelace emergency department.

Dr. Jon Mustonen, an emergency physician at St. Joseph Medical Center, also said he is seeing more "disgruntled" patients from University Hospital's crowded emergency department.

"We don't turn anybody away, and they know that," Mustonen said.

University Hospital has formed a task force to analyze how its emergency department handles hundreds of tasks, from ordering lab tests to handling discharge paperwork, in the hope of saving time.

"What we want to do is cut those waits," said Roth of the UNM School of Medicine. "Waiting five hours in pain can seem like an eternity."

The Legislature last year tried to address the problem by authorizing insurance companies to offer an inexpensive, bare-bones plan for the working poor. Lovelace Inc. has proposed such a plan, which is awaiting state approval.

"We're all aware of the problem. We're trying to nibble away at the statistics," said Sen. Janice Paster, D-Albuquerque.

Counties use gross-receipts tax revenue to pay hospital care of indigent residents, but a law that went into effect this year allows the money to also be used for primary care.

"To my knowledge, there is not any county taking that option as of yet, but I think they may in the future," said Lea County Manager Scott Vinson.

Another law passed last year relaxed eligiblity requirements for the state Medicaid program to pay for prenatal care for pregnant women and their children less than 1 year old.

But emergency physicians say those changes are Band-Aids. A national health plan is the only long-term solution for providing adequate, efficient care for people who can't afford insurance, many say.

"We have a systematic problem without a simplistic answer," Dr. E. Jackson Allison, president-elect of the American College of Emergency Physicians, said in a telephone interview. "Unfortunately, things will get worse before they get better. Unfortunately, there are going to be some catastrophies in this realm."

He said the government's inability to come up with a national health-care system will force the uninsured to seek care from the only place many of them can get it — emergency rooms.

"It's a bind," Allison said. "They don't belong there, but we realize that if it wasn't for us, they wouldn't be getting care."

Oak Ridge Associated Universities
Medical Sciences Division
Revision 24 May 1991

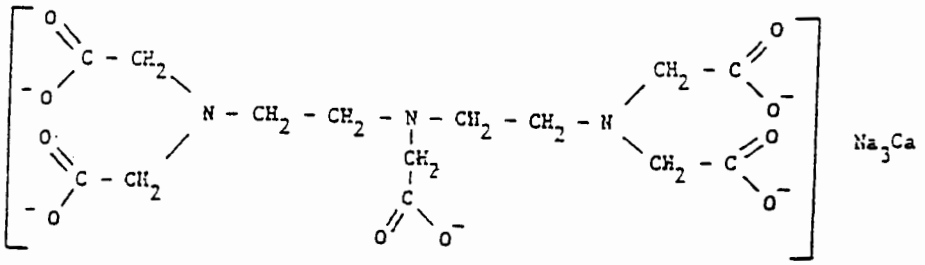
Ca-DTPA (Trisodium calcium diethylenetriamenepentaacetate)

INFORMATIONAL MATERIAL

PACKAGE INSERT

Note: Some vials may be labeled as "Calcium chel 330." This is the same drug.

Structural formula



DESCRIPTION

IND 4041, Trisodium calcium diethylenetriaminepentaacetate (Ca-DTPA), is a calcium salt of DTPA. It has been used in the U.S. as a chelating agent for plutonium and some other various transuranic elements such as americium, californium, and curium. DTPA is also commonly used in lesser concentrations as a chelating vehicle radioisotopic in FDA-approved nuclear medicine studies.

The Ca-DTPA is distributed by Oak Ridge Associated Universities (ORAU) under contract with the U.S. Department of Energy (DOE), Contract No. DE-AC05-76OR00033. ORAU manages the FDA Investigational New Drug (IND) authorizations for Ca-DTPA and the analogous Zn-DTPA for (DOE). A review of the use of DTPA drugs (Ca-DTPA and Zn-DTPA) in decorporation therapy in the United States from 1958 through 1987 has been published.[1]

CLINICAL PHARMACOLOGY

DTPA belongs to the group of synthetic polyamino polycarboxylic acids which form stable complexes (metal chelates) with a large number of metal ions. When releasing a metal such as calcium, it binds to another metal of greater binding power and carries it to the kidneys where it is then excreted in the urine.

The plasma half-life of DTPA is 20-60 minutes. Almost the entire administered dose is excreted in 12 hours, with only a small amount bound to plasma proteins, having a half-life of >20 hours. DTPA undergoes only a minimal amount of metabolic change in the body. Only a very minor release of acetate groups has been demonstrated and splitting of ethylene groups has not been detected. Following intravenous administration Ca-DTPA is rapidly distributed throughout the extracellular fluid space. No significant amount of DTPA penetrates into erythrocytes or other tissue. No accumulation of DTPA in specific organs has been observed. There is little or no binding of the chelate by the renal parenchyma, and it is promptly cleared from the body by glomerular filtration. Tubular excretion was not observed. Although the chelate gives useful information on the glomerular filtration rate, the variable percent which is protein bound leads to a measured clearance rate which is lower than that determined by inulin clearance. In stool samples tested with radioactively marked chelating agents, only a very small amount of radioactivity (<3%) was detected.

Ca-DTPA can deplete the body of zinc and to a lesser extent manganese with repeated dosing. The amount of zinc lost is determined by the amount of DTPA and the frequency of dosage. From depletion of these essential trace metals, Ca-DTPA can then interfere with necessary mitotic cellular processes. Over longer time periods, depletion of zinc due to Ca-DTPA therapy has resulted in transient inhibition of a metalloenzyme, B-aminolevulinic acid dehydratase (ALAD), in the blood, although without observable clinical effect. Clinical zinc depletion appears to be avoidable by giving zinc replacement concomitantly.

Ca-DTPA is approximately 10 times more effective than Zn-DTPA for initial chelation of transuranics; therefore, Ca-DTPA should be used whenever larger body burdens of transuranics are involved. Ca-DTPA is the form of choice for initial patient management unless contraindicated. After approximately 24 hours, however, Zn-DTPA is for all practical purposes as effective as Ca-DTPA, since the inefficiency of both agents is about the same. This comparable efficacy, coupled with its lesser toxicity, makes Zn-DTPA the preferred

agent for protracted therapy.

INDICATIONS AND USAGE

Ca-DTPA and Zn-DTPA effectively chelate several transuranium ions (plutonium, americium, berkelium, curium, and californium). Their clinical use has been primarily for treatment of internal contamination with plutonium and americium. One patient contaminated with in excess of 1 mCi of americium had 99% of the total body burden removed with prolonged therapy over 4 years with a combination of Ca-DTPA/Zn-DTPA therapy.[6]

The efficacy of Ca-DTPA and/or Zn-DTPA treatment for plutonium incorporations is good for soluble salts, such as the nitrate or chloride, but is essentially nil for highly insoluble compounds, such as the high-fired oxide. The same characteristics are noted experimentally when a soluble (monomeric) form of plutonium is administered that gradually converts to less soluble (polymeric) forms as it is distributed and deposited in various tissues in the body. Thus, chelation is highly dependent not only on the metal itself, but also on the chemical and physical characteristics of the compound at the time of DTPA administration. Because the efficiency of chelation decreases with time DTPA should be given within 6 hrs of exposure.

CONTRAINDICATIONS

Ca-DTPA is contraindicated for minors, pregnant women, nephrotics, and persons with bone marrow depression. (Such patients may be treated with Zn-DTPA).

Ca-DTPA is not approved under the current IND as a chelator for uranium or neptunium. Incorporation of uranium, an actinide, is not to be treated with DTPA because of the risk of renal damage from the excretion of uranium.[2] DTPA appears to form an unstable complex with neptunium, which actually can contribute to increased bone deposition of this actinide.[3]

WARNINGS AND PRECAUTIONS

1) Ca-DTPA treatment is contraindicated where there is known pre-existing serious kidney disease or depressed myelopoietic function (e.g., pathologic leukopenia or thrombocytopenia).

2) Kidney function should be normal. Urinalysis should be normal prior to each use. If proteinuria, blood or casts are present, discontinue drug administrations.

3) Fractionation of the recommended 1 g dose (several smaller doses per day) is contraindicated.

4) Check blood pressure during infusion.

5) Discontinue drug if diarrhea occurs.

Pregnancy Category D

Teratogenicity and fetal death have occurred in mice following five daily injections of 720-2880 μmol Ca-DTPA/kg given throughout the entire gestation. However daily doses of 360 μmol Ca-DTPA/kg in mice, about 10 times the daily human dose, produced no harmful effects.

Studies of 2 pregnant beagles given daily injections of Ca-DTPA at 30 μmol/kg, a daily dose comparable to 1 g in a 70 kg man, starting at 15 days of gestation until the end of pregnancy, have shown severe effects (especially brain damage in the fetuses).[7]

On the basis of these results and the lesser daily intake of zinc by humans compared to rats and mice, it has been postulated that some toxic effects on the human fetus might occur at the recommended daily dose levels of about 30 μmol Ca-DTPA/kg. In the same experiments Zn-DTPA did not give similar toxicity. Zn-DTPA is preferred and should be used if available to treat a pregnant female with internal transuranic contamination, although it is doubtful that a single or even several well-spaced doses of Ca-DTPA would be harmful to the pregnant female or fetus, especially if prophylactic zinc is given.

ADVERSE REACTIONS

No serious toxicity in man has been reported as a result of over 600 Ca-DTPA administrations in recommended doses. When given repeatedly, with short intervals for recovery, Ca-DTPA treatment in man may cause nausea, vomiting, diarrhea, chills, fever, pruritus, and muscle cramps in the first 24 hours. Anosmia (loss of the sense of smell) was observed in one individual after 123 g of Ca-DTPA over twenty-seven months of therapy and possibly could have been related to zinc depletion. After 100 days of no further DTPA administration, the patient's sense of smell began to return.

OVERDOSAGE

Studies in animals indicate that the toxicity of Ca-DTPA depends on the total dose and the dose schedule. When administered to animals in high doses (>= 2000 μmol/kg - clinical dose range is 10-30 μmol/kg), it can produce severe lesions of the kidneys, intestinal mucosa, and liver, and can even be lethal. Increased toxicity from fractionated dose schedules has been demonstrated in dog experiments in which injections at human dose levels, 5.8 μmol/kg of Ca-DTPA given every 5 hours were fatal as early as four days after the onset of treatment. The most significant injury occurs in the intestinal epithelium. In rats, continuous infusion of similar total doses per day caused death in 8-14 days, but the same dose given as a single daily injection failed to elicit this response. Toxicity in these cases apparently resulted from depletion of the Zn and Mn ions needed in the enzymatic steps leading to DNA synthesis that renews the epithelial cells in the intestinal epithelium. No untoward effects in rats were noted with doses of 100 μmol Ca-DTPA given twice weekly and apparently there was no influence on Zn or Mn concentrations over a 44-week period.

In one patient, long-term, low-dose Ca-DTPA administration, 1 g per week, showed no adverse effects after one month of such administration.[6] Urinary zinc excretion studies suggest that the zinc supply is quickly replenished under this treatment regimen and that any partial depletion of the zinc stores, if it occurs at all, would be transient.

DOSAGE AND ADMINISTRATION

Each dose of Ca-DTPA should be 1 g (4.0 ml). Doses should not be fractionated. The route of administration may be either intravenous injection of the undiluted solution over a period of 3-4 minutes, intravenous infusion (250 ml D5W or normal saline), or inhalation in a nebulizer (1:1 dilution with water or saline). Intravenous administration should not be protracted over more than 2 hours.

Clinical experience has shown that aerosol inhalation of Ca-DTPA is more effective than intramuscular injection, apparently because diffusion to the body from the lung is slower than from muscle, and results in a longer lasting plasma level. The same relationship exists when comparing the effectiveness of aerosol inhalation of Ca-DTPA to intravenous injection.

Ca-DTPA may be administered undiluted by intramuscular injection when intravenous administration is not practical, although significant pain at the injection site has resulted when this route is used. Addition of 1-2% procaine to the undiluted Ca-DTPA prior to intramuscular injection has proven to be helpful.

The chelating efficacy is greatest immediately or within one hour of exposure, when the radionuclide is circulating in or available to the tissue fluids and plasma. However, a post-exposure interval > 1 hour <u>does</u> <u>not</u> preclude the administration and effective action of Ca-DTPA.

Combined Ca-DTPA/Zn-DTPA Therapy Guidelines

It must be noted that this is a general guide for DTPA therapy and that treatment must be specifically tailored for individual patients. Ca-DTPA and Zn-DTPA generally can be thought of as two components of transuranic decorporation therapy. If there is any contraindication to the use of Ca-DTPA, the same dose of Zn-DTPA may be substituted.

A. On assurance that a credible incident has occurred and the exposed person(s) at risk had in all likelihood received internal transuranic contamination:

1. Obtain signature on informed consent form for DTPA therapy (which should cover both Ca and Zn forms).

2. Obtain base-line blood and urine samples (CBC with differential, BUN, serum creatinine, urinalysis and urine radioassay).

3. Administer 1 g (4.0 ml of 0.5 M) Ca-DTPA by the most appropriate route for the particular case.

4. Begin collection of ALL urine and fecal samples for bioassay. Whole body and chest counting should be performed. Blood assays are done if the initial urinalysis was positive for transuranic contamination.

5. If long-term use of Ca-DTPA is contemplated, one should consider the use of supplimental zinc therapy (one 220-mg zinc sulfate tablet daily delivers 50 mg zinc).

6. Repeat doses of 1 g Zn-DTPA daily for up to 5 days if the radioassay data or history indicate the need for additional chelation. Keep in mind that the majority of patients in the past have received only one dose of DTPA.

7. Although no significant side effects of DTPA at the recommended dosage level are known and there are no known contraindications to its use, urinalysis and complete blood counts should be done on the day following each treatment with DTPA, and the patient's pulse and blood pressure also should be monitored to determine any effect of the drug. Bioassay results and any side

effects should be noted and recorded on the standard treatment form and reported to ORAU for the annual DTPA usage survey.

8. Additional tests may be ordered at the discretion of the investigator.

B. Before, during and after chelation therapy, pertinent measurements for radioactivity should be made to determine the efficacy of treatment. By the fifth day, evaluate bioassay data for body-burden estimation and decide whether further chelation is necessary. IF SO, a Zn-DTPA treatment regimen should be implemented.

1. Begin therapy regime by administration of Zn-DTPA on a two-dose per week basis, 1 g Zn-DTPA doses, until such time as excretion rate of transuranic is not increased by Zn-DTPA administration.

2. Wait four to six months, re-establish base-line urinary excretion-rate value and give a 1 g Zn-DTPA dose by an appropriate route. Obtain bioassay of urinary excretion to determine whether the Zn-DTPA increased excretion of the contaminant. IF SO,

3. Begin a second course of Zn-DTPA treatment on a two dose per week basis as in (1) above.

C. If bioassay data indicates that contamination was not in excess of minimally detectable amounts, then further therapy is not recommended.

D. When patient is released from further therapy, he should be followed at the routine intervals established by occupational practice. A urinalysis is recommended at these examinations.

E. It is recommended that at the time of an employment termination, the physician should ascertain at the physical examination the person's plans so he can forward the history to an M.D. of the patient's choice. In addition, the M.D. should offer the person the opportunity to be followed medically by the DOE follow-up system. This should be done in order to ensure continuity of patient care and assist if the person again should again become contaminated and require therapy at another plant. site.

Patients who have received extensive chronic incorporation of transuranics require unusual therapy and will be treated largely according to the discretion of the investigator. In the past, treatment has not exceeded three 1 g doses during any 24-hour period. Doses should be administered by the route considered most appropriate for the particular case.

HOW SUPPLIED

Each ampule provided contains 1 g Ca-DTPA, 0.5 M in 4.0 ml (25%) water. The solution should be clear, colorless, and free of crystalline or other material. The ampules should be stored in a cool place and away from sunlight.

As a part of the management of the IND for Ca-DTPA, chemists at Oak Ridge Associated Universities carry out annual analytical tests on randomly selected ampules of the drug. There is no indication that deterioration, pyrogenicity, or loss of sterility occur when the ampules are stored at room temperature. However, if any problem of this nature should be observed, all co-investigators would, of course, be notified immediately. Likewise, any signs of deterioration (discoloration or cloudiness) of the solution or reaction on the part of the patient should be reported at once to one of the persons listed below.

The Food and Drug Administration (FDA) requires that the Sponsor and Manager(s) of the IND be in a position to account for all ampules sent to investigator-physicians. Please, therefore, set up an accounting system on the supplies of Ca-DTPA and be prepared to report your experience annually, including observations on the safety and efficacy of the Ca-DTPA used according to the protocols you submitted with your original request for Ca-DTPA. The Manager(s) of the Ca-DTPA IND will contact you in June each year to obtain your report which will be incorporated into ORAU's summary report to the FDA for the 12-month period.

Questions regarding the use of Ca-DTPA may be referred to one of the following personnel at the Medical Sciences Division of Oak Ridge Associated Universities, P.O. Box 117, Oak Ridge, TN 37831-0117:

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EXHIBIT 9

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● *Paper*

A 42-y MEDICAL FOLLOW-UP OF MANHATTAN PROJECT PLUTONIUM WORKERS

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***Abstract*—Twenty-six white male subjects, who worked with plutonium (^{239}Pu) during World War II at Los Alamos, have been given medical examinations periodically over a period of 42 y to identify potential health effects. Inhalation was the primary mode of Pu exposures. The latest examinations, including urine bioassay and *in-vivo* measurements for radioactivity, were performed in late 1986 and 1987. The average age of the 22 living subjects in 1986 was 66 y. The diseases and physical changes noted in these persons are characteristic of a male population in their 60s. Estimates of individual Pu depositions, including lung burdens, as of 1987 or at time of death range from 52 to 3180 Bq (1.4 to 86 nCi) with a median value of 500 Bq (13.5 nCi). Four persons from the original group had died as of 1987. The causes of death were lung cancer, myocardial infarction, accidental injury, and respiratory failure due to pneumonia/congestive heart failure. Expected deaths based on U.S. death rates of white males, adjusted for age and calendar year, are 9.2 based on U.S. rates (standardized mortality ratio = 0.41). Subsequent to 1987, three additional deaths occurred from atherosclerotic heart disease, lung cancer, and osteogenic sarcoma. The bone sarcoma case is discussed in terms of Pu exposure, the natural incidence of this disease, anatomical location of the tumor, and bone tumors observed in Pu-exposed dogs. Plutonium deposition in this man is estimated to have been below current radiation protection guidelines.**

INTRODUCTION

'HIS REPORT is the fourth in a series of studies that docments the health experience of 26 persons exposed to ^{39}Pu (designated as Pu hereafter) in 1944 and 1945 Hempelmann et al. 1973; Voelz et al. 1979, 1985). They 'orked on the Manhattan Project during World War II : Los Alamos, NM. This Project, which designed and uilt the first atomic bomb, involved chemical and metlurgical research of Pu as well as fabrication of Pu parts.

In 1951–1952, Drs. Louis Hempelmann and Wright angham began these studies of Los Alamos workers who ere judged to have the highest internal depositions of ı as a result of their work in 1944 and 1945 (Hempelann et al. 1973). This early reference describes the status '25 living subjects at the time, but not Subject 15, who ıs deceased and added back into the group in later pub-:ations. Their selection of 26 subjects was based on the story of individual job assignments, work conditions, d the results of Pu measurements in urine samples taken ıring that period.

The purpose of this study is to maintain long-term rveillance of this unique group of workers in order to ımate the Pu deposition throughout their lifetime and maintain detailed medical records. This information can then be used to compare with existing Pu dosimetry models, radiobiological information, and human epidemiologic studies of Pu workers.

The Pu work in 1944–1945 was partly done in chemical fume hoods, but some operations were performed in open rooms. Balances, centrifuges, and other equipment were used with Pu in open rooms; serious Pu contamination of the work rooms resulted from the uncontained nature of these operations. Personal protective clothing and equipment included rubber gloves, coveralls, and half-face respirators. The previous publications of this study series (Hempelmann et al. 1973; Voelz et al. 1979, 1985) described the exposure conditions and individual exposures in more detail.

Inhalation of Pu particles was the principal mode of exposure to this group of workers. Nose swipes taken on these men at work were often found to contain from hundreds to thousands of α counts per minute (Hempelmann et al. 1973). Intake through contaminated wounds was less important; nevertheless, eight of these persons have a history of potentially contaminated wounds and three had contaminated chemical burns (Voelz et al. 1985). In retrospect, only two injury events appear likely to have contributed significantly in Pu uptake: About 70 Bq (2 nCi) of Pu was measured in 1945 in excised tissue from a wound in the left thumb of Subject 20 and about 280 Bq Pu (7.5 nCi) is still measurable in a former wound site of the right index fingertip of Subject 1.

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Table 1. Medical examination procedures.

Interval medical history	Electrocardiogram (resting)
Physical examination	Pulmonary spirometry
Visual acuity test	Sputum cytology
Audiometry	Complete blood count
Roentgenograms	Urinalysis (clinical)
Chest (PA and lateral)	
Pelvis (AP)	Blood chemistry tests[a]
Right femur and knee	
Dental (r. upper 1st. molar)	Lymphocyte subset analysis

[a] Blood chemistry tests include calcium, inorganic phosphorus, glucose, urea nitrogen, uric acid, cholesterol, high density cholesterol, triglycerides, total protein, albumin, globulin, total bilirubin, direct bilirubin, alkaline phosphatase, LDH, SGOT, SGPT, gamma GTP, creatinine, sodium, potassium chlorides, and carbon dioxide.

These Pu-exposed workers have had medical examinations about every 5 y since 1952. This report documents and discusses the results of the latest examinations done in 1986–1987. In addition, information is provided on three individuals who have died since 1987.

METHODS

All 22 living subjects were brought back to Los Alamos for this study during the period from September 1986 to October 1987. Examinations were conducted to determine health status and to update our estimates of their Pu internal depositions.

The medical examinations and clinical tests used in this study are those employed routinely by the Occupational Medicine Group at the Los Alamos National Laboratory. Special samples were also collected for sputum cytology and peripheral lymphocyte subset analyses. The methodology used for the lymphocyte subset study has been previously described (Stewart et al. 1988). Table 1 lists the medical examination procedures performed in this study.

Our estimated Pu deposition in each individual relies on measurements of Pu excreted in urine. All urine was collected during the entire time the individual was in Los Alamos for his examination. The collection time varied from about 24 to 48 h. The samples were analyzed for Pu using the standard radiochemical method used at Los Alamos (Gautier 1987).

The estimation of residual Pu deposition in the whole body was calculated from the urine excretion data using the PUQFUA3 program developed by Lawrence (1987). PUQFUA3 is an acronym that stands for *PU* Body Burden (*Q*) *F*rom *U*rine *A*ssay, Third Version. The whole-body deposition is estimated for each year using all available urine data for the individual. Partitioning of the whole-body deposition to organs is based on autopsy distributions found in Los Alamos workers. Annual effective whole-body and organ dose equivalents were calculated using the models described in ICRP Publication 30, *Limits for Intakes of Radionuclides by Workers* (1979). The annual dose equivalents can then be summed to give the cumulative total dose equivalent through any given year.

Each person was extensively monitored for internal contamination of selected radionuclides. A total of seven direct *in-vivo* measurements was made on each subject. Several of these measurements were made simultaneously, which shortens the time required for the entire procedure to less than 2 h. Table 2 is a summary of *in-vivo* measurement techniques used to measure internal contamination, including the organs of interest measured, some details of the measurement techniques, detectors used, and minimum detectable activity. Hand counts, although listed in Table 2, were not made on persons who previously have had negative hand counts.

Mortality rates of the Manhattan District Pu workers were evaluated in two ways. First, standardized mortality ratios were calculated to compare the number of deaths observed in this group with the number expected based on U.S. white male rates adjusted for age and calendar

Table 2. *In-vivo* measurements for internal contamination (Vasilik and Aiken 1983; Vasilik et al. 1984).

Organ of interest	Energy range for major radionuclides (keV)	Minimum detectable activity (Bq)	Type of detector
A. **33-min count**			
1. Chest	10–140	2035 (^{239}Pu)	Dual 12.7 cm Phoswich
2. Liver	10–200	37 (^{235}U, ^{241}Am)	HpGe[a]
3. Whole body	80–1600	74–111 (fission products)	Ge(Li)[b]
B. **20-min count**			
4. Hand count	10–140	37 (^{239}Pu)	Dual 12.7 cm
	10–140	7 (^{241}Am)	Phoswich
C. **17-min count**			
5. Liver	10–140	NA(^{239}Pu, ^{241}Am)	Single 12.7 cm Phoswich
6. Thyroid	10–200	NA	HpGe[a]
7. Skull	10–140	NA (^{241}Am)	Dual 12.7 cm Phoswich
8. Left ankle	10–200	NA	HpGe[a]

[a] HpGe = Hyperpure germanium crystal.
[b] Large volume (16.5% efficient) lithium-drifted germanium detector.

Table 3. Estimated Pu deposition.

I.D.	Estimated Pu deposition Bq (nCi) 1987	nCi 1982[a]	Total GBq-s (nCi-y) 1987
7	3180 (86)	62	2710 (2320)
3	2550 (69)	95	5480 (4690)
4	2150 (58)	63	3810 (3260)
9	2000 (54)	40	3540 (3030)
8	1780 (48)	34	1280 (1100)
5	1630 (44)	55	3670 (3140)
1	1590 (43)	51	2460 (2110)
6	1590 (43)	42	2250 (1930)
17	1260 (34)	34	2250 (1930)
18	1110 (30)	33	1910 (1640)
16[b]	670 (18)	7	383 (328)
12	560 (15)	18	1020 (876)
10[b]	520 (14)	14	975 (835)
20	480 (13)	39	859 (736)
11	480 (13)	11	882 (755)
19	410 (11)	10	648 (555)
15[b]	370 (10)	10	218 (187)
24	370 (10)	11	499 (427)
21	370 (10)	8	514 (440)
23	310 (8.3)	8	556 (476)
22	290 (7.9)	8	230 (197)
27[b]	270 (7.4)	7	371 (318)
2	270 (7.2)	8	379 (325)
25	180 (4.8)	3	182 (156)
26	110 (3.0)	4	148 (127)
13	52 (1.4)	2	65 (56)
edian	500 (13.5)	12.5	870 (745)

[a] Values in nCi as published in Voelz et al. (1985).
[b] Deceased. Plutonium deposition and total nCi-years estimated ough year of death.

ır using the Monson program (Monson 1974). The l of study date for this analysis was the end of 1986. e second method of evaluation was an internal comison between the mortality in the Pu worker group that of unexposed contemporary Los Alamos workers. selection criteria for the comparison group were: 1) Alamos male workers hired in 1943–1945; 2) born ıin the same range of birth years (1908–1925) as the workers; and 3) without history or evidence of Pu osure. A total of 876 workers met the criteria, and all used in the analyses. Vital status for these workers known through 1983. This internal comparison study made by computing a stratified maximum likelihood ıate of the rate ratio and 95% approximate confidence s using the method of Rothman and Boice (1979).

RESULTS OF DOSIMETRY AND RADIOACTIVITY MEASUREMENTS

Key to our understanding of the internal α radiation in these persons is the estimation of Pu deposition ccurred primarily in 1944–1945 and its subsequent ion in the body. This estimate for these individuals rincipally on measurements of Pu excretion in urine se direct *in-vivo* measurements of ^{239}Pu or ^{241}Am usually have not been above our minimum detection limits.

The estimated Pu depositions in these men at the end of 1987 or through the date of their death cover an interesting spectrum of values from 52 to 3180 Bq (1.4 to 86 nCi). In terms of the former lifetime occupational protection guideline of 1480 Bq (40 nCi), the range is from less than 5% to over 200% of the guideline. The results of the calculation of internal deposition of Pu as of the end of 1987 are listed in Table 3. These values consider all urine samples collected since 1944. Some urine sample results are determined, however, to be outliers by a confirmation process built into the PUQFUA3 program. The Table also lists the published 1982 estimates for comparison (Voelz et al. 1985).

Comparison of the 1982 and 1987 estimates shows the majority have had little change. The 1987 median estimate of 500 Bq (13.5 nCi) is nearly the same as the 1982 median. Subjects 7, 3, 9, 8, 16, and 20 show significant changes between the 1982 and 1987 estimates of Pu deposition. These differences are attributable primarily to the Pu measurements in their latest (1986–1987) urine samples. The 1982 estimate of 259 Bq (7 nCi) deposition for Subject 16 was wrong because an erroneous urine value was used. The 1987 estimate of 670 Bq (18 nCi) is the corrected value. For Subject 20, the Pu excretion in the 1986 sample was much lower (3.7 Bq per 24 h sample) than the 1981 sample (26 Bq per 24 h sample). The 1986 sample was confirmed by later samples. As a result, the 1981 sample is considered to be invalid by the PUQFUA3 confirmation criteria and is not used in calculating the 1987 estimate. Nonconfirmation of the 1981 sample resulted in the lower 1987 estimate.

In addition to estimating the residual internal Pu deposition at a specific point in time, it is particularly useful to integrate the activity deposited in the body over time since exposure. For this purpose we have used the unit gigabecquerel-s. This unit is the summation of Pu α disintegrations in the total body since the initial exposure. In Table 3 are listed the gigabecquerel-s (nCi-y) estimated for each person through 1987 or the year of death. Comparison of the cumulative α disintegrations estimate and the latest 1987 Pu deposition for each individual shows some significant differences in their order and correlation. These differences are probably due to the particle sizes

Table 4. Examples of calculated organ dose equivalents through 1987 for six Manhattan District Pu workers.

ID No.	GBq-s	Dose in sieverts Bone surface	Liver	Lung
3	5480	57	12	38
4	3810	40	8.1	26
18	1910	20	4.1	13
20	859	9	1.8	5.9
24	499	5.2	1.1	3.4
13	65	0.68	0.14	0.45

and chemical forms of the individual exposures as well as an effect of the time intervals between urine samples that influence the PUQFUA calculations.

The gigabecquerel-s estimate for each individual is the basis on which organ dose equivalents are calculated using the methods described in ICRP Publication 30 (1979). Bone surface, liver, and lung doses for selected individuals are listed in Table 4. These calculated doses are provided as examples of organ dose equivalents that may have occurred to these individuals. Such calculations must be recognized as crude estimates with wide margins of error. This is true not only because of errors in estimating the Pu deposition, but also the inestimable differences in internal distribution between organs from one exposed individual to another. This has been shown repeatedly in the autopsy tissue studies. For example, Kathren et al. (1988) reviewed 43 autopsies for ^{239}Pu deposition and showed that the bone content on average was 53 ± 18% of the total in bone plus liver. The range of actual values was from 23 to 97%! Thus, the potential variation in organ distribution from individual to individual is huge. Lung depositions may have even greater variations than in other organs depending on mode of exposure and the physical and chemical characteristics of inhaled particles. We have not found a means to take such individual distributional differences into account in making dose estimates. Thus, a standard calculational model, similar to that described in ICRP Publication 30 but using the average organ partitioning observed from autopsy data from former Los Alamos workers, is used to obtain "standard" values such as shown in Table 4.

Direct *in-vivo* measurements of whole-body and regional body radioactivity generally did not show activity above background, similar to results in previous examinations of this group. This is not particularly surprising because the 1944–1945 exposures were to highly purified ^{239}Pu with little Am or other radionuclides. With currently available methods, the minimum detectable activity of Pu by direct counting is high (see Table 2). Thus, this result is not viewed to be in conflict with the estimates derived by urine bioassay results.

A count of the right hand of Subject 1 showed 280 Bq Pu (7.5 ± 1.4 nCi). This activity is in the tip of his right index finger, the site of a Pu-contaminated wound in July 1944. This result is consistent with earlier measurements reported. There are no physical changes noted at the site of activity.

RESULTS OF MEDICAL STUDIES

All 22 living persons in this study were given comprehensive medical examinations at Los Alamos during the period from September 1986 through October 1987. The ages of these individuals as of the end of 1986 ranged from 61–78 y. The median age was 64 y.

The principal medical findings and health status of these individuals are listed in Table 5. The medical diagnoses are not unusual or unexpected for males above 60 y of age: degenerative joint disease (nine individuals); elevated blood pressure (eight); benign prostatic hypertrophy or chronic prostatitis (six); arteriosclerotic vascular disease in extremities (five); overweight (three); history of skin cancers (including one melanoma) (three); chronic obstructive lung disease in several smokers (three); and coronary artery disease or abnormal electrocardiogram (three). Other diagnoses include Paget's Disease of bone, cataracts, diabetes mellitus, and blindness from glaucoma, each of which was found only in one individual. Cancer was not known, diagnosed, or suspected in any person at the time of examination, except for the past history of skin cancer in three individuals.

Occupational histories on these men do not show significant change since the last two reports (Voelz et al. 1979, 1985). These men are either retired or in current jobs with little or no hazard potential.

Current smoking histories on these men are listed in Table 5. The lifetime cigarette smoking experience is expressed in terms of pack-years. A pack-year results from smoking one pack per day for a period of 1 y. Only two individuals (Subject 4 and 11) were active cigarette smokers at the time of their last examination. Twelve persons are former cigarette smokers; eight individuals have never smoked.

Sputum samples satisfactory for cell studies were obtained from 18 of the subjects. No malignant cells were identified in the samples. Inadequate volume of sputum and/or lack of cells were responsible for unsatisfactory tests for Subjects 18, 19, 24, and 25.

Chest x rays showed minor changes in five individuals, which were interpreted as chronic pulmonary fibrosis and emphysema changes. The small density nodule noted in Subject 3 in 1981 was not present this time. Subject 9 was found to have a nodular density and pleural plaque in his left lung, which may be residual scarring from pneumonia in 1985.

The bone x rays and dental x ray of the right upper first molar did not uncover new pathology. The bone changes associated with Paget's Disease in Subject 9 has not changed significantly in 5 y. Subjects 5, 11, and 13 have each had previously identified sclerotic "bone islands" visualized by x ray. These artifacts have not changed appreciably and are not considered to be significant findings.

The results of the special lymphocyte study have been published (Voelz et al. 1989). The ratios of T-helper (T_H) lymphocytes to T-suppressor (T_S) cells were elevated for 5 of 11 persons with Pu depositions above 500 Bq (13.5 nCi) compared with ratios in the control persons. These differences appeared to be due to a decrease in T_S lymphocytes as a result of altered radiosensitivity, which was demonstrated in cultured cells subjected to *in-vitro* x-ray radiation. The significance of these findings is unknown. Additional studies are needed.

MORTALITY

Four persons in this group of 26 Pu workers had died by the end of 1986. Of these four deaths, two occurred

Table 5. Summary of major medical findings, 1986–1987 examinations.

ID No.	Pu (Bq)	Age (1986)	Smoking history (1982–1986)	Medical events and tests since 1981	Medical diagnoses
1	1590	68	9 pack-years. Quit cigarettes in 1984; 6–8 cigars per day.	Old fibrotic changes and punctate calcifications in chest x ray.	Recurrent bursitis left shoulder. Slight osteoarthritis in hips and spine.
2	270	65	25 pack-years. Quit cigarettes in 1972; smokes 7–8 cigars per day.	Gall bladder resection, 1984.	Mild obstructive lung disease. Hamartoma resection, right lung, 1971.
3	2550	64	91 pack-years. Quit cigarettes in 1986.	Cholesterol = 262 (N = 120–250).	Mild chronic obstructive lung disease, chronic bronchitis, borderline hypertension.
4	2150	66	50 pack-years. One-half pack per day and pipe smoker.	BUN = 35 (N = 8–24); creatinine = 2.1 (N = 0.5–1.5); uric acid = 9.7 (N = 3.9–9).	Mild hypertension being treated. Osteoarthritis of spine and hips. History of benign colon polyps. Retinal hemorrhage, 1980.
5	1630	68	Never	Cataract surgery, 1984.	Hypertension being treated. Slight benign prostatic hypertrophy.
6	1590	66	38 pack-years. Quit cigarettes in 1971; quit cigars in 1977.	Cholesterol = 258 (N = 120–250).	Rectal polyps removed, 1979.
7	3180	78	Never	Cataract surgery, 1985; potassium = 5.5 (N = 3.4–5.2); SGOT = 43 (N = 8–36).	Prostatectomy, 1979; benign prostatic hypertrophy.
8	1780	63	Never	Potassium = 3.0 (N = 3.4–5.2); uric acid = 10 (N = 3.9–9.0); cholesterol = 253 (N = 120–250); triglycerides = 196 (N = 30–170).	Hypertension being treated; overweight.
9	2000	71	27 pack-years. Quit cigarettes in 1982.	Pneumonia and urinary tract infection, 1985; alk. phosphatase, 320 mg dL^{-1} (N = 30–125).	Asymptomatic Paget's Disease in pelvic bones; hypertension; overweight; auto accident (1979), head and neck injuries.
1	480	64	74 pack-years. 1.5–2 packs per day since age 13.	Degenerative joint disease in cervical spine.	Diabetes mellitus since 1975. Chronic bronchitis; chronic obstructive pulmonary disease.
2	560	75	Never	Skin cancers removed from forehead; degenerative joint disease in hips.	Hemorrhoids. Varicose veins in legs. Previous skin cancers on left hand, right cheek. History of hiatal hernia and duodenal ulcer.
	52	69	6 pack-years. Quit cigarettes in 1972.	Malaria, 1985; cholesterol = 272 (N = 120–250); x-ray "bone island" density in ileum increased slightly since 1982.	Malignant melanoma on skin of anterior chest, excised 1971. Benign prostatic hypertrophy.
	1260	64	36 pack-years. Quit cigarettes in 1976.	None	Acute gout, 1966.
	1110	62	Pipe smoker for 30 y, stopped in 1985.	Coronary angioplasty, 1985; ECG—1° AV block and left ventricular strain.	Hypertension, under treatment.
	410	62	Never	Abnormal electrocardiogram, right bundle branch block.	Normal
	480	63	Never	None	Blind from glaucoma, bilateral (1968); benign prostatic hypertrophy.
	370	61	26 pack-years. Quit cigarettes in 1972. Pipe and cigars for 19 y; quit in 1982.	Cholesterol = 269 (N = 120–250); triglycerides = 210 (N = 30–170).	Benign prostatic hypertrophy; moderately overweight.
	290	62	30 pack-years. Quit cigarettes in 1956. Smoked pipe for 26 y; quit in 1980.	Hypothyroidism under treatment since 1985.	Hearing loss at high frequencies.
	310	61	Never	None	Normal
	370	62	Never	None	Chronic prostatitis; kidney stones 1965, 1983, 1985; mild hypertension.
	180	68	43 pack-years. Quit cigarettes in 1980. Smoked pipe for 5 y; quit in 1969.	X ray showed arterial calcification in legs.	Myocardial infarctions, 1979, 1980; coronary bypass surgery, 1980; skin cancers (two)—resected from face.
	110	63	30 pack-years. Quit cigarettes in 1967. Smoked pipe for 31 y; quit in 1974.	Cholesterol = 307 (N = 120–250).	Hypertension under treatment; atherosclerotic artery disease, iliac and femoral arteries; degenerative joint disease, hips and knee.

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SUMMARY OF SUPPLEMENTAL AFFIDAVIT OF
MARION DEMING, R.N.

Marion Deming, a Registered Nurse who recently conducted a survey of hospitals along the WIPP route concerning their emergency preparedness, offers her response to those portions of the affidavit of Robert C. Ricks which address the survey. (¶ 2).

To assess the preparedness of the hospitals to respond to WIPP-related emergencies, Ms. Deming primarily surveyed those health care workers who would be providing direct assistance to contaminated patients. (¶ 10). Through use of a detailed questionnaire, Ms. Deming was able to obtain a wide variety of information, including: (1) general information about each hospital surveyed, such as the numbers of emergency room staff persons and beds, (2) the amount and level of special training received by health care workers, (3) the availability of facilities and supplies necessary to adequately handle a WIPP-related emergency, (4) the availability of pharmaceuticals, especially DTPA, (5) whether baseline health studies have been done for all employees and whether they have been personally fit-tested for protective equipment. (¶¶ 4-8). Ms. Deming concludes that the absence of DTPA, the lack of alpha emitter detectors, the lack of rigorous and detailed hands-on training, and the unavailability of decontamination plans and facilities show that the hospitals fail to realize the serious hazards associated with the transportation of wastes to the WIPP site. (¶ 13).

AFFIDAVIT OF MARION DEMING

I, Marion Deming, being duly sworn and deposed state as follows:

1. I have read the Affidavit of Robert C. Ricks, M.S., Ph.D. Based on my personal knowledge and experience, I wish to comment on portions of his Affidavit.

2. Dr. Ricks, at paragraph seven of his Affidavit, questions the validity of the survey which I conducted regarding emergency preparedness at hospitals along the WIPP route. Dr. Ricks indicates an interest in the survey questions I asked, to whom they survey questions were directed, and a description of the criteria by which the responses were evaluated.

3. As to the questions asked, prior to conducting the WIPP survey, I developed a lengthy Questionnaire for Health Care Workers on WIPP Accident Preparedness. This Questionnaire is attached hereto as Exhibit A.

4. The first part of the Questionnaire asks general questions about each hospital surveyed: the number of emergency room staff persons; the number of radiology staff persons; the number of emergency room beds; the number of operating rooms; the nature of the ambulance service for the area; and whether the fire department is volunteer or professional. The general questions also called for a diagram of the floor plan of the emergency room as well as a diagram of the emergency room entrances. I did make a physical tour of all facilities surveyed.

5. The second part of the Questionnaire contains nine questions related to training. These questions include: whether the training has hands-on drills for proficiency; certification for proficiency; refresher courses and other drills; the numbers of emergency room staff personnel who have received on-site hands-on training; whether the hospital has a policy for addressing radioactive and chemical contamination victims; and the identity of and other information about the radiation safety officer at the hospital.

6. The next section of the Questionnaire includes fourteen questions on facilities and supplies. This portion of the Questionnaire asks about separate decontamination facilities for the emergency room; a separate entrance for contaminated patients; the availability of a separate collection system for contaminated water; the availability of a separate air ventilation and circulation system to avoid contamination of the entire hospital; the availability of alpha detectors and beta/gamma detectors; training on the operation and calibration of these detectors; the availability of special instruments for collection of laboratory specimens from contaminated patients and lead-lined equipment to transport those specimens to a laboratory; the availability of personal protective equipment, including respirators and clothing; training in the use, cleaning and maintenance of respirators; the availability of appropriate floor and wall coverings to isolate any radiation contamination; and the availability of showers and a decontamination area for the staff.

7. The next section of the Questionnaire focuses on pharmaceuticals, and specifically about the availability of DTPA, including in aerosol form.

8. Finally, the Questionnaire contains a section on employee health studies. These questions ask whether baseline health studies have been done for all employees; whether the employees have been personally fit-tested for respirators and other personal protective equipment; and the extent of health insurance coverage for radiation caused illness or other chemical exposure.

9. I was able to complete Questionnaires for all of the New Mexico hospitals along the WIPP route, with the exception of Carlsbad and Hobbs.

10. At each of the hospitals surveyed, I was most interested in obtaining responses from those health care employees who would be providing direct assistance to contaminated patients. For this reason, I primarily surveyed those nurses who were in

charge of the emergency rooms at the time that I was there. I believe that obtaining information from those employees responsible for direct patient care is the best gauge of the preparedness of the hospitals to respond to WIPP-related medical emergencies. If those health care employees are unaware of the required procedures and precautions in treating contaminated patients, all communities along the WIPP route are in danger. In my view, it is irrelevant if the top management of the hospitals have received some information about WIPP-related emergency preparedness, if the employees "in the trenches" do not have this vital information.

11. The criteria I used in developing the survey and in reaching the conclusions I did are the following: 29 C.F.R. Section 1910.120 (OSHA Standards); Mettler, Kelsey, and Ricks, ed., *Medical Management of Radiation Accidents,* C.R.C. Press, Inc., Boca Raton, Florida; and the 1990 training manual developed by the Oil, Chemical and Atomic Workers (OCAW) for employees exposed to plutonium and other forms of radiation at work.

12. Based on the information that I have gained in the course of my survey of the hospitals, I believe the training has tended to minimize the hazards associated with exposure to plutonium, and other forms of radiation. For example, I know that the training conducted at the University of New Mexico Hospital has stated plutonium is only dangerous if eaten. It thus ignores the well accepted fact that if plutonium particles are inhaled, they are also extremely hazardous.

13. The absence of DTPA at the hospitals; the lack of alpha emitter detectors at those hospitals; the lack of rigorous and detailed hands-on training; and the unavailability of decontamination plans and facilities at these hospitals reflect that those in control of WIPP emergency preparedness appear to be taking less than seriously the very real hazards associated with the transportation of wastes to the WIPP site. If plutonium

indeed poses no real health risks, one can only wonder about the expenditure of nearly $1 billion for the construction of WIPP, whose purpose is to dispose safely of radioactive waste.

14. Contrary to Dr. Ricks's statements in his Affidavit that workers exposed to plutonium at DOE facilities have not experienced any increased cancer risk attributable to their exposure to plutonium, a number of scientific studies have reached essentially contrary conclusions. One study found that the death rate of Rocky Flats workers exposed to plutonium and other forms of radiation, as compared with that of Rocky Flats workers who remained unexposed, is 422% higher. This study covered the years 1952 through 1979. Wilkenson, G., *et al.*, "Mortality Among Plutonium and Other Radiation Workers at a Plutonium Weapons Facility," *American Journal of Epidemiology*, 231-50 (1987).

15. Based on discussions that I have had with health care employees at the hospitals I surveyed, I found that they are extremely concerned about facing the very troubling dilemma of choosing between their own health and safety and their obligations to care for the sick and injured. If the transportation of wastes to WIPP takes place before appropriate emergency response procedures, training, and equipment are in place, this dilemma will become reality for all health care workers at hospitals along the WIPP route.

COMMONWEALTH OF PENNSYLVANIA
) ss.
COUNTY OF PHILADELPHIA)

SUBSCRIBED, SWORN TO AND ACKNOWLEDGED before me by Marion Deming this the 4TH day of November, 1991.

X Marion Deming
Marion Deming

Kelly Lynn Pokrass
NOTARY PUBLIC

My Commission Expires:
May 11 1992

QUESTIONNAIRE FOR HEALTH CARE WORKERS
WIPP ACCIDENT PREPAREDNESS

Hospital_____

Address_____

Phone No._____

Number of ER Staff Persons (nurses, techs, physicians, support personnel) _____

Number of Radiology staff_____ Respiratory_____

Lab_____

#ER beds_____

#OR rooms_____

Primary ambulance service/EMTs for area_____

Fire Department volunteer/professional

****

Floorplan/Diagram of ER, ER entrances

EXHIBIT
A

TRAINING

1. How many ER staff persons have had on-site, hands-on training for radioactive and chemical contamination victims?

2. How many persons in other departments have been trained?

3. How long was the training? Lecture segment? Hands-on segment?

4. Have you been post-tested or certified for proficiency?

5. Do you have regularly scheduled refresher courses and drill? How often?

6. Were the drills evaluated?

7. Do you have a provision for training new employees?

8. Does your hospital have a policy for caring for radioactive and chemical contamination victims? Where is it kept? Do you know how to find it?

9. Who is your radiation safety officer? Do you know how to reach this person 24 hrs. a day?

COMMENTS:

FACILITIES/SUPPLIES

1. Does your ER have a separate entrance for contaminated victims?

2. Does your ER have a decontamination room and holding area?

3. How many patients can be accommodated in the decontamination area?

4. Is there a separate water collection system not draining into city water?

5. Does your ER have a non-circulating air-flow system?

6. Do you have an air sampler for chemical contamination analysis?

7. Do you have both beta/gamma and alpha geiger counters? How many of each?

8. Do you know how to operate and calibrate these geiger counters? Are they checked regularly?

9. Do you have special instruments for collection of lab specimens from contaminated patients and lead-lined "pigs" to transport specimens to the lab? Where will you transport them for analysis?

10. Do you have pencil and ring dosimeters? How many?

11. Do you have ample gloves, masks, gowns, waterproof shoe coverings, respirators, waterproof aprons, bunny suits readily available? Are these supplies inventoried regularly?

12. Have staff been trained in respirator use, cleaning, and maintenance?

13. Do you have an ample supply of non-skid waterproof floor and wall covering?

14. Do you have showers and a decontamination area for staff?

COMMENTS:

PHARMACEUTICALS

1. Do you have DTPA available in your hospital? How much?

2. Do you have DTPA in aerosol form?

3. Do you have Prussian Blue available in your hospital?

COMMENTS:

EMPLOYEE HEALTH STUDIES

1. Have baseline health studies been done for all employees?

2. Have you been fit-tested for personal protective equipment and respirators?

3. Have you been specially fitted for respirator?

4. Will your health insurance cover illness caused by radiation or chemical exposure? Does your hospital provide insurance?

COMMENTS:

SUMMARY OF AFFIDAVIT OF
LYNN W. GELHAR

Dr. Gelhar is a Professor of Civil Engineering at Massachusetts Institute of Technology. He is a subsurface hydrologist. The discipline of subsurface hydrology involves the flow and transport of liquids and gases through bodies of rock and, thus, relates to the performance of a geologic repository, because a main path of escape of radioactivity is through ground water. He has sat on the DOE Review Panel for the Office of Health and Environmental Research, the Consultants Panel on Waste Management for the DOE Hanford Site, and the New Mexico Governor's Advisory Committee on the Waste Isolation Pilot Plant. (¶¶ 15-17, 20).

Dr. Gelhar testifies that the bin-scale tests planned for the WIPP cannot be regarded as necessary to demonstrate compliance with regulations applicable to the disposal of radioactive waste, 40 C.F.R. Part 191 B, or hazardous waste, 40 C.F.R. Part 268. (¶ 2).

The bin tests are designed to develop data on gas generation rates and gas composition. The process of performance assessment of the WIPP involves computer modeling development and the examination of radioactivity release "scenarios." These studies have not progressed enough to show that the rate of gas generation in waste is an unknown factor whose improved determination will strongly influence the outcome of the WIPP performance assessment. Thus, there is no scientific demonstration of the need for the bin-scale tests. (¶¶ 26-38).

AFFIDAVIT OF LYNN W. GELHAR

Lynn W. Gelhar under penalty of perjury states as follows:

1. I am a Professor of Civil Engineering at the Massachusetts Institute of Technology.

2. I make this affidavit to demonstrate that the bin-scale tests planned by the Department of Energy ("DOE") to be conducted underground at the Waste Isolation Pilot Plant ("WIPP"), as currently configured, cannot be regarded as necessary to demonstrate compliance with the regulations applicable to the disposal of transuranic radioactive waste, 40 C.F.R. Part 191 B, or hazardous waste, 40 C.F.R. Part 268. I also show herein that there is no necessity to conduct the tests, even if they were expected to provide critical data, underground at the WIPP.

3. To address my qualifications: I received my B.S. degree in Civil Engineering in 1959, my M.S. degree in Civil Engineering in 1960, and my Ph.D. in Civil Engineering in 1964. All of these degrees were received from the University of Wisconsin.

4. I worked for the Soil Conservation Service of the Department of Agriculture as a Civil Engineer in 1959 through mid-1960. In June 1960 I took a position as Junior Engineer with Fairbanks Morse & Co. in Beloit, Wisconsin.

5. In September 1961 I became a Research Assistant and Instructor with the University of Wisconsin. I held this position through the completion of my doctorate studies in mid-1964.

6. In July 1964 through August 1973 I taught first as Assistant Professor and later as Associate Professor of Civil Engineering at the Massachusetts Institute of Technology. During this period I also did research at Stanford University during sabbatical leave in early 1971.

7. In September 1973 through June 1982 I taught at the New Mexico Institute of Mining and Technology in Socorro, first as Associate Professor of Hydrology and later as Professor of Hydrology and Program Coordinator for Hydrology. During this period in January through June 1979 I worked as a part-time member of the New Mexico Environmental Evaluation Group, analyzing the progress of the WIPP project on behalf of the State of New Mexico. Also, in early 1978 I taught during a sabbatical leave at the University of Karlsruhe and at the Ecole des Mines de Paris.

8. In July 1982 I joined the faculty of Massachusetts Institute of Technology as a Professor of Civil Engineering, a position which I now hold. I have also taught during sabbatical leave in 1986-87 at the Royal Institute of Technology, Stockholm, the Federal Institute of Technology, Zurich, and the University of Western Australia.

9. I received the O.E. Meinzer Award from the Geological Society of America in 1987. In 1983 I was elected a Fellow in the American Geophysical Union. I received the Robert E. Horton Award of the American Geophysical Union in 1982. These awards all specifically recognized my contributions in the field of

stochastic subsurface hydrology, that is, the probabilistic treatment of the flow of water through earth and rock.

10. I have served on four technical committees of the American Society of Civil Engineers in the period 1972 through 1984.

11. I have served on three technical committees of the American Geophysical Union in the period 1983 through 1988. I also served as associate editor of the journal, Water Resources Research, in 1981 through 1986.

12. I have served on three technical committees of the International Association for Hydraulic Research in the period 1972 through 1985.

13. I have served on the U.S. National Committee of the International Association of Hydrological Sciences in 1980 through 1985 and in 1981 through 1988 served as associate editor of the journal, Hydrological Science Bulletin.

14. I have been a member of the Geophysics Study Committee of the National Research Council since 1988.

15. At the invitation of the United States Department of Energy ("DOE") I sat on its Review Panel for the Office of Health and Environmental Research in 1983.

16. Also in 1988 I sat on the Consultants Panel on Waste Management for the DOE Hanford Site, in Washington.

17. At the request of the State of New Mexico I was a member of the Governor's Advisory Committee on the Waste Isolation Pilot Plant in 1975 through 1980.

18. I also served as a member of the New Mexico Water Resources Research Institute Review Board in 1975 through 1982.

19. I have published, as author or co-author, approximately 123 scientific articles and presented 122 scientific papers at scholarly meetings. A list of my publications is attached to my resume, which is exhibit A hereto.

20. My particular area of study is the field of subsurface hydrology. Subsurface hydrology comprises the study of the flow and transport of water and other liquids and gases through porous or fractured media, such as bodies of rock and earth. The discipline of subsurface hydrology is directly pertinent to a study of the performance of the WIPP as a geologic repository, because the principal potential path of release of radioactivity is through the dissolution of radionuclides in ground water and the escape of ground water by natural or manmade routes to the biosphere.

21. I have previously examined the WIPP site as part of the early examination by the Environmental Evaluation Group ("EEG"). This investigation led to the publication of a report in 1979.

22. I have now been retained as a consultant on behalf of the State of New Mexico to review and comment upon the scientific significance of the bin-scale tests. In studying the issues I have examined the following materials:

a. 40 C.F.R. Part 191

b. Test Plan: Alcove CH TRU Tests (SAND 90 8499)

c. Test Plan: Bin CH TRU Tests (SAND 90 8500)

d. Test Plan: Performance Assessment (DOE WIPP 89-011)

e. Test Plan Addendum #1: Bin scale tests (SAND 90-2082)

f. Status Report: Potential for Long-Term Isolation (SAND 90-0616)

g. Preliminary Comparison with 40 C.F.R. Part 191 B. (SAND 90-2347)

h. WIPP Performance Assessment: 1990 Snapshot (SAND 90-2338)

i. Status of the WIPP Project (Neill & Chaturvedi) (Waste Mgmt. '91).

j. WIPP FSAR Addendum (July 1991) (WP 02-9 Rev. 0) (excerpts)

k. Letter, EEG to Hunt (DOE), Aug. 9, 1991

l. Critical Experiments and Time Lines (W.D. Weart, SNL (Aug. 12, 1991)

m. Evaluation of the DOE Plan for Radioactive Experiments and Operational Demonstration at WIPP, L. Chaturvedi, Sept. 1989 (EEG-42)

n. Comments on WIPP and British Thinking Concerning Gas Generation within Nuclear Waste Repositories, A.R. Lappin, Sandia National Laboratories (Nov. 27, 1989).

23. The regulations which set forth the standards applicable to disposal of transuranic waste are published at 40 C.F.R. Part 191 B. These standards were issued by the Environmental Protection Agency ("EPA"). The standards applicable to disposal of untreated hazardous waste are set forth at 40 C.F.R. Part 268.

24. The EPA radiation standards call for a demonstration of compliance which is made by a process known as a "performance assessment." This process seeks to establish that the facility and design will meet specified limits upon the probability and the amount of any release of radioactivity. Specifically, there is a containment requirement, which requires that a release of radioactivity to the biosphere in excess of a stated amount (depending on the total quantity disposed) not have a likelihood of more than one in ten of occurring in the 10,000 years after disposal. It also requires that a release in excess of ten times the stated amount shall not have a likelihood of more than one in 1,000 of occurring in the same time frame. Further, there is a limitation on radiation dosage to a single individual. (40 C.F.R. §§ 191.13(a), 191.15).

25. Compliance with the EPA disposal standards is not required to be demonstrated by means of on-site experiments with radioactive waste. A probabilistic risk analysis is to be used to show compliance.

26. The performance assessment process seeks to identify those events and processes which might give rise to a release, examine the effects of the processes on the disposal system, quantify the possible releases of radioactivity, and estimate the likelihood of releases at varying levels. The final product is a "complementary cumulative distribution function" ("CCDF") -- a graphic representation of the magnitude of all releases of

radioactivity over the forthcoming 10,000 years at various levels of probability.

27. Sandia National Laboratories ("Sandia") is now engaged in carrying out a performance assessment of the WIPP. Under Sandia's approach, a CCDF is to be constructed for each identified "scenario" depicting a possible avenue of release of radioactivity, and it is intended that the individual CCDF's will be added to express the system's overall likelihood of releases of various sizes.

28. To estimate the likelihood and consequences of a release for a particular scenario, Sandia has chosen the course of first developing conceptual models of the various elements of the disposal system that are involved in a particular scenario. The conceptual models are converted to computer model descriptions, which can be used to examine the behavior of elements of the disposal system under different conditions.

29. The release scenarios are then analyzed to determine the degree of importance of various different elements of a release scenario to the ultimate release of radioactivity. This method of analysis is known as sensitivity analysis.

30. The stated objective of the bin-scale tests is to determine the gas generation rate and gas composition from various transuranic waste types over time, in conditions of the presence or absence of brine and other materials. (January 1990 test plan (SAND 90 8500), at 14-15). The purpose is, in other words, to limit the variables to specified waste forms, fixed

amounts of brine, and certain other additions and to ascertain the rate at which these materials generate gas.

31. However, it appears that the performance assessment process has not yet progressed to the point that a sensitivity analysis with respect to the rate of gas generation can be conducted. In these circumstances, it is not possible to state that the rate of gas generation is an unknown factor whose improved determination will strongly influence the outcome of the performance assessment. In a word, there is no scientific demonstration of the need for the bin-scale tests.

32. To explain further, the 1990 Preliminary Comparison says that the status of compliance assessment conceptual models of gas generation by corrosion and by biological means is "preliminary" (Table V-7), which is explained to mean "intuitive and incomplete" (at V-107). Thus, the computer models of these processes are still at an early stage.

33. The 1990 Preliminary Comparison also says that "[s]imulations that incorporate gas are preliminary, and cannot be used to quantify sensitivity of the modeling system to gas generation." (Id. VI-1). Thus, it is not yet possible to show the importance of gas generation to the performance assessment.

34. Two studies in the 1990 Preliminary Comparison involve gas generation, but neither of these indicates that the rate of gas generation is a critical factor in the performance assessment. The first study (at VI-22) depicts gas saturation in various components of the repository. The study does not

appear to vary the gas generation rate to test the importance of that factor and, thus, does not tend to establish the importance of that factor.

35. The second study analyzes flow of (presumably radioactive) brine from the repository into an intruding drill hole using a simplified one-dimensional model. (at VI-28). Gas generation rates were varied in this study between the estimate in a previous Sandia study (Lappin, et al. 1989) and ten percent of that value. The study showed that the most important factor in escape of brine was permeability of an overlying anhydrite layer. The study did not show that the gas generation rate was important to the occurrence of a release of brine, because the results showed that brine would escape both at the maximum gas generation rate and at ten percent of that rate, and that a lesser amount of brine would escape at half the maximum rate. Thus, radioactive brine escapes at all levels of gas generation. This study suggests that the rate of gas generation may not, itself, be an important factor in the outcome of the performance assessment.

36. However, it must be emphasized that the actual future performance of the WIPP repository is a matter whose complexity is hardly approached by the conceptual models represented in the 1990 Preliminary Comparison. The possible release of radioactivity from the repository depends upon highly complex and interrelated actions influenced by the rate of closure of the surrounding rocks, the amount of brine flowing into the

repository, the interaction between brine and waste to produce gas, the consumption of water in gas generation, the permeability of the surrounding rock to gas and to brine as affected by gas pressure, the effect of gas pressure on gas generation, the effect of gas pressure on rock closure, and certainly other factors. Whether all of these elements of the behavior of the repository can ever be modeled with sufficient accuracy so that its future behavior can reasonably be predicted, even probabilistically, is a highly speculative matter. In any case, it has not yet been done to the point that anyone can say that, if the rate of gas generation is better ascertained in tests, we will know whether the facility will pass the EPA radiation standards (or the hazardous waste regulations, for that matter).

37. Sandia's own 1990 Preliminary Comparison makes this point when it says that the studies to date merely illustrate the general approach to a study of the effects of gas generation, that they do not show that gas generation data are critical to a performance assessment, and that further studies are needed after improved conceptual models are developed to describe the interrelated processes of gas generation, brine saturation, salt creep, and permeability:

> "Results presented here for gas generation are preliminary, and are primarily a demonstration of the methodology that will be further developed to assess the effects of gas generation on repository performance. More detailed analyses, requiring two-dimensional modeling of two-phase flow

> following intrusion, will be conducted after the two dimensional version of BRAGFLO is verified. Conceptual models and data must also be developed to describe adequately the coupled processes of gas-generation, brine saturation, and salt creep. For the simulations presented in the preceding sections, gas-generation rates were assumed to be independent of brine saturation. As discussed qualitatively in Chapter V ("Waste Panel Modeling"), gas generation consumes water, and rates will drop as gas displaces brine from the waste. Simulations also assumed that permeability of the anhydrite remains constant, rather than a function of gas pressure that opens pre-existing fractures as gas migrates away from the waste panels. Two-dimensional BRAGFLO simulations will include these two important factors. The importance of other modeling issues (Table V-7) will be assessed through sensitivity analyses." (Id. VI-32 through VI-33).

Until the new conceptual models are developed to describe the interrelated processes, and the "more detailed analyses" are completed, it will not be correct to assert that tests must be done to determine gas generation rates in order to find out whether the WIPP will comply with the EPA disposal standards.

38. Current information appears to indicate that it is not critical to determine the exact rate of gas generation, because the range of expected gas generation rates is sufficiently high to create difficulties with the performance assessment. Recent analyses by Sandia and by the Environmental Evaluation Group point to a rate of gas generation of from 2.5 to 5 moles per drum per year. (Chaturvedi, L., 1989, Evaluation of the DOE Plans for Radioactive Experiments and Operational Demonstration at WIPP: Sept. 1989, Environmental Evaluation Group Report,

EEG-42 at 15-16). At the same time, Sandia has estimated that a gas generation rate of only 0.1 to 0.3 moles per drum per year will give rise to gas pressure in the repository that is equal to lithostatic pressure. (Lappin, A.R., Comments on WIPP and British Thinking Concerning Gas Generation Within Nuclear Waste Repositories, presentation to Radioactive and Hazardous Materials Committee, Nov. 27, 1989). If such pressures are exceeded, as could be the case at the projected gas generation rates, gas pressures would tend to increase the permeability in the vicinity of the repository and thereby increase the likelihood that radioactive brine would escape from the repository.

39. In addition, there appear to be various safety-related and practical constraints which must also be considered in any evaluation of the data to be derived from the underground tests. I understand that the DOE at present is not prepared to conduct the following tests because of such constraints:

a. "wet bin" tests

b. leaching/solubility tests

c. alcove tests

40. The only tests which the DOE appears to be prepared to conduct underground at the WIPP are the dry bin-scale tests. However, these are the least critical tests to the performance assessment. The dry bin tests will generate data reflecting the rate of gas generation by waste which is not in contact with brine. Such information relates only to the operational phase

of the repository, prior to permanent disposal, when it is not anticipated that significant quantities of brine will remain in the repository horizon, because brine will be removed by the ventilation system. However, information about the operational phase will not solve supposed performance assessment issues, such as whether the amount of gas generated from brine-soaked waste in a sealed repository will affect the repository's compliance with long-term disposal standards.

41. As another limitation, Sandia has concluded that the bin and instrumentation design are not "inherently safe" and not adequate for operations above 50% of the lower flammability limit (A. Lappin and M. Molecke, Memorandum of Record, April 17, 1991, at 2). Therefore, the equipment is only usable for tests with "wastes for which net gas-generation rates are on the order of 0.1 moles/drum/year," which "essentially permits only radiolytic gas degradation" (Id. 2,4). The effects of radiolytic gas generation are of minor interest compared to the effects of corrosion and biological action in generating gas. Sandia has estimated that only 0.005 moles/drum/year of gas will be produced by radioloysis. (Test Plan: WIPP Bin-Scale CH TRU Waste Tests, SAND 90-8500, at 118 (January 1990)). In comparison, 0.85 moles/drum/year is expected to be produced by microbial action and 1.7 moles/drum/year by anaerobic corrosion. (Lappin, et al., 1990). This is a severe limitation on the bin-scale tests.

42. Further, under the Final Safety Analysis Report Addendum a procedure of test bin gas monitoring and purging with inert gas is required. (FSAR Addendum, dry bin scale tests § 10.1.2). Thus, "experimental bins must be purged if the concentration of any flammable gas within the bin reaches 50% of the lower limit for flammability" (A. Lappin and M. Molecke, April 17, 1991, at 1).

43. Sandia has concluded that "[b]ecause of the purging restraint, it appears that only 'dry' low-organic or other 'low-gas generating' wastes can be tested without modification to the present testing plans and/or the bin and attached instrumentation." (Id. 2). But tests confined to low gas generating wastes will not provide much information about gas generation by all of the waste types that will be in the repository, which is the presumed aim of the tests.

44. Sandia has also concluded that as to high-gas-generating wastes, regular purging of the flammable gases destroys the utility of the test data for the performance assessment:

> "The major consequence of using purging to control bin flammability-safety concerns is to render the resultant data as applicable only to the short-term (early-years) of repository operation. Resultant data interpretations will be of little use for PA [performance assessment] predictive modeling, as claimed by the project,

and may not support initial receipt of such wastes at the WIPP, for purposes of evaluating compliance with 40 C.F.R. 191 Part B" (Id. 3-4. See also pp. 5-8.)

45. It goes without saying that the bin tests do not need to be conducted at the WIPP or underground at all. The bins are to be sealed at the storage site and transported to the WIPP in air-tight conditions. After their arrival, the repository atmosphere will not communicate with the bin atmosphere. The bins will be under positive pressure. The bin tests, as so configured, are independent of the physical location of the bins.

46. The test plans themselves state that the bin-scale tests need not be conducted at the WIPP: "It is not mandatory on a scientific basis that these bin-scale tests be conducted at the WIPP." (January 1990 test plan, at 28).

47. Experimental scientists are trained not to subject others to unnecessary risks. These concerns are particularly acute when dealing with radioactive materials, when considering field experiments in inherently dangerous locations, such as underground mines, and when exposing the public to risks, such as the risks of transporting radioactive materials. In general, such risks should not be created unless the anticipated benefits outweigh the risks. In this instance, the benefits to be gained from the bin-scale tests have not been established and cannot

justify the risks involved. I therefore cannot regard these tests as a responsible scientific effort.

I declare under penalty of perjury that the foregoing is true and correct. Executed: 1 Nov, 1991.

LYNN W. GELHAR

EXHIBIT A

PROFESSIONAL BIOGRAPHY

Lynn W. Gelhar

Currently a Professor in the Department of Civil Engineering at Massachusetts Institute of Technology, he previously taught at New Mexico Institute of Mining and Technology where he headed the graduate program in hydrology. Prior to that he taught at MIT and the University of Wisconsin where he received a doctorate in 1964. Sabbatical leaves included visiting positions at Stanford University, University of Karlsruhe, School of Mines in Paris, Royal Institute of Technology in Stockholm, Swiss Federal Institute of Technology, University of Western Australia and the Commonwealth Scientific and Industrial Research Organization in Australia.

His research activities encompass a broad range of basic and applied topics including early fluid mechanics studies on turbulent and stratified flows. Groundwater research areas include: dispersion in nonuniform flow, stochastic analysis of temporal and spatial variability, saline water development, hydrogeochemical modeling of irrigation return flow salinity control, geothermal flow simulation, lumped parameter flow and transport models, phreatic aquifer well hydraulics, parameter estimation, tracer test analysis, radioactive waste isolation in bedded salt, and stochastic management models. His current research activities encompass stochastic theories of transport processes for unsaturated flow, fractured media, chemically heterogeneous media, and variable viscosity fluids, controlled field experiments on macrodispersion in aquifers and unsaturated flow, and large-scale supercomputer simulation of flow and transport in heterogeneous porous media.

He is recognized as a leading authority on stochastic subsurface hydrology. In 1982 he received the American Geophysical Union's Horton Award in recognition of his pioneering work in stochastic subsurface hydrology, and in 1983 was elected a Fellow in the American Geophysical Union, cited particularly for work in stochastic methods. In 1987 he was named recipient of the O.E. Meinzer Award by the Geological Society of America for three papers dealing with stochastic methods. He is currently preparing a textbook entitled Stochastic Subsurface Hydrology, to be published by Prentice-Hall, Inc. and has authored over 100 technical publications. He has extensive consulting experience with government and industry on aspects of groundwater hydrology, dealing particularly with problems of hazardous and radioactive waste disposal.

Biographical and Professional Record

LYNN W. GELHAR

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Cambridge, Massachusetts 02139
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Date of Birth: July 15, 1936

Professional Specialization

Groundwater Hydrology
Stochastic Subsurface Hydrology
Groundwater Contaminant Transport

Education

University of Wisconsin, B. S. in Civil Engineering, January 1959
University of Wisconsin, M. S. in Civil Engineering, June 1960
University of Wisconsin, Ph.D. in Civil Engineering, August 1964

Professional Employment

Sabbatical leave, Royal Institute of Technology (KTH), Stockholm; Federal Institute of Technology, Zurich; University of Western Australia, Perth, 6/86-5/87.
Massachusetts Institute of Technology (MIT), Cambridge, Massachusetts,
Professor of Civil Engineering, 7/82 -
Sabbatical leave, University of Karlsruhe and Ecole des Mines de Paris (Fontainebleau), 1/78-7/78
New Mexico Institute of Mining and Technology (NMT), Socorro, New Mexico
Professor of Hydrology and Program Coordinator for Hydrology, 9/76-6/82
Associate Professor of Hydrology, 9/73-8/76
Sabbatical leave at Stanford University, Stanford, California, 1/71-7/71
Massachusetts Institute of Technology, Cambridge, Massachusetts
Associate Professor of Civil Engineering, 7/69-8/73
Assistant Professor of Civil Engineering, 7/64-7/69
University of Wisconsin (UW), Madison, Wisconsin, Research Assistant and Instructor, 9/61-6/64
Fairbanks Morse & Co., Beloit, Wisconsin, Junior Engineer, 6/60-9/61
Soil Conservation Service, USDA, Madison, Wisconsin, Civil Engineer, 1/59-5/60

Honors and Awards

O.E. Meinzer Award, Geological Society of America, 1987
Fellow, American Geophysical Union, 1983
Robert E. Horton Award, American Geophysical Union, 1982
Ford Postdoctoral Fellow, MIT, 1964-1966
National Science Foundation Graduate Fellow, 1964
Tau Beta Pi, Chi Epsilon, Sigma Xi

Academic Experience

Teaching:
- Advanced Subsurface Hydrology (MIT)
- Groundwater Hydrology (MIT)
- Stochastic Methods in Subsurface Hydrology (NMT)

- Flow through Porous Media (NMT)
- Water Quality Modeling (MIT, NMT)
- Groundwater Modeling (NMT)
- Advanced Hydromechanics (MIT)
- Engineering Analysis (MIT)
- Hydrologic Design (UW)

Thesis Supervision: 20 M.S., 23 Ph.D.

Professional Membership and Service

American Society of Civil Engineers
- Groundwater Hydrology Committee, 1972-1976
- Fluid Dynamics Committee, 1974-1976
- Task Committee on Calibration and Verification in Groundwater Modeling, 1974-1977
- Hydraulics Division Awards Committee 1980-1984

American Geophysical Union
- Associate Editor, Water Resources Research, 1981-1986
- Hydrology Section Nominations Committee, 1983
- Search Committee for Water Resources Research Editor, 1984
- Horton Medal Subcommittee, 1984-1988

International Association for Hydraulic Research
- Porous Media Committee, 1972-1977
- Organizing committee for the conference, The Stochastic Approach to Subsurface Flow, Fontainebleau, France, June 1985

International Association of Hydrological Sciences
- U. S. National Committee, 1980-1985
- Associate Editor, Hydrological Sciences Bulletin, 1981-1988

Editorial Board, Transport in Porous Media, 1986-

Co-convener of the Geological Society of America Penrose Conference on Geostatistical Concepts and Stochastic Methods in Hydrogeology, Vancouver, B. C., August 1977

International Groundwater Modeling Center, Butler University, Indiana,
- Technical Advisory Committee, 1983-1986

State of New Mexico
- Governor's Advisory Committee on WIPP (radioactive waste disposal site), 1975-1980
- Water Resources Research Institute Review Board, 1975-1982

U. S. Department of Energy
- Review Panel for Office of Health and Environmental Research, 1983
- Consultants Panel on Waste Management for the Hanford Site, 1988

National Research Council, Geophysics Study Committee, 1988-

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Lynn W. Gelhar

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115. Tompson, A.F.B. and L.W. Gelhar, "Numerical Simulation of Solute Transport in Three-Dimensional, Randomly Heterogeneous Porous Media", Water Resources Research, 26, 10:2541-2562, 1990.

116. Springer, R.K. and L.W. Gelhar, "Characterization of Large-Scale Aquifer Heterogeneity in Glacial Outwash by Analysis of Slug Tests With Oscillatory Responses, Cape Cod, Massachusetts" to be presented at Monterey conference.

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118. Brainard, E.C. and L.W. Gelhar, "Influence of Vertical Flow on Groundwater Transport", Ground Water, in press, 1991.

119. Polmann, D.J., D. McLaughlin, S. Luis, L.W. Gelhar and R. Ababou, "Stochastic Modeling of Large-Scale Flow in Heterogeneous Unsaturated Soils", Water Resources Research, in press, 1991.

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123. Gelhar, L.W., C. Welty and K.R. Rehfeldt, "A Critical Review of Data on Field Scale Dispersion in Aquifers", Water Resources Research, submitted April, 1991.

CONFERENCE PAPERS, INVITED LECTURES, SEMINARS AND WORKSHOPS

Gelhar, L.W., "Continuing Education, the Role of the University," invited paper presented at ASCE Water Resources Engineering Conference, Mobile, Alabama, March 1965.

Gelhar, L.W., and Monkmeyer, Peter L., "Turbulent Helical Flow in an Annulus," paper presented at ASCE Water Resources Engineering Conference, Denver, Colorado, May 1966.

Gelhar, L.W., "Comments on Selective Withdrawal from Density-Stratified Reservoirs," invited discussion paper at ASCE Specialty Conference on Current Research into the Effects of Reservoirs on Water Quality, Portland, Oregon, January 1968.

Ruff, J.F., and Gelhar, L.W., "Turbulent Shear Flow in a Porous Boundary," paper presented at ASCE Water Resources Engineering Conference, Phoenix, Arizona, January 1971.

Gelhar, L.W., "Modeling the Long Island Ground Water System," invited lecture at California Institute of Technology, April 1971.

Gelhar, L.W., "Subsurface Water Quality," invited report at Third Fort Collins International Hydrology Symposium, June 1971.

Collins, M.A., and Gelhar, L.W., "Some Steady State and Transient Characteristics of the Long Island Aquifer Systems as Determined by a Vertical Hele-Shaw Models," paper presented at 19th Annual Specialty Conference of the Hydraulics Div., ASCE, Iowa City, Iowa, August 1971.

Gelhar, L.W., "The Viscous Analog in Ground Water Modelling," invited paper presented at the 20th Annual Specialty Conference of the Hydraulics Div., ASCE, Ithaca, New York, August 1972.

Gelhar, L.W., and Wilson, J.L., "Ground Water Quality Modeling," invited paper presented at Second National Ground Water Quality Symposium, Denver, Colorado, September 1974.

Gelhar, L.W., and Wilson, J.L., "Solute Transport in the Unsaturated Zone," paper presented at AGU Fall Annual Meeting, EOS, Vol. 56, No. 12, p. 979, December 1975.

Gelhar, L.W., "A Comparison of Groundwater Quality Modeling Techniques," invited lecture

at Water Research Center Conference on Groundwater Quality-Measurement, Prediction and Protection, Reading, England, September 1976.

Gelhar, L.W., "Stochastic Analysis of Flow in Aquifers," invited lecture at Symposium on Advances in Groundwater Hydrology, American Water Resources Assoc., Chicago, Illinois, September 1976.

Gelhar, L.W., "Spectral Theory in Analysis of Temporal and Spatial Variability in Groundwater Flow" and "Stochastic Analysis of Macroscopic Dispersion," keynote lectures at the Geological Society of America Penrose Conference on Geostatistical Concepts and Stochastic Methods in Hydrogeology, Vancouver, B.C., August 1977.

Gelhar, L.W., "A Summary of Research in Groundwater Hydrology at New Mexico Institute of Mining and Technology," seminar presented at University of Stuttgart, Stuttgart, Germany, January 1978.

Gelhar, L.W., "Groundwater Quality Models: Review, Calibration and Application," seminar presented at University of Karlsruhe, Karlsruhe, Germany, January 1978.

Gelhar, L.W., "Stochastic Analysis of Groundwater Systems: Temporal Variability," seminar presented at University of Karlsruhe, Karlsruhe, Germany, February 1978.

Gelhar, L.W., "Stochastic Analysis of Spatial Variability in Subsurface Flows," seminar presented at University of Karlsruhe, Karlsruhe, Germany, February 1978.

Gelhar, L.W., "Stochastic Analysis of Macrodispersion in Aquifers," seminar presented at University of Strasbourg, Strasbourg, France, March 1978.

Gelhar, L.W., "Stochastic Analysis of Macrodispersion in Aquifers," seminar presented at University of Stuttgart, Stuttgart, Germany, March 1978.

Gelhar, L.W., "Stochastic Analysis of Macrodispersion in Aquifers," seminar presented at Water Research Centre, Medmenham, England, March 1978.

Gelhar, L.W., "Stochastic Analysis of Macrodispersion in Aquifers," presented at the International Seminar in Hydrology and Water Resources, Caracas, Venezuela, March 1978.

Gelhar, L.W., "Calibration of Lumped Parameter Groundwater Models: Application to the

Mesilla Valley, New Mexico," seminar presented at Ecole des Mines, Fontainebleau, France, May 1978.

Gelhar, L.W., "Stochastic Analysis of Spatial Variability in Subsurface Flows," seminar presented at Ecole des Mines, Fontainebleau, France. May 1978.

Gelhar, L.W., Four lectures presented at Conference sur l'Analyses Stochastique des Ecoulements en Milieu Poreux et la Macrodispersion, Fontainebleau, France, June 1978.

McLin, S.G., and Gelhar, L.W., "Predicting Irrigation Return Flow Water Quantity and Quality with a Lumped Parameter Hydrosalinity Model," Paper H-12 presented at the American Geophysical Union Fall Meeting, San Francisco, Cal., EOS, Vol. 59, 1062, December 1978.

Gelhar, L.W., "Stochastic Analysis of Macrodispersion in Aquifers," seminar presented at the University of Arizona, Tucson, Arizona, February 1979.

Gelhar, L.W., "Calibration of Lumped Parameter Groundwater Models: Application to the Mesilla Valley, New Mexico," seminar presented at University of Arizona, Tucson, Arizona, February 1979.

Gelhar, L.W., "Stochastic Analysis of Subsurface Flow," invited lecture presented at the annual meeting of the American Society of Agronomy, Fort Collins, Colorado, August 1979.

Gelhar, L.W., "Recent Developments in Stochastic Models of Dispersion," presented at the UNESCO Workshop on Radionuclide Field Tests at the University of Arizona, September 1979.

Gelhar, L.W., "Stochastic Analysis of Macrodispersion in Aquifers," seminar presented at the University of Illinois, September 1979.

Gelhar, L.W., "Open Questions on the Groundwater Hydrology and Related Aspects of the WIPP site," presented at the meeting on Geotechnical Consideration for Radiological Hazard Assessment for WIPP sponsored by the Environmental Evaluation Group, State of New Mexico, Albuquerque, New Mexico, January 1980.

Gelhar, L.W., "Stochastic Analysis of Macrodispersion in Aquifers," seminar presented at Colorado State University, March 1980.

Gutjahr, A., and Gelhar, L.W., "Comparisons of Stochastic Models of Subsurface Flow,"

presented at the AGU Spring Meeting, Toronto, Canada, EOS, Vol. 61, No. 17, p. 239, November 1980.

Bakr, A.A., Gelhar, L.W. and five others, "Tracer Test for Determination of Field Dispersivity in a Basalt Interflow," paper presented at the AGU Fall Meeting, San Francisco, Cal., EOS, Vol. 61, No. 46, November 1980.

Gelhar, L.W., "Stochastic Analysis of Macrodispersion in Aquifers," seminar presented at MIT, Cambridge, Massachusetts, June 1981.

Gelhar, L.W., "Stochastic Problems and Methods of Dealing with Spatial Variability in Hydrologic Modeling," invited lecture presented at the AGU Chapman Conference on Spatial Variability in Hydrologic Modeling, Pingree Park, Colorado, July 1981.

Mizell, S.A., Gelhar, L.W., and Gutjahr, A.L., "Stochastic Analysis of Two-Dimensional Groundwater Flow," paper presented at the AGU Chapman Conference on Spatial Variability in Hydrologic Modeling, Pingree Park, Colorado, July 1981.

Yeh, T.C. and Gelhar, L.W., "Effects of Field Variability on Unsaturated Flow," poster paper presented at the AGU Chapman Conference on Spatial Variability in Hydrologic Modeling, Pingree Park, Colorado, July 1981.

Duffy, C.J., and Gelhar, L.W., and Gutjahr, A.L., "Stochastic Analysis of One-Dimensional Solute Transport in a Nonuniform Groundwater Flow Field," paper presented at the AGU Fall Meeting, San Francisco, Cal., EOS, Vol. 62, No. 45, p. 868, December 1981.

Gelhar, L.W., "Three-Dimensional Stochastic Analysis of Macroscopic Dispersion in Anisotropic Porous Media," invited paper presented at the Euromech Colloqium on Flow and Transport in Porous Media, Delft, The Netherlands, September 1981.

Gelhar, L.W., "Stochastic Analysis of Flow and Solute Transport," invited paper presented at the Symposium on Unsaturated Flow and Transport Modeling, Seattle, Washington, March 1982.

Gelhar, L.W., and Axness, C.A., "Stochastic Analysis of Macrodispersion in Three Dimensionally Heterogeneous Aquifers," invited paper presented at American Chemical Society National Meeting, Las Vegas, Nevada, March 1982.

Yeh, T.C., and Gelhar, L.W., "Unsaturated Flow in Heterogeneous Soils," paper presented at

the AGU Spring Meeting, Philadelphia, PA, EOS, Vol. 63, No. 18, p. 328, June 1982.

Gelhar, L.W., "Macrodispersion in Aquifers," lecture presented at research workshop on Hawaii groundwater hydrologic problems, University of Hawaii, June 1982.

Gelhar, L.W., "Stochastic Analysis of Flow in Heterogeneous Porous Media," invited lecture presented at the NATO Advanced Study Institute on Mechanics of Fluids in Porous Media, University of Delaware, July 1982.

Gelhar, L.W., "Stochastic Analysis to Unsaturated Flow: Some Waste Disposal Implications," seminar presented at MIT, Cambridge, Mass., November 1982.

Duffy, C.J., and Gelhar, L.W., "The Power Spectra and Frequency Response of Water Quality Parameters in Groundwater Systems," paper presented at the AGU Fall Meeting, San Francisco, Cal., EOS, Vol. 63, No. 45, p. 936, December 1982.

Gelhar, L.W., "Contaminant Transport Processes at Hazardous Waste Sites," invited lecture presented at the Boston Society of Civil Engineers, Hazardous Waste Section Meeting, April 1983.

Duffy, C.J., and Gelhar, L.W., and Wierenga, P.J., "Stochastic Models for Agricultural Drainage Systems," paper presented at the ASCE Irrigation and Drainage Division Specialty Conference, Jackson, Wyoming, July 1983.

Gelhar, L.W., "Field-Scale Dispersion in Aquifers," invited paper presented at the ASCE Hydraulics Division Specialty Conference, Cambridge, Massachusetts, August 1983.

Gelhar, L.W., "Field-scale dispersion phenomena: porous versus fractured media," paper presented at Basalt Waste Isolation Project Workshop on Field Methods of Assessments of Radionuclide Sorption, Richland, WA, September 1983.

Gelhar, L.W., "Overview of Groundwater Transport Studies," presented at Solid Waste Environment Studies Meeting, Electric Power Research Institute, Phoenix, AZ, November 1983.

Gelhar, L.W., "Stochastic models of unsaturated flow," paper presented at NRC Workshop on Transport through Unsaturated Fractured Rock, University of Arizona, Tucson, AZ, January 1984.

Gelhar, L.W., "Field-scale dispersive transport experiments in the saturated and unsaturated

67(16), p. 286, 1986.

Gelhar, L.W., "Field-scale dispersion in aquifers: stochastic theory, simulations and field observations," seminar presented at University of Western Australia, Perth, February 1987.

Gelhar, L.W., "Stochastic modeling of unsaturated flow and transport," seminar presented at CSIRO Division of Groundwater Research, Perth, Western Australia, March 1987.

Rehfeldt, K.R. and L.W. Gelhar, "Measurements of the small scale hydraulic conductivity of heterogeneous unconsolidated porous material in fully screened wells using a borehole flowmeter," paper presented at the AGU Spring Meeting, Baltimore, MD, EOS, 68(16), p. 303, April 1987.

Ababou, R. and L.W. Gelhar, "Iterative solution of large finite difference systems with random coefficients," paper presented at the First International Conference on Industrial and Applied Mathematics, Paris, France, June 1987.

Gelhar, L.W., Three lectures at the short course on Modeling Pollutant Movement in Groundwater, University of Wisconsin, Sept. 1987.

Gelhar, L.W., "Stochastic analysis of unsaturated contaminant transport," talk presented at the U.S. Nuclear Regulatory Commission, Bethesda, Maryland, September, 1987.

Gelhar, L.W., The macrodispersion experiment at the Columbus, Miss field site, presented at Electric Power Research Institute Meeting on Land and Water Quality Studies, Nashville, October 1987.

Gelhar, L.W., "Field-scale dispersion processes: stochastic theory, numerical experiments and field observations," seminar presented at New Mexico Institute of Mining and Technology, Socorro, October 1987.

Welty, C. and Gelhar, L.W., "Stochastic analysis of the effects of viscosity variability on macroscopic longitudinal dispersivity in heterogeneous porous media," paper presented at the AGU Fall Meeting, San Francisco, CA, EOS, 68(44), p. 1262, November 1987.

Ababou, R., Gelhar, L.W., and McLaughlin, D., "Three-dimensional groundwater flow in random media: direct simulation versus spectral theory," paper presented at the AGU Fall Meeting, San Francisco, CA, EOS, 68(44), p. 1265, November 1987.

Gelhar, L.W., "Field-scale dispersion in aquifers," lecture presented at General Motors Research Laboratory, Warren, MI, January 1988.

Gelhar, L.W., "Stochastic modeling of subsurface contaminated transport," seminar presented at the Conference on Mathematical Modeling of Fate, Transport and Effects of Pollutants in the Environment, Cornell University Center for Applied Mathematics, Ithaca, NY, March 1988.

Ababou, R. and Gelhar, L.W., "Unsaturated moisture plumes in heterogeneous soils: high resolution numerical experiments," paper presented at conference on Validation of Flow and Transport Models for the Unsaturated Zone, Ruidoso, New Mexico, May 1988.

Gelhar, L.W., "The stochastic revolution and model validation," paper presented at conference on Validation of Flow and Transport Models for the Unsaturated Zone, Ruidoso, New Mexico, May 1988.

Gelhar, L.W., "Dispersion in aquifers: stochastic theory, numerical simulations and field experiments," lecture at Shell Development Laboratory, Houston, TX, May 1988.

Ababou, R. and L.W. Gelhar, "A high-resolution finite difference simulator for 3D unsaturated flow," paper presented at VII International Conference on Computational Methods in Water Resources, June 1988.

Gelhar, L.W., "Stochastic theory and modeling experience," presented at INTRAVAL Workshop on Unsaturated Zone Test Cases, Rockville, MD, July 1988.

Gelhar, L.W. and C. Welty, "Stochastic analysis of large scale transport processes," invited lecture at Gordon Research Conference on Modeling of Flow in Permeable Media, Plymouth, NH, August 1988.

Gelhar, L.W., "Analysis of macrodispersion experiments," presented at Electric Power Research Institute Meeting on Land and Water Quality Studies Program, Grants Pass, OR, Sept. 1988.

Gelhar, L.W., Three lectures at short course on Modeling Pollutant Movement in Groundwater, University of Wisconsin, Sept. 1988.

Rehfeldt, K.R., L.W. Gelhar, J.M. Boggs, and J.B. Southard, "Comparison of log conductivity covariance estimates from flowmeter, surface resistivity, streaming potential,

slug test, core, facies, and grain size data", Geological Society of America Annual Meeting, Abstract No. 26108, Denver, October 1988.

Gelhar, L.W., "Application of stochastic methods to flow and transport modeling of unsaturated porous media," talk presented at meeting of NRC Nuclear Safety Research Review Committee, Tucson, AZ, October 1988.

Ababou, R. and L.W. Gelhar, "Convergence of strongly implicit procedure for large random finite difference systems," presented at Workshop on Practical Iterative Methods for Large Scale Computations, University of Minnesota, October 1988.

Gelhar, L.W., "Preliminary results of the MADE large-scale tracer experiment", presented at the Electric Power Research Institute Meeting on The Land and Water Quality Studies Program, Nashville, TN, October 1988.

Ababou, R. and L.W. Gelhar, "Scale-Dependent Variability in Subsurface Hydrology: Self-Similarity and Spectral Conditioning," paper presented at the AGU Fall Meeting, San Francisco, CA, EOS, 69(44), p. 1191, November 1988.

Gelhar, L. W., "Modeling unsaturated flow," three lectures at a MIT workshop presented at U.S. Nuclear Regulatory Commission, Bethesda, Maryland, January 1989.

Gelhar, L. W., "Field-scale dispersion in aquifers," invited lecture at the International Symposium on Contaminant Transport in Groundwater, Stuttgart, April 1989.

Welty, C., and L.W. Gelhar, "Stochastic analysis of the effects of density variability on macrodispersion in heterogeneous porous media", presented at AGU Spring Meeting, EOS Vol 70, No. 15, p. 340, May 1989.

Gelhar, L. W., "Macrodispersion in aquifers," seminar presented at Dartmouth College, Hanover, New Hampshire, June 1989.

Gelhar, L. W., "Field-scale transport processes in aquifers," seminar presented at the University of Nevada, Reno, August 1989.

Gelhar, L. W., Field-scale transport processes in heterogeneous soils," invited lecture at Workshop on Field-Scale Water and Solute Flux in Soils, Ascona, Switzerland, September 1989.

Rajaram, H. and Gelhar, L. W., "Three-dimensional spatial moments analysis of the Borden tracer test," paper presented at the AGU Fall Meeting, San Francisco, California, EOS, 70 (43), p1092, December 1989.

Gelhar, L. W., "Transport in heterogeneous media," invited talk at workshop on Multicomponent Models and Expert Systems, Subsurface Science Program, Department of Energy, Gaithersburg, Maryland, December 1989.

Gelhar, L.W., series of 5 lectures presented at the short course "Flow and Transport in Heterogeneous Porous and Fractured Media", Swiss Federal Institute of Technology, Zurich, March 1990.

Rehfeldt, K.R. and L.W. Gelhar, "Stochastic analysis of dispersion in unsteady flow through heterogeneous porous media", presented at Western Pacific Geophysics Meeting, Kanazawa, Japan, August, 1990.

Gelhar, L.W., "Stochastic characterization of subsurface flows", invited lecture at Fifth Annual Canadian/American Conference on Hydrogeology, Calgary, Canada, September, 1990.

Gelhar, L.W., "Field scale dispersion in aquifers: comparison of theories and experiments", invited lecture at the International Conference on Transport and Mass Exchange Processes in Sand and Gravel Aquifers, Ottawa, Canada, October, 1990.

Miralles-Wilhelm, F., L.W. Gelhar and V. Kapoor, "Effects of hetergeneities on field-scale bidegradation in groundwater", paper presented at Fall AGU Meeting, San Francisco, CA, EOS, 71(43), p. 1304, 1990.

SUMMARY OF AFFIDAVIT OF
ANN S. MAEST

Dr. Maest is an aqueous geochemist who is an independent environmental consultant. She has conducted research in deep-basin brines which are directly relevant to proposed tests at the WIPP site. While at the Environmental Defense Fund she filed joint comments to the EPA on the DOE's RCRA No-Migration Petition. (¶ 2).

Dr. Maest testifies that the bin tests will provide very little, if any, relevant data for determining the long-term safety and viability of the disposal of transuranic waste at the WIPP, because:

1. There is inadequate waste characterization of the test bin materials. (¶¶ 4-7).

2. Only the gas phase will be analyzed during the bin tests. (¶ 8).

3. Test conditions have little relevance to actual repository conditions. (¶¶ 9-12).

4. The bin tests have little relevance to remote-handled transuranic waste. (¶ 13).

5. Laboratory tests would enable closer experimental control and in numerous respects would produce superior results. (¶¶ 14-15).

Dr. Maest points out also that safety factors render the conduct of the tests extremely dangerous, especially to workers at the WIPP site. (¶ 3).

Various safety related constraints have prevented the DOE from being prepared at present to conduct the wet bin, leaching/solubility, and alcove tests. (¶ 39).

The dry bin tests will not generate information relevant to the disposal phase of the repository, because they will not involve waste which is in contact with brine. Thus, they will not help to solve long-term performance assessment issues. (¶ 40).

It also appears that the DOE is limited in its technical ability to test wastes which generate significant amounts of gas and can only measure radiolytic gas degration, which is of minor interest (¶41).

Further, it appears that a gas purging requirement for high gas generating wastes destroys the utility of the test data for the performance assessment. (¶¶ 42-44).

In addition, it is not necessary to conduct the bin tests at the WIPP or underground at all. (¶¶ 45-46).

The benefits to be gained from the bin-scale tests have not been established and cannot justify the risks involved. Dr. Gelhar cannot regard these tests as a responsible scientific effort. (¶ 47).

AFFIDAVIT OF ANN S. MAEST, Ph.D.

I, Ann S. Maest, state under penalty of perjury as follows:

1. I make this affidavit to demonstrate that the proposed bin-scale tests will provide very little information which is useful for conducting a performance assessment of the WIPP site. The bin-scale tests certainly cannot be regarded as necessary to a performance assessment.

2. I am an aqueous geochemist working as a technical environmental consultant in Boulder, Colorado. My area of expertise is the fate and transport of contaminants in groundwater/aquifer and surface water systems. For my dissertation at Princeton University (1984) I conducted high temperature and pressure laboratory experiments that simulated the near-field environment in a high level radioactive water repository. These experiments and subsequent publications investigated the effects of temperature and chelating agents (used to decontaminate radioactive materials and nuclear power plants, etc.) on the transport of radionuclides in subsurface environments. While at the U.S. Geological Survey in Menlo Park, California (1983-1989), I conducted field, laboratory and experimental work and have published on deep-basin brines. This work included geochemical modeling of heavy metal transport and organic complexing under highly saline conditions. These research studies have direct relevance to tests proposed to be conducted at the WIPP site in New Mexico. While at the Environmental Defense Fund in Washington, D.C. (1989-1991), I filed joint comments to the EPA on DOE's RCRA No-Migration Petition for conducting tests at the WIPP site (June 5. 1990) (see Attachment 1).

3. The bin tests, as described in the Test Plan and Final Safety Analysis Report (FSAR) and Addendum will provide very little, if any, relevant data for determining the long-term safety and viability of disposal of TRU waste at the WIPP site. The reasoning for this statement is four-fold: 1) there is inadequate waste characterization of the test bin materials; 2) only the gas phase will be analyzed during the bin tests; 3) test conditions have little relevance to actual repository conditions, and 4) the bin tests have little relevance to RH-TRU wastes. In addition to the scientific inadequacy of the bin tests, safety factors (discussed in the August 9, 1991 Environmental Evaluation Group letter to Arlen Hunt) render the conducting of the bin tests in-situ extremely dangerous, especially to workers at the WIPP site.

4. Inadequate waste characterization. The pre-test waste characterization includes: headspace gas sampling, radionuclide distribution analysis, assay of test wastes, identification of methods for analyzing TRU mixed wastes for RCRA hazardous constituents, use of Real Time Radiography and videotape, and ensuring test wastes comply with WIPP Acceptance Criteria, Revision 3 and TRUPACT II Authorized Methods for Payload Control (FSAR Addendum, pg. 1-6, July 1991). Wastes that fall outside of the "envelope" described by the 12 parameters listed in the FSAR Addendum (pg. 1-6) may either be reprocessed, used in tests without analysis, or an analysis will be performed to show the non-representative wastes can meet Performance Assessment requirements. Although "assay of test wastes" could result in an adequate waste characterization, this term can imply either quantitative or qualitative analysis, and a detailed analytical plan must be submitted before tests begin. "Identification of methods for analyzing TRU mixed wastes..." does not imply that the mixed wastes will actually be analyzed, only that methods will be identified.

5. In the RCRA Conditional No-Migration determination for the test phase, EPA stated that "headspace testing of every drum or individual container on a continuing basis may pose a significant burden on DOE...once sufficient data have been collected, however, EPA will consider the extent to which continued testing is necessary" (55FR47717, Nov. 14, 1990). If continued waste characterization is not deemed necessary, knowledge of the composition of the bin contents will then rely upon "process knowledge." Under previous reliance on process description, DOE predicted that hazardous constituents would not be present, yet subsequent analyses indicated that they were present (55FR13087, Apr. 6, 1990).

6. If starting materials are not fully characterized, starting compositions will be unknown and the mechanisms for the experimental results produced will be unknown. If the mechanisms are unknown, it is impossible to write the reactions and equations required for modeling the fate of waste in the repository. Without adequate waste characterization, the fate and transport of waste in the subsurface (i.e., in the Culebra Dolomite or marker beds) cannot be modeled. Uncertainties about gas generation rate and potential are in large part based on inadequate waste characterization.

7. Only laboratory tests will be able to outline the range of conditions and concentrations that are acceptable or not acceptable for disposal of wastes at WIPP. Wastes to be disposed of can then be characterized to determine if they fall within acceptable ranges, given an assumed aquifer composition and hydrophysicochemical and biological conditions. If wastes do not fall in these pre-determined acceptable ranges, treatment or reprocessing must be conducted. The

bin tests, as described, will provide very little, if any, information necessary to evaluate the fate and transport of wastes in the repository.

8. Only the gas phase will be analyzed during bin tests. Headspace analyses are only acceptable for homogeneous wastes with high vapor pressure where the starting composition and volumes are well known. For heterogeneous mixtures with different partitioning coefficients between liquid and vapor, liquid analyses must also be conducted. The generation of gas in the bins and in the repository, if wastes are emplaced, is a function of changes in the composition of starting materials, including organic sludges and corrosive metal solids and metals in inorganic and organic sludges. Biological reactions do not always result in products that are exclusively in the gaseous phases. For example, acetaldehyde, a soluble metabolite, can form from fermentation of C_2 compounds. Without analysis of the dissolved and solid phases in the test bins during experiments, the reactions taking place in the bin cannot be determined. A rate expression is always written as a function of changes in the starting materials. If the rate is more than first order with respect to the starting materials, an analysis of materials at the end of the experiment will miss important information that relates to the initial rate of gas generation. Therefore, without analyzing changes in the starting materials with time during the experiment, the rate of gas generation cannot be quantitatively determined.

9. Relevance to actual repository conditions. As stated in the Test Plan (Jan 1990), the bin-scale tests "do not directly experience the impacts of the repository environment on waste degradation (p. 28). "Each bin will function as a nominally independent, isolated (emphasis added), and controlled test system." (p.32) "The leak-tight (emphasis added) bins will have a closely controlled and sealed test environment..." (p. 36) Clearly, and as stated in the Test Plan, "it isn't mandatory that bin-scale tests be conducted the WIPP..." (p. 28). Conducting bin tests on the surface in a quarantined, controlled environment would result in better temperature control, easier access for sampling, attainment of quicker results, minimization of costs, and an alleviation of waste transport, repository safety, and retrievability concerns. In light of serious questions concerning the retrievability and safety of underground tests, and the fact that bin test will not "see" repository conditions, laboratory tests and better designed at-surface bin-scale test are the only appropriate tests to conduct to meet the goals of the test plan.

10. As stated in the FSAR Addendum (July, 1991), "The DOE must gather sufficient data during the Bin-Scale Test to demonstrate that no hazardous wastes will migrate beyond the disposal unit boundary for 10,000 years after closure. One of the principal questions...is the rate of gas generation and the potential for gas pressure to exceed lithostatic pressure and cause the rock to

fracture..." (p. 3-3). Experiments designed to determine how much gas will be generated will not, alone, answer questions about the effect of greater than lithostatic pressure building up in the repository. The bin-scale tests will not be able to simulate dissipation of gas into the Salado; only laboratory tests can provide the high pressure gas results needed to determine if gas generation and dissipation will be a major concern for complying with 40CFR191B and for meeting conditions of the final No-Migration Petition. According to experts in the field (John Bredehoeft), even with the laboratory experiments, it is unclear that gas dissipation can be adequately quantified because of the uncertainties associated with the permeability cut-off for the validity of Darcy's flow (see Bredehoeft, J.D., "Will salt repositories be dry?" Eos, 121, 1988). According to Bredehoeft's research, if Darcy flow applies only in the near-field environment, this will minimize brine inflow but maximize potential for build up of greater than lithostatic pressures in the repository. These uncertainties mandate that treatment or reprocessing of wastes that are capable of generating unacceptable levels of gas be seriously evaluated.

11. As discussed in Neill and Chaturvedi ("Status of the WIPP Project", Presented at the Waste Management '91 Conference at Tucson, AZ, March 1991, p. 9), the bin-scale tests will most likely require purging of bins to lower concentrations of flammable gases. The effects of purging on the validity of the bin-scale tests is currently unknown. However, purging will either change the total pressure in the bins or change the composition of gases in the bin or both. This will certainly shift the equilibrium in the purged bins and change the reactant:product ratio, which will likely change the rate and character of gas generation. These changes will likely render the results uninterpretable, although -- as discussed previously -- the results are already expected to be uninterpretable because of inadequate waste characterization and the lack of sampling of non-volatile phases during the bin-scale experiments.

12. The bin-scale tests are also expected to have less relevance to the repository environment because of the composition of the artificial brine being used. The brine composition is described as 95% artificial brine ("Brine A") and 5% actual Salado brine. The artificial brine contains no organic compounds, such as those that may be present in actual Salado brine. The presence of these organic compounds, i.e., acetate, could greatly influence gas generation and consumption. Salado brines must be analyzed for acetate and other metabolites, and these should be added in appropriate amounts to the experiments conducted, both laboratory and bin-scale. In addition, the use of only a small percentage of Salado brine and salt may minimize microbial reactions in the experiments. If anything, microbes present in the Salado should be isolated and inoculated into experiments in concentrated amounts in order to speed up reaction time and minimize the length of the experiments. Finally, the wet bin

tests may be conducted with 10% brine to simulate saturated conditions. However, only <1% brine is allowable according to WIPP Waste Acceptance Criteria, if wastes are to be shipped to another site for disposal after testing.

13. Bin tests have little relevance to RH-TRU wastes. The bin-scale tests, as planned, will not simulate the behavior of RH (remote handled) TRU wastes. RH-TRU wastes are intended to be placed in casks directly into holes in the Salado walls. Although there are smaller amounts of RH-TRU wastes, compared to amounts of CH (contact handled)-TRU wastes, 7500 casks of RH-TRU wastes are proposed to be disposed of at WIPP. These wastes are a greater safety concern than the CH-TRU wastes, and their behavior must be simulated, preferably in laboratory tests, in order to meet requirements of the final RCRA No-Migration petition.

14. Superiority of laboratory tests. The only advantages of the bin-scale tests are that they use actual waste and they are at a scale closer to reality. With adequate waste characterization, actual waste would not need to be used in any tests. Laboratory tests are more reproducible because they are more easily controlled and they can bracket possible acceptable compositional ranges, once waste characteristics are identified. Laboratory tests are the only tests that can predict chemical behavior and transport of hazardous and radioactive constituents in the repository under varying pH, Eh, and pressure regimes. They are also the only means for estimating the importance of chelation and colloidal transport, which are potentially important release mechanisms for contaminants to the surface environment. The effect of organic compounds and solvents, chelating agents and microbial inoculants that are present in actual waste and the repository can be evaluated under more controlled conditions in laboratory experiments. And, as discussed above, only the laboratory test are capable of simulating gas dissipation into the repository -- a very important parameter for determining potential for migration of hazardous or contaminated materials beyond the facility boundary.

15. Finally, and importantly, the bin-scale tests as designed will not allow for separation of the effects of different components of the waste package on gas generation and consumption. As stated in the FSAR Addendum, only laboratory tests can "facilitate quantification of the effects of significant chemical processes under experimental conditions that isolate each process from the effects of other processes, yet are nonetheless realistic" (p. 1-6). Without this isolation of processes, reactions for determining migration potential cannot be written, and transport of contaminants cannot be modeled.

16. In conclusion, based on scientific and safety concerns, the bin-scale tests as designed place considerable and unnecessary risk on human health and will provide very little, if any, interpretable information for determining the behavior of hazardous and radioactive constituents in the repository over time.

I declare under penalty of perjury, that the foregoing is true and correct.

Ann S. Maest

Ann S. Maest, Ph.D.
1085 8th Street
Boulder, CO 80302

Executed in Boulder, Colorado on 18 October, 1991.

JOINT COMMENTS ON THE PROPOSED CONDITIONAL "NO MIGRATION" VARIANCE FROM LAND DISPOSAL RESTRICTIONS TO THE DEPARTMENT OF ENERGY'S WASTE ISOLATION PILOT PLANT (WIPP)

55 Federal Register 13008 (April 6, 1990)

June 5, 1990

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example, the contents of unbroken bottles and vials, and the solvents in crusted sludge will not be accurately detected in the vapor at the top of a drum.

2. Intergranular Brine Exacerbates Gas Generation Problems

The relatively recent recognition that the WIPP repository is not a dry repository but instead contains up to two percent brine,[85] has important implications for gas generation and dissipation, and therefore repository integrity and safety, at WIPP. Brines collected from the floor holes and weeps at WIPP have much higher potassium to magnesium ratios than, and are otherwise geochemically distinct from, fluid inclusions in the Salado Formation.[86] This indicates that intergranular brine may be present in the Salado Formation.

DOE previously believed that brines were only present in fluid inclusions in the salt and that heat would be required to cause migration of these brines toward the waste. In fact, migration of the intergranular brines can be driven solely by pressure gradients and need not be driven only by thermal gradients, which is the case for fluid inclusions. Therefore, the excavations of rooms in the repository has and will continue

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[85] 55 Fed. Reg. 13080, April 6, 1990

[86] Stein, C.L. and Krumhansl, JL 1986. Chemistry of Brines in Salt from the Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico: A Preliminary Investigation, SAND85-0897, Sandia National Laboratories, Albuquerque, New Mexico; and DOE 1989, Draft Supplemental Environmental Impact Statement, Volumes 1 and 2, DOE/EIS-0026-DS, at p. 4-31, Figure 4.10.

to cause brine to migrate to areas where the TRU waste is intended to be stored.

As brine accumulates in the rooms, corrosion of the drums in which the wastes are stored will produce hydrogen gas via oxidation of the canisters. In addition, radiolytic and microbial processes will also produce gas. The low permeability of the Salado and the presence of intergranular brine will inhibit diffusion of gas into the Salado Formation, resulting in back pressure that could cause greater than lithostatic pressure to develop.

This situation is unacceptable in the repository because it may result in, as stated by EPA,[87] near-field fracturing of the Salado, impeding the structural closing of the repository and/or the escape of gases or brines around the shaft and panel seals.

3. Laboratory, Not Repository Experiments, are Needed to Resolve Concerns about Exceeding Lithostatic Pressures

In its proposed variance, EPA stated that the potential for gas pressure exceeding lithostatic "will not be a concern during the test phase."[88] Tests designed to quantify the rate of gas generation alone will not answer questions about the effect of greater than lithostatic pressures on the integrity of the repository (<u>see</u> Section IV.A.). Clearly, if the rooms take up to

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[87] 55 <u>Fed</u>. <u>Reg</u>. 13083, April 6, 1990.

[88] 55 <u>Fed</u>. <u>Reg</u>. 13083, April 6, 1990.

200 years to close around the waste, this cannot be simulated in-situ, and instead requires laboratory experiments to address the effect of the presence of gas at greater than lithostatic pressure in the repository.

The closing of the rooms in the repository is a function of the rate of salt creep, the existence of a pressure gradient between brine in the formation and brine in the excavated areas and the pressure of gases in the repository after waste emplacement.[89] As long as a pressure gradient exists, brines will continue to migrate toward the excavated areas. If gas pressures build up in the rooms containing the waste to greater than lithostatic pressure, this could cause the repository to remain open indefinitely. The complexity and length of time to room closure could vary from 100 years[90] to an indefinite amount of time. This clearly indicates that the process cannot be simulated in-situ, and instead requires laboratory experiments to address the effect on the repository. These experiments should be conducted in high-temperature-and-pressure autoclaves using representative repository materials, brines, and radio-labelled gases.

The release of less than 5 moles/drum/year of gas at a permeability of 10^{-9} to 10^{-8} darcy in the presence of saturated

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[89] Chaturvedi, L, Channell, JK, and Chapman, JB, 1988, "Potential Problems Resulting from the Plans for the First Five Years of the WIPP Project," Waste Management '88, Edited by R.G. Post and M.E. Wacks, Vol 2, pp. 355-364.

[90] Nowak, E.J., 1988, "Assessment of Brine Inflow to WIPP Disposal Rooms," Sandia National Laboratory.

pore spaces in the Salado will lead to mine inflation.[91] In order to avoid this scenario and its negative implications for repository integrity and safety, treatment of the wastes before emplacement should be seriously considered.

J. EPA HAS NOT ADDRESSED SIGNIFICANT BRINE SEEPAGE ISSUES

1. EPA Improperly Accepts DOE's Inaccurate Brine Modelling and Sampling Methods

The second potential long-term migration route of hazardous constituents out of WIPP is via the seepage of brine to usable aquifers or to the surface. EPA currently believes that brine inflow is stress-driven and there is little to no contribution from far-field brine migration. This belief is contradicted by Bredehoeft's[92] and others' views that permeabilities (which have been measured and used in their calculations) in the far-field are low, but that Darcy flow does apply throughout the repository, and brine inflow in the near-field is controlled by far-field permeability. The assumption of Darcy flow in the far-field is thought by EPA to be conservative because it does not result in a zero far-field flow rate and does[93] indicate maximum brine inflow. However, this is not conservative for gas dissipation in to the Salado if the intergranular areas are saturated with brine. What is

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[91] Chaturvedi, 1988.

[92] Bredehoeft, J.D., "Will Salt Repositories be Dry?" Eos, 121, 1988.

[93] Error at 55 Fed. Reg. 13080.

conservative for brine inflow is non-conservative for gas dissipation if the intergranular areas are saturated with brine.

If far-field Darcy flow is assumed, modeling will result in the maximum amount of brine entering the repository rooms but it will allow maximum gas dissipation into the Salado. If Darcy permeability is valid only in disturbed areas but zero far-field permeability is assumed, the model will predict less brine migrating into the rooms, but there will also be less dissipation of gas into the repository. Hence, it is impossible to optimize for both minimum brine inflow and maximum gas dissipation. It is also possible that the question of Darcy flow vs. non-Darcy flow cannot be resolved by field measurements. In addition, there is no consensus among hydrologists about the permeability of cutoffs for the validity of Darcy flow.

There are also problems with the estimation of the amount of brine inflow to the WIPP site. The methods by which the brine is collected are inaccurate and in many cases this may severely underestimate the quantity of brine inflow to the repository. Extensive evaporation was shown to occur during sample collection, and the bailing techniques used to remove the brine did not remove all of the brine in the holes.[94] Both of these conditions underestimate brine inflow. In some cases the volume of brine was estimated by using the height and average diameter of the column instead of physically collecting the brine. Because of salt creep the columns can deform

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[94] SEIS, at p. E-6

significantly, rendering this technique extremely inaccurate. In addition, steady-state brine inflow conditions may be determined only from many years of observation,[95] and because of heterogeneities in the Salado proximal holes produced very different amounts of brine. All these inaccuracies and uncertainties engender very little faith in the measured estimates of brine inflow, which can clearly at this point only be considered minimum values. Better sample collection procedures should be implemented for brine inflow studies conducted during the test period, especially those that minimize evaporation of brine and allow for accurate collection of brine in sample holes.

2. EPA Improperly Accepts DOE's Optimistic Assumptions About the Potential for Dissolution

EPA states that shallow dissolution in the Salado can only occur if halite-undersaturated waters gain access to the Rustler Formation, and that this will not occur because the Rustler/Salado contact contains water that is saturated with respect to halite.[96] However, DOE's SEIS indicates that the total range of total dissolved solids (TDS) in Rustler Formation water varies between 4000 - 300,000 mg/l, that Rustler water

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[95] Deal, D.E., 1988. Brine Seepage to the Waste Isolation WIPP excavations. Conference Waste Management, 1988 Proceeding of Feb. 28-March 3, 1988, University of Arizona.

[96] 55 Fed. Reg. 13081, April 6, 1990.

chemistry is more variable than originally thought, and that more sampling is indicated.[97]

In its proposed variance, EPA described flow as being upward through the Rustler and away from the Salado, and concluded that dissolution of the Salado from Rustler waters should not be a concern.[98] In the SEIS, however, flow is described as being downward toward the Salado if the Bell Canyon and the Rustler were interconnected.[99] This situation could develop as a result of: (1) human intrusion, (2) the development of dissolution features in the Salado and/or (3) the release of a radioactive slurry to the surface. Since there are potentially economic materials present at and near the repository (potash, oil and gas), and because EPA can only assume knowledge of the repository for 100 years after decommissioning and the wastes will remain hazardous for far longer, human intrusion scenarios should be considered during the test phase.

In addition to intergranular brine, water from the Rustler Formation has been shown to leak into the Salado, when no grouting is used, at a rate of 60 ml/second.[100] This is not a non-trivial rate.[101] The concrete-lining and grouting of the

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[97] SEIS, 1989, at p. 4-17.

[98] 55 Fed. Reg. 13081, April 6, 1990.

[99] SEIS, 1989, p. 4-16.

[100] 55 Fed. Reg. 13080, April 6, 1990.

[101] 0.06 l/sec x 60 sec/min x 60 min/hr. x 24 hr./day x 365.25 days/yr x 200 years = 378,691,200 l/200 years = 100 million gallons/200 years.

shafts will limit inflow of Rustler Formation water to the Salado with proper maintenance over the operating life of the facility. However, it is questionable that proper maintenance of the shafts will continue unabated and without fail for 200 years. It is possible that leaking from the Rustler could cause the formation of breccia pipes.[102] Modeling exercises should consider what amount of leaking of undersaturated waters from the Rustler to the Salado can occur without the formation of shallow dissolution feature or breccia pipes.

Only two breccia pipes were tested in the WIPP area. These were found to be related to soluble units overlying the Capitan Reef. EPA's proposed variance considers two scenarios for collapse: formation of caverns inside the Capitan or the influx of water to the Salado from outside sources through fractures. EPA then concludes (based on DOE conclusions) that there is not a potential problem because the Capitan Formation does not underlie the WIPP site. This does not address the second possibility for formation of breccia pipes, the influx of water from outside sources, for instance from the Rustler or along marker beds. More breccia pipes should be examined in the area, and alternative sources of water should be considered and modeled during the test phase.

Related uncertainties involve the chemistry of the backfill materials and the brines. The clays used as backfill

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[102] Conduits to the surface formed from dissolution of salt at depth by waters undersaturated with respect to halite.

materials cannot be modeled using equilibrium thermodynamic models because they are not stoichiometric mineral assemblages. This necessitates that a number of laboratory experiments be conducted with a representative sampling of the backfill materials to determine how it will behave under repository conditions. The dissolved organic carbon content and composition of the brines is not sufficiently known. If hydrocarbon gases are generated, the interaction between these gases and dissolved organic constituents in the brines should be considered during the test phase. A more complete characterization of the organic composition of the Salado brines is indicated.

K. EPA'S CONDITIONAL "NO-MIGRATION VARIANCE" IS ACTUALLY A "TWO-MILES-OF-MIGRATION VARIANCE"

As discussed above, in EPA's proposed variance,[103] Congress established a "no-migration" standard "for as long as the wastes remain hazardous." For WIPP, the Agency interprets "no migration" as allowing migration of two miles in any direction to the boundary of the 4-mile by 4-mile site.[104] Such an interpretation is totally contrary to the congressional intent and can in no way be supported. EPA must reject any interpretation that would allow any wastes to migrate to the boundary of the site.

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[103] 55 Fed. Reg. at 13072-13073.

[104] 55 Fed. Reg. at 13075.

SUMMARY OF AFFIDAVIT OF
MARVIN RESNIKOFF, Ph.D.

Dr. Resnikoff is a physicist who specializes in issues related to the transportation of nuclear waste.

Dr. Resnikoff concludes that the DOE's evaluations of risk associated with the transportation of nuclear waste to the WIPP site greatly underestimate the probability and consequences of a transportation accident. (¶ 2).

Regarding the probability of a transportation accident, the DOE uses an unrealistically low accident rate for trucks. The DOE also incorrectly assumes the probability of an impact and the probability of a fire are independent. The consequences of both events occurring simultaneously is much more severe then if they occur independently. (¶ 14).

The DOE employs an outdated and low number to estimate cancer fatalities resulting from a transportation accident. The present factor employed by the National Academy of Sciences is a factor of four greater. (¶ 20). The DOE exercises conducted in Colorado and Artesia, New Mexico assume a minor accident. A fire and major release would easily overcome the capabilities of emergency personnel whose training in preparation for a radiation related accident is inadequate. The notion that such personnel could be trained and equipped to wash out the lungs of downwind persons who inhale plutonium is preposterous. (¶ 21).

UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF COLUMBIA

STATE OF NEW MEXICO, ex rel. TOM UDALL, Attorney General Plaintiffs, v. JAMES D. WATKINS, Secretary of the Department of Energy, MANUEL LUJAN, JR., Secretary of the Department of the Interior, DAVE O'NEAL, Assistant Secretary of the Department of the Interior, CY JAMISON, Director of the Bureau of Land Management, United States Department of the Interior, Defendants.	)	Civ Action No. 91-2527 (JGP)

Affidavit Of Marvin Resnikoff, Ph.D.

I, Marvin Resnikoff, being first duly sworn, depose and state as follows:

1. I am Senior Associate at Radioactive Waste Management Associates, a private consulting firm based in New York City. Our office is located at 306 W. 38th Street, New York, NY 10018. My resume is attached as Exhibit A. A description of Radioactive Waste Management Associates and a list of our present clients is attached as Exhibit B.

2. I am a physicist and have worked full-time on radioactive waste issues, including high-level waste transportation and storage issues, since 1974. I make this affidavit to show the Court that the Department of Energy's evaluation of risks associated with the transportation of nuclear wastes to the WIPP site greatly underestimates the probability and consequences of a transportation accident.

3. In 1983, I prepared affidavits on behalf of Southwest Research and Information Center in a proceeding before the U.S. District Court regarding the adequacy of the "Preliminary WIPP Transportation Analysis," prepared by Westinghouse for the Department of Energy. Southwest Research and Information Center is a public interest organization based in Albuquerque, New Mexico. I concluded that the WIPP Final Environmental Impact Statement (FEIS) was not adequate in its discussion of the risks associated with the transportation of nuclear wastes to the WIPP site. There, like here, it underestimated the probability and consequences of a transportation accident.

4. In 1990 and 1991 I prepared affidavits on behalf of the Sierra Club Legal Defense Fund in a federal court suit regarding the adequacy of the Department of Energy's Environmental Assessment for shipments of irradiated fuel from Taiwan through Portsmouth, Virginia. In 1986, I prepared an affidavit on behalf of the Northwest Inland Water Resources on the same issue for shipments through West Coast ports. As a result of the latter court action, the U.S. District Court for the District of Washington required the Department of Energy to draft an Environmental Assessment.

5. In addition to the federal court suit of the Sierra Club Legal Defense Fund, I am presently working on high-level waste transportation issues for the Nuclear Waste Projects Office, State of Nevada. These two projects involve transport cask vulnerability and risk assessment. I am also working on a range of low-level waste and nuclear fuel cycle issues.

6. During the two year period 1981-1983, I directed a study on the transportation and storage of nuclear waste for the Council of Economic Priorities, a New York based research organization. The study I co-authored titled, *The Next Nuclear Gamble, Transportation and Storage of Nuclear Waste*, details the hazard of transporting

nuclear fuel and outlines safer options. During the course of this investigation I read hundreds of reports on the transportation and storage of nuclear materials, including every major study published by the Department of Energy, the Department of Transportation and the Nuclear Regulatory Commission. In my present position, I continue to keep abreast of the latest developments in the field of high-level waste transportation and storage.

7. In 1987 I was a consultant to the State of Alaska Attorney General on the subject of air transportation of plutonium. In 1985, I served as a consultant to the State of Utah in preparing comments on the transportation sections of the draft Environmental Assessments for a high-level waste repository in Utah. In 1984, I served as a consultant to the Town and Country Planning Association on the transportation of nuclear fuel through London, and prepared testimony for the Sizewell B Public Inquiry. I have served as a consultant to the Illinois Attorney General on the expansion of the spent fuel pools at GE's Morris Operation and Commonwealth Edison's Zion reactors. I was part of an international team of experts for the State of Lower Saxony, West Germany, the Gorleben International Review, which reviewed the plans of the nuclear industry to locate a reprocessing and waste disposal operation at Gorleben, West Germany. In 1983, I completed a study for the US Environmental Protection Agency on the costs/benefits of recycling plutonium. In 1975 I prepared affidavits on behalf of the New York Attorney General in proceedings before the U.S. District Court, New York, on air shipments of plutonium through New York's Kennedy Airport, and transport of irradiated fuel through New York City. I was an invited speaker at the 1976 Canadian meeting of the American Nuclear Society to discuss the risk of transporting plutonium by air.

8. I have testified over 30 times before State Legislatures and the U.S. Congress as an expert on issues related to nuclear energy, including the economics of reprocessing, the long-term radiation hazards of decommissioning nuclear reactors, and the problems of transporting nuclear materials.

9. Between 1974 and 1981, I was employed as a lecturer at Rachel Carson College, an undergraduate environmental studies division of the State University of New York at Buffalo, where I taught energy courses. During the years 1975- 1977 I also worked for the New York Public Interest Research Group. In 1973 I was a Fulbright lecturer in the area of group theory and particle physics at Universidad de Chile in Santiago, Chile. From 1967 to 1973 I was an Assistant Professor of Physics at the State University of New York at Buffalo. I have written numerous papers in the area of particle physics, performed under grants from the National Science Foundation.

10. In 1965 I graduated from the University of Michigan with a Doctor of Philosophy in Theoretical Physics, specializing in group theory and particle physics. I received a Bachelors of Arts and Masters of Science in mathematics and physics from the same institution.

11. In preparing this affidavit, I have carefully reviewed the Department of Energy's FSEIS[1], the Department's preparations for the proposed shipments of plutonium-contaminated waste to the WIPP facility and a report on nuclear transportation by the Western Governor's Association. I also reviewed the affidavit of Robert C. Ricks in this proceeding. As an independent check of the Department's calculations of the consequences of an accident in transporting plutonium-contaminated waste to the WIPP

1 Department of Energy, *Final Supplemental Environmental Impact Statement, Waste Isolation Pilot Plant*, DOE/EIS-0026-FS, January 1990.

facility, I employed the computer program PATHRAE-T, developed from an Environmental Protection Agency computer code by a Department of Energy contractor[2], to calculate the downwind lung doses due to a credible transportation accident.

12. Since the TRUPACT-II containers have not been tested to destruction, it is impossible to know with certainty how much radioactivity would be released in a severe accident. The Department estimates that 0.02% of the radioactive inventory of three TRUPACT-II containers would be released to the environment in respirable form. This is based on high-level waste cask data. But this argument by analogy is flawed because high-level waste casks are much more sturdily constructed, with at least four inches of stainless steel and at least five inches of lead (or uranium). In contrast, the TRUPACT-II container has 3/4 inches of stainless steel and 10 inches of foam. In a severe accident, a much greater fraction of the contents are likely to be released compared to a high-level waste container. According to estimates by Nuclear Regulatory Commission contractors[3], up to 2.7% of the radioactive contents could be released from the much more ruggedly constructed high-level waste container. In agreement with these estimates, I assume 2.7% of the contents of a TRUPACT-II container could be released to the environment in a severe accident.

13. The Department underestimates the consequences of a transportation accident in several other ways:

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2 RAE85A Sandquist, GM et al, Exposures and Health Effects from Spent Fuel Transportation, RAE-8339/12-1, prepared for the Department of Energy by Rogers & Associates Engineering Corporation, Salt Lake City, November 1985.
RAE85B Sandquist, GM et al, "The PATHRAE-T Performance Assessment Code for Analyzing Risks from Radioactive Wastes," RAE-8339/12-2, Rogers & Associates Engineering Corporation, Salt Lake City, December 1985.

3 WR Rhyne, *etal*, *A Scoping Study of Spent Fuel Cask Transportation Accidents*, NUREG/CR-0811, prepared by Science Applications for the Nuclear Regulatory Commission, June 1979.

a. The SEIS assumes no breach of the TRUPACT-II container. Because of the relatively thin walls for this type B container, a low speed puncture with a hard steel punch could easily breach the container and internal 55-gallon drums.

b. With no breach of the TRUPACT-II container, the SEIS assumes little internal oxygen would be available to combust the contents. The Department's calculations assume that only CO and not CO_2 is generated. In contrast, Nuclear Regulatory Commission contractors assume that nuclear fuel could be oxidized in a high-level waste cask accident.

c. The SEIS does not assume steam will be generated in an accident involving a fire. In a thermal environment, steam could pressurize the 55-gallon drums and be a driving force to expel radioactive particulates. In Appendix D of the SEIS, all Plutonium-contaminated waste is assumed to be solid and dry, yet Appendix B states that some older Plutonium-contaminated waste is damp.

14. The Department has also greatly underestimated the probability of a severe accident in two ways:

a. The Department assumes that the probability of an impact and the probability of a fire are independent. This is incorrect since almost all high impact accidents are associated with fires. The consequence of both events occurring simultaneously is much more serious than the sum of consequences of an impact and of fire.

b. The Department also takes an unrealistically low accident rate for trucks. The overall accident rate assumed by the Department is 1.1×10^{-6} accidents per km travelled. But the accident rate for heavy trucks, greater than five tons, is a factor of 2.5 times greater.

15. If the TRUPACT-II containers and internal 55-gallon drums were damaged and radioactive materials released in a severe accident involving a major fire, the heat would lift a radioactive cloud which would then travel downwind. As the cloud moved downwind, it would disperse and radioactive particulates would settle out. Intake of radioactivity by downwind persons could occur in a variety of ways. Persons downwind would receive a radiation dose by inhaling radioactive materials. This would primarily contribute to a lung dose. Plutonium is an extremely carcinogenic material. In addition, penetrating radiation from the passing cloud would contribute to a dose to the whole body. Depending on the mitigating actions taken, radiation doses could also arise from possible contamination of water supplies and foodstuffs, including milk. Major radiation exposures would arise from ground contamination. Particulates which settle out of the passing cloud would give rise to a penetrating radiation dose which would continue until the area were decontaminated, or the radioactivity decayed to background levels, a period of several hundred years. These latter effects are ignored here. Only the potential lung doses are calculated.

At greater economic cost, it is clearly possible to quarantine and decontaminate an area, thereby lessening the number of health effects. These economic costs were not calculated in the SEIS.

16. Because of the loft due to the heat of a major fire, the highest radioactive concentrations would not occur near the accident, but further downwind. Other factors that must be taken into account are the air turbulence and wind speed. For the calculations conducted here, I assumed radioactivity would be lofted 20 meters under average turbulence (D, Pasquill) conditions. Under these conditions, most of the radioactivity would deposit itself in a broader cigar-shaped pattern within 60 km

downwind. If the meteorological conditions were instead stable, the lung doses would be higher, but the geographic spread would be less.

17. Assuming average turbulence, the lung doses to downwind persons inhaling plutonium are shown in the Figure, Exhibit C. Because I assume a fire lofts plutonium 20 meters in the air, the maximum lung dose is incurred 600 meters downwind, and does not drop to zero until 60 km downwind. The maximum lung dose is 1200 rems, a level likely to cause cancer. In contrast, in Appendix D, SEIS, the Department estimates the maximum dose to be 0.16 rems. This dose would also be increased due to resuspension of plutonium, but I have ignored this effect in my calculations. In addition, I expect an equal number of non-fatal cancers and genetic effects.

18. I have not estimated the total number of cancers that may be incurred. This depends strongly on where and when the accident takes place. If the accident takes place near an urban area, the population density could be higher depending on the time of day (rush hour, business hours).

19. Accident consequences are also a function of the training and equipping of local emergency personnel. Efficient evacuation will mean less persons inhale plutonium contamination. This uncertainty is not reflected in the SEIS.

20. The number of latent cancer fatalities also depends on the assumed dose-response relationship. The dose-response relationship is the relation between population dose in person-rems and the number of resultant cancer fatalities. The Department employs an outdated and low number, 2.8×10^{-4} latent cancer fatalities for each person-rem. The present factor employed by the National Academy of Sciences is a factor of

four greater[4]. Some independent scientists[5] claim the relationship should be greater by a factor of 12. The SEIS does not even recognize the existence of a controversy in the health physics community regarding this dose-effect relationship.

21. In view of the possible consequences of a transportation accident, the training of emergency personnel and general preparation for a radiation-related accident appears pitifully inadequate. The exercises conducted in Colorado Springs[6] assumes a small fire. The exercise program at Artesia, New Mexico also assumes a minor accident.[7] A fire and major release however would easily overcome the capabilities of local emergency personnel. The notion that sufficient emergency personnel could be trained and equipped to wash out the lungs of downwind persons who inhale plutonium, as claimed by Robert C. Ricks[8], is preposterous.

22. Likewise, the view of the Western Governors' Association[9] that "states along the route from the Idaho National Engineering Labs and Rocky Flats are ready for the first test-phase shipments of contact-handled TRU-waste," is seriously open to question. The Western States are assured by "USDOE's commitment to use a strong shipping package." The Western States claim the TRUPACT-II container, coupled with states efforts to prepare for an accident, "makes it unlikely that citizens will be exposed to dangerous levels of radiation." Indeed many components of the Western Governors' accident prevention and emergency preparedness program are desirable, and, if effective,

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4 National Academy of Sciences, *Health Effects of Exposure to Low Levels of Ionizing Radiation, BEIR V*, National Academy Press, 1990.

5 J Gofman, MD, *Radiation-Induced Cancer from Low-Dose Exposure: An Independent Analysis*, Committee for Nuclear Responsibility, San Francisco, 1990

6 Department of Energy, "WIPP Shipment Exercise Program, Full-Scale Exercise," Colorado Springs, Colorado, November 8, 1990.

7 State of New Mexico, Office of Emergency Planning and Coordination, "WIPP Shipment Exercise Program, Full-Scale Highway," September 14, 1991.

8 Robert C. Ricks, "Affidavit of Robert C. Ricks, M.S., Ph.D.," October 25, 1991, US District Court for the District of Columbia, Civil Action No. 91-2527 (JGP).

9 Western Governors' Association, Technical Advisory Group for WIPP Transport, "Report to the Western Governors and Secretary of Energy, Safe Transport of Transuranic Wastes to the Waste Isolation Pilot Plant," funded by the Department of Energy, June 1991.

could reduce the consequences of an accident. Safety audits and avoidance of unsafe driving conditions will reduce the likelihood of an accident. But the steps being proposed by the Western Governors cannot eliminate severe accidents nor overcome the inherent design defect of the TRUPACT-II containers, namely their thin walls, amounting to 3/4" of stainless steel. A severe accident with a release of plutonium could easily overcome local emergency facilities and personnel.

23. In my opinion, the risk of an accident in the transportation of plutonium-contaminated waste to the WIPP site can and should be significantly reduced, primarily by developing a more rugged shipping container. In addition, the Department of Energy has greatly underestimated both the probability and consequences of a transportation accident in several significant ways.

Marvin Resnikoff, Ph.D.

State of New York)
) ss.
County of New York)

Subscribed, sworn to and acknowledged before me this the 9th day of November, 1991.

Nov 11, 1991
NYC

NOTARY PUBLIC

My Commission Expires:

BERNARD WASSERSTEIN
Notary Public, State of New York
No. 01wa-4840697
Qualified in Kings County
Commission Expires April 30, 1993

EXHIBIT A

Dr. Marvin Resnikoff

Radioactive Waste Management Associates
306 W. 38th St., Rm. 1508
New York, NY 10018
(212) 629-5612

507 W. 111th St, #62
New York, NY 10025
(212) 866-2987

EXPERIENCE:

April 1989 - present **Senior Associate**, Radioactive Waste Management Associates, management of consulting firm focussed on radioactive waste issues, evaluation of nuclear transportation and military and commercial radioactive waste disposal facilities.

1978 - 1981; 1983 - April 1989 **Research Director**, Radioactive Waste Campaign, directed research program for Campaign, including research for all fact sheets and the two books, *Living Without Landfills*, and *Deadly Defense*. The fact sheets dealt with low-level radioactive waste landfills, incineration of radioactive waste, transportation of high-level waste and decommissioning of nuclear reactors. Responsible for fund-raising, budget preparation and project management.

1981 - 1983 **Project Director**, Council on Economic Priorities, directed project which produced the report *The Next Nuclear Gamble*, on transportation and storage of high-level waste.

1974 - 1981 **Instructor**, Rachel Carson College, State University of New York at Buffalo, taught classes on energy and the environment, and conducted research into the economics of recycling of plutonium from irradiated fuel under a grant from the Environmental Protection Agency.

1975 - 1976 **Project Coordinator**, SUNY at Buffalo, New York Public Interest Research Group, assisted students on research projects, including project on waste from decommissioning nuclear reactor.

1973 **Fulbright Fellowship** at the Universidad de Chile, conducting research in elementary particle physics.

1967 - 1972 **Assistant Professor of Physics**, SUNY at Buffalo, conducted research in elementary particle physics and taught range of graduate and undergraduate physics courses.

1965 - 1967 **Research Associate**, Department of Physics, University of Maryland, conducted research into elementary particle physics.

EDUCATION

University of Michigan
Ann Arbor, Michigan

PhD in Physics, June 1965
M.S. in Physics, Jan 1962
B.A. in Physics/Math, June 1959

Reports, Publications and Papers 1985-1991

January 1985 "U.S. Radioactive Landfill Experience," paper, presented to the Annual Institute of British Geographers in Leeds, England. Incorporated into Nuclear Power in Crisis: Politics and Planning for the Nuclear State, edited by Blowers, A., and Pepper, D., Nichols Publishing Co. (1987).

February 1985 "Comments on the transportation sections of the draft Environmental Assessment for a high level waste repository in Utah," prepared for the State of Utah.

March 1985 Testimony before the House Committee on Interior and Insular Affairs on the long-lived hazard of "low-level" radioactive waste.

May 1985 "Radioactive Waste Incineration in Bladen County, What's Coming Out of the Stack?," Campaign report on the environmental impact of incinerating radioactive waste in Bladen County, North Carolina, 33 pages.

August 1985 Paper submitted to the House Energy and Commerce Committee, on the hazard of long-lived low-level waste.

September 1985 "Radioactive Waste Incineration in Parks Township, Pennsylvania, What's Coming Out of the Stack?," Campaign report on the environmental impact of incinerating radioactive waste in Parks Township, Pennsylvania, 32 pages.

February 1986 "Alternatives to Radioactive Landfills, An Environmental Perspective," paper presented at the International Symposium on Alternatives to Radioactive Landfills, Chicago, Ill. Paper incorporated in the Proceedings, published by the Illinois Dept of Nuclear Safety and the Central Midwest Compact Commission.

June 1986 "Feed Materials Production Center, Uranium Contamination of Off-site Wells," Campaign report prepared with Dana Coyle on the health impact of uranium contamination of off-site wells, 35 pages.

June 1986 Testimony on behalf of the Northwest Inland Waters Coalition, a public interest organization, for the Federal District Court, State of Washington, on the need for an Environmental Impact Statement to evaluate the import of irradiated nuclear fuel from Taiwan through the Port of Seattle.

July 1986 Paper on the Kerr-McGee uranium conversion facility near Salisaw, Oklahoma presented to conference organized by Native Americans for a Clean Environment.

July 1986
September 1986 Affidavit in Federal Court in New York City on behalf of a Warwick, New York public interest group (WARD), and in New Jersey State Courts on behalf of the New York-New Jersey Trails Conference, opposing plans by the New Jersey Department of Environmental Protection to move radium residues from Montclair to Vernon, New Jersey.

August, 1986 Supplement to June 1986 Campaign report on the Feed Materials Production Center discussing contamination of public water supplies, 20 pages.

September 1986 "Disposal of high-level waste in Canada," paper presented at high-level waste conference, Winnipeg, Manitoba. Workshop on the transportation of irradiated fuel in Canada. Incorporated into Challenges to Nuclear Waste, Proceedings of Nuclear Waste Issues

Conference, Sept 12-14, 1986, edited by Weiser, A., Concerned Citizens of Manitoba, Winnipeg, Manitoba, 1987.

November 1986 Associates report to the State of Kansas on draft Request for Proposal for contractor to the Central States Compact, 10 pages.

November 1986 "Transportation of irradiated fuel," paper presented to a subcommittee of the National Association of Attorneys General, Las Vegas, Nevada.

December 1986 Associates affidavit prepared for the Coalition on West Valley Nuclear Wastes and the Radioactive Waste Campaign in a successful U.S. District Court action on the need for a federal Environmental Impact Statement before disposing of low-level waste at West Valley.

February 1987 "Off-site radioactive contamination at DOE's Oak Ridge, Tennessee facility," Campaign report prepared wi th Dana Coyle on radioactive leakage from the Oak Ridge Reservation, 65 pages.

May 1987 "At-reactor storage of irradiated fuel," paper presented at conference sponsored by Blue Ridge Environmental Defense League and other citizen organizations at Maryville, Tennessee.

June 1987 Associates affidavit prepared for the Sierra Club Legal Defense Fund on the need for an Environmental Impact Statement before incinerating plutonium-contaminated waste at the Rocky Flats Plant.

September 1987 *Living Without Landfills*, Campaign book on the hazard of radioactive landfills, and safer alternatives, 119 pages.

September 1987 Associates affidavit prepared on behalf of the Alaska Attorney General in a U.S. District Court action on the need for a federal Environmental Impact Statement for air shipments of plutonium in Alaska.

November 1987 "Low-level waste in Michigan," talk before a joint session of the Michigan Legislature, East Lansing, Michigan.

February 1988 Testimony before the Vermont House Committee on Natural Resources and the Environment, Montpelier, Vermont.

May 1988 Talks at Chadron State College (Chadron, Neb), Alliance, and Scottsbluff, on "low-level" waste in the Central States.

June 1988 Co-authored the Radioactive Waste Campaign's *Deadly Defense*, 170 page book on radioactive waste at nuclear weapons facilities. Released at a national press conference in Washington, D.C.

June 1988 Wayne and Clark counties, Illinois; public meetings near proposed llw dump sites; jointly-sponsored with local groups (Individuals for a Clean Environment)

July 1988 Briefing before Congressional Legislative Assistants on the findings of *Deadly Defense*, jointly conducted with the Sierra Club and sponsored by Representative Don Bonker.

September 1988 Reno, NV; talk before Northern Colorado Gaming Executives re. transportation of irradiated fuel to a proposed high-level waste repository; jointly sponsored by Citizens Alert and State of Nevada

September 1988 "Rebuttal of NRC Critique of *Living Without Landfills*, 12 pages.

October 1988 Boulder, CO; talk, participation in conference and chapter of book, Environmental Impacts of Warfare; sponsored by the Sierra Club.

November 1988 Nucla, CO; prepared testimony before Colorado Department of Health re. suitability of proposed "low-level" waste disposal site in Uravan, Colorado on behalf of Western Colorado Congress.

November 1988 Augusta, Maine; participation in debate sponsored by the Maine Low-Level Radioactive Waste Authority

December 1988 Preparation of court affidavit re. proposed irradiated fuel shipments from Taiwan through Portsmouth, Virginia, before the United States District Court, District Of Columbia, on behalf of the Sierra Club Legal Defense Fund.

February 1989 "Uranium Releases at Fernald, Radiation Doses to Nearby Residents," report released by the Radioactive Waste Campaign at Cincinnati, Ohio press conference.

April 1989 "Risks of Low-Level Radioactive Waste Transportation," 8-page fact sheet, prepared for the Radioactive Waste Campaign.

May 12, 1989, "Preliminary Report on RI/FS Study," prepared on behalf of Maxey Flats Concerned Citizens, Flemingsburg, Kentucky.

August 30, 1989, "Analysis of RADTRAN Computer Model," paper presented at meeting of the American Nuclear Society Meeting, Las Vegas, Nevada.

October 1989 "Report on Maxey Flats Remediation Program," 75-page report, prepared for Maxey Flats Concerned Citizens, Inc.

November 1989 "RADTRAN Analysis," 60-page report on the probability and consequences of accidents in transporting high-level waste to the proposed Yucca Mountain repository, prepared for the University of Nevada, Las Vegas.

April 9, 1990 "Comments on the Final Supplemental Environmental Impact Statement, Waste Isolation Pilot Plant," on behalf of Concerned Citizens for Nuclear Safety, Santa Fe, New Mexico.

April 25, 1990, talk before the Hazardous Materials/Nuclear Symposium on nuclear transportation issues, Ely, Nevada.

April 26, 1990, Statement before the Nevada Commission on Nuclear Projects on nuclear transportation issues, Las Vegas, Nevada.

July 19, 1990, "Report on Feasibility Study, Risk Assessment, App. D, iodine hazard," prepared on behalf of Maxey Flats Concerned Citizens, Flemingsburg, Kentucky.

August 1, 1990, "Report on the State of Kentucky, Maxey Flats Closure Plan," prepared on behalf of Maxey Flats Concerned Citizens, Flemingsburg, Kentucky.

August 1990 Preparation of second court affidavit re. proposed irradiated fuel shipments from Taiwan through Portsmouth, Virginia, before the United States District Court, District Of Columbia, on behalf of the Sierra Club Legal Defense Fund.

October 22, 1990, "Review of Environmental Report for the Central Interstate Compact Low-level Radioactive Waste Facility," on behalf of Heartland Operation to Protect the Environment, Auburn, Nebraska.

December 1990 Preparation of third court affidavit re. proposed irradiated fuel shipments from Taiwan through Portsmouth, Virginia, before the United States District Court, District Of Columbia, on behalf of the Sierra Club Legal Defense Fund.

February 8, 1991, "Review of 'Risk Assessment and Safety Analysis, University of Michigan Waste Handling Facility,' on behalf of No. Campus Residents Council, Ann Arbor, Michigan.

April 1, 1991, "Health and Safety Impact of NMI," on behalf of Citizens Concerned About NMI, Concord, Massachusetts.

May 6, 1991, "Comments on Final Environmental Impact Statement, Prairie Island Independent Spent Fuel Storage Installation," on behalf of the Sioux Tribal Council, Red Wing, Minnesota.

May 16, 1991, "Managing Low-Level Radioactive Waste," talk at Future Options Symposium, International Institute for Low Level Radioactive Waste, East Lansing, Michigan.

May 23, 1991, "Radiac Accident Analysis," prepared on behalf of the Radioactive Waste Campaign, Brooklyn, New York.

May 30, 1991, "Nuclear Power in the United States," talk sponsored by the Green Party, Rikstag, Green Party Group Room, Stockholm, Sweden.

June 20, 1991, "Comments on the Department of Energy Environmental Assessment on Off-Site Fuels Policy," prepared on behalf of the Sierra Club Legal Defense Fund, Washington, D.C.

July 1, 1991, "Comments on the Final Environmental Impact Statement for the Proposed Ward Valley Low-level Waste Landfill," submitted to the California Department of Health Services, on behalf of Don't Waste California.

July 12, 1991, "Comments on EPA Proposed Plan," prepared on behalf of Maxey Flats Concerned Citizens, Flemingsburg, Kentucky.

Radioactive Waste Management Associates

Radioactive Waste Management Associates is an independent consulting firm established April 1989 to assist state and local governments and citizen organizations in dealing with waste management issues. We are a team of scientists, economists and engineers who carefully evaluate the impact of proposed and extant radioactive waste facilities. We perform engineering and economic analyses of low level waste facilities, develop cost-based waste disposal pricing systems, and evaluate the impacts of transporting radioactive waste and clean-up options on the public health and the environment. As seen below, we have extensive experience in working with local and state governments and citizen organizations. We have an extensive library of publications on low-level waste issues. Many of us have facility in FORTRAN programming, useful for the computer models employed for this project.

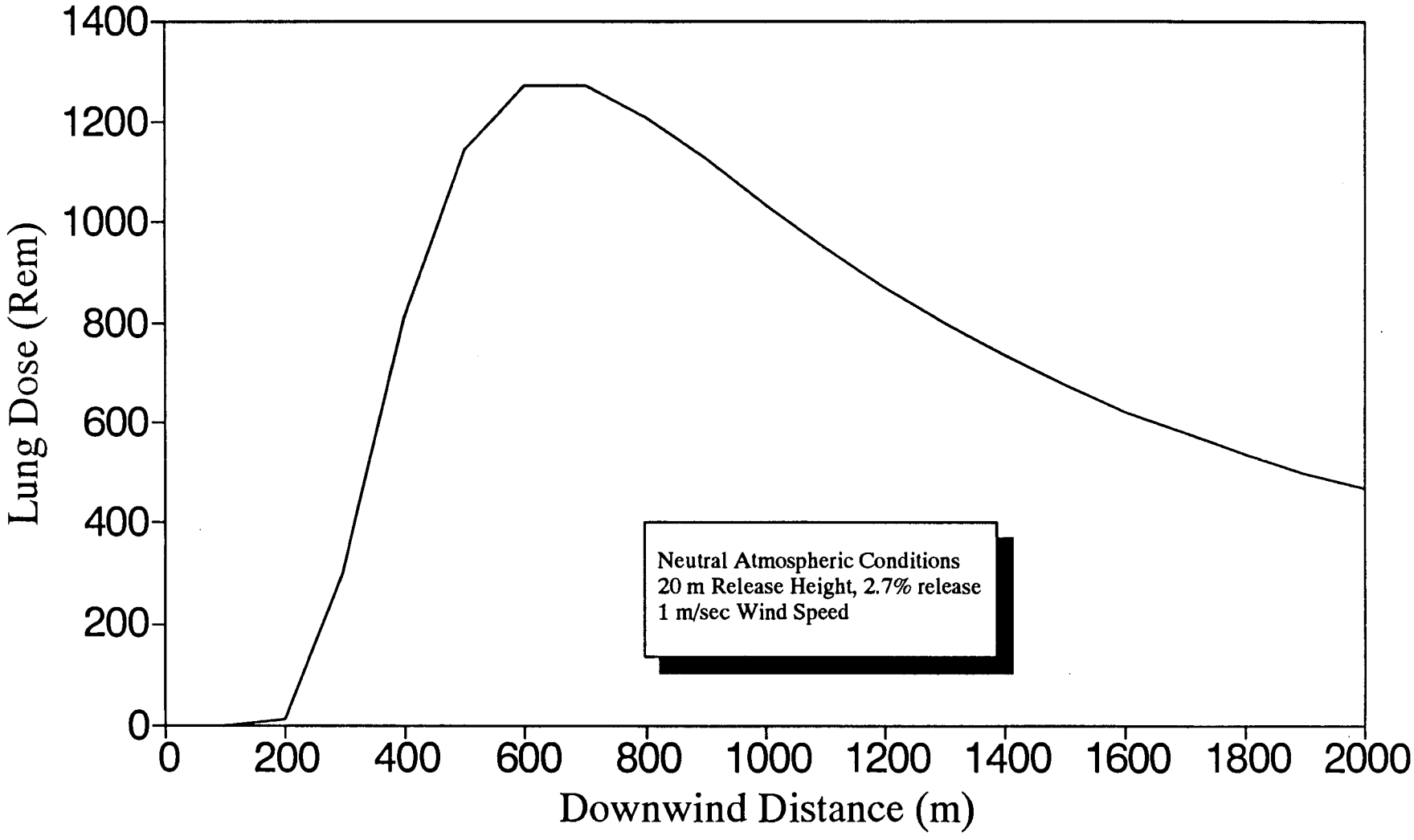
Our clients this year include the following:

Organization	Location	Project
Concerned Citizens of Clark County	Marshall, IL	Proposed LLW Facility, Ill Siting Commission Hearings
Citizens Concerned about NMI	Concord, MA	Remediation of U basin at NMI
Coalition of Environmental Groups	Toronto, OH	Ontario Environmental Assessment Board Hearings
Maxey Flats Concerned Citizens	Flemingsburg, KY	RI/FS Proceeding on Maxey Flats landfill
Northwatch Coalition	North Bay, OH	Ontario Environmental Assessment Board Hearings
Novak Farms Toxic Comm	McDonough, NY	RI/FS Proceeding on Novak Farms dump
Nuclear Waste Project Office State of Nevada	Carson Cty, NV	Transport Cask Vulnerability
Radioactive Waste Campaign	Warwick, NY	Review Radiac SAR
Sierra Club Legal Defense Fund/Don't Waste California	San Francisco, CA	EIS on LLW Disposal
Sierra Club Legal Defense Fund/Inland Waters Coalition	Washngton, DC	EA on DOE Off-Site Policy
Sioux Tribal Council	Welch, MN	Irradiated Fuel Storage at Prairie Island
Towns of East Windsor, Ellington and South Windsor	Connecticut	Proposed LLRW Facility

EXHIBIT C

WIPP Transportation Accident

SRP CH-TRU Waste



SUMMARY OF AFFIDAVIT OF
EDWIN W. ROEDDER

Dr. Roedder is an Associate in the Department of Earth and Planetary Sciences at Harvard University and a geochemist. He serves on the National Academy of Sciences - National Research Council Panel on Coupled Hydrologic/Tectonic/ Hydrothermal Systems at Yucca Mountain, a proposed high-level waste repository. Dr. Roedder has studied issues of nuclear waste disposal since the 1950's and published widely on the subject. On behalf of Sandia National Laboratories he has studied the Salado Formation in which the WIPP was mined. (¶¶ 13-14).

Dr. Roedder testifies that the EPA disposal standards that the WIPP must meet do not require on-site tests with radioactive waste. (¶ 18).

The DOE does not have enough quantified and pertinent data to be able to identify the particular gas generation rate data that will play an important part in the performance assessment process, and it cannot now be said that the underground bin tests will provide such data. (¶ 25).

Basic safety questions remain concerning the bin-scale tests, making it necessary to scrutinize any claim that it is necessary to permit the tests. These include the serious issues of roof stability, extraction or cementation of radioactive liquids, and radioactive fluid handling in leaching/solubility tests. (¶ 30).

The dry bin tests do not reproduce repository conditions, which might be asserted to be important to a performance

assessment. (¶ 31). Also, the requirement to purge bins containing high-gas-generating waste to prevent the buildup of flammable gases creates insurmountable operational problems and destroys the utility of the test data for the performance assessment. (¶¶ 31-35).

There is no need to conduct any of the underground bin tests at the WIPP. Since the benefits expected from the dry bin-scale experiments are practically non-existent, and there are undeniable risks, Dr. Roedder regards the underground dry bin-scale tests as a scientifically irresponsible venture. (¶¶ 36-38).

AFFIDAVIT OF EDWIN W. ROEDDER

Edwin W. Roedder under penalty of perjury states as follows:

1. I am an Associate in the Department of Earth and Planetary Sciences at Harvard University.

2. I make this affidavit to show the Court that there is no scientific justification for conducting the proposed underground bin-scale tests at the Waste Isolation Pilot Plant ("WIPP").

3. My scientific background is in the field of geochemistry. I received my B.A. degree in geology from Lehigh University in 1941, an M.A. degree in geology from Columbia University in 1947, and a Ph.D. degree in geology in 1950 from Columbia University. I also hold the honorary degree of Doctor of Science from Lehigh University (1976).

4. After receiving my B.A. degree I took a position as Research Engineer with the Research Department of Bethlehem Steel Corp., a position which I held from 1941 through 1946.

5. I taught as Assistant Professor and Associate Professor of Mineralogy at the University of Utah in 1950 through 1955.

6. I was employed by the United States Geological Survey in the period 1955 through 1987. I served as Chief of the Solid State Group in the Geochemistry and Petrology Branch in 1955 to 1960. I was a Staff Geologist from 1960 to 1962, in 1962 through 1974 I held the position of Geologist, and from 1974 through 1987 I held the position of Research Geologist.

7. In 1987 I became an Associate in the Department of Earth and Planetary Sciences at Harvard, a position which I still hold.

8. In 1954-55 I served as a member of the Committee on Geochemical Research of the National Science Foundation. From 1961 through 1964 I was a member of the Advisory Panel on Earth Science of the National Science Foundation.

9. In 1973 I received the Exceptional Scientific Achievement Medal of the National Aeronautics and Space Administration. I received the Werner Medal of the German Mineralogical Society in 1985. I received the Roebling Medal of the Mineralogical Society of America in 1986. I received the Penrose Medal of the Society of Economic Geologists in 1988.

10. I am a member of the National Academy of Sciences, which is a body of approximately 1500 scientists who are elected to membership based upon their professional accomplishments.

11. I am a member of the National Academy of Sciences - National Research Council Panel on Coupled Hydrologic/Tectonic/Hydrothermal Systems at Yucca Mountain, a proposed high-level waste repository.

12. I am also a member of the Society of Economic Geologists. I served as President of the Geochemical Society in 1976-77. I served as Vice President of the Mineralogical Society of America in 1981-82 and as President of that Society in 1982-83. I am a member of the American Geophysical Union.

13. Since the 1950's I have pursued studies in the field of nuclear waste disposal, in addition to other interests. Most of my publications are listed on the attached exhibit A. My work in

the field of the WIPP and nuclear waste disposal in general includes the following:

a. Problems in the disposal of acid aluminum nitrate high-level radioactive waste solutions: U.S.G.S. Bull. 1088 (1958).

b. Preliminary report on study of fluid inclusions in core samples from ERDA No 9 borehole, nuclear waste site, New Mexico: Report on contract to Sandia Laboratories, June 27, 1977, 29 pp. (with H.E. Belkin) (1977).

c. Fluids present during the diagenetic history of the Salado salt beds, Delaware Basin, Southeastern New Mexico as recorded by fluid inclusions, Amer. Geophys. Union Trans. vol. 59, no. 4, p. 226 (abst.) (with H.E. Belkin) (1978).

d. Fluid inclusions in core samples from ERDA No 9 borehole, WIPP site, New Mexico: Report on contract to Sandia Laboratories, Jan. 1, 1978 (with H.E. Belkin) (1978).

e. Application of studies of fluid inclusions in Permian Salado salt, New Mexico, to problems of siting the Waste Isolation Pilot Plant, in Scientific Basis for Nuclear Waste Management, Vol. 1, G.J. McCarthy, Editor: New York, Plenum Pub. Corp., p. 313-321 (with H.E. Belkin) (1979).

f. Fluid inclusion study on core samples of salt from the Rayburn and Vacherie Domes, Louisiana: U.S. Geol. Survey Open File Report 79-1675, 25 pp. (with H.E. Belkin) (1979)

g. Migration of fluid inclusions in Waste Isolation Pilot Plant site salt in thermal gradients (abst.): Materials Research Society Symposium G, Scientific Basis for Nuclear Waste Management, Cambridge, Nov. 26-30, 1979 (with H. E. Belkin) (1979).

h. Summary of U.S. Geological Survey investigations of fluid-rock-waste reactions in evaporite environments under repository conditions, in Underground disposal of radioactive wastes, vol. I Proceedings IAEA Symposium, Helsinki, 1979; Vienna, Internat. Atomic Energy Agency, p. 335-344 (with D.B. Stewart, B. F. Jones, and R.W. Potter III) (1980).

i. Thermal gradient migration of fluid inclusions in single crystals of salt from the Waste Isolation Pilot Plant site (WIPP): Scientific Basis for Nuclear Waste

Management, v. 2, C.J.M. Northrup, Jr., Ed.: New York, Plenum Press, p. 453-64 (with H.E. Belkin) (1980).

j. Migration of fluid inclusions in polycrystalline salt under thermal gradients in the laboratory and in Salt Block II (abst.): Proc. 1980 Natl. Waste Terminal Storage Program Information Meeting, ONWI 212, p. 361-363 (with H.E. Belkin) (1980).

k. Petrographic study of fluid inclusions in salt core samples from Asse mine, Federal Republic of Germany: U.S. Geol. Survey Open File Report 81-1128, 32 pp. (with H.E. Belkin)(1980)

l. Water content in Palo Duro salt, Randall and Swisher County cores, in Gustafson, T.C., and others, Geology and geohydrology of the Palo Duro basin, Texas Panhandle: The University of Texas at Austin, Bureau of Economic Geology Circular 81-3, p. 119-122. (with R.L. Bassett) (1981).

m. Problems in determination of the water content of rock-salt samples and its significance in nuclear-waste storage siting: Geology, v. 7, p. 525-530. (with R.L. Bassett) (1981).

n. Fluid inclusion studies, pp. 35-39 in R. Schneider and N.J. Trask, U.S. Geological Survey Research in Radioactive Waste Disposal - Fiscal Year 1980, USGS Open File Report 82-509, p. 21-24. (1982).

o. A critique of "Brine migration in salt and its implications in the geologic disposal of nuclear waste", Oak Ridge National Laboratory Report 5818, by G.H. Jenks and H.C. Claiborne, U.S. Geol. Survey Open File Report 82-1131, 31 pp. (with I-Ming Chou) (1982).

p. Application of studies of fluid inclusions in salt samples to the problems of nuclear waste storage: Acta Geologica Polonica, v. 32, no. 1-2, p. 109-133 (in English with Polish abstract). (1982)

q. Possible Permian diurnal periodicity in NaCl precipitation, Palo Duro Basin, Texas. In Gustavson, T.C., et. al., Geology and geohydrology of the Palo Duro Basin, Texas Panhandle - a report on the progress of nuclear waste isolation feasibility studies (1981): The Univ. of Texas at Austin, Bureau of Economic Geology Geological Circular 82-7, p. 101-104. (1982)

r. Fluid inclusions in salt, in R. Schneider and N.J. Trask, U.S. Geological Survey Research in Radioactive Waste

Disposal - Fiscal Year 1981, Water Resources Investigations Report 83-4105, p. 62-64. (1983)

s. Final report on a study of fluid inclusions in core from Gibson Dome No. 1 bore, Paradox Basin, Utah: U.S. Geol. Survey Open File Report 84-696, 16 pp. (1984).

t. The fluids in salt. American Mineralogist, v. 69. p. 413-439. (1984).

u. Progress report on studies of the chemical composition of fluid inclusions in Palo Duro Basin salt: Texas Bur. Econ. Geol. Open File Report OF-WTWI-1985-30, 233 p. (with W.M. d'Angelo, A.F. Dorrzapf, Jr., and P.J. Aruscavage) (1985).

v. Composition of fluid inclusions in salt beds (abst.): European Current Research on Fluid Inclusions, 8th Symposium Abstracts, p. 106. (1985).

w. Fluid inclusions in salt, Palo Duro Basin, Texas, in U.S. Geol. Survey Water-Resources Investigations Report 87-4009, p. 30-34. (1986).

x. The origin of fluids in the salt beds of the Delaware Basin, New Mexico and Texas: Applied Geochem., v.1, p.265-271. (with J.R. O'Neil, C.M. Johnson, and L.D. White) (1986).

y. Composition of fluid inclusions in Permian salt beds, Palo Duro Basin, Texas: Chem. Geology, v. 61 p. 79-90. (with W.M. d'Angelo, A.F. Dorrzapf, Jr., and P.J. Aruscavage) (1987).

z. Formation, handling, storage and disposal of nuclear wastes: Journal of Geological Education, v. 38, p. 380-392 (1990).

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14. I have had an interest in the WIPP project since the mid-1970's, when I conducted studies on behalf of Sandia National Laboratories ("Sandia") of fluid inclusions in the Salado Formation salt deposits in which the repository has since been mined.

15. I have been retained as a consultant by the State of New Mexico to examine and comment upon the proposed underground bin-scale tests planned to be conducted by Sandia on behalf of the Department of Energy ("DOE") at the WIPP.

16. Among the materials that I have reviewed are the Test Plan: Bin CH TRU Tests (SAND 90 8500)(Jan. 1990), the Test Plan Addendum #1: Bin-Scale CH TRU Waste Tests (SAND 90-2082)(Dec. 1990), the Preliminary Comparison with 40 C.F.R. Part 191, Subpart B (SAND 90-2347)(Dec. 1990), and the FSAR Addendum, Dry Bin-Scale Test (WP 02-9 Rev. 0) (Aug. 1991).

17. The Environmental Protection Agency ("EPA") is responsible for issuing regulations which a nuclear waste repository must meet before it may be used for the permanent disposal of radioactive waste. The EPA disposal regulations set limits on the likelihood and total amount of radioactivity releases. They are set forth in 40 C.F.R. 191 Part B. The process of demonstrating compliance with these regulations is known as a performance assessment.

18. The EPA radiation standards do not require that compliance be established by means of experiments on site using radioactive waste. Rather, compliance is to be established by a probabilistic risk analysis.

19. Sandia is conducting the performance assessment of the WIPP. Part of this process is the development of conceptual models of various parts of the disposal system and the surrounding area. Those conceptual models are then converted into computer models.

Using the computer models, and complex programs, various "release scenarios"--events possibly leading to a release of radioactivity to the biosphere--are examined to determine their likelihood and consequences.

20. Since the conceptual models contain various unknown or uncertain elements, the analyses to be conducted by Sandia include "sensitivity" studies, designed to determine the degree of importance of the unknown or uncertain data to the conclusion of the performance assessment.

21. Sandia's test plan states that the bin-scale tests are intended to quantify the amount of gas generated by various transuranic radioactive waste types in contact with brine and other repository materials. (Jan. 1990 Bin-Scale Test Plan at 14-15) (SAND 90-8500).

22. However, the 1990 Preliminary Comparison indicates that there has been no sensitivity analysis addressed to the rate of gas generation in connection with any of the release scenarios.

23. In fact, the conceptual models concerning gas generation by corrosion or microbial action are still undeveloped, according to the 1990 Preliminary Comparison (Chapter V). Therefore, sensitivity to gas generation cannot be quantified at this time (1990 Preliminary Comparison, Chapter VI).

24. Previous analyses have indicated a rate of gas generation, where waste is in contact with brine, in the range of 2.5 to 5 moles/drum/year. (Chaturvedi, L., 1989, Evaluation of the DOE plans for radioactive experiments and operational demonstration

at WIPP: Sept. 1989, Environmental Evaluation Group Report, EEG-42 at 15-16.). It has also been estimated that a gas generation rate of only 0.1 to 0.3 moles/drum/year will give rise to pressures that equal the underground lithostatic pressure. (Lappin, A.R., Comments on WIPP and British Thinking Concerning Gas Generation Within Nuclear Waste-Repositories, presentation to Radioactive and Hazardous Materials Committee, Nov. 27, 1989.). If such pressures are exceeded, it is said that gas pressures would prevent the salt beds from closing around the waste. This would probably cause difficulties in proving compliance with the EPA radiation standards.

25. In the present state of information, the DOE does not have enough quantified and pertinent data about the numerous variables affecting gas pressure in the repository to be able to identify the particular gas generation rate data that will play an important part in the performance assessment process, and it cannot now be said that the underground bin tests will provide such data.

26. Many variables may influence the rate of gas generation, the nature, and the amount of gas. These include the amount of brine in the repository, the rate of closure of the salt beds, the permeability of the surrounding rock, and other factors. Some of the factors are interdependent. Following normal scientific procedures, a series of scoping experiments would be designed and carried out that increase in precision, degree of control, and correspondence with repository conditions to develop data on such factors. Such experiments would normally be carried out in the

laboratory, to the extent possible. Data from such experiments would tend to narrow the range of uncertainty as to such factors and point out the variables, or combinations of variables, that may be important in affecting gas generation. Data from such experiments could be used as well in constructing and validating models which would be used to study possible release scenarios.

27. From the study of release scenarios it would be possible to determine which variables or combinations of variables are the most important factors in controlling the severity of a release of radioactivity. Such studies may lead to the exclusion of certain discretionary variables from consideration (e.g., waste types, containment vessels, etc.) as presenting too high a probability of release. Other variables may be excluded from further study if inconsequential to a possible release.

28. In the process of studying release scenarios it may be found both that certain variables have a wide range of possible values and that the value selected within such variation is important to the severity of a release. Based on such findings it may then be possible to design new experiments, focused on reducing the uncertainty as to the value of such variables. As regards gas generation rate data, the status of information has not reached the level necessary to design such experiments.

29. At some stage in this iterative process the degree of uncertainty in the quantification of the factors involved in the models of the various release scenarios may become sufficiently small that the resulting probabilistic risk analysis for each

release scenario comes within the limits set by 40 C.F.R. Part 191 B. From a review of the evidence currently available (e.g., Preliminary Comparison with 40 C.F.R. Part 191, Subpart B, for the Waste Isolation Pilot Plant, Dec. 1990, SAND 90-2347; Anderson, D.R., et. al., 1991, WIPP Performance Assessment: A 1990 Snapshot of Compliance With 40 C.F.R. 191, Subpart B (SAND 90-2338)) it is obvious that the present data have too large a range of uncertainly for this last step.

30. Moreover, basic safety questions remain concerning the bin-scale tests, and these safety questions make it necessary to scrutinize carefully any claim that it is essential to permit the tests. It is not essential to conduct experiments that violate basic concepts of safe laboratory practice. The FSAR Addendum, Dry Bin-Scale Test (WP 02-9 Rev. 0) (Aug. 1991), and comments by the Environmental Evaluation Group (August 9, 1991) raise the serious issue of the roof stability of the test room. In addition, the Test Plan Addendum #1: WIPP Bin-Scale CH TRU Waste Tests (SAND 90-2082) (Dec. 1990) states that, before wet bin tests can be conducted a system must be developed to extract or cement radioactive liquids (Id. 84-85), and this has not been done. Similarly, the leaching/solubility tests, which also involve radioactive fluid handling, will require an entire new test plan, which does not exist yet (Id. 13). The resolution of these safety problems may substantially alter the character of the tests. The DOE cannot properly plan certain tests that it asserts will be essential until the safety problems have been resolved, any

necessary changes have been made in the tests, and a complete plan for the proposed tests can be presented and evaluated.

31. The immediate test plan involves only the dry bin-scale tests. These tests do not include the addition of brine to the waste. Brine is, however, expected to be present in the repository after disposal, and it is expected to contribute to the production of any gas. Thus, the dry bin tests, without any brine, do not reproduce repository conditions after disposal, which might be asserted to be important to a performance assessment.

32. Moreover, I note from a Sandia memorandum of record (Lappin and Molecke, April 17, 1991 at 2) that safety constraints severely limit the number of bins and the types of waste that can be used in bin tests. The tests can evidently measure only gas generation by radiolysis from dry low-organic or other low-gas-generating wastes. Such information is far from the information about corrosion and microbial action--the main gas producers--which is the stated aim of the tests.

33. The Sandia memorandum also says that the safety requirement to purge the bins frequently with an inert gas, to prevent the buildup of flammable gasses, if gas is generated at the rates and compositions previously estimated, both creates "insurmountable" (at 7) operational problems and destroys the utility of the data from such bins for a performance assessment, because the gas will not be representative of long-term repository conditions. Thus the stated objective of the bin-scale tests cannot be attained.

34. The memorandum also says that, in any case, only four high-gas-generating bins could be operated and purged regularly, because of equipment limitations (at 7). Clearly, bin tests with approximately 100 bins are not possible under such conditions.

35. In this situation, it is very clear that the bin tests in their present state of preparation will not be applicable to the performance assessment process.

36. Most fundamentally, there is no need to conduct any of the underground bin tests <u>at the WIPP</u>. The January 1990 bin-scale test plan expressly says that there is no scientific reason to conduct these tests at the WIPP (at 28-29). The bins are sealed and leak-tight and, we hope, do not exchange any gaseous, liquid, or solid matter with the repository environment. The bin tests could easily be conducted in a laboratory setting and if so might avoid some of the safety constraints arising from the underground setting.

37. The January 1990 bin-scale test plan (SAND 90 8500) lists the advantages and disadvantages of conducting the bin-scale tests at the WIPP compared with other locations. The "deciding factors" are listed (at 28-29), but to the extent they are said to favor the WIPP, they only involve matters of logistics and timing. The most important item is "time availability to meet WIPP [performance assessment] needs." But it is now clear that the experimental data will not contribute to the performance assessment (Lappin and Molecke, April 17, 1991); thus, the most important asserted justification for holding the tests at the WIPP has disappeared.

The other factors involve availability of alternative facilities. If the tests truly need to be done--which has not been established--it is hard to believe that other facilities cannot be made available by the time the various tests are ready to proceed. Moreover, it is conceded that radiological safety would be at least as well served at another location (Id. 29), and there would be a decreased transportation risk if the tests are not done at the WIPP. (Id.). There is no justification for holding these tests at the WIPP.

38. Conducting underground tests with radioactive waste at the WIPP violates two principles of experimental practice: First, experiments with radioactivity should not be conducted unless the perceived benefits outweigh the risks. Second, experiments in a field setting--e.g., underground--should not create unnecessary risks. Since the benefits expected from the dry bin-scale experiments are practically non-existent, and there are undeniable risks, I regard the underground dry bin-scale tests as a scientifically irresponsible venture.

I declare under penalty of perjury that the foregoing is true and correct. Executed: October 30, 1991.

Edwin W. Roedder

EDWIN W. ROEDDER

JANUARY 1990

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SUMMARY OF AFFIDAVIT OF
BARRY E. SCHEETZ

Dr. Scheetz is a Professor of Materials at the Pennsylvania State University associated with the Materials Research Laboratory. He is a geochemist whose primary work involves nuclear waste disposal. He has collaborated with Sandia National Laboratories in the development of shaft seals for the WIPP facility. (¶¶ 1-5).

Dr. Scheetz testifies that the main purpose of the bin-scale tests is to quantify gas generation as it would occur in the repository after disposal. However, based upon the status of the "performance assessment" of the WIPP being done by Sandia to determine whether the WIPP will comply with EPA disposal standards, it is not possible to state that the rate of gas generation is an important unknown, or uncertain, factor in the process of performance assessment. The studies of gas generation have not gone far enough so that one can identify the unknown factors related to it which are important to an assessment of compliance with EPA standards (¶¶ 17-26).

Various of the proposed on-site tests -- wet bin tests, leaching/solubility tests, and alcone tests -- are not ready to proceed due to unresolved safety problems. The resolution of these problems may change the nature and usefulness of the experiments; only after such resolution can the need for such tests be evaluated. (¶¶ 27-32).

The dry bin-scale tests are the least useful for the performance assessment, since they generate data only concerning

the operational phase, not the phase of permanent disposal. The dry bin-scale tests will not generate significant quantities of gas and will not contribute to modeling of disposal conditions. In any event, the amount of gas which will be present in the repository after disposal depends on numerous factors not disclosed by bin tests, such as brine quantity, closure rate, and porosity and permeability. (¶¶ 33-35).

Further safety-related constraints on the bin tests, adopted to prevent bin explosions, mean that only low-gas-generating wastes can be tested, which miss the main point of the bin tests. Bins with high-gas-generating wastes must be purged every nine to ten days; this process destroys the utility of the test data for the performance assessment. (¶¶ 36-41).

There is no scientific need to conduct the bin tests at the WIPP. Since the data generated is of the most minor importance and cannot be shown to contribute to performance assessment, there is no justification, in Dr. Scheetz's opinion, for conducting the bin tests at the WIPP. (¶¶ 42-43).

AFFIDAVIT OF BARRY E. SCHEETZ

Barry E. Scheetz under penalty of perjury states as follows:

1. I am a Professor of Materials at Pennsylvania State University and am associated with the Materials Research Laboratory.

2. I make this affidavit to show the Court that the bin scale tests proposed to be conducted by the Department of Energy ("DOE") at the Waste Isolation Pilot Plant ("WIPP"), to the extent they are now ready to be conducted, (1) could as easily be conducted in a laboratory setting and gain nothing from being conducted in the underground repository and (2) if conducted at the WIPP will not generate useful information for purposes of the performance assessment of the repository either under standards applicable to disposal of radioactive waste (40 C.F.R. Part 191 B) or under standards applicable to disposal of hazardous waste (40 C.F.R. Part 268).

3. To summarize my scientific background: I acquired a B.S. degree in Chemical Education from Bloomsburg State College in 1967 and a M.S. degree in Geochemistry from The Pennsylvania State University in 1972. In 1976 I received my Ph.D. in Geochemistry and Mineralogy from The Pennsylvania State University.

4. My work since 1976 has primarily involved nuclear waste management. I have studied and published on issues involving radioactive waste isolation by various methods of treatment and cementation, interactions among waste and backfill in repository

simulations, stability of nuclear waste forms, and hydrothermal reactions to various nuclear waste forms.

5. I have previous experience with the WIPP, in that I have collaborated with Sandia National Laboratory ("Sandia") in the development of cements for use in the shaft seals for the WIPP facility. I am co-author of a study for Sandia entitled "Salt-Grout Interface and Salt Consolidation Studies," published in the Sandia Annual Report, 1987. A copy of the form of resume maintained by the University is attached as exhibit A. This resume includes a list of publications, grants, patents, and other information concerning my scientific background.

6. I have published the following articles in refereed scientific journals concerning problems in the area of nuclear waste management.

a. "Interactions Between Nuclear Waste and Surrounding Rocks," Nature 273, 216-217 (1978). Co-Author.

b. "Hydrothermal Reactivity of Simulated Nuclear Waste Forms and Water-Catalyzed Waste-Rock Interactions," Scientific Basis for Nuclear Waste Management, Vol. 1, G.J. McCarthy (Ed.), Plenum Press, NY, 471-478 (1979). Co-Author.

c. "Role of Admixtures in Preparing Dense Cements for Radioactive Waste Isolation," Scientific Basis for Nuclear Waste Management, Vol. 1, G.J. McCarthy (Ed.), Plenum Press, NY, 461-466 (1979). Co-Author.

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7. I have been retained as a consultant to the State of New Mexico to assess the scientific significance of the bin-scale tests proposed to be conducted at the WIPP under the rules applicable to radioactive waste disposal and disposal of hazardous waste.

8. I have reviewed various materials concerning the performance assessment of the WIPP:

a. 40 C.F.R. Part 191

b. Test Plan: Alcove CH TRU Tests (SAND 90 8499)

c. Test Plan: Bin CH TRU Tests (SAND 90 8500)

d. Test Plan: Performance Assessment (DOE WIPP 89-011)

e. Test Plan Addendum #1: Bin scale tests (SAND 90-2082)

f. Status Report: Potential for Long-Term Isolation (SAND 90-0616)

g. Preliminary Comparison with 40 C.F.R. Part 191 B (SAND 90-2347)

h. WIPP Performance Assessment: 1990 Snapshot (SAND 90-2338)

i. Status of the WIPP Project (Neill & Chaturvedi) (Waste Mgmt. '91)

j. WIPP FSAR Addendum (July 1991) (WP 02-9 Rev. 0) (excerpts)

K. Letter, EEG to Hunt (DOE), Aug. 9, 1991

l. Critical Experiments and Time Lines (W.D. Weart, SNL) (Aug. 12, 1991)

9. The regulations which contain the standards that the WIPP facility must meet to be employed as a nuclear waste repository were promulgated by the Environmental Protection Agency ("EPA") and are set forth, as issued in 1985, at 40 C.F.R. Part 191 B. I understand that the regulations were vacated by the Court of Appeals for the First Circuit but that the DOE has continued with a Performance Assessment using the 1985 standards, pending reissuance of new standards.

10. The regulations applicable to disposal of hazardous waste were promulgated by the EPA under the Resource Conservation and Recovery Act and are set forth in 40 C.F.R. Part 268.

11. The EPA radiation standards impose a test in terms of probabilities. The standards include a containment requirement, which provides that a release of radioactivity to the biosphere of a specified amount, depending on the total amount of waste, shall not have a probability of more than one in ten of occurring in the 10,000 years after disposal, and shall not have a probability of more than one in 1,000 of exceeding ten times the release limit in that time period. (40 C.F.R. §191.13 (a)). There is also a limitation on radiation dosage to any individual. (40 C.F.R. §191.15)

12. As I understand it, the process of demonstrating compliance with the EPA radiation standards is referred to as a "performance assessment." (40 C.F.R. §191.12 (q)) Briefly, a performance assessment seeks to identify the processes which might affect the disposal system, examine the effects of such processes on the system's performance, and estimate the cumulative release of radionuclides, considering the associated uncertainties. The estimates are to be expressed in an overall probability distribution of cumulative releases. (Id.) In other words, the intended product is a graphic representation showing probability of releases on the vertical axis and the sum of all releases on the horizontal axis. Such a graph, showing the magnitude of cumulative

releases at different levels of probability, is known as a complementary cumulative distribution function ("CCDF").

13. The approach employed by Sandia National Laboratories ("Sandia") in conducting a performance assessment involves the production of complementary cumulative distribution functions for various sets of "scenarios" depicting possible releases of radioactivity. Ultimately, the CCDF's for individual scenarios will be summed to express the overall likelihood of release to the biosphere.

14. The likelihood and consequences of a release for each scenario are examined by first developing conceptual models of pertinent elements of the disposal system. These conceptual models are thus expressed as mathematical computer model descriptions, for example, of the geology of the disposal site, hydrologic and gas-flow characteristics, gas generation characteristics, and repository seal characteristics.

15. Using the computer model descriptions, the release scenarios are examined to determine the degree of importance of uncertain or unknown elements of the scenario--parameters--to the likelihood and the consequences of a release of radioactivity. This is the process of sensitivity analysis.

16. The original bin-scale test plan (January 1990) set down several test objectives. The principal goal of the tests is to "[q]uantify with a high degree of control gas generation--and depletion--rates, and compositions from actual TRU wastes, as a function of waste type, time, and interactions with brines and

other repository natural and engineered barrier materials." (WIPP Test Plan: Bin CH TRU Tests (SAND 90 8500), at 14-15 (Jan 1990)). Thus, the main goal is to measure the gas which is generated by transuranic waste in a repository after disposal. The purpose is said to be to "establish an acceptable level of confidence in the WIPP PA [Performance Assessment] calculations." (Id.)

17. Based upon a review of the Preliminary Comparison with 40 C.F.R. Part 191, Subpart B for the Waste Isolation Pilot Plant, December 1990, there has not yet been any sensitivity analysis of the parameter of the rate of gas generation as it may affect any of the release scenarios. Thus, it is not possible to state as a scientific matter that the rate of gas generation is an important unknown, or uncertain, factor in the process of performance assessment.

18. The 1990 Preliminary Comparison also states that the current status of the compliance assessment conceptual models of gas generation by corrosion and gas generation by biological means is "preliminary" (Table V-7), which means that "understanding of the component or subsystem is intuitive and incomplete" (Id. V-107). Thus, the development of a computer model which describes the process of gas generation has not gone far enough so that it can identify the unknown factors related to gas generation which are important to an assessment of compliance with the EPA radiation standards.

19. In fact, the 1990 Preliminary Comparison expressly states that "[s]imulations that incorporate gas are preliminary, and

cannot be used to quantify sensitivity of the modeling system to gas generation." (Id. VI-1). In other words, the computer models cannot be used to show that gas generation information is important.

20. The 1990 Preliminary Comparison contains other sensitivity studies with regard to (a) scenario probability assignment, (b) radionuclide transport submodel, (c) multiple human intrusion events, and (d) waste modification. Each of these sensitivity studies omits consideration of gas pressurization (Id. VI-7, VI-10, VI-12, VI-15, VI-19). Thus, none of these studies can be used to assess or assert the importance of gas generation data.

21. The 1990 Preliminary Comparison incorporates two preliminary simulations involving gas generation. Neither of these indicates that the precise rate of gas generation is a critical factor in assessing repository performance.

22. The first of these simulations involves a depiction of gas saturation in various elements of the undisturbed repository, using existing gas generation data (Id. VI-22). The study as published does not vary the gas generation rate to determine the significance of that factor, and the results do not tend to establish the importance of the precise gas generation rate.

23. The second of these simulations analyzes flow of brine from the repository into a hypothetical bore hole, drilled in future oil and gas exploration (Id. VI-28). In this study gas generation rates were varied, along with other factors, to determine the amount of escaping brine (Id.). The gas generation

rates were varied between the highest rate anticipated in a certain study (Lappin et al., Systems Analysis, Long-Term Radionuclide Transport, and Dose Assessments, Waste Isolation Pilot Plant (WIPP), March 1989 (SAND 89-0462)), and ten percent of that value (at VI-28; Table VI-4). The study showed that the most important factor in escape of brine was permeability of an anhydrite layer above the waste room. Using the highest anticipated permeability, some brine would escape.

24. However, the gas generation rate was not shown to be a critical factor, because the study showed that brine would escape both at the maximum expected gas generation rate and at one tenth of that rate, and a lesser amount would escape at half the maximum generation rate. (Table VI-5). In other words, at all levels of gas generation, brine escapes.

25. More basically, the 1990 study employs several unrealistic assumptions. The 1990 Preliminary Comparison states that further studies need to be done after a "two dimensional" computer program is developed, and after conceptual models are developed to describe the <u>actual</u> interrelated processes of gas generation, brine saturation, salt creep, and permeability. Until that time, the 1990 studies merely illustrate a general approach and do not establish the importance of gas generation data in the real world:

> "Results presented here for gas generation are preliminary, and are primarily a demonstration of the methodology that will be further developed to assess the effects of gas generation on repository performance. More detailed analyses, requiring two-dimensional modeling of two-phase flow following intrusion, will be

> conducted after the two dimensional version of BRAGFLO is verified. Conceptual models and data must also be developed to describe adequately the coupled processes of gas-generation, brine saturation, and salt creep. For the simulations presented in the preceding sections, gas-generation rates were assumed to be independent of brine saturation. As discussed qualitatively in Chapter V ("Waste Panel Modeling"), gas generation consumes water, and rates will drop as gas displaces brine from the waste. Simulations also assumed that permeability of the anhydrite remains constant, rather than a function of gas pressure that opens pre-existing fractures as gas migrates away from the waste panels. Two-dimensional BRAGFLO simulations will include these two important factors. The importance of other modeling issues (Table V-7) will be assessed through sensitivity analyses." (Id. VI-32 through VI-33).

26. Until the necessary computer programs and conceptual models are developed, and sensitivity studies are conducted with them, it is not possible for the DOE to assert that it is important to identify gas generation rates, to determine whether the WIPP will comply with the EPA radiation standards.

27. Assertions of the necessity to proceed with bin-scale tests must also be examined from the viewpoint of safety-related constraints. Various of the proposed tests have unresolved problems, and the resolution of these problems may change the nature and usefulness of the experiments. Where the DOE has not resolved safety and feasibility questions, it cannot be contended that the Court would interfere with necessary experiments if it ordered that the tests be postponed.

28. The proposed tests are described in the January 1990 Alcove test plan; the January 1990 Bin scale test plan; the April 1990 Test plan, covering all proposed tests; and the December 1990 Bin scale test addendum.

29. The following proposed tests are simply not prepared to be conducted at present:

a. "wet bin" tests

b. leaching/solubility tests

c. alcove tests

30. The wet bin tests involve the addition of up to 120 liters of brine to the test bins (see Test Plan Addendum #1, WIPP Bin-Scale CH TRU Waste Tests at 19 (Dec. 1990)). However, the WIPP waste acceptance criteria do not allow disposal of waste containing more than 1% free liquids, and the added brine would exceed the 1% limit. Therefore, the brine at some point must be removed by draining or pumping or some form of solidification in place. No procedure has been developed to accomplish this removal (Id. 84-85), which under DOE order 6430.1A requires a containment to prevent the possible release of radioactive liquids.

31. The leaching/solubility tests involve determination of the extent to which radionuclides become dissolved in brine. Such tests will involve addition of brine to waste and the periodic sampling of brine. However, the extraction of radioactive liquid requires a containment to prevent the release of radioactivity in event of a spill. (DOE Order 6430.1A, Sec. 1325). No such procedure exists to extract liquids safely. The leaching/ solubility tests will be the subject of a separate test plan, which has not yet been issued. (See Test Plan Addendum #1: WIPP Bin-Scale CH TRU Waste Tests, at 13 (Dec. 1990)). When and if such a plan is issued, the need for such tests can be evaluated.

32. In addition, the alcove tests are also unprepared to proceed, because no means has been developed to seal the alcoves to prevent escape of gas. The current DOE plans anticipate that the seal will not even be tested until 1993 (W.Weart presentation, Aug. 12, 1991). Thus, the alcove tests cannot proceed at present. Again, the need for such tests can be assessed when their configuration is established.

33. The only tests which the DOE appears to be prepared to conduct are the dry bin-scale tests. However, these are the least justifiable tests from the standpoint of a performance assessment. In these tests no brine is added to the waste. The dry bin tests will generate data reflecting the rate of gas generation only during the operational phase of the repository, prior to permanent disposal. During the operational phase, it is not anticipated that significant quantities of brine will enter and remain in the repository horizon, because brine will be removed by the ventilation system. Information about the operational phase is not material to whether the amount of gas generated from brine-soaked waste in a sealed repository will affect the repository's compliance with long-term disposal standards.

34. Not only do such tests fail to duplicate disposal conditions but also they will fail to generate significant quantities of gas, because the presence of brine is necessary to corrosion and biological action, which are the primary gas-producing reactions. In consequence, the results of dry bin tests

will not contribute materially to modeling of disposal conditions or the level of confidence in performance assessment calculations.

35. Moreover, even if Sandia were prepared to conduct experiments to determine the rate of gas generation by a given amount of waste and brine, such experiments would not disclose how much gas would, in fact, be present in the repository after disposal. Only after modeling the interrelated elements of brine quantity, room closure rate, rock porosity and permeability and other factors will scientists be able to determine whether the rate of generation of gas from specific waste types in contact with specific amounts of brine is an important variable which needs to be established experimentally.

36. The Court should also be aware of additional safety-related constraints upon the bin tests which drastically inhibit the utility of the test information. Under the Final Safety Analysis Report Addendum a procedure of test bin gas monitoring and purging with inert gas is required. (FSAR Addendum, dry bin scale tests §10.1.2). This requirement means that "experimental bins must be purged if the concentration of any flammable gas within the bin reaches 50% of the lower limit for flammability" (Memorandum, A. Lappin and M. Molecke, April 17, 1991, at 1, ex. B hereto). The flammable gases include hydrogen (a product of corrosion, e.g., of steel waste drums) and methane (a product of biological action upon organic wastes).

37. Sandia has concluded that the bin and instrumentation design are not "inherently safe" and not adequate for operations

above 50% of the lower flammability limit (Id. 2). As a result, the equipment is only usable for tests with "wastes for which net gas-generation rates are on the order of 0.1 moles/drum/year," which "essentially permits only radiolytic gas degradation" (Id. 2,4). The effects of radiolytic gas generation are of very minor interest compared to the effects of corrosion and biological action, and there is clearly no present need to conduct tests simply to hone the understanding of radiolysis. Sandia has estimated that only 0.005 moles/drum/year of gas will be produced by radiolysis. (Test Plan: WIPP Bin-Scale CH TRU Waste Tests, SAND 90-8500, at 118 (January 1990)). In comparison, 0.85 moles/drum/year is expected to be produced by microbial action and 1.7 moles/drum/year may be produced by anaerobic corrosion. (Lappin, et al., 1990). The amount of gas produced by radiolysis, in other words, is minuscule and is not the sort of information that might be useful in predicting significant interactions among gas, brine, room closure, and rock permeability.

38. Sandia has stated that "[b]ecause of the purging restraint, it appears that only 'dry' low-organic or other 'low-gas generating' wastes can be tested without modification to the present testing plans and/or the bin and attached instrumentation." (Memorandum, A. Lappin and M. Molecke, April 17, 1991, at 2) But tests with low gas generating wastes miss the main point of the bin tests, which is to study and measure the generation of gas in the repository after disposal (See January 1990 bin-scale test plan at 14-15).

39. More importantly, Sandia has also concluded that, even if bins can be altered to contain flammable gases, purging of the flammable gases regularly--every nine to ten days (Id. 7)--destroys the utility of the test data for the performance assessment:

> "The major consequence of using purging to control bin flammability-safety concerns is to render the resultant data as applicable only to the short-term (early-years) of repository operation. Resultant data interpretations will be of little use for PA [performance assessment] predictive modeling, as claimed by the project, and may not support initial receipt of such wastes at the WIPP, for purposes of evaluating compliance with 40 C.F.R. 191 Part B" (Id. 3-4)

40. Sandia has concluded that, as a result, it cannot claim that the tests are necessary either for the performance assessment under the radioactive waste disposal standards, 40 C.F.R. 191 Part B, or for determination of compliance under the hazardous waste regulations, 40 C.F.R. Part 268. The consequences of bin purging are:

> "1. Inability to claim that gas compositions measured during the experiments are representative of those expected under realistic, long-term repository conditions, as justified in the Test Plan. The required number of bin purges for wastes that generate gases at high rates would completely eliminate the present objective of having gas

compositions in the bin tests approach or simulate those expected under long-term repository conditions." (Id. 5).

* * *

"2. Inability to claim, as a defensible fallback that the experimentally measured, but purged and therefore non-representative gas compositions and generation rates are "bounding" and therefore usable for purposes of Performance Assessment (PA)" (Id. 6).

* * *

"4. Inability to claim that the experimental (bin internal) oxidation potential is in any way representative of that expected in the long-term." (Id. 7).

* * *

"5. Inability to conduct more than about four (4) bin tests on high gas generating HO [high organic] or PS [process sludge] wastes in the WIPP underground, if the proposed FSAR Addendum purging approach is adopted, and as presently constrained by the 3L/min. maximum (input) flow rate for the VOC-manifold system. This not a firm estimate; however, it indicates the extremely limited utility of the WIPP underground as presently constrained." (Id. 7)

* * *

"6. Inability to distinguish between general waste-degradation mechanisms (e.g. radiolysis and anaerobic

corrosion), due to elimination of minor gases (potentially to less than detectable levels) by frequent purging. The long-term interactions that occur at high-gas concentrations, e.g., poisoning or (microbial) fertilization, will be prevented and not investigated." (Id. 7).

* * *

"8. Elimination of the ability to investigate microbial degradation of [volatile organic compounds] in a realistically simulated repository environment... Without such demonstration, compliance with respect to 40 C.F.R. 268 may prove difficult or impossible." (Id. 8).

41. Sandia also has concluded that the "operational problems involved in frequent purging of any significant number of bins also appear to be insurmountable at present." (Id. 7) For instance, only one bin can be purged at once, and it takes three to five days to complete purging. Purging must be performed every nine to ten days. (Id.) Simple arithmetic shows that the DOE is not prepared to set up an underground laboratory containing approximately 100 bins.

42. Problems of this nature raise the obvious question: Why is it necessary to conduct the bin tests at the WIPP? In fact, there is no scientific need to conduct the bin tests at the WIPP. The bin-scale tests are planned to be conducted in bins which are loaded with waste at the place of storage, e.g., Idaho National

Engineering Laboratory, sealed and maintained under pressure throughout the test period. The only occasion for communicating with the bin atmosphere is to extract gas for testing or monitoring, to relieve excessive gas pressure, or to purge potentially explosive gases. These operations could be conducted at any location. To conduct them at the WIPP site or underground adds nothing to the experiment.

43. The January 1990 Bin-Scale test plan states that the tests do not have to be conducted at the WIPP: "It is not mandatory on a scientific basis that these bin-scale tests be conducted at the WIPP. The waste-filled test bins do not directly experience the impacts of the repository environment on waste degradation..." (at 28). I agree with these statements. There is no scientific requirement to conduct the bin tests at the WIPP--even assuming they could be safely and feasibly completed and would generate demonstrably relevant data. Since the data generated is of the most minor importance and cannot be shown to contribute to performance assessment, there is no justification, in my opinion, for conducting the bin tests at the WIPP.

I declare under penalty of perjury that the foregoing is true and correct. Executed: ~~October~~ NOVEMBER 8, 1991.

Barry E. Scheetz

BARRY E. SCHEETZ

I. TEACHING ABILITY AND EFFECTIVENESS

A. Courses Taught in Resident Instruction

PA Teaching Certificate-Pennsylvania

Course No.	Credits	Title	Course Instructor
GSCI4	3	Mineralogy	D.K. Smith
CERSE400	3	Nonmetallic Crystal Chem.	R.E. Newnham
GM512	3	Principals of Crystal Chem.	W.B. White
SSS590	1	Chemistry of Cements	D.M. Roy/ G.W. Grutzeck
MATSI597	3	Materials Science of Radioactive Wastes	W.B. White
GEOL509	3	Construction Materials	D. Gold

[Since Dr. Scheetz's position at the Materials Research Laboratory from Fall 1976 to present is not affiliated with another College, he does not maintain a regular teaching schedule. However, there are opportunities to teach as a substitute for faculty who are temporarily out of town or on sabbatical. A record of the semester taught, enrollment and class hours per week is not available, nor are student evaluations due to the irregularity of teaching. Dr. Scheetz is not compensated for teaching.]

B. Continuing Education Instruction

N/A

C. Correspondence Course Instruction

N/A

D. Advising Responsibilities

Eric Plesko, M.S., Solid State Science, 1981.
Lisa Bratten, M.S., Geochemistry, 1982.
Paul Sliva, M.S., Solid State Science, 1983.
Gerald Cox, M.S., Environmental Pollution Control, 1988.
Paul Sliva, Ph.D., Solid State Science, 1988.
Lorie Urenovitch, M.S., Environmental Pollution Control, 1988.
Jeffery Hoffer, M.S., Environmental Pollution Control, 1989.
Christopher Abate, M.S., Environmental Pollution Control, 1990.
Petra M. Heiland, M.S., Solid State Science, 1990.
Scott Atkinson, M.S., Environmental Pollution Control, 1990.
Diane Dopkin, M.S., Environmental Pollution Control [in progress].
Norman Sands, Ph.D., Solid State Science, 1991.

Joon Lee, Ph.D., Solid State Science [in progress].
Kathlene Mayes, M.S., Environmental Pollution Control, 1991.
Yan Chen, M.S., Electrical Engineering, (1991)
Christopher Fontana, M.S., Environmental Pollution Control [in progress].
Russell Earl, M.S., Environmental Pollution Control [in progress].

II. RESEARCH OR CREATIVE ACCOMPLISHMENT

A. Publications

1. Articles Published in Refereed Journals

White, W.B., G.J. McCarthy, and B.E. Scheetz, "Optical Spectra of Cr, Ni and Co Containing Pyroxenes," Am. Mineral. 50, 72-89 (1971). Co-Author.

Scheetz, B.E., and W.B. White, "Synthesis and Optical Absorption Spectra of Cr^{2+} Containing Orthosilicates," Cont. Mineral. and Petrol. 37, 221-227 (1972). Co-Author.

Scheetz, B.E., and W.B. White, "The Vibrational Spectra of Alkaline Earth Double Carbonate Minerals," Am. Mineral. 62, 36-50 (1977). Co-Author.

Burgner, R.P., B.E. Scheetz, and W.B. White, "Vibrational Structure of S_2 Luminescence in Scapolite," Phys. Chem. Minerals 2, 317-324 (1978). Co-Author.

McCarthy, G.J., W.B. White, B.E. Scheetz, S. Komarneni, D.K. Smith, and D.M. Roy, "Interactions Between Nuclear Waste and Surrounding Rocks," Nature 273, 216-217 (1978). Co-Author.

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Scheetz, Barry E. And Jefferson P. Hoffer, "Characterization of Sodium Siliate Activated Portland Cement: I. Matrices for Low-Level Radioactive Waste Form, " American Concrete Insitute (March 1991), Co-Author.

Lee, J.H., D.M. Roy, L.H. Licastro and B.E. Scheetz, "A Study of concrete for the Tumulus Disposal Units in Low-Level Radioactive Waste Management," Am. Ceram. Soc. 5th International Symposium on Radioactive and Hazardous Waste (April 1991)., Co-Author.

Scheetz, Barry E. and Della M. Roy, "The Chemistry of Cementitious Systems for Waste Management: The Penn State Experience," Am. Chem. Soc., Environmental Science Symposium (August 1991), Co-Author.

8. Manuscripts in Progress

Scheetz, Barry E., Christopher M. Stevenson, and K. Vedam, "Spectroscopic Ellipsometry: An Alternative Analyitical Method to Achieve Angstrom Resolution of Obsidian Hydration Rims." Co-Author.

Silsbee, M.R., D.M. Roy, and B.E. Scheetz, "An Evaluation of the Usefulness of Various Distribution Functions for Describing Mercury Intrusion Porosimetry Data." Co-Author.

Barnes, Mary W., Della M. Roy, and Barry E. Scheetz, "The Relation of Microstructure to Composition and Formation Temperature of Al-Substituted Tobermorite." Co-Author.

Barnes, M.W., and B.E. Scheetz, "A Review of the Al-Substituted Carbon Silicate Hydrates and Their Coexisting Phases in the Hydration of Zeolites at 100-300°C." Co-Author.

Barnes, M.W., B.E. Scheetz, and D.M. Roy, The Effect of Chemically Adjusting Cement Composition and Leachability of Waste Forms." Co-Author.

Silsbee, Michael R., Amitabha Kumar, and Barry E. Scheetz, "Intrepretation of Pore Structure in Cementitious Solids By the Use of Fractal Geometry." Co-Author.

Scheetz, Barry E., Lauren Zellmer, and William B. White, "Vibrational Spectra of the Melilite Structure: II. Akermanite-Gehlenite Solid Solution." Co-Author.

Scheetz, Barry E., Richard Mohler, and William B. White, "Raman Spectra and the Intrepretation of Acentricity in 1:3 Stoichiometric Spinel." Co-Author.

Scheetz, Barry E., and William B. White, "Vibrational Spectra of the Melilite Structure: I. Selected Single Crystal Data." Co-Author.

Scheetz, Barry E., Lauren Zellmer, and William B. White, "Vibrational Spectra of the Melilite Structure: III. Effects of Anion Substitution." Co-Author.

Pommersheim, James M., and Barry E. Scheetz, "Transient Measurement of the Permeability of Cementitious Materials Using Pressure Pulse Testing--Theory." Co-Author.

Scheetz, Barry E., and Rustum Roy, "Mineral Models for Hazardous Waste Fixation: A Second Generation." Co-Author.

Hoffer, Jeffery, and Barry E. Scheetz, "Characterization of Cement/Silicate for Low Level Nuclear Waste Forms." Co-Author.

Urenovitch, Lauren, and Barry E. Scheetz, "Characterization and Utilization of Foundry Bag House Dust as a Reactive Mineral Admixture in Concrete." Co-Author.

9. Cooperative Extension Service Bulletins and Circulars

N/A

B. Research Projects, Grants and Contracts

1. Completed

Date:	1 October 1978 to 30 September 1979
Title:	Determining Interactions Between Spent Unreprocessed Fuel (SURF), Supercalcine, High-level Waste Glass and Basalt
Funded by:	Rockwell Hanford Operations
Amount:	$184,843
Contribution:	Principal Investigator

Date:	1 October 1979 to 30 September 1980
Title:	Quantitative Estimates of the Compositions of Solid and Liquid Phases Stable Under Hydrothermal Conditions
Funded by:	Rockwell Hanford Operations
Amount:	$140,000
Contribution:	Principal Investigator

Date: 1 October 1982 to 30 September 1983
Title: The Immobilization of Heavy Metal Cations in Plating Liquor Wastes
Funded by: The Office of Hazardous and Toxic Waste Management
Amount: $50,000
Contribution: Principal Investigator

Date: 1 October 1984 to 30 September 1985
Title: Synthesis and Characterization of Non-Linear Optic Materials
Funded by: Lawrence Livermore National Laboratory
Amount: $220,073
Contribution: Co-Principal Investigator

Date: 1 August 1985 to 31 July 1986
Title: Equipment for a Particulate Characterization Facility
Funded by: National Science Foundation; Division of Materials Research
Amount: $156,690
Contribution: Co-Principal Investigator

Date: 1 April 1985 to 31 March 1986
Title: Preparation of X-Ray Powder Data for Synthesized Compounds
Funded by: Joint Committee on Powder Diffraction, GRANT-IN-AID
Amount: $4,000
Contribution: Principal Investigator

Date: 1 September 1985 to 31 August 1986
Title: Foundry Sand Reclamation
Funded by: Ben Franklin Partnership Program
Amount: $125,000
Contribution: Co-Principal Investigator

Date: 1 October 1985 to 30 September 1986
Title: Synthesis and Characterization of Non-Linear Materials
Funded by: Lawrence Livermore National Laboratory
Amount: $221,163
Contribution: Co-Principal Investigator

Date: 1 April 1986 to 31 March 1987
Title: Preparation of X-Ray Powder Data for Synthesized Compounds
Funded by: Joint Committee on Powder Diffraction, Grant-in-Aid
Amount: $12,000
Contribution: Principal Investigator

Date: 1 September 1986 to 31 August 1987
Title: Regional Foundry Sand Disposal
Funded by: Ben Franklin Partnership Program
Amount: $136,155
Contribution: Co-Principal Investigator

Date: 28 October 1986 to 30 September 1987
Title: Grout-Salt Interface Studies
Funded by: Sandia National Laboratory
Amount: $98,470
Contribution: Co-Principal Investigator

Date: 1 April 1987 to 31 March 1988
Title: Preparation of X-Ray Powder Data for Synthesized Compounds
Funded by: Joint Committee on Powder Diffraction, Grant-in-Aid
Amount: $15,000
Contribution: Principal Investigator

Date: 1 August 1987 to 31 July 1989
Title: Development of a Predictive Model for Acid Mine Drainage: Based Upon State-of-the-Art-Overburden Characterization
Funded by: Pennsylvania Energy Development Authority
Amount: $223,521
Contribution: Principal Investigator

Date: 1 September 1987 to 31 August 1988
Title: Regional Foundry Sand Disposal and Reclamation Site
Funded by: Ben Franklin Partnership Program
Amount: $164,487
Contribution: Co-Principal Investigator

Date: 1 October 1987 to 30 August 1990
Title: Concrete Microstructure
Funded by: Strategic Highway Research Program
Amount: $811,316
Contribution: Co-Principal Investigator

Date: 1 April 1988 to 31 March 1989
Title: Preparation of X-Ray Powder Data for Synthesized Compounds
Funded by: Joint Committee on Powder Diffraction, Grant-in-Aid
Amount: $25,000
Contribution: Principal Investigator

Date: 1 September 1988 to 31 August 1989
Title: Regional Foundry Sand Disposal and Reclamation Site
Funded by: Ben Franklin Partnership Program
Amount: $246,088
Contribution: Co-Principal Investigator

Date: 15 March 1989 to 15 September 1989
Title: John Priestley Archaeological Sample Characterization
Funded by: Pennsylvaia Historical and Museum Commission
Amount: $2,000
Contribution: Principal Investigator

Date: 15 February 1990 to 14 May 1990
Title: NP-Analysis
Funded by: Bradford Coal Co.
Amount: $11,000
Contribution: Principal Investigator

Date: 1 April 1988 to 31 March 91
Title: Processing and Properties of Chemically-Derived Calcium Silicate Cements
Funded by: Air Force Office of Scientific Research
Amount to: $267,604
Contribution: Co-Principal Investigator

Date: October 1989 to December 1991
Title: Improving the Characterization of Sulfur in Overburdens and Coals Using State-of-the-Art-Technology
Funded by: Office of Surface Mining
Amount: $150,000
Contribution: Principal Investigator

Date: 1 July 1990 to 31 December 1990
Title: Characterization of Trace Elements in Prehistoric Clay Pots
Funded by: Pennsylvaia Historical and Museum Commission
Amount: $1,000
Contribution: Principal Investigator

Date: 1 October 1990 - 28 February 1991
Title: The Chemical Characterization of Jaspers from Pennsylvania and Delaware
Funded by: Pennsylvania Historical and Museum Commission
Amount: $23,986
Contribution: Co-Principal Investigator

2. In Progress

Date: 1 April 1989 to 31 March 1990
Title: Preparation of X-Ray Powder Data for Synthesized Compounds
Funded by: Joint Committee on Powder Diffraction
Amount: $18,000
Contribution: Principal Investigator

Date: 1 July 1990 - 31 June 1991
Title: Characterization of Sulfur in Coals and Associated Overburdens
Funded by: National Mine Land Reclamation Center
Amount: $71,292
Contribution: Principal Investigator

3. Funded

N/A

4. Proposed

a. Rejected

Date: 1 August 1981 -3 July 1984
Title: An Integrated Technical Assistance and Reseach Program for Hazardous and Toxic Waste Management
Submitted to: Pennsylvania Department of Environmental Resources
Amount: $470,000
Contribution: Co-Principal Investigator

Date:	1 August 1981 - 30 July 1982
Title:	Chemical Modification of Fly Ash for Enhanced Utilization of Industrial Waste Material
Submitted to:	Office of Fossil Energy, Department of Energy
Amount:	$67,119
Contribution:	Co-Principal Investigator

Date:	1 April 1982 - 31 March 1983
Title:	Luminescence in Dental Porcelains
Submitted to:	Johnson and Johnson Dental Products Co.
Amount:	$37,102
Contribution:	Principal Investigator

Date:	1 March 1982 - 31 December 1982
Title:	Selection of Solidification Materials for ICPP Waste
Submitted to:	Delaware Custom Material
Amount:	$59,977
Contribution:	Principal Investigator

Date:	1 April 1983 - 31 March 1984
Title:	X-ray Diffraction Facility for Materials Research
Submitted to:	Department of Defense
Amount:	$131,311
Contribution:	Co-Principal Investigator

Date:	15 April 1984 - 14 March 1985
Title:	DOD-University Research Instrument Program for X-ray Diffractometer System
Submitted to:	Department of Defense
Amount:	$98,483
Contribution:	Co-Principal Investigator

Date:	1 July 1984 - 31 September 1984
Title:	Low Temperature Chemically Bonded Ceramics for Hardened Structures
Submitted to:	Air Force Office of Scientific Research
Amount:	$19,994
Contribution:	Principal Investigator

Date:	1 June 1985 - 31 May 1986
Title:	Excavation of a Late Classic Maya Lime Kiln (Mound 70-32) at Copan, Honduras
Submitted to:	Getty Foundation
Amount:	$4,422
Contribution:	Co-Principal Investigator

Date:	1 January 1986 - 31 December 1990
Title:	Experimentally Derived Hydration Rates and the Role of Composition in the Diffusion Process
Submitted to:	National Science Foundation
Amount:	$346,640
Contribution:	Co-Principal Investigator

Date: 1 August 1986 - 31 July 1990
Title: Center for Advanced Cement Matrix Composite Materials
Submitted to: Air Force Office of Scientific Research
Amount: $2,915,945
Contribution: Principal Investigator

Date: 1 January 1987 - 31 December 1988
Title: John Priestly Archaeological Sample Characterization
Submitted to: Pennsylvania Historical and Museum Commission
Amount: $2,000
Contribution: Principal Investigator

Date: 1 July 1987 - 30 June 1988
Title: The Chemical Characterizaton of Prehistoric Lithic Sources in Pennsylvania
Submitted to: Pennsylvania Historical and Museum Commission
Amount: $12,324
Contribution: Co-Principal Investigator

Date: 1 July 1987 - 30 June 1988
Title: Engineering Research Equipment Grant: X-ray Diffraction Facility Upgrade
Submitted to: National Science Foundation
Amount: $99,277
Contribution: Co-Principal Investigator

Date: 1 July 1987 - 30 June 1988
Title: Equipment for a Scanning Electron Microscopy Facility
Submitted to: National Science Foundation
Amount: $346,605
Contribution: Co-Principal Investigator

Date: 1 September 1987 - 31 August 1988
Title: A Scanning Electron Microscope Facility
Submitted to: Department of Energy
Amount: $259,954
Contribution: Co-Principal Investigator

Date: 1 September 1987 - 30 August 1992
Title: The Establishment and Operation of a Center for Nuclear Waste Regulatory Analysis at The Pennsylvania State University
Submitted to: Nuclear Regulatory Commission
Amount: $42,550,000
Contribution: Co-Principal Investigator

Date: 1 April 1988 - 31 October 1990
Title: Evaluation Procedures for Deicing Chemicals and Improved Sodium Chloride
Submitted to: Strategic Highway Research Program
Amount: $593,577
Contribution: Co-Principal Investigator

Date: 1 May 1988 - 31 April 1993
Title: Hazardous Substance Research Center for EPA Regions III and V
Submitted to: Environmental Protection Agency
Amount: $175,000
Contribution: Co-Principal Investigator
Date: 1 November 1988 - 31 October 1991
Title: Phase Chemistry of Al-Substituted Calcium Silicate Hydrate and Related Calcium Aluminate Silicate Hydrates
Submitted to: National Science Foundation
Amount: $153,583
Contribution: Co-Principal Investigator

Date: 1 May 1989 - 31 April 1991
Title: Development of Mechanistic Model for Set Control of Calcium Aluminate Cement
Submitted to: Office of Naval Research
Amount: $331,536
Contribution: Co-Principal Investigator

Date: 1 July 1990 - 31 June 1991
Title: Determination of Carbonate Control of Alkalinity in Acid Mine Drainage
Submitted to: National Mine Land Reclamation Center
Amount: $81,329
Contribution: Principal Investigator

Date: Equipment grant 1 year
Title: Scanning Electron Microscopy Facility
Submitted to: Department of Energy
Amount: $367,300
Contribution: Co-Principal Investigator

Date: 1 September 1990 - 31 August 1993
Title: Coal Industry Waste Utilization in Novel Hydration Binders
Submitted to: Pittsburgh Energy Technology Center
Amount: $199,734
Contribution: Principal Investigator

Date: 1 October 1990 - 28 February 1991
Title: The Chemical Characterization of Jaspers from Pennsylvania and Delaware
Submitted to: Pennsylvania Historical and Museum Commission
Amount: $23,986
Contribution: Co-Principal Investigator

Date: 1 November 1990 - 31 December 1992
Title: Phase Chemistry of Al-Substituted Calcium Silicate Hydrates and Related Calcium Aluminate Silicate Hydrates
Submitted to: National Science Foundation
Amount: $237,486
Contribution: Co-Principal Investigator

Date: 1 January 1990 - 31 August 1990
Title: Implement Recent Advances in Overburdern Characterization to Predict Occurrence of Acid Mine Drainage
Submitted to: Ben Franklin Partnership
Amount: $94,867
Contribution: Principal Investigator

b. Rejected

Date: 1 August 1990 - 31 July 1992
Title: Controlled Study of the Effect of Alkaline Addition to Surface Mine Overburden
Submitted to: Pennsylvania Energy Development Authority
Amount: $250,000
Contribution: Co-Principal Investigator

C. Graduate Thesis Supervised, Types of Degrees and Years Granted

Eric Plesko, Phase Relationships in the System K_2O,UO_3,SiO_2,H_2O, M.S., Solid State Science (1981).

Lisa Bratten, Geochemistry Partitioning of Radionuclides in a Hydrogeological Environment, M.S., Geochemistry (1982).

Paul Sliva, Application of Phosphate-Based Cement to the Immobilization of Defense Nuclear Waste, M.S., Solid State Science (1983).

Gerald Cox, Geochemical Modeling of an Acid Pickeling Waste Disposal Site, M.S., Environmental Pollution Control (1988).

Paul Sliva, Application of Densified Low Temperature Chemically Bonded Ceramics to the Formation of Low Permeativity Substrates, Ph.D., Solid State Science (1988).

Lorie Urenovitch, Characterization and Utilization of Metal Finishing Wastes from Ferrous and Non-Ferrous Foundry Operations, M.S., Environmental Pollution Control (1988).

Jefferson P. Hoffer, Characterization and Performance Assessment of an Aqueous Silicate Modified Portland Cement-Based Nuclear Waste Form, M.S., Environmental Pollution Control (1989).

Christopher Abate, Stability and Dissolution Kinetics of Expansive, Cementitious Calcium Chloro-Aluminate Phases in Low Water Activity Solutions, M.S., Environmental Pollution Control (1990).

Petra M. Heiland, Processing and Properties of Chemically Derived Calcium Silicate Quartzites, M.S., Solid State Science (1990).

Scott Atkinson, Characterization and Utilization of Scrubber Sludge Wastes from Ferrous and Non-Ferrous Foundry Operations, M.S., Environmental Pollution Control (1991).

Diane Dopkin, Characterization and Utilization of Slag Wastes from Copula and Electric Furnace Operations of Ferrous and Non-Ferrous Foundries, M.S., Environmental Pollution Control [in progress].

Norman S. Sand, Partially Sintered, Tape Cast Calcium Aluminate with Controlled Porosity, M.S., Solid State Science (1991).

D. Membership on Graduate Degree Candidates' Committees

Ishii Tautamu, M.S., Solid State Science (1981)
Amitabha Kumar, M.S., Solid State Science (1982)
Charlet Stramburg, M.S., Agronomy (1983)
Catherine Chess, M.S., Solid State Science (1983)
Alieta Tesar, M.S., Ceramic Science (1983)
Amitabha Das, M.S., Solid State Science (1984)
Mohamad Khalil, Ph.D., Nuclear Engineering (1984)
Amitabha Kumar, Ph.D., Solid State Science (1985)
Marianela Perez, Ph.D., Solid State Science (1986)
Shawshem Lee, M.S., Solid State Science (1986)
Per Anderson, Ph.D., Solid State Science (1987)
Robert Luhrs, M.S., Environmental Pollution Control (1987)
Pamula Kisler, Ph.D., Solid State Science (1988)
Michael Silsbee, Ph.D., Solid State Science (1988)
Cheryl Vaughan, Ph.D., Solid State Science (1989)
Ira Sasowsky, Ph.D., Geosciences (1989)
Douglas Watson, M.S. Solid State Science (1991)

E. Supervision of Visiting Scientists and Visiting Students

1. Visiting Scientists

George Kirov, National Academy of Sciences, Sophia, Bulgaria, "Anion Modifications to the Crystal Morphology of Hydrothermally Grown Quartz" (1982).

W. Fajun, Institute of Building Materials, Department of Materials Science and Engineering, Wuhan, Hubei, People's Republic of China, "Stability of NZP" (1985).

John Thompson, MRL High School Teacher Summer Intern Program, "Development of Alkali-Activated Fly Ash Cement" (1990).
Anthony Raftery, Physics Department, Queensland University, Australia (1991).

2. Visiting Students

Kristina von Rein, 'Examensarbete', The Royal Institute of Technology, Stockholm, Sweden, "Process Densification of A Cement-Based Nuclear Waste Form" (1984).

3. United States Navy ROTC Program, The Pennsylvania State University

Brent Beabout, "Development of PARTPAC -- A Computer Code for Estimation of Densest Packing of Particles" (1987).

Daniel Bailey, "Establishment of an Experimental Laboratory Procedure for Estimating Densest Packing in Concrete Components" (1988).

4. Ceramic Science Undergraduate Research

Jeff Marx, "Evaluation of Phosphate Materials with Quartz Structures as Electronic Substrate Materials" (1990).

Neil Smith, "Development of Controlled Porosity Calcium Aluminate Substrate Materials" (1990).

Robert Alexander, "Crystal Chemistry of Si-Substitution Into Ettringite" (1990).

F. Creative Accomplishment

N/A

G. Other Evidence of Research Accomplishment

a. Scientific Photographs Resulting from Research Have Been Published in:

Earth and Mineral Sciences 50 (2), pp. 13 and 18 (Dec. 1981).
Nuclear Technology 56 (2) (Feb. 1982) [cover photographs].
Materials Research Laboratory, The Departmental Brochure (1987).
Science 250 (21 Dec. 1990) [cover photograph],
Pergaman Journal of Waste & Recycling Advertisement Brochure (JEU12) (11/90).

b. Patent Applications

Cementitious Composite Materials with Stainless Steel Particles
Patent # 4,482,385
Gotzmer, J.M. Rizer, J.A. Satkowski and B.E. Scheetz
Awarded: 13 Nov. 1984

This patent has also been or will be issued in the following organizations and countries:

World Patent Corporation Patent # 8,500,385
European Patent Office Patent # 149,644
Australian Patent # 8,431,072
Brazil Patent # 8,406,963
Japan (issued)
South Africa (pending)
Israel (pending)
Italy (pending)
Austria (pending)
Belgium (pending)
France (pending)
Luxenborg (pending)
Netherlands (pending)
Sweden (pending)
Switzerland (pending)
United Kingdom (pending)
West Germany (pending)
Denmark (pending)
Canada (pending)
Hong Kong (pending)
Singapore (pending)

Cementitious Composite Materials
Patent # 4,505,333
Hahn, J.M. Rizer and B. E. Scheetz
Awarded: 12 Dec. 1984

Composite Material - Comprising Portland Cement, Silica Fume, Super-Plasticizer, Antifoam Filler and Water
Patent # 4,505,753
Scheetz, B.E., J.M. Rizer and M. Hahn
Awarded: 19 March 1985

This patent has also been or will be issued in the following organizations and countries:

World Patent Corporation Patent # 8,500,359
European Patent Office Patent # 148,935
Australia Patent # 8,406,962
Brazil Patent # 8,406,962
Japan Patent # 60,501,707
South Africa (pending)
Israel (pending)
Italy (pending)
Austria (pending)
Belgium (pending)
France (pending)
Luxenborg (pending)
Netherlands (pending)
Sweden (pending)
Switzerland (pending)
United Kingdom (pending)
West Germany (pending)
Denmark (pending)
Canada (pending)
Hong Kong (pending)
Singapore (pending)

c. Industrial Development

Submission of Licensing Application to NRC for Low-Level Radioactive Waste, DCM (1988).

Development and Licensing of a Monofill for Foundry Residual Waste in Berks County, PA, 1989

d. Equipment and Operational Procedures Developed for Use Within MRL

Uniaxial water/gas permeability apparatus
Triaxial water permeability apparatus
Triaxial pulsed water permeability apparatus

Apparatus for determination of linear
Expansion/shrinkage of grout as a function of
Temperature and confining pressure

Designed and rebuilt three laboratories designated for the hydrothermal testing of materials. This included small low volume capabilities as well as large volume multi-sample capability and sampling at T and P apparatus.

Designed and constructed apparatus to obtain water permeability measurements of cementitious materials both as uniaxial measurements at elevated pressure and at isostatic conditions.

Designed and constructed apparatus for linear shrinkage of cementitious materials.

Designed and constructed a one-pass hydrothermal system capable of 400°C at 10,000 psi.

e. Materials Prepared as Standard Reference Patterns for JCPDS-ICDD, Swarthmore, PA

Published in Set 38 (1988)

Barium Zirconium Germanium Oxide	$BaZrGe_3O_9$
Strontium Sodium Potassium Niobium Oxide	$Sr_2Na_{0.5}K_{0.5}Nb_5O_{15}$
Barium Hafnium Germanium Oxide	$BaHfGe_3O_9$
Lithium Vanadium Oxide	Li_3VO_4
Aluminum Gadolinium Borate	$Al_3GdB_4O_{12}$
Sodium Niobium Tantalum Oxide	$NaNb_{0.5}Ta_{0.5}O_3$
Strontium Bismuth Titanium Niobium Oxide	$Sr_5BiTi_3Nb_7O_{30}$
Calcium Aluminum Lanthanum Oxide	$CaLaAl_3O_7$
Lithium Niobium Tantalum Oxide	$LiNb_{0.5}Ta_{0.5}O_3$
Sodium Barium Tungsten Niobium Oxide	$Na_3Ba_3WNb_9O_{30}$
Barium Titanium Germanium Silicate	$Ba_2Ti(Ge_{1.6}Si_{0.4})O_8$
Sodium Potassium Barium Strontium Niobium	$Na_{0.5}K_{0.5}BaSrNb_5O_{15}$
Sodium Barium Strontium Niobium Oxide	$NaBaSrNb_5O_{15}$
Potassium Barium Strontium Niobium Oxide	$KBaSrNb_5O_{15}$
Iron Bismuth Titanium Oxide	$FeBiBi_4Ti_3O_{15}$
Sodium Barium Lanthanum Niobium Oxide	$Na_3Ba_2LaNb_{10}O_{30}$
Cesium Lithium Tungsten Oxide	$CsLiWO_4$
Cesium Lithium Molybdenum Oxide	$CsLiMoO_4$
Sodium Barium Gadolinium Niobium Oxide	$Na_3Ba_2GdNb_{10}O_{30}$
Barium Titanium Germanium Silicon Oxide	$Ba_2TiGe_{0.4}Si_{1.6}O_8$
Cesium Lithium Tungsten Molybdenum Oxide	$CsLiW_{0.5}Mo_{0.5}O_4$
Cesium Lithium Tungsten Molybdenum Oxide	$CsLiW_{0.1}Mo_{0.9}O_4$
Sodium Barium Tungsten Niobium Oxide	$Na_4Ba_2W_2Nb_8O_{30}$
Barium Titanium Germanium Silicon Oxide	$Ba_2TiGe_{1.2}Si_{0.8}O_8$
Manganese Ytterbium Oxide	$MnYbO_3$
Zinc Gallium Oxide	$ZnGa_2O_4$
Cesium Lithium Tungsten Molybdenum Oxide	$CsLiW_{0.9}Mo_{0.1}O_4$
Strontium Titanium Silicon Oxide	$Sr_2TiSi_2O_8$
Sodium Lead Tantalate Oxide	$NaPb_2Ta_5O_{15}$
Barium Sodium Niobium Tantalum Oxide	$Ba_2NaNb_{1.25}Ta_{3.75}O_{15}$

Barium Sodium Tantalum Oxide	$Ba_2NaTa_5O_{15}$
Barium Calcium Borate	$Ba_2Ca(B_3O_6)_2$
Barium Sodium Niobium Tantalum Oxide	$Ba_2NaNb_{3.75}Ta_{1.25}O_{15}$
Gadolinium Phosphate Hydrate	$GdPO_4H_2O$
Bismuth Titanium Niobium Oxide	Bi_3TiNbO_9
Barium Cobalt Borate	$Ba_2Co(B_3O_6)_2$
Strontium Zinc Silicate	$Sr_2ZnSi_2O_7$
Potassium Lanthanum Tantalum Oxide	$K_2LaTa_5O_{15}$
Potassium Neodymium Niobium Oxide	$K_2NdNb_5O_{15}$
Strontium Gallium Germanium Oxide	$Sr_3Ga_2Ge_4O_{14}$
Calcium Gallium Germanium Oxide	$Ca_2Ga_2GeO_7$
Barium Titanium Niobium Oxide	$Ba_6Ti_2Nb_8O_{30}$
Sodium Barium Yttrium Niobium Oxide	$NaBa_3YNb_{10}O_{30}$
Barium Lanthanum Titanium Niobium Oxide	$Ba_3La_3Ti_5Nb_5O_{30}$
Lithium Zinc Vanadium Oxide	$LiZnVO_4$
Strontium Aluminum Silicon Oxide	$Sr_2Al_2SiO_7$
Potassium Antimony Germanium Oxide	$KSbGe_3O_9$

Published in Set 39 (1989)

Calcium Aluminum Gallium Silicate	$Ca_2Al_{0.4}Ga_{1.6}SiO_7$
Strontium Barium Titanium Niobium Oxide	$Sr_2Ba_4Ti_2Nb_8O_{30}$
Potassium Samarium Niobium Oxide	$K_2SmNb_5O_{15}$
Lithium Sodium Titanium Barium Niobium Oxide	$Li_4Na_2Ti_4Ba_4Nb_6O_{30}$
Zinc Borate (high)	$Zn(BO_2)_2$
Calcium Lanthanum Gallium Oxide	$CaLaGa_3O_7$
Potassium Europium Niobium Oxide	$K_2EuNb_5O_{15}$
Potassium Lanthanum Niobium Oxide	$K_2LaNb_5O_{15}$
Potassium Calcium Strontium Niobium Oxide	$KCaSrNb_5O_{15}$
Sodium Barium Europium Niobium Oxide	$Na_3Ba_2EuNb_{10}O_{30}$
Sodium Strontium Barium Niobium Oxide	$NaSr_{1.2}Ba_{0.8}Nb_5O_{15}$
Barium Sodium Gadolinium Niobium Oxide	$Ba_3NaGdNb_{10}O_{30}$
Strontium Sodium Tantalum Oxide	$Sr_2NaTa_5O_{15}$
Barium Lanthanum Titanium Niobium Oxide	$Ba_5LaTi_3Nb_7O_{30}$
Barium Lithium Tantalum Oxide	$Ba_2LiTa_5O_{15}$
Lead Potassium Tantalum Oxide	$Pb_2KTa_5O_{15}$
Calcium Europium Gallium Aluminum Oxide	$CaEuGaAl_2O_7$
Potassium Strontium Tungsten Niobium Oxide	$K_3Sr_3WNb_9O_{30}$
Potassium Gadolinium Tantalum Oxide	$K_2GdTa_5O_{15}$
Potassium Europium Tantalum Oxide	$K_2EuTa_5O_{15}$

Accepted for Set 40 (1990)

Sodium Barium Holmium Tantalum Oxide	$NaBa_3HoTa_{10}O_{30}$
Potassium Holmium Niobium Oxide	$K_2HoNb_5O_{15}$
Sodium Barium Tungsten Tantalum Oxide	$Na_4Ba_3W_2Ta_8O_{30}$
Potassium Barium Niobium Oxide	$KBa_3Nb_7O_{21}$
Strontium Bismuth Titanium Tantalum Oxide	$Sr_5BiTi_3Ta_7O_{30}$
Potassium Strontium Tantalum Oxide	$KSr_2Ta_5O_{15}$

Potassium Barium Tantalum Oxide	$KBa_2Ta_5O_{15}$
Sodium Lead Niobium Oxide	$NaPb_2Nb_5O_{15}$
Sodium Barium Holmium Niobium Oxide	$Na_3Ba_2HoNb_{10}O_{30}$
Lithium Potassium Tantalum Oxide	$Li_2K_3Ta_5O_{15}$
Sodium Barium Titanium Niobium Oxide	$NaBa_5TiNb_9O_{30}$
Potassium Calcium Strontium Tantalum Oxide	$KCaSrTa_5O_{15}$
Sodium Barium Strontium Tantalum Oxide	$NaBaSrTa_5O_{15}$
Potassium Barium Strontium Tantalum Oxide	$KBaSrTa_5O_{15}$
Sodium Barium Tungsten Tantalum Oxide	$Na_4Ba_2W_2Ta_8O_{30}$

III. SCHOLARSHIP AND MASTERY OF SUBJECT MATTER

A. Record of Pursuit of Advanced Degree and/or Further Academic Studies

B.S., Chemical Education, Bloomsburg State College, 1967.
M.S., Geochemistry, The Pennsylvania State University, 1972.
Ph.D., Geochemistry and Mineralogy, The Pennsylvania State University, 1976.

B. Record of Participation in Workshops, Seminars and Short Courses

Technical editor of the Department of Energy sponsored workshop of Nuclear Waste Management, The Pennsylvania State University, University Park, PA (July 1977).

Scheetz, Barry E., and G.J. McCarthy, "Geochemical Factors of Waste Isolation," RHO-BWI-78-100, Rockwell Hanford Operations, Richland, WA (1978). Speaker.

Scheetz, Barry E., "Necessary Research Underlying Tailored Cementitious Materials for Borehole Plugging," RHO-BWI-78-100, Rockwell Hanford Operations, Richland, WA (1978). Speaker.

McCarthy, G.J., S. Komarneni, and Barry E. Scheetz, "The Chemical Reactions of Simulated SURF and Columbia River Basalt," RHO-BWI-78-100, Rockwell Hanford Operations, Richland, WA (1978). Co-Author.

"Hydrothermal Interactions Between Nuclear Wastes and Host Rocks during the Thermal Period," Repository Considerations Workshop. Rockwell Hanford Operations, Richland, WA (June 1978) (with G.J. McCarthy).

White, William B., Gregory J. McCarthy, Barry E. Scheetz, W. Phelps Freeborn, and Sridhar Komarneni, "Brine-Wasteform Interactions Under Mild Hydrothermal Conditions," Proceedings of the National Waste Terminal Storage Program Information Meeting, Office of Nuclear Waste Isolation, Columbus, OH (Nov. 1979). Co-Investigator.

"Status of the Static, Closed-System Hydrothermal Experiments of Simulated Nuclear Waste Forms," Basalt Waste Isolation Project Workshop, Richland, WA (December 1979).

Grutzeck, M.W., B.E. Scheetz, E.L. White, and D.M. Roy, "Modified Cement-Based Borehole Plugging Materials: Properties and Potential Longevity," Workshop on Borehole and Shaft Plugging, Columbus, OH (May 1980). Co-Investigator.

Scheetz, B.E., "Modified Cement-Based Borehole Plugging Materials: Properties and Potential Longevity," OECD/ONWI Workshop on Borehole Shaft Plugging, Columbus, OH (May 1980).

Scheetz, B.E., "Dissolution of Aluminum, Titanium and Zirconium," Annual Argonne Workshop: Comparative Leaching Behavior of Radioactive Waste Forms, Chicago, IL (Sept. 1980).

Scheetz, Barry E., W.B. White, and S.D. Atkinson, "Dissolution of Aluminum-, Titanium- and Zirconium-Based Crystalline Waste Forms Components Under

Hydrothermal Conditions," Workshop on Wasteform Leachability, Argonne National Laboratory (Sept. 1980). Speaker.

Roy, D.M., Barry E. Scheetz, L.D. Wakeley, and M.W. Barnes, "Leach Characterization of Cement Encapsulated Waste," Conference on the Leachability of Radioactive Solids, Oak Ridge National Laboratory, Gatlinburg, TN (Dec. 1980). Speaker.

Scheetz, Barry E., EPRI Workshop on Systems Design and Concrete Durability of Cements for Low Level Nuclear Waste Proposal, Washington, D.C. (1984). Panel Participant.

Scheetz, Barry E., "Geochemical Evaluation of Grout Similar to the Topopah Spring Member Tuff," Design Requirements and Materials Recommendation Workshop, Sandia National Laboratories, November 12, 1984

Scheetz, Barry E., "Full-Scale Borehole Sealing Tests," Workshop on Bench Scale Borehole Sealing Tests, Office of Nuclear Waste Isolation, Columbus, OH (Dec. 1985). Speaker.

Scheetz, Barry E., "Geochemical Stability and Longevity of Concrete," Technical Exchange Program Information Meeting with the Federal Republic of Germany (1986). Speaker.

Scheetz, Barry E., Workshop on Sealing and Backfilling of a Salt Repository, II-3, Department of Energy, Albuquerque, NM (Sept. 1986). Speaker.

Scheetz, Barry E., "Benchscale Borehole Plugging Tests," Technical Exchange Program Information Meeting with the Federal Republic of Germany, Workshop on Sealing and Backfilling of a Salt Repository, II-3, Department of Energy, Albuquerque, NM (Sept. 1986). Speaker.

Scheetz, Barry E., Workshop on Leaching, Part II, Waste Management Technology Center, Oak Ridge National Laboratory, Oak Ridge, TN (1988). Leader of working group on leach theory.

C. Papers Presented at Technical and Professional Meetings

"Vibrational Spectra of Selected Melilite Minerals," American Geophysical Union, Washington, D.C. (April 1973). Presentor.

"A Vibrational Study of the Order/Disorder in the Alkaline-Earth Double Carbonates," American Geophysical Union, Washington, D.C. (June 1975). Presentor.

"Raman Spectral Studies of Order/Disorder in Cordierite," American Geophysical Union, Washington, D.C. (April 1976). Presentor.

"Defect Structure of Magnesium Aluminate Spinel Determined by Raman Spectroscopy, American Crystallographic Association, Asilmore, CA (Feb. 1977). Presentor.

"Hydrothermal Reactivity of Simulated Nuclear Waste Forms and Water-Catalyzed Waste-Rock Interactions," Materials Research Society, Boston, MA (Nov. 1978). Co-Author.

"Effect of Mix Rheology, Admixtures and Salts Upon Physical and Mechanical Properties of Hardened Cement Pastes," 7th International Congress on the Chemistry of Cements, Paris, France (May 1979). Co-Author.

"Synthetic Mineral Nuclear Waste Ceramics," American Nuclear Society, San Francisco, CA (July 1979). Presentor.

"Temperature Ceramic Waste Form: Characterization of Supercalcine-Based Monazite-Cement Composite," Materials Research Society, Boston, MA (Nov. 1979). Co-Author.

"Permeability Measurements on Cementitious Materials for Nuclear Waste Isolation," Materials Research Society, Boston, MA (Nov. 1979). Presentor.

"Role of Admixtures in Preparing Dense Cements for Radioactive Waste Isolation," Materials Research Society, Boston, MA (Nov. 1979). Co-Author.

"Shale Rocks as Nuclear Waste Repositories: Hydrothermal Reactions with Glass, Ceramic and Spent Fuel Rods," Materials Research Society, Boston, MA (Nov. 1979). Co-Author.

"Comparison of Tailored Cement Formulation for Borehole Plugging in Crystalline Silicate Rocks and Evaporate Mineral Sequences," Materials Research Society, Boston, MA (Nov. 1979). Co-Author.

"Hydrothermal Interactions of Simulated Nuclear Waste Glass in the Presence of Basalt," Materials Research Society, Boston, MA (Nov. 1979). Presentor.

"Brine-Waste Interactions Under Mild Hydrothermal Conditions," Materials Research Society, Boston, MA (Nov. 1979). Co-Author.

"Laboratory Alteration of a Columbia River Basalt by Hot Groundwater: An Application to Deep Geological Disposal of Nuclear Waste," Geological Society of America, San Diego, CA (Nov. 1979). Co-Author.

"Effect of Composition of Additives Upon Microstructure of Hydrated Portland Cement Composites," Third Annual Conference on Cement and Clinker Microscopy, Houston, TX (March 1980). Presentor.

"Phase Equilibria of Weeksite and Related Phases in the System K_2O-UO_3-SiO_2-H_2O," Northeast Section of the Geological Society of America, Philadelphia, PA (March 1980). Co-Author.

"Preparation and Characterization of Cementitious Mixes With and Without Admixtures," American Ceramic Society, Chicago, IL (April 1980). Co-Author.

"Stability of Ceramic Nuclear Waste Forms in the Presence of Hydrothermal Solutions," American Ceramic Society, Chicago, IL (April 1980). Co-Author.

"Supercalcine-Ceramic- and Calcine-Cement Radioactive Waste Forms," American Ceramic Society, Chicago, IL (April 1980). Presentor.

"The Geochemistry of Nuclear Waste in Shale Repositories," Geological Society of America, San Diego, CA (Spring 1980). Co-Author.

"Hydrothermal Interaction of a Ceramic Waste Form Basalt," Alternate Nuclear Waste Forms and Interactions in Geologic Media, Oak Ridge National Laboratory, Gatlinburg, TN (May 1980). Presentor.

"Application of Gandolfi X-Ray Diffraction to the Characterization of Reaction Products from the Alteration of Simulated Nuclear Wastes," 23rd Denver X-Ray Conference, Denver, CO (Aug. 1980). Co-Author.

"Stability of Simulated Spent Fuel in Hydrothermal Solutions: Is Spent Fuel a Stable Waste Form?" Materials Research Society, Boston, MA (Nov. 1980). Co-Author.

"Characteristics of a High-Waste-Loading Cement-Based Waste Form for the Savannah River Wastes," Materials Research Society, Boston, MA (Nov. 1980). Presentor.

"Low-Temperature Tailored Ceramic Radioactive Waste Form: Comparative Studies," Materials Research Society, Boston, MA (Nov. 1980). Co-Author.

"Permeability and Chemical Analyses for Permeating Fluids of Various Borehole Plugging Materials and Low Temperature Ceramic Radioactive Waste Forms," Materials Research Society, Boston, MA (Nov. 1980). Presentor.

"Comparative Study of Hydrothermal Stability Experiments: Application to Simulated Nuclear Waste Forms," Oak Ridge National Laboratory Conference on the Leachability of Radioactive Solids, Gatlinburg, TN (Dec. 1980). Presentor.

"Leach Characterization of Cement Encapsulated Wastes," Oak Ridge National Laboratory Conference on the Leachability of Radioactive Solids, Gatlinburg, TN (Dec. 1980). Co-Author.

"Properties of Cement Solidified Radioactive Waste Forms with High Levels of Loading," American Ceramic Society, Washington, D.C. (April 1981). Presentor.

"Cement Composites Using Industrial By-Products: Preparation and Properties," XIII Conference on Silicate Industry and Silicate Science, Budapest, Hungary (June 1981). Co-Author.

"Backfill-Waste Interactions in Repository Simulating Tests," Materials Research Society, Boston, MA (Nov. 1981). Co-Author.

"Backfill Simulated Waste Interactions Under Radwaste Repository Conditions," Materials Research Society, Boston, MA (Nov. 1981). Co-Author.

"Dissolution of Simulated Spent Fuel in Hydrothermal Solutions," Materials Research Society, Boston, MA (Nov. 1981). Co-Author.

"The System $SrMoO_4$-$BaMoO_4$-$CaMoO_4$: Compatibility Relations, the Implications for Supercalcine Ceramics," Materials Research Society, Boston, MA (Nov. 1981). Presentor.

"Stability of I and Sr Radiophases in Cement Matrices," Materials Research Society, Boston, MA (Nov. 1981). Co-Author.

"Studies of Pollucite," Materials Research Society, Boston, MA (Nov. 1981). Co-Author.

"Physical and Chemical Behavior of Selectively Etched Flyashes," Materials Research Society, Boston, MA (Nov. 1981). Presentor.

"Leaching Mechanisms in Composite of Nuclear Waste with Cement," American Ceramic Society, Cincinnati, OH (April 1982). Co-Author.

"Pore Structure of Leached Cement-Based Nuclear Waste Forms," American Ceramic Society, Cincinnati, OH (April 1982). Presentor.

"Hydroxylated Aluminum Phosphate Ceramics for Encapsulation of High-Alumina Nuclear Defense Waste," American Ceramic Society, Cincinnati, OH (April 1982). Co-Author.

"Compatability Relationships in the Fe-U-O-H System at 400°C: The Implications of the Ferric-Ferrous Buffer for the Immobilization of Uranium and Transuranic Elements," Materials Research Society, Boston, MA (Nov. 1982). Presentor.

"Hydrothermal Simulation of Ion Migration in Selected Argillaceous Sediments: Implication for Backfill Design," Materials Research Society, Boston, MA (Nov. 1982). Presentor.

"Comparison of Tuff and Flyash in Cement," American Ceramic Society, Chicago, IL (April 1983). Co-Author.

"An ICPP Aluminum Phosphate Ceramic Waste Form: Synthesis and Room Temperature Aqueous Stability," American Ceramic Society, Chicago, IL (April 1983). Co-Author.

"Thermal Stability of an ICPP Aluminate Phosphate Waste Form in Aqueous Solutions," American Ceramic Society, Pittsburgh, PA (April 1984). Co-Author.

"Laser Raman Microprobe Characterization of Fly Ash,"Advances in Materials Characterization II, Alfred, NY (July 1984). Co-Author.

"The Devolpment of a High Strength Cementitious Tooling/ Molding Material," Materials Research Society, Boston, MA (Nov. 1984). Co-Author.

"Optimized Hign Strength Mortars: Effects of Chemistry, Particle Packing and Interface Bonding," Materials Research Society, Boston, MA (Nov. 1984). Co-Author.

"Stability of NZP Waste Forms and Their Application to ICPP Wastes," Materials Research Society, Boston, MA (Nov. 1984). Presentor.

"The Role of Boron in Monitoring the Leaching of Borosilicate Glass Waste Forms," Materials Research Society, Boston, MA (Nov. 1984). Presentor.

"Geochemical Performance Evaluation and Characterization of a Potential Cementitious Repository Sealing Material for Application in the Topopah Spring Tuff NNWSI Investigations," Materials Research Society, Boston, MA (Nov. 1984). Presentor.

"Characterization of Crystalline Phases in Fly Ash by Microfocus Laser Raman Spectroscopy," Materials Research Society, Boston, MA (Nov. 1984). Presentor.

"Large-Scale Laboratory Permeability Testing on Potential Repository Rocks," American Ceramic Society, Boston, MA (April 1985). Presentor.

"The Effect of Chemically Adjusting Cement Compositions on Leachability of Waste Ions," American Ceramic Society, Cincinnati, OH (April 1985). Co-Author.

"Laser Raman Microprobe Characterization of Density Separated Fly Ash," CANMET/ACI, Madrid, Spain (Winter 1986). Presentor.

"Elevated Temperature Stability of Cementitious Sealants for a Deep Geological Repository in Tuff," Los Alamos National Laboratory, American Ceramic Society, Chicago, IL (May 1986). Presentor.

"Chemically Bonded Calcium Aluminate Cement as a Substrate Material," American Ceramic Society, Chicago, IL (May 1986). Presentor.

"Preliminary Dissolution Model Applicable to Shaft Seal Durability," American Ceramic Society, Chicago, IL (May 1986). Presentor.

"Low Frequency Dielectric Response of Calcium Aluminate Cements: The Role of Organic versus Inorganic Polymers as Rheological Aids," American Ceramic Society, Chicago, IL (Fall 1986). Co-Author.

"Interpretation of Pore Structure in Cementitious Solids by the Use of Fractal Geometry," Materials Research Society, Boston, MA (Nov. 1987). Presentor.

"High Frequency Dielectric Response of Calcium Aluminate Cements: Potential Packaging Substrate Materials," Materials Research Society, Boston, MA (Nov. 1987). Co-Author.

"PARTPAC - A Computer Code for Calculating Particle Packing," American Concrete Institute, Orlando, FL (Spring 1989). Presentor.

"The Chemistry of Al-Tobermorite and its Co-existing Phases at 175°C," Materials Research Society, Boston, MA (Nov. 1989). Co-Author.

"Concrete Permeability and its Relation to Pore Structure," Transportation Research Board, Washington, D.C. (Jan. 1990). Co-Author.

"Packing and Rheological Models and their Predicitve Capacity for Concrete Properties," Transportation Research Board, Washington, D.C. (Jan. 1990). Presentor.

"Effects of Packing on Concrete Properties Optimization," Transportation Reserach Board, Washington D.C. (Jan. 1991), Presentor.

"Hydration and Curing Characteristics of Plan and Blended Cement Concretes," TRD, Washington D.C., (Jan. 1991), Presentor.

"An Examination of Variations in the Structural Parameter of Pyrite Using Powder X-ray Diffraction and the Rutveld Method of Structure Refinement," PICXUR, Honolulu, HI (August 1991).

"A Study of Concrete for the Tumulus Disposal Units in Low-Level Radioactive Waste Management," Amer. Ceram. Soc. (April 1991).

Barnes, M.W. and B.E. Scheetz, "Waste Disposal Chemistry: Al-Tobermorite and Si-Substituted Hydrogarnet," TERRA cognita (1987), Co-Author

Scheetz, Barry E. and Jefferson P. Hoffer, "Characterization of a Sodium Silicate Activated Cement-Aluminosilicate Low-Level Radioactive Waste Form," American Concrete Institute (March 1991).

Scheetz, Barry E. & Della M. Roy, "The Chemistry of Cementitious Systems for Waste Management: The Penn State Experience," American Chemical Society, Environmental Science Symposium, New York (August 1991).

D. Description of Speaking Engagements

"Vibrational Spectra of Selected Melelite Minerals," 6th Annual Graduate Student Colloquium in the Geological Sciences, The Pennsylvania State University, University Park, PA (April 1973).

"A Vibrational Study of the Order/Disorder in the Alkaline-Earth Double Carbonates," 8th Annual Graduate Student Colloquium in the Geological Sciences, The Pennsylvania State University, University Park, PA (April 1975).

"Hydrothermal Stability of Nuclear Waste Glass," United States Geological Survey, Menlo Park, CA (June 1978).

"Stability of Crystalline Nuclear Wasteform vs. Glassy /Wasteforms," Thousand Oaks Research Center, Rockwell International, Thousand Oaks, CA (Feb. 1980).

"Chemical Reactivity of Duplex-Coated Ceramic Wasteforms," General Atomic, San Diego, CA (Feb. 1980).

"Nuclear Waste: Is it a Problem Without a Solution?," The American Society of Mechanical Engineers, Williamsport, PA (March 1980).

"Nuclear Waste: Is it a Problem Without a Solution?," Central Pennsylvania Section of The American Society of Mechanical Engineers (March 1980).

"Nuclear Waste Form Stability," Department of Physics, Millersville State College (Oct. 1980).

Eleven lectures on nuclear and hazardous waste management, Westinghouse Advanced School in Power Systems Engineering, The Pennsylvania State University, University Park, PA (1980-1990).

"Basalt Nuclear Waste Interactions," Pacific Northwest Laboratories, Batelle Memorial Institute, Richland, WA (May 1982).

"Grout Development of Sealing in Nuclear Waste Repositories," Chemical Technologies Division, Oak Ridge National Laboratory, Oak Ridge, TN (1982).

"Immobilization of Hazardous Wastes: Radioactive vs. Chemical," Office of Hazardous Waste Management, The Pennsylvania State University, University Park, PA (1982).

"Nuclear Waste Management: An Overview," Ecology Seminar, Chemistry Department, The Pennsylvania State University, University Park, PA (Oct. 1982).

Colloquium: Nuclear Waste Disposal, Purdue University (Feb. 1984).

"Radiation and Its Applications," Philadelphia Electric Company, Limerick Atomic Information Center, Pottstown, PA (1982, 1983).

"Tailored Ceramic Waste Forms for Hazardous Chemical Wastes," Office of Hazardous Waste Management, The Pennsylvania State University, University Park, PA (1983).

Commencement Speaker at Shamokin Area School District (May 1985).

"The Role of Crystallography in Nuclear Waste Management," Colloquium on Careers in Science, State College High School (1985).

"Waste (Nuclear and Hazardous) Solidification," Consortium on Cemically Bonded Ceramics, The Pennsylvania State University, University Park, PA (1985).

"An Overview of Nuclear Waste Management," The Pennsylvania State University, Capitol Campus (Oct. 1985).

"A Review of the Patent Literature on CBC Coatings," Consortium on Chemically Bonded Ceramics, The Pennsylvania Sate University, University Park, PA (1986).

Commencement Speaker at Kutztown Area School District (May 1986).

"Recent Advances in the Studies of Obsidian Age Dating," Department of Geology, University of New Mexico, Los Cruces, NM (Sept. 1986).

"Geomorphology of the Nittany Valley," Bald Eagle Chapter of the Society for Pennsylvania Archaeology, State College, PA (Jan. 1987).

"Geochemical Origins of Archaeological Lithic Materials in the Nittany Valley," Bald Eagle Chapter of the Society for Pennsylvania Archaeology, State College, PA (Feb. 1987).

"Archaeology of Caves of the Western Nittany Valley," Bald Eagle Chapter of the Society for Pennsylvania Archaeology, State College, PA (March 1987).

"Recent Advances in the Studies of Obsidian Age Dating," Bald Eagle Chapter of the Society for Pennsylvania Archaeology, State College, PA (Oct. 1987).

Thirteen Lectures Delivered at Tongji University, Center for Research and Analysis, Shanghai, People's Republic of China (April 1989):

> Examination of Conventional Concrete Formulations Design in Light of Theoretical Modeling of Particle Packing
>
> Laser Raman Microprobe Characterization of Fly Ash
>
> Development and Characterization of Tuff Compatible Concrete (Parts I and II)
>
> High-Tech Application of Calcium Aluminate Cement as Low Permitivity Substrates
>
> Development of Ultra-High Strength in Portland Cement for High-Tech Applications

Development of High Strength MDF Cements Based on Portland Cement Composites

Characterization and Mechanical Properties of SSPC Concretes

International Center for Diffraction Data: Who They Are and What They Do!

Use of the Powder Diffraction File (Parts I and II)

Characterization of a Na-Silicate/Cement Low-Level Nuclear Waste Form (Parts I & II)

"International Center for Diffraction Data: Who They Are and What They Do!" 3-hour lecture to technical staff, Building Materials Research Institute Beijing, People's Republic of China (April 1989).

"Calcium Aluminate Cement as a Low Permitivity Substrate," AKZO Review, The Pennsylvania State University, PA (1989).

"X-Ray Diffraction in a Student Environment," Philips Electronic Instruments, Inc., Mahwah, NY (1989).

"Scientific Basis for the Immobilization of Heavy Metal Wastes in Cement," Consortium on Chemically Bonded Ceramics, Washington, DC (1989).

"Large Volume Utilization of Fluidized Bed Combustion Ashes," Anthracite Region Independent Power Producers Association, Pottsville, PA (1990).

"Use of Alkali-Activated Fly Ash Cements in Abandoned Mine Site Remediation," Babbs Creek Trust Fund Committee of the Pennsylvania Environmental Defense Foundation, Morris, PA (1990).

"Large Volume Uses of Alkali-Activated Cement in the Mining Environment," Pennsylvania Department of Environmental Resources, Surface Mining Section, State College, PA (1990).

"Large Volume Uses of Alkali-Activated Cement in the Mining Environment," Pennsylvania Department of Environmental Resources, Bureau Central Office and District Office Permitting Staff, State College, PA (1990).

"Pyrite Oxidization in Coal Spoils," Pennsylvania Department of Environmental Resources Regional Chemists, State College, PA (1990).

"Characterization and Source Identification of Jaspers in Pennsylvania," Bald Eagle Chapter of the Society for PA Archaeology (Nov. 1990).

"Partially Sintered Tape Cast Materials with Controlled Porosity," AKZO Corp., Dobbs Ferry, NY (Nov. 30, 1990).

"Sodium Silicate Activated Portland Cements," PQ Corp., Easton, PA (Sept. 1991).

E. Consulting Activities

Corning, Pittsburgh, PA and State College, PA
Xerox, Rochester, NY

Delaware Custom Materials, State College, PA
Johnson and Johnson, Princeton, NJ
East Earl Township, Lancaster County, PA
CEMCOM Research Associates, Lanham, MD
Tele-Media, Astibula, OH
Westinghouse, Pittsburgh, PA
Owens-Corning, Toledo, OH
Mead, Dallas, TX
United Technologies, Hartford, CN
TRIMA, Pittsburgh, PA
General Motors, Detroit, MI
Snow, Christensen and Martineau Associates, Salt Lake City, UT
Dunstun, Inc., Lakewood, CO
GTE Sylvania, Towanda, PA
Frank, Bernstein, Conaway & Goldman, Baltimore, MD
Morgan, Lewis and Bockius, Philadelphia, PA
George Keros Industries, Detroit, MI
Phoenix Environmental, Williamsport, PA
R.J. Lee Group, Monroeville, PA
Vitramon, Bridgeport, CT
Delta Chemical, Inc., Searsport, MA
Armstrong World Industries, Lancaster, PA
Martin Marietta Energy Systems, Inc., Oak Ridge, TN
Permagrain, Karthaus, PA

F. Description of New Courses or Cooperative Extension Programs Developed

"X-ray Difffraction Clinic: Advanced Diffraction Techniques: Laboratory Program on Data Analysis Using PC-Based Computers," Materials Research Laboratory, The Pennsylvania State University, University Park, PA (1990-1991). Lecturer. Enrollment: 34

G. Description of New Computer Software Programs Developed

Programs Developed for Internal MRL Use

Normative phase composition for cement clinker from bulk chemical compositions.

Normalized bulk chemical compositions of concretes from components in the system CaO-SiO_2-Al_2O_3.

Supervised Programs Developed for Internal MRL Use

Control and data collection for pulsed permeability

Control and data collection for fluorescence microscopy

Control and data collection for x-ray powder diffraction

Modeling of borehole and shaft seal dissolution

PARTPAC--calculation of random packing of dry solids.

H. Description of New Methods of Teaching Established Courses

N/A

I. List of Honors or Awards for Scholarship or Professional Activity

National Internship, Argonne National Laboratory, 1972
National Academy of Sciences Visiting Scholar to China, 1989

J. Record of Membership and Active Participation in Professional and Learned Societies

1. Memberships

Mineralogical Society of America
Materials Research Society
American Ceramic Society
Sigma Xi
National Speleological Society
American Concrete Institute
Joint Committee on Powder Diffraction Standards-International Centre for Diffraction Data

2. Offices Held

N/A

3. Activities

Co-Chair of Symposium 'Characterization, Utilization and Immobilization of Hazardous Industrial Materials,' Materials Research Society (1983).

Co-Chair of Symposium 'Characterization, Utilization and Immobilization of Coal Combustion Wastes,' Materials Research Society (1984).

Chair of Workshop on Chemically Bonded Ceramics, The Pennsylvania State University (1984).

Finance Committee of the Materials Research Society (1985-1988).

Papers and Program Committee, Cement Division of American Ceramic Society (1985-1987).

Program Chair, Cements Division of the American Ceramic Society (1987).

Co-Chair of the Materials Research Society Meeting (Dec. 1987).

Executive Committee, Cements Division of the American Ceramic Society (1987).

Program Committee of the Materials Research Society (1987-1989).

Chair of the Task Group on Cementitious Materials, JCPDS- ICDD Committee on Target Materials (1987-Present).

Chair of the Task Group on Standardization of Raman Data, JCPDS-ICDD (1987-Present).

Continuing Education Committee of the Materials Research Society (1988-1990).

Chair of the Academic Affairs Committee of the Materials Research Society (1988-Present).

Nominated for 1st Vice President of the Materials Research Society (direct succession to President) (1988).

Co-Chair of Symposium 'Specialty Cements,' Materials Research Society (1989).

Advisory Committee for SPECTRUM '90, Nuclear and Hazardous Waste Management International Topical Meeting (1989).

4. Peer Reviewer for Professional Journals

Cement and Concrete Research
Journal Material Research
Journal American Ceramic Society
Nuclear Technology
Materials Research Bulletin

K. List of Grants and Contracts for Teaching Improvement or for Teaching Programs

N/A

IV. SERVICE TO THE UNIVERSITY AND THE PUBLIC

A. Service to the University

1. Record of Committee Work

Member, MRL equipment committee, 1983-1989.
Co-Chair, 1991-Present.

IRP faculty representative, Senior Vice-President for Research and Graduate Studies Employee Opinion Survey Response Committee, 1989-Present.

SSS faculty representative, Strategic Plan Update for IRP Programs, Sept. 1989.

Member, University Faculties and Graduate School

Associate Member, Graduate School, 1976 - present

Member, Solid State Science Faculty, 1976 - present

Member, Environmental Pollution Control Faculty, 1985 - present

Member, Entrance Requirements, Candidacy & Comprehensive Committee IRP Program in Materials.

2. Participation in Governance Bodies and Related Activities

Faculty Advisor to The Pennsylvania State University Chapter of the Materials Research Society (1987-Present).

3. Record of Adminstrative Support Work

Principal responsibility for maintainance and operation of centralized MRL X-ray diffraction facility.

Faculty backup for SEM facility. Share responsibility for centralized furnace room and hydrothermal laboratory.

4. Record of Contributions to Equal Opportunity and Cultural Diversity Programs

N/A

5. Record of Service to the Office of the Vice President for Research and Graduate Studies.

Coordinated, wrote portions of, edited, and published a proposal to the U.S. Nuclear Regulatory Commission in response to solicitation number RS-NMS-87-005 for the establishment of a Center for Nuclear Waste Analysis at The Pennsylvania State University. This 800 page proposal was submitted jointly with MIT and Franklin

Research Institute for a 5-year program renewable for an additional 20 years at $50,000,000/period.

B. Service to the Public

1. Participation in Community Affairs

Boy Scouts of America: Troop 31 committee member (1986-1989); Merit Badge Counselor; Committee Chair (1990-Present).

Bald Eagle Chapter of the Society for Pennsylvania Archaeology: President (1989-1990), Vice President (1988-1989).

Lemont Village Association: Co-Founder (1976); Board of Directors (1976-1984).

2. Service to Governmental Agencies

Environmental Consultant to East Earl Township, Lancaster County, PA
Peer reviewer for National Science Foundation
Peer reviewer for National Institute of Health
Peer reviewer for National Science and Engineering Research Council of Canada
Department of Energy

3. Service to Industry

President of BSSS Ltd., Lemont, PA.

4. Service to Public and Private Organizations

Materials Research Laboratory representative for United Way (1983)

EXHIBIT B

Date: April 17, 1991

To: MEMO OF RECORD

From: Al Lappin - 6340A and Martin Molecka - 6345

Subject: Summary of Estimated Consequences of Proposed FSAR Related Purging Requirements for Bin-Scale Tests

This Memo of Record addresses the gas-compositional consequences and overall programmatic implications to the WIPP bin-scale CH TRU waste test program that result from proposed bin purging. Supporting calculations on gas concentration changes caused by purging are documented in a (separate) memo by Jim Nowak dated April 4, 1991. These significant consequences are caused by various interpretations of the draft FSAR Addendum for "dry" bin tests, specifically the proposed requirement to purge bins for gas flammability control.

The site-proposed FSAR interpretation is that, for purposes of evaluating and controlling flammability: a) it must be assumed that oxygen is present in the experimental bins at <u>all</u> times, regardless of any experimentally governed anaerobic bin atmosphere; and b) that experimental bins must be purged if the concentration of any flammable gas within the bin reaches 50% of the lower limit for flammability, assuming oxygen is present at any time. For the specific case of hydrogen, we assume that the upper and lower concentration limits for purging are 2% (50% of the lower limit for flammability; initiation of purging) and 0.4% (10% of the limit; end point for purging), respectively. For methane, the other major flammable gas produced, the corresponding limits are 2.5% and 0.5%.

In contrast, the technical approach defined in both the Bin-Scale Test Plan and the Test Plan Addendum has been to allow the concentrations of potentially flammable gases in both anaerobic and (depleted oxygen, but still) aerobic bins to increase as close as possible to those concentrations expected at long times. This specifically means that concentrations of hydrogen or methane much higher than 2.0 - 2.5% are expected. These gases could asymptotically approach their long-term compositions, with concentrations greater than 70% possible. Initial gas concentration vs. time calculations indicate that such high levels of gas (hydrogen or methane) conceivably could be generated in a matter of <u>months</u> under the appropriate (long-term realistic) test conditions.

This approach has been maintained by Sandia through both the DOE approval cycle for the Test Plan Addendum (completed 12/90) and a later "consistency check" between the Test Plan Addendum and the draft FSAR Addendum (completed 1/91). However, as noted below, <u>major</u> inconsistencies in FSAR Addendum interpretations at the site still appear to exist. In addition, these various interpretations are not, to our knowledge, clearly documented.

We also must note, however, that it has become apparent during the Sandia Internal Design Review (SIDR) process for the bin tests that our own approach to gas flammability probably has not been internally consistent. Specifically, with the exception of the solenoid-actuated, pressure-relief valve loop, the prototype bin instrumentation was not specifically selected to be "inherently safe" for use with potentially flammable gas mixtures. For example, neither the pump included as part of the gas-recirculation loop nor the pumps included on the oxygen-gettering cart are "inherently safe." Therefore, the present bin and instrumentation are not, in fact, adequate for experimental operations above 50% of the lower flammability limit. We plan on incorporating "inherently safe" components in the near-future, as soon as practicable, i.e., after the ORR.

It must be emphasized that for all options discussed in this memo, for limited quantities of low-gas generating TRU wastes only, there are no anticipated impacts to the current schedules for the WIPP Integrated System Checkout (ISC), Operations Readiness Review (ORR), or first waste receipt.

I. SUMMARY OF CONCLUSIONS
(NOTE: Supporting details are presented later in this memo.)

A. If the FSAR addendum must be interpreted to require bin purging at 1/2 of the lower flammability limit concentrations of H_2 and/or CH_4, then the present bin and instrumentation design will probably be adequate for use in experiments at the WIPP or elsewhere, with only those types of wastes for which net gas-generation rates are on the order of 0.1 moles/drum/year (0.6 moles/bin/year) or less. This FSAR interpretation assumes that oxygen must be considered to be present at all times, even though it is experimentally governed at levels that technically preclude flammability potentials and is monitored frequently. Because of the purging restraint, it appears that only "dry" low-organic or other "low-gas generating" wastes can be tested without modification to the present testing plans and/or the bin and attached instrumentation. Bin-scale testing of most high-gas generation high-organic wastes and process sludges, to obtain data relevant for long-term (predictive) WIPP performance assessment (PA) purposes, appears to be precluded.

B. If the FSAR addendum must be interpreted to require purging, there are multiple negative impacts on the interpretations and technical validity of resultant test gas data. Gas mechanistic interpretations based on obtained short-term data are not relevant to the post-closure period of the repository; any resultant predictions will not be defensible for WIPP PA purposes. Gas data will, however, be relevant for repository operational-safety evaluation purposes; wastes that exhibit

unacceptably high-gas generation rates may be relegated to further Level-II treatment or reprocessing.

In addition, there may be an inability to conduct more than about four (4) bin tests on any high-gas generating wastes in the WIPP underground, as presently constrained by the 3L/min. maximum flow rate for the VOC-manifold system. The VOC monitoring system was not designed to accommodate the potentially high concentrations or volumes of VOCs to be purged; site compliance with respect to 40 CFR 268 may prove difficult. The VOC monitoring system will require some redesign.

C. Before any decision is made to eliminate potentially flammable gas compositions in the WIPP underground for purposes of bin testing, the potential impacts of this decision on full-scale operations at the WIPP must be considered carefully. High-gas generating wastes amount to greater than 60 volume % of wastes presently planned for WIPP repository isolation; these would be precluded. Safety-related implications to waste generator sites must also be seriously considered. These other sites do not have the capability of purging their stored wastes to control both potential and documented concentrations of flammable gases.

D. The proposed interpretation of the draft FSAR Addendum approach to gas flammability is, in our technical opinion, inconsistent with the present bin and instrumentation designs and documented test objectives, <u>except for low-organic or</u> (specially treated or modified) <u>Level II wastes</u>. There appear to be several alternative approaches to the problem of gas flammability during the bin tests at the WIPP. These alternatives include:

1. Initiate the bin experiments at WIPP using only low-gas generating low-organic and/or Level II treated wastes; limited types of high-organic wastes, e.g., leaded rubber waste (TRUCON content code 123/223), might also be acceptable. This approach incorporates about 18 to 24 waste-filled test bins, assuming that the proposed FSAR approach cannot be modified. There is a <u>significant risk</u> that much of the Phase 0 bin test program <u>and most of Phases 1 and 2 could not be conducted</u> for purposes of collecting data required for long-term WIPP PA, however.

2. Aggressively pursue redesign of the bin and related instrumentation, and/or physical constraints and administrative procedures, to be "inherently safe" for experiments involving potentially flammable gas mixtures. This redesign must be a total integrated (i.e., WID, SNL, and WPO) system-engineering approach. This approach also includes strict procedures for minimizing oxygen content in the bins and monitoring for oxygen frequently. This is

the technique documented in the Test Plan and Test Plan Addendum, and approved by the WPO.

3. Completion of a probabilistic risk assessment, <u>including</u> estimated frequencies and consequences of assumed accident scenarios. This approach may or may not need to be combined with modifications of the bin and related instrumentation.

4. Evaluate the possibilities of incremental compliance assessment and/or additional treatment (reprocessing) of high-gas generating high-organic and/or process sludge wastes so that they might be brought to the WIPP for testing (and future emplacement).

In summary, the problems and consequences discussed above raise significant concerns about bin-scale testing or future waste emplacement for high-gas generating, high-organic wastes and process sludges. The major consequence of using purging to control bin flammability-safety concerns is to render the resultant data as applicable only to the short-term (early years) of repository operation. Resultant data interpretations will be of little use for PA predictive modeling, as claimed by the project, and may not support initial receipt of such wastes at the WIPP, for purposes of evaluating compliance with 40CFR191 Part B. The data <u>may</u>, however, be critical in evaluating the several timeframes (described in the Rationale document) that pertain to the time period between the waste transportation calculations (that extend only to 66 days after TRUPACT if loading) and calculations for 40CFR191 Part B (that start 100 years after repository decommissioning).

It must be stated that these consequences do <u>not</u> appear to impact the validity and conduct of a limited scope of planned bin tests with low-gas generating, "dry" low-organic wastes or Level II treated wastes.

Further details of these individual conclusions and consequences on the presently defined bin-scale test program are discussed in the following section.

II. <u>SUPPORTING DETAILS</u>

A. With the FSAR Addendum interpreted to require bin purging at 1/2 of the lower limit of flammability concentrations of H_2 and/or CH_4, the present bin and instrumentation design will probably be adequate for use in experiments at the WIPP or elsewhere, with only those types of wastes for which net gas-generation rates are on the order of 0.1 moles/drum/year (0.6 moles/bin/year) or less. Basically, this level of gas generation essentially permits only radiolytic gas degradation; this gas rate could be initiated by about 10 grams of ^{wg}Pu per drum, average. Both microbial and anaerobic

corrosion processes (and potential synergistic interactions) have the potential to produce significantly greater amounts of gas, as measured in laboratory tests and predicted from existing lab data.

With the purging restraint, the waste types which presently appear to remain appropriate for experiments addressing long-term PA are:

1. "Dry" low-organic (LO) wastes (including the metal container materials), i.e. about 15 Phase 0 test bins of low-organic wastes to which additional brine is not added. At present, this appears to be the only waste category which can be tested without some modification to present equipment and planning.

2. "Dry" Level II treated wastes, i.e. those treated to reduce gas generation rates significantly (however, the theoretical gas-generation potentials are not reduced by such treatment). This could include about 6 Phase 0 test bins of existing TRUCON code 114/214 (cemented inorganic particulate) and possibly 126/226 (cemented organic process solid) wastes.

3. "Wet" and "dry" low-organic wastes, in test Phases 1, 2, and 3. However, these tests would need to be modified to eliminate the metal container materials (wire mesh or metal drums for supercompacted wastes). "Wet" TRUCON code 117/217 (mixed metal) wastes would have to be excluded totally. These limitations are required because of the potential high rate of hydrogen generation by anaerobic corrosion of mild steel under "wet" conditions. This category could potentially include up to about 21 bins of waste in the later phases.

4. "Wet" Level II treated wastes, in test Phases 1, 2, and 3. No estimate of total test bins in this category can be made yet, the number depends on both test results and contingencies. However, these tests would need to be modified to eliminate the steel metal container material (including wire mesh). This limitation is required for the reasons described for "wet" LO wastes. Elimination of steel waste containers for test purposes also would imply that such containers cannot be used in WIPP operational waste emplacement. This is a Level II treatment decision that should be made by DOE (both HQ and WPO) as it has consequences for future waste packaging (or repackaging) at the generator sites.

Some "dry" high-organic (HO) wastes might also be acceptable, such as 3 test bins of leaded rubber (TRUCON code 123/223) wastes; these wastes are tentatively expected to have a low rate of gas generation. In addition, some other "dry" high-organic wastes without the metal containers materials might also be acceptable; however, this hope is contrary to previous laboratory experimental results obtained by Molecke that indicate that "as-received" water

contents are more than sufficient to initiate significant microbial activity. AT this time, the uncertainty in the rate and gas compositions of microbial activity under "dry" and "humid" conditions is the greatest uncertainty in the evaluation of the present bin testing program for "dry" high-organic, high-cellulosic content wastes.

B. If the draft FSAR Addendum continues to be interpreted as requiring bin purging for flammability control, multiple limitations (to the original test objectives) will originate from the following major factors:

1. Inability to claim that gas compositions measured during the experiments are representative of those expected under realistic, long-term repository conditions, as justified in the Test Plan. The required number of bin purges for wastes that generate gases at high rates would completely eliminate the present objective of having gas compositions in the bin tests approach or simulate those expected under long-term repository conditions. Remember, the long-term gas compositions will asymptotically approach the integrated compositions of the gases generated/released by the wastes. These compositions are actually approached more rapidly as a result of bin venting (refer to supporting memo by Nowak for calculations), but would not be approached at all in the event of frequent bin purging.

The gas concentrations in purged bins could never approach self-limiting concentrations, i.e., concentrations potentially capable of either poisoning, catalyzing, or fertilizing other reactions and/or interactions. The experimental "time clock" would essentially be reset to time t - 0 after every purge cycle.

2. Inability to claim, as a defensible fallback, that the experimentally measured, but purged and therefore non-representative gas compositions and generation rates are "bounding" and therefore usable for purposes of Performance Assessment (PA). Gas production rates and potentials from microbial degradation mechanisms would be particularly suspect. If the only realistic mechanism prevented by eliminating high concentrations of flammable gases is self-poisoning (e.g. poisoning of microbial activity by high concentrations of H_2), the measured generation rates should be bounding. However, we cannot presently demonstrate that there are not "fertilizers" which, if allowed to be present in their undisturbed concentrations, would initiate microbial reactions which would not be observed in repeatedly purged bins. One specific "fertilizer" is water. We expect rates of microbial activity to be sensitive to the relative humidity within the bin. The internal bin relative humidity that is buffered by the as-received (sorbed) water content of the wastes remains unknown. Some water vapor will be removed from the bin during each purge cycle (refer also to the purging depletion of VOCs, in item #8,

below); this removal will continuously lower the relative humidity. Assuming that the vapor pressure of water in Ar gas is similar to that in air, there is a real risk that the (purged) relative humidity will decrease to below some critical minimum level of water vapor, below which microbial activity cannot occur. This would result in unrealistically low, "favorable" bur erroneous, gas-generation rates.

Therefore, we cannot presently defend a "bounding" argument. The consequences or options of claiming that the experimentally measured rates are minima have not been evaluated in detail. Experimental determination of minimal gas-generation rates may be worthwhile,, depending on the decision making logic involved in WIPP performance evaluations.

3. Inability to evaluate the gas production from ALL CH TRU wastes in inventory and to-be-generated, to evaluate their suitability for repository isolation. Suspected high-gas generating wastes might be precluded from acceptance, due to a lack of relevant test data caused by the operational purge constraints. Most process sludge (PS) wastes might be judged unacceptable at WIPP because they generate flammable gas mixtures (including oxygen), mixtures that are not controllable by purging or minimization of the initial oxygen concentration. The precedent for further treatment or repository exclusion of PS and other suspected high-gas generating wastes could be implied or forced. Such wastes include more than 60 volume % of all CH TRU wastes in inventory: ~45 vol % HO + ~15 % PS + ?% 117/217 (mixed corroding metals) + ??.

With purging, data gathered would not be relevant for performance assessment predictive purposes. Gas data obtained from high-gas generating wastes would, however, be quite relevant for evaluating (waste type specific) safety issues during the operational-phase time period of the repository. Decisions on the repository acceptability or nonacceptability of specific wastes (by TRUCON content code), or decisions on the need for further waste treatment or reprocessing, could be based on the observed gas data plus supporting safety and PA evaluations.

4. Inability to claim that the experimental (bin internal) oxidation potential is in any way representative of that expected in the long-term. The time required for equilibration of the oxidation potential within experimental bins remains unknown. One major objective of the bin tests always has been to allow the oxidation potential to "float" to values controlled by competing degradation mechanisms, after initial purging/gettering. However, we expect that frequent purging would make this "floating" impossible, with the result that the oxidation potential within the bins would be completely dominated by that or the purge gas. Purging consequences on anaerobic corrosion and microbial

degradation cannot be predicted; interpretations based on such data would not be defensible.

5. Inability to conduct more than about four (4) bin tests on high-gas generating HO or PS wastes in the WIPP underground, if the proposed FSAR Addendum purging approach is adopted, and as presently constrained by the 3L/min. maximum (input) flow rate for the VOC-manifold system. This is not a firm estimate; however, it indicates the extremely limited utility of the WIPP underground as presently constrained.

The operational problems involved in frequent purging of any significant number of bins also appear to be insurmountable at present. For example, the presently mandated flow-rate limit of 3L/min on the underground VOC manifold system dictates a purge time of about 3 to 5 days (depending on waste type and initial gas composition), and dictates that only one bin can be purged at a given time. For a bin generating gas at the rates and compositions estimated in the WIPP FSEIS, purging would be required approximately every 9 to 10 days (see supporting memo by Nowak). Gas production data also would be lost during the 3-5 day purge time of the total 12-15 day (generation + purge) cycle.

To our knowledge, the VOC-collection system, while it was originally intended to be able to deal with simultaneous venting of up to about 125 bins, has never been designed to be able to accommodate the volumes of total purged gases or the potentially high concentrations of VOCs that might be released as a result of frequent bin purging in the WIPP underground. The supporting calculations by Nowak give some indication of the volumes of VOCs that might be involved on a per bin basis. We must note that this problem is a direct impact of the No-Migration Determination. An engineering modification or redesign of the VOC-collection system is called for.

6. Inability to distinguish between general waste-degradation mechanisms (e.g. radiolysis and anaerobic corrosion), due to elimination of minor gases (potentially to less than detectable levels) by frequent purging. The long-term interactions that occur at high-gas concentrations, e.g., poisoning or (microbial) fertilization, will be prevented and not investigated. This interpretation by mechanism is a critical element for formulating long-term, gas-production predictive models, as required for WIPP PA purposes.

For example, in the case of high-cellulosic wastes, the intent is to distinguish the amount of hydrogen generated by radiolysis from that generated by anaerobic corrosion. This separation is based on the fact that hydrogen and carbon monoxide (CO) are generated at a ratio of approximately 5:1 in radiolysis of cellulosics. If CO is eliminated by frequent purging, this distinction will not be possible. Minor microbial degradation

mechanisms could also produce gases that are 2 to 3 orders of magnitude smaller than the hydrogen production rate. Such gases would probably not be detectable in the proposed purging regime.

7. The resulting need for a large number of additional gas samples, i.e, inability to decrease sampling frequencies as a function of time, as described in the Test Plan. A minimum of two or three gas samples will be required to define the gas compositions and kinetics of generation within the bin, before and after bin purging. Without this definition no reliable generated gas or VOC gas mass-balance can be maintained, nor can the effectiveness of purging be experimentally verified (except with the on-line O_2 monitoring).

With the proposed FSAR approach to flammability by purging, evaluations of steady-state gas-generation rates would appear to require steady-state sampling and analyses rates. The amount of extra effort and expense for both increased bin gas sampling plus analyses and frequent purging would be negatively balanced with resulting gas data that would be essentially uninterpretible due to the sampling, purging and potential nonhomogeneous gas-mixing complexities.

8. Elimination of the ability to investigate microbial degradation of VOCs in a realistically simulated repository environment. As noted in the Rationale Report, WIPP compliance with RCRA (40 CFR 268) will require demonstration that: A) VOCs will not leave the WIPP repository at all; b) VOC concentrations, as they leave the repository, are below health-based standards; or c) VOC concentrations will be degraded microbially or by some other mechanism before they reach the site boundary. The proposed FSAR approach would eliminate the ability to investigate microbial degradation of VOCs in a realistically simulated repository environment. Without such demonstration, compliance with respect to 40 CFR 268 may prove difficult or impossible.

Calculations by Nowak indicate that VOC concentrations could be flushed to essentially zero concentration after several purge cycles; VOC data would become essentially uninterpretible, not useful for WIPP RCRA evaluations.

NOTE: The only positive result of frequent purging would appear to be that the purging process would serve to eliminate VOCs and define a realistic VOC source term for the wastes, if the conventional wisdom that the VOC source term is "small" is realistic. However, the removal of VOCs by purging may be viewed as "waste treatment" by various reviewers or regulators; this is an activity that presumably is not allowed at the WIPP.

C. Before any decision is made to eliminate potentially flammable gas compositions in the WIPP underground for purposes of bin

testing, the potential impacts of this decision on full-scale operations at the WIPP and at waste generators also must be considered carefully.

There appears to be a significant risk that elimination of flammable gas mixtures for purposes of bin tests might result in an inability to dispose of untreated high-organic wastes and/or process sludges at the WIPP, given the present facility and seal design. Undesirable precedents also might be placed back onto other DOE waste generator-storage facilities because they do not have the ability to purge their high-gas generating wastes.

We are aware of only verbal, undocumented arguments supporting the claim that the risks involved in bin tests vs. those involved for full-scale waste emplacement are significantly different. Basically, our concern is that, while the arguments (summarized below) are straightforward, they may well not be defensible before a critical, technical peer review such as the NAS, the Blue Ribbon Panel, or state regulators. Postulated arguments are:

1. The "exposure time" for the bin tests in five years or more, because the rooms in which the tests will be conducted will not be back-filled, and experimental personnel must be present in the room "continuously" as a routine part of experimental operations. Therefore, in the absence of absolutely reliable administrative and/or experimental controls, potentially flammable gas mixture simply must be eliminated.

2. In contrast, the "exposure time" during full-scale operations will be greatly reduced to six months or less, as a result of the fact that individual waste-emplacement rooms will be backfilled as waste is emplaced, with a nominal period of active ventilation in any given room of approximately six months. Therefore (the argument goes), flammable gas compositions, while not acceptable for purposes of bin tests (or, by implication, alcove tests), are acceptable for full-scale operations at the WIPP. This argument simply ignores the relative quantities (and risks) of wastes between limited bin-scale test emplacements and full-scale waste emplacement operations.

We do not believe this argument is valid. As noted in the memo by Slezak and Lappin prepared in January, 1990, while flammable gas compositions are not expected to be generated while an individual waste-emplacement room is actively ventilated, such gas compositions may well be generated in the headspace above an entire waste panel within approximately three years of the nominal time panel-seal emplacement. Therefore, we believe, as pointed out in the recent "Rationale Report," that the question really boils down to evaluation of the timing relationship between the beginning of drum breaching within individual panels, the generation of a flammable/detonable gas composition in the panel headspace (which was historically assumed to occur) and the time at which panel

seals become effective for purposes of controlling gas permeabilities.

Work is ongoing at Sandia to reduce or eliminate the time period between panel-seal emplacement and their effectiveness for gas permeability. However, to our knowledge, no changes have yet been implemented in the tentatively approved conceptual design. We believe that with the present design there is an expected time interval over which the panel seals are not expected to be effective.

Therefore, we believe that, if exposed to critical outside review (and contrary to the conclusions reached by Slezak and Lappin), we must recognize that there is a realistic potential for deflagration/detonation of flammable gases within the headspace above backfilled wastes in an individual waste-emplacement panel, following panel-seal emplacement but prior to panel-seal effectiveness, and still during the nominal WIPP operational phase of 25 or 30 years.

Until this uncertainty is resolved or eliminated, we believe there is a serious risk of concluding that since flammable gas compositions are not acceptable for purposes of bin testing, they are also not acceptable for purposes of full-scale WIPP operations.

By direct analogy, a conclusion that flammable gas concentrations are unacceptable for purposes of bin testing might have unforeseen consequences on interim storage of individual waste drums at the waste generators. To our knowledge, flammage and even detonable gas compositions have been measured in the headspaces of unvented drums. While we understand, based on verbal information only, that flammable/detonable gas compositions have not been measured within vented drums, we are not aware of either the size or the quality of the data supporting this conclusion. Documented data does exist for flammable concentrations of gases within non-vented (sealed with permeable gasket) drums at Los Alamos and Savannah River; the analogy to INEL is obvious. This situation, very akin to the potential (non-purged) situation within test bins, has apparently been safely accommodated at the generator sites.

Secondly, since approximately 125,000 of the 136,000 drum-equivalents of waste presently existing at RFP and INEL are unvented, such a decision to purge at WIPP might call into direct question the safety of existing interim storage at these sites. It must be recognized that such concerns would be strongly contrary to the operational experience that flammable/detonable gas compositions, while they are KNOWN to be present (especially in the case of process sludges) have not represented any significant operational risk.

D. In light of the fact that the proposed interpretation of the FSAR Addendum approach (to purge for controlling gas

flammability) is inconsistent with the present bin and instrumentation designs, except for low-gas generating wastes, there appear to be several alternative approaches to the problem of gas flammability during the bin tests and during full-scale operations at the WIPP. After subsequent review and selection of these alternatives, the project's decision on which course to follow must be documented clearly and unambiguously in the FSAR Addendum.

As noted in the Rationale Report, the problem of gas flammability during full-scale operations could be obviated by changing or modifying the design and/or emplacement of the panel seals, to ensure that these seals become effective for purposes of gas permeability <u>before</u> there was any significant chance of flammable gas compositions developing within the panel headspace. This favorable assumption <u>was</u> made by Slezak and Lappin. Calculations by Slezak indicated that, if it was effective for purposes of permeability control, the simple mass of the grout component of the composite panel seal would eliminate any credible risk of mechanical displacement or rupture of the panel seal in response to a realistic but bounding detonation in the room headspace in the adjacent waste-emplacement panel.

As specifically regards the bin tests, there appear to be several broad alternatives:

1. Work within the present experimental limitations and possible operational constraints at the WIPP, accepting the proposed FSAR interpretation, and follow the logical consequences through:

a) for purposes of long-term PA data, experiment only with low-gas generating wastes and/or Level II treated wastes;

b) consider a change in container material to eliminate steel drums, unless laboratory results reliably indicate that corrosion under "humid" conditions really <u>is</u> near zero;

c) carefully evaluate the overall applicability of tests for high-gas generating, frequently purged bins, for considerations of safety-related issues <u>during</u> the short-term operational phase;

d) reconsider the "incremental compliance" approach, emphasizing low-organic and Level II treated wastes; and/or

e) consider DOE system-wide reprocessing of sludges and/or high-organic wastes, based on the inability to conduct experiments with these wastes at WIPP that adequately address long-term PA issues.

The overall test program would have to be "down-sized," to account for all types of high-gas generating CH TRU wastes eliminated from the testing scheme. The project test program objectives would probably need to be restated and rejustified for external review and regulatory agencies.

2. Aggressively pursue both redesign the bin and associated instrumentation to be certifiably "inherently safe" and elimination of the proposed FSAR constraint for high-organic and sludge wastes. Our understanding is that this would be equivalent to a requirement that the bin and instrumentation: a) would not serve as a potential source of ignition; and b) would survive any detonation which might occur within the bin.

In order for there not to be a "hiatus" in experimentation, this approach requires that, by the time high-organic wastes and/or sludges are available for testing, both the FSAR interpretation and appropriate portions of the bin and related instrumentation can be modified to allow experimentation with high concentrations of potentially flammable gases. For example, one approach might include reducing the available free volumes within the test bins, to limits below which detonations could not be supported or propagated. Alternatively, the bin itself might be strengthened to withstand internal detonation, even if this did occur.

At any rate, a first step in such an approach would be to evaluate the potential stored energy within any experimental bin. The results might indicate that there was not significant concern with distribution of particulates, even in the event of a fire, or that reduction of the free volume within the bin might eliminate the chance of fire propagation.

Again, we do not believe that bin, bin instrumentation, and VOC monitoring system redesign is necessary for purposes of initiating testing with "dry" low-organic wastes. This course would probably permit the current schedule for the ISC, ORR, and first waste receipt (for very limited quantities of wastes) at WIPP to remain undisturbed. However, we do believe that a thorough redesign of the bin and related instrumentation, with the major objective of being able to deal with potentially flammable gas compositions is in order, and should receive relatively high priority as soon as possible. This redesign could acceptably follow the current schedule for the ORR.

3. Complete a realistic probabilistic risk assessment, including the risks due to potentially flammable bins and related accidents. This approach would explicitly require that the estimated consequences and frequencies of the assumed accidents be evaluated. Further strict administrative controls for safe WIPP test conduct should also be instituted. The results of such a study plus controls might be that the risks were deemed to be acceptable.

4. Consider the DOE system options for further waste treatment or reprocessing for high-gas generating wastes, as proposed by the Engineering Alternatives Task Force (EATF).

We firmly believe that the bin-scale test program can be optimized further so that the quantity and quality of resultant data are maintained at defensible levels while the perceived levels of operational safety are still acceptably high. We look forward to working with all site participants to achieve these goals.

Sandia will continue to provide advice and technical interpretations to the WPO and DOE HQ on the course and consequences of the bin-scale test program, no matter which course of action is selected by WPO. We also are offering our assistance in helping to modify the (still draft) FSAR Addendum, to both document the selected course of action and to interpret its impacts on site safety. The FSAR Addendum must be clearly stated so that no interpretive ambiguities remain, both within the project and in external review groups.

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from: Al Lappin - 6340A and Martin Molecke - 6345

subject: Summary of Estimated Consequences of Proposed FSAR-Related Purging Requirements for Bin-Scale Tests

This Memo of Record addresses the gas-compositional consequences and overall programmatic implications to the WIPP bin-scale CH TRU waste test program that result from proposed bin purging. Supporting calculations on gas concentration changes caused by purging are documented in a (separate) memo by Jim Nowak, dated April 4, 1991. These significant consequences are caused by various interpretations of the draft FSAR Addendum for "dry" bin tests, specifically the proposed requirement to purge bins for gas flammability control.

The site-proposed FSAR interpretation is that, for purposes of evaluating and controlling flammability: a) it must be assumed that oxygen is present in the experimental bins at <u>all</u> times, regardless of any experimentally governed anaerobic bin atmosphere; and b) that experimental bins must be purged if the concentration of any flammable gas within the bin reaches 50% of the lower limit for flammability, assuming oxygen is present at any time. For the specific case of hydrogen, we assume that the upper and lower concentration limits for purging are 2% (50% of the lower limit for flammability; initiation of purging) and 0.4% (10% of the limit; end point for purging), respectively. For methane, the other major flammable gas produced, the corresponding limits are 2.5% and 0.5%.

In contrast, the technical approach defined in both the Bin-Scale Test Plan and the Test Plan Addendum has been to allow the concentrations of potentially flammable gases in both anaerobic and (depleted oxygen, but still) aerobic bins to increase as close as possible to those concentrations expected at long times. This specifically means that concentrations of hydrogen or methane much higher than 2.0 - 2.5% are expected. These gases could asymptotically approach their long-term compositions, with concentrations greater than 70% possible. Initial gas concentration vs. time calculations indicate that such high levels of gas (hydrogen or methane) conceivably could be generated in a matter of <u>months</u> under the appropriate (long-term realistic) test conditions.

This approach has been maintained by Sandia through both the DOE approval cycle for the Test Plan Addendum (completed 12/90) and a later "consistency check" between the Test Plan Addendum and the draft FSAR Addendum (completed 1/91). However, as noted below, <u>major</u> inconsistencies in FSAR Addendum interpretations at the site still appear to exist. In addition, these various interpretations are not, to our knowledge, clearly documented.

We also must note, however, that it has become apparent during the Sandia Internal Design Review (SIDR) process for the bin tests that our

own approach to gas flammability probably has not been internally consistent. Specifically, with the exception of the solenoid-actuated, pressure-relief valve loop, the prototype bin instrumentation was not specifically selected to be "inherently safe" for use with potentially flammable gas mixtures. For example, neither the pump included as part of the gas-recirculation loop nor the pumps included on the oxygen-gettering cart are "inherently safe." Therefore, the present bin and instrumentation are not, in fact, adequate for experimental operations above 50% of the lower flammability limit. We plan on incorporating "inherently safe" components in the near-future, as soon as practicable, i.e., after the CRR.

It must be emphasized that for all options discussed in this memo, for limited quantities of low-gas generating TRU wastes only, there are no anticipated impacts to the current schedules for the WIPP Integrated System Checkout (ISC), Operational Readiness Review (ORR), or first waste receipt. [illegible] approach is adopted, and as presently constrained by the VOC-manifold system.

I. SUMMARY OF CONCLUSIONS

(NOTE: Supporting details are presented later in this memo.)

A. If the FSAR addendum must be interpreted to require bin purging at 1/2 of the lower flammability limit concentrations of H_2 and/or CH_4, then the present bin and instrumentation design will probably be adequate for use in experiments at the WIPP or elsewhere, with only those types of wastes for which net gas-generation rates are on the order of 0.1 moles/drum/year (0.6 moles/bin/year) or less. This FSAR interpretation assumes that oxygen must be considered to be present at all times, even though it is experimentally governed at levels that technically preclude flammability potentials and is monitored frequently. Because of the purging restraint, it appears that only "dry" low-organic or other "low-gas generating" wastes can be tested without modification to the present testing plans and/or the bin and attached instrumentation. Bin-scale testing of most high-gas generation high-organic wastes and process sludges, to obtain data relevant for long-term (predictive) WIPP performance assessment (PA) purposes, appears to be precluded.

B. If the FSAR addendum must be interpreted to require purging, there are multiple negative impacts on the interpretations and technical validity of resultant test gas data. Gas mechanistic interpretations based on obtained short-term data are not relevant to the post-closure period of the repository; any resultant predictions will not be defensible for WIPP PA purposes. Gas data will, however, be relevant for repository operational-safety evaluation purposes; wastes that exhibit unacceptably high-gas generation rates may be relegated to further Level-II treatment or reprocessing.

In addition, there may be an inability to conduct more than about four (4) bin tests on any high-gas generating wastes in the WIPP underground, as presently constrained by the 3L/min. maximum flow rate for the VOC-manifold system. The VOC monitoring system was not designed to accommodate the potentially high concentrations or volumes of VOCs to be purged; site compliance with respect to 40 CFR

268 may prove difficult. The VOC monitoring system will require some redesign.

C. Before any decision is made to eliminate potentially flammable gas compositions in the WIPP underground for purposes of bin testing, the potential impacts of this decision on full-scale operations at the WIPP must be considered carefully. High-gas generating wastes amount to greater than 60 volume % of wastes presently planned for WIPP repository isolation; these would be precluded. Safety-related implications to waste generator sites must also be carefully considered. These other sites do not have the capability of purging their stored wastes to control both potential and documented concentrations of flammable gases.

D. The proposed interpretation of the draft WIPP Program approach to gas flammability is, in our technical opinion, inconsistent with the present bin and instrumentation designs and documented test objectives, <u>except for low-organic or</u> (specially treated or modified) <u>Level II wastes</u>. There appear to be several alternative approaches to the problem of gas flammability during the bin tests at the WIPP. These alternatives include:

1. Initiate the bin experiments at WIPP using only low-gas generating low-organic and/or Level II treated wastes; limited types of high-organic wastes, e.g., leaded rubber waste (TRUCON content code 123/223), might also be acceptable. This approach incorporates about 18 to 24 waste-filled test bins, assuming that the proposed FSAR approach cannot be modified. There is a <u>significant risk</u> that much of the Phase 0 bin test program <u>and most of Phases 1 and 2 could not be conducted</u> for purposes of collecting data required for long-term WIPP PA, however.

2. Aggressively pursue redesign of the bin and related instrumentation, and/or physical constraints and administrative procedures, to be "inherently safe" for experiments involving potentially flammable gas mixtures. This redesign must be a total integrated (i.e., WID, SNL, and WPO) system-engineering approach. This approach also includes strict procedures for minimizing oxygen content in the bins and monitoring for oxygen frequently. This is the technique documented in the Test Plan and Test Plan Addendum, and approved by the WPO.

3. Completion of a probabilistic risk assessment, <u>including</u> estimated frequencies and consequences of assumed accident scenarios. This approach may or may not need to be combined with modifications of the bin and related instrumentation.

4. Evaluate the possibilities of incremental compliance assessment and/or additional treatment (reprocessing) of high-gas generating high-organic and/or process sludge wastes so that they might be brought to the WIPP for testing (and future emplacement).

In summary, the problems and consequences discussed above raise significant concerns about bin-scale testing or future waste emplacement for high-gas generating, high-organic wastes and process sludges. The major

consequence of using purging to control bin flammability-safety concerns is to render the resultant data as applicable only to the short-term (early years) of repository operation. Resultant data interpretations will be of little use for PA predictive modeling, as claimed by the project, and may not support initial receipt of such wastes at the WIPP, for purposes of evaluating compliance with 40CFR191 Part B. The data may, however, be critical in evaluating the several timeframes (described in the Rationale document) that pertain to the time period between the waste transportation calculations (that extend only to 60 days after TRUPACT-II loading) and calculations for 40CFR191 Part B (that start 100 years after repository decommissioning). [illegible] significantly different. [illegible] below are [illegible]

It must be stated that these consequences do not appear to impact the validity and conduct of a limited scope of planned bin tests with low-gas generating, "dry" low-organic wastes or Level II treated wastes.

Further details of these individual conclusions and consequences on the presently defined bin-scale test program are discussed in the following section.

II. SUPPORTING DETAILS

A. With the FSAR Addendum interpreted to require bin purging at 1/2 of the lower limit of flammability concentrations of H_2 and/or CH_4, the present bin and instrumentation design will probably be adequate for use in experiments at the WIPP or elsewhere, with only those types of wastes for which net gas-generation rates are on the order of 0.1 moles/drum/ year (0.6 moles/bin/year) or less. Basically, this level of gas generation essentially permits only radiolytic gas degradation; this gas rate could be initiated by about 10 grams of ^{239}Pu per drum, average. Both microbial and anaerobic corrosion processes (and potential synergistic interactions) have the potential to produce significantly greater amounts of gas, as measured in laboratory tests and predicted from existing lab data.

With the purging restraint, the waste types which presently appear to remain appropriate for experiments addressing long-term PA are:

1. "Dry" low-organic (LO) wastes (including the metal container materials), i.e. about 15 Phase 0 test bins of low-organic wastes to which additional brine is not added. At present, this appears to be the only waste category which can be tested without some modification to present equipment and planning.

2. "Dry" Level II treated wastes, i.e. those treated to reduce gas generation rates significantly (however, the theoretical gas-generation potentials are not reduced by such treatment). This could include about 6 Phase 0 test bins of existing TRUCON code 114/214 (cemented inorganic particulate) and possibly 126/226 (cemented organic process solid) wastes.

3. "Wet" and "dry" low-organic wastes, in test Phases 1, 2, and 3. However, these tests would need to be modified to eliminate the metal con-

tainer materials (wire mesh or metal drums for supercompacted wastes). "Wet" TRUCON code 117/217 (mixed metal) wastes would have to be excluded totally. These limitations are required because of the potential high rate of hydrogen generation by anaerobic corrosion of mild steel under "wet" conditions. This category could potentially include up to about 21 bins of waste in the later phases. [illegible] operational phase of 5 or 10 years.

4. "Wet" Level II treated wastes, in test Phases 1, 2, and 3. No estimate of total test bins in this category can be made yet; the number depends on both test results and contingencies. However, these wastes would need to be modified to eliminate the steel metal container material (including wire mesh). This limitation is required for the reasons described for "wet" LO wastes. Elimination of steel waste containers for test purposes also would imply that such containers cannot be used for WIPP operational waste emplacements in [illegible] treatment decision that should be made by DOE (both HQ and [illegible]) at the consequences for future waste packaging (or repackaging) at the generator sites [illegible].

Some "dry" high-organic (HO) wastes might also be acceptable, such as 3 test bins of leaded rubber (TRUCON code 123/223) wastes; these wastes are tentatively expected to have a low rate of gas generation. In addition, some other "dry" high-organic wastes <u>without</u> the metal container materials might also be acceptable; however, this hope is contrary to previous laboratory experimental results obtained by Molecke that indicate that "as-received" water contents are more than sufficient to initiate significant microbial activity. At this time, the uncertainty in the rate and gas compositions of microbial activity under "dry" and "humid" conditions is the greatest uncertainty in the evaluation of the present bin testing program for "dry" high-organic, high-cellulosic content wastes.

B. If the draft FSAR Addendum continues to be interpreted as requiring bin purging for flammability control, multiple limitations (to the original test objectives) will originate from the following major factors:

1. Inability to claim that gas compositions measured during the experiments are representative of those expected under realistic, long-term repository conditions, as justified in the Test Plan. The required number of bin purges for wastes that generate gases at high rates would completely eliminate the present objective of having gas compositions in the bin tests approach or simulate those <u>expected</u> under long-term repository conditions. Remember, the long-term gas compositions will asymptotically approach the integrated compositions of the gases generated/released by the wastes. These compositions are actually approached more rapidly as a result of bin <u>venting</u> (refer to supporting memo by Nowak for calculations), but would not be approached at all in the event of frequent bin purging.

The gas concentrations in purged bins could never approach self-limiting concentrations, i.e., concentrations potentially capable of either poisoning, catalyzing, or fertilizing other reactions and/or interac-

tions. The experimental "time clock" would essentially be reset to time t = 0 after every purge cycle.

2. Inability to claim, as a defensible fallback, that the experimentally measured, but purged and therefore non-representative gas compositions and generation rates are "bounding" and therefore usable for purposes of Performance Assessment (PA). Gas production rates and potentials from microbial degradation mechanisms would be particularly suspect. If the only realistic mechanism prevented by eliminating high concentrations of flammable gases is self-poisoning (e.g. poisoning of microbial activity by high concentrations of H_2), the measured generation rates would be bounding. However, we cannot presently demonstrate that there are not "fertilizers" which, if allowed to be present in their undisturbed concentrations, would initiate microbial reactions which would not be observed in repeatedly purged bins. One specific "fertilizer" is water. We suspect rates of microbial activity to be sensitive to the relative humidity within the bin. The internal bin relative humidity that is buffered by the as-received (sorbed) water content of the wastes remains unknown. Some water vapor will be removed from the bin during each purge cycle (refer also to the purging depletion of VOCs, in item #8, below); this removal will continuously lower the relative humidity. Assuming that the vapor pressure of water in Ar gas is similar to that in air, there is a real risk that the (purged) relative humidity will decrease to below some critical minimum level of water vapor, below which microbial activity cannot occur. This would result in unrealistically low, "favorable" but erroneous, gas-generation rates.

Therefore, we cannot presently defend a "bounding" argument. The consequences or options of claiming that the experimentally measured rates are <u>minima</u> have not been evaluated in detail. Experimental determination of <u>minimal</u> gas-generation rates may be worthwhile, depending on the decision making logic involved in WIPP performance evaluations.

3. Inability to evaluate the gas production from ALL CH TRU wastes in inventory and to-be-generated, to evaluate their suitability for repository isolation. Suspected high-gas generating wastes might be precluded from acceptance, due to a lack of relevant test data caused by the operational purge constraints. Most process sludge (PS) wastes might be judged <u>unacceptable at WIPP</u> because they generate flammable gas mixtures (including oxygen), mixtures that are not controllable by purging or minimization of the initial oxygen concentration. The precedent for further treatment or repository exclusion of PS and other suspected high-gas generating wastes could be implied or forced. Such wastes include more than 60 volume % of all CH TRU wastes in inventory: ~45 vol % HD + ~15 % PS + ?% 117/217 (mixed corroding metals) + ??.

With purging, data gathered would not be relevant for performance assessment predictive purposes. Gas data obtained from high-gas generating wastes would, however, be quite relevant for evaluating (waste type specific) safety issues during the operational-phase time period of the repository. Decisions on the repository acceptability or nonacceptability of specific wastes (by TRUCON content code), or decisions on the need for further waste treatment or reprocessing, could be based on the observed gas data plus supporting safety and PA evaluations.

4. Inability to claim that the experimental (bin internal) oxidation potential is in any way representative of that expected in the long-term. The time required for equilibration of the oxidation potential within experimental bins remains unknown. One major objective of the bin tests always has been to allow the oxidation potential to "float" to values controlled by competing degradation mechanisms, after initial purging/gettering. However, we expect that frequent purging would make this "floating" impossible, with the result that the oxidation potential within the bins would be completely dominated by that of the purge gas. Purging consequences on anaerobic corrosion and microbial degradation cannot be predicted; interpretations based on such data would not be defensible.

5. Inability to conduct more than about four (4) bin tests on high-gas generating HO or PS wastes in the WIPP underground, if the proposed FSAR Addendum purging approach is adopted, and as presently constrained by the 3L/min. maximum (input) flow rate for the VOC-manifold system. This is not a firm estimate; however, it indicates the extremely limited utility of the WIPP underground as presently constrained.

The operational problems involved in frequent purging of any significant number of bins also appear to be insurmountable at present. For example, the presently mandated flow-rate limit of 3L/min on the underground VOC manifold system dictates a purge time of about 3 to 5 days (depending on waste type and initial gas composition), and dictates that only one bin can be purged at a given time. For a bin generating gas at the rates and compositions estimated in the WIPP FSEIS, purging would be required approximately every 9 to 10 days (see supporting memo by Nowak). Gas production data also would be lost during the 3-5 day purge time of the total 12-15 day (generation + purge) cycle.

To our knowledge, the VOC-collection system, while it was originally intended to be able to deal with simultaneous venting of up to about 125 bins, has never been designed to be able to accommodate the volumes of total purged gases or the potentially high concentrations of VOCs that might be released as a result of frequent bin purging in the WIPP underground. The supporting calculations by Nowak give some indication of the volumes of VOCs that might be involved on a per bin basis. We must note that this problem is a direct impact of the No-Migration Determination. An engineering modification or redesign of the VOC-collection system is called for.

6. Inability to distinguish between general waste-degradation mechanisms (e.g. radiolysis and anaerobic corrosion), due to elimination of minor gases (potentially to less than detectable levels) by frequent purging. The long-term interactions that occur at high-gas concentrations, e.g., poisoning or (microbial) fertilization, will be prevented and not investigated. This interpretation by mechanism is a critical element for formulating long-term, gas-production predictive models, as required for WIPP PA purposes.

For example, in the case of high-cellulosic wastes, the intent is to distinguish the amount of hydrogen generated by radiolysis from that generated by anaerobic corrosion. This separation is based on the fact that

hydrogen and carbon monoxide (CO) are generated at a ratio of approximately 5:1 in radiolysis of cellulosics. If CO is eliminated by frequent purging, this distinction will not be possible. Minor microbial degradation mechanisms could also produce gases that are 2 to 3 orders of magnitude smaller than the hydrogen production rate. Such gases would probably not be detectable in the proposed purging regime.

7. The resulting need for a large number of additional gas samples, i.e. inability to decrease sampling frequencies as a function of time, as described in the Test Plan. A minimum of two or three gas samples will be required to define the gas compositions and kinetics of generation within the bin, before and after bin purging. Without this definition no reliable generated gas or VOC gas mass-balance can be maintained, nor can the effectiveness of purging be experimentally verified (except with the on-line O_2 monitoring).

With the proposed FSAR approach to flammability by purging, evaluations of steady-state gas-generation rates would appear to require steady-state sampling and analyses rates. The amount of extra effort and expense for both increased bin gas sampling plus analyses and frequent purging would be negatively balanced with resulting gas data that would be essentially uninterpretible due to the sampling, purging and potential nonhomogeneous gas-mixing complexities.

8. Elimination of the ability to investigate microbial degradation of VOCs in a realistically simulated repository environment. As noted in the Rationale Report, WIPP compliance with RCRA (40 CFR 268) will require demonstration that: a) VOCs will not leave the WIPP repository at all; b) VOC concentrations, as they leave the repository, are below health-based standards; or c) VOC concentrations will be degraded microbially or by some other mechanism <u>before</u> they reach the site boundary. The proposed FSAR approach would eliminate the ability to investigate microbial degradation of VOCs in a realistically simulated repository environment. Without such demonstration, compliance with respect to 40 CFR 268 may prove difficult or impossible.

Calculations by Nowak indicate that VOC concentrations could be flushed to essentially zero concentration after several purge cycles; VOC data would become essentially uninterpretible, not useful for WIPP RCRA evaluations.

NOTE: The only positive result of frequent purging would appear to be that the purging process would serve to eliminate VOCs and define a realistic VOC source term for the wastes, <u>if</u> the conventional wisdom that the VOC source term is "small" is realistic. However, the removal of VOCs by purging may be viewed as "waste treatment" by various reviewers or regulators; this is an activity that presumably is not allowed at the WIPP.

C. Before any decision is made to eliminate potentially flammable gas compositions in the WIPP underground for purposes of bin testing, the potential impacts of this decision on full-scale operations at the WIPP and at waste generators also must be considered carefully.

There appears to be a significant risk that elimination of flammable gas mixtures for purposes of bin tests might result in an inability to dispose of untreated high-organic wastes, and/or process sludges at the WIPP, given the present facility and seal design. Undesirable precedents also might be placed back onto other DOE waste generator-storage facilities because they do not have the ability to purge their high-gas generating wastes.

We are aware of only verbal, undocumented arguments supporting the claim that the risks involved in bin tests vs. those involved for full-scale waste emplacement are significantly different. Basically, our concern is that, while the arguments (summarized below) are straightforward, they may well not be defensible before a critical, technical peer review such as the NAS, the Blue Ribbon Panel, or state regulators. Postulated arguments are:

1. The "exposure time" for the bin tests is five years or more, because the rooms in which the tests will be conducted will not be backfilled, and experimental personnel must be present in the room "continuously" as a routine part of experimental operations. Therefore, in the absence of absolutely reliable administrative and/or experimental controls, potentially flammable gas mixtures simply must be eliminated.

2. In contrast, the "exposure time" during full-scale operations will be greatly reduced, to six months or less, as a result of the fact that individual waste-emplacement rooms will be backfilled as waste is emplaced, with a nominal period of active ventilation in any given room of approximately six months. Therefore (the argument goes) flammable gas compositions, while not acceptable for purposes of bin tests (or, by implication, alcove tests), are acceptable for full-scale operations at the WIPP. This argument simply ignores the relative quantities (and risks) of wastes between limited bin-scale test emplacements and full-scale waste emplacement operations.

We do not believe this argument is valid. As noted in the memo by Slezak and Lappin prepared in January, 1990, while flammable gas compositions are not expected to be generated while an individual waste-emplacement room is actively ventilated, such gas compositions may well be generated in the headspace above an entire waste panel within approximately three years of the nominal time of panel-seal emplacement. Therefore, we believe, as pointed out in the recent "Rationale Report," that the question really boils down to evaluation of the timing relationship between the beginning of drum breaching within individual panels, the generation of a flammable/detonable gas composition in the panel headspace (which was historically assumed to occur) and the time at which panel seals become effective for purposes of controlling gas permeabilities.

Work is ongoing at Sandia to reduce or eliminate the time period between panel-seal emplacement and their effectiveness for gas permeability. However, to our knowledge, no changes have yet been implemented in the tentatively approved conceptual design. We believe that with the present design there is an expected time interval over which the panel seals are not expected to be effective.

Therefore, we believe that, if exposed to critical outside review (and contrary to the conclusions reached by Slezak and Lappin), we must recognize that there is a realistic potential for deflagration/detonation of flammable gases within the headspace above backfilled wastes in an individual waste-emplacement panel, following panel-seal emplacement but prior to panel-seal effectiveness, and still during the nominal WIPP operational phase of 25 or 30 years.

Until this uncertainty is resolved or eliminated, we believe there is a serious risk of concluding that since flammable gas compositions are not acceptable for purposes of bin testing, they are also not acceptable for purposes of full-scale WIPP operations.

By direct analogy, a conclusion that flammable gas concentrations are unacceptable for purposes of bin testing might have unforeseen consequences on interim storage of individual waste drums at the waste generators. To our knowledge, flammable and even detonable gas compositions have been measured in the headspaces of unvented drums. While we understand, based on verbal information only, that flammable/detonable gas compositions have not been measured within vented drums, we are not aware of either the size or the quality of the data supporting this conclusion. Documented data does exist for flammable concentrations of gases within non-vented (sealed with permeable gasket) drums at Los Alamos and Savannah River; the analogy to INEL is obvious. This situation, very akin to the potential (non-purged) situation within test bins, has apparently been safely accommodated at the generator sites.

Secondly, since approximately 125,000 of the 136,000 drum-equivalents of waste presently existing at RFP and INEL are unvented, such a decision to purge at WIPP might call into direct question the safety of existing interim storage at these sites. It must be recognized that such concerns would be strongly contrary to the operational experience that flammable/detonable gas compositions, while they are KNOWN to be present (especially in the case of process sludges) have not represented any significant operational risk.

D. In light of the fact that the proposed interpretation of the FSAR-Addendum approach (to purge for controlling gas flammability) is inconsistent with the present bin and instrumentation designs, except for low-gas generating wastes, there appear to be several alternative approaches to the problem of gas flammability during the bin tests and during full-scale operations at the WIPP. After subsequent review and selection of these alternatives, the project's decision on which course to follow must be documented clearly and unambiguously in the FSAR Addendum.

As noted in the Rationale Report, the problem of gas flammability during full-scale operations could be obviated by changing or modifying the design and/or emplacement of the panel seals, to ensure that these seals became effective for purposes of gas permeability <u>before</u> there was any significant chance of flammable gas compositions developing within the panel headspace. This favorable assumption <u>was</u> made by Slezak and Lappin. Calculations by Slezak indicated that, if it was effective for

purposes of permeability control, the simple mass of the grout component of the composite panel seal would eliminate any credible risk of mechanical displacement or rupture of the panel seal in response to a realistic but bounding detonation in the room headspace in the adjacent waste-emplacement panel.

As specifically regards the bin tests, there appear to be several broad alternatives:

1. Work within the present experimental limitations and possible operational constraints at the WIPP, accepting the proposed FSAR interpretation, and follow the logical consequences through:

a) for purposes of long-term PA data, experiment only with low-gas generating wastes and/or Level II treated wastes;

b) consider a change in container material to eliminate steel drums, unless laboratory results reliably indicate that corrosion under "humid" conditions really is near zero;

c) carefully evaluate the overall applicability of tests for high-gas generating, frequently purged bins, for considerations of safety-related issues during the short-term operational phase;

d) reconsider the "incremental compliance" approach, emphasizing low-organic and Level II treated wastes; and/or

e) consider DOE system-wide reprocessing of sludges and/or high-organic wastes, based on the inability to conduct experiments with these wastes at WIPP that adequately address long-term PA issues.

The overall test program would have to be "down-sized," to account for all types of high-gas generating CH TRU wastes eliminated from the testing scheme. The project test program objectives would probably need to be restated and rejustified for external review and regulatory agencies.

2. Aggressively pursue both redesign the bin and associated instrumentation to be certifiably "inherently safe" and elimination of the proposed FSAR constraint for high-organic and sludge wastes. Our understanding is that this would be equivalent to a requirement that the bin and instrumentation: a) would not serve as a potential source of ignition; and b) would survive any detonation which might occur within the bin.

In order for there not to be a "hiatus" in experimentation, this approach requires that, by the time high-organic wastes and/or sludges are available for testing, both the FSAR interpretation and appropriate portions of the bin and related instrumentation can be modified to allow experimentation with high concentrations of potentially flammable gases. For example, one approach might include reducing the available free volumes within the test bins, to limits below which detonations could not be supported or propagated. Alternatively, the bin itself might be strengthened to withstand internal detonation, even if this did occur.

At any rate, a first step in such an approach would be to evaluate the potential stored energy within any experimental bin. The results might indicate that there was not significant concern with distribution of particulates, even in the event of a fire, or that reduction of the free volume within the bin might eliminate the chance of fire propagation.

Again, we do not believe that bin, bin instrumentation, and VOC monitoring system redesign is necessary for purposes of initiating testing with "dry" low-organic wastes. This course would probably permit the current schedule for the IBC, ORR, and first waste receipt (for very limited quantities of wastes) at WIPP to remain undisturbed. However, we do believe that a thorough redesign of the bin and related instrumentation, with the major objective of being able to deal with potentially flammable gas compositions in in order, and should receive relatively high priority as soon as possible. This redesign could acceptably follow the current schedule for the ORR.

3. Complete a realistic probabilistic risk assessment, including the risks due to potentially flammable bins and related accidents. This approach would explicitly require that the estimated consequences and frequencies of the assumed accidents be evaluated. Further strict administrative controls for safe WIPP test conduct should also be instituted. The results of such a study plus controls might be that the risks were deemed to be acceptable.

4. Consider the DOE system options for further waste treatment or reprocessing for high-gas generating wastes, as proposed by the Engineering Alternatives Task Force (EATF).

We firmly believe that the bin-scale test program can be optimized further so that the quantity and quality of resultant data are maintained at defensible levels while the perceived levels of operational safety are still acceptably high. We look forward to working with all site participants to achieve these goals.

Sandia will continue to provide advice and technical interpretations to the WPO and DOE HQ on the course and consequences of the bin-scale test program, no matter which course of action is selected by WPO. We also are offering our assistance in helping to modify the (still draft) FSAR Addendum, to both document the selected course of action and to interpret its impacts on site safety. The FSAR Addendum must be clearly stated so that no interpretive ambiguities remain, both within the project and in external review groups.

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9325 - L.A. Kracko
9325 - H.C. Ogden
6340A- A.R. Lappin
6345 - M.A. Molecke

SUMMARY OF AFFIDAVIT OF
SHOSEI SERATA

Dr. Serata is the President of Serata Geomechanics, a research and consulting firm in the field of geomechanics and problems of mine stability.

Dr. Serata testifies that the design of the WIPP storage area disregards principles of geomechanics and is inherently unstable. There is a present risk that the roof of Room 1, Panel 1 will collapse. It is highly inadvisable to introduce radioactive waste into that room because of the risk that the waste may become non-retrievable. The risks of personal injury, radioactivity contamination, and other damage are grave and imminent. (¶ 2).

In 1979 Dr. Serata was retained by the DOE's design contractor for the WIPP, and he advised the DOE that it would encounter serious problems if stress control methods were not used at the WIPP. The DOE instead adopted a traditional and nonscientific design, and Dr. Serata resigned. (¶¶ 14-17).

Room 1, Panel 1 is already in a state of progressive failure, demonstrating acceleration of closure, and will collapse in the near future. The proposed supplemental support system can do little to prevent the failure of the room. Acceleration is a clear danger signal and portends the failure of Room 1, Panel 1 in the near future. Activities should not take place in that room. (¶¶ 20-26).

The supplemental support system will not significantly postpone the failure of the roof of Room 1, Panel 1. The

overlying salt formation in which the bolts are anchored is failing. The design assumes that the system need only bear the weight of the 2.12 meter roof formation, ignoring the major role of lateral stresses, which are the real cause of failure. Bolting will only accelerate the failure of deeper formations. The designers assume only 1/2" per year of lateral movement, but the data show more movement than that. The designers' computer model does not include brittle fracturing behavior, which is the main mechanism of the present roof failure. (¶¶ 27-31).

Equipment access height required for Room 1, Panel 1 is almost certain to be lost in a very short time, by reason of room closure. (¶ 34).

Further, there is no warning system that will provide six months of safe access after a decision to retrieve waste. The DOE apparently disregards acceleration of closure. In the absence of another scientifically supported method of identifying forthcoming roof failure, to emplace radioactive waste in the room is irresponsible. (¶¶ 32-33).

If waste is emplaced in Room 1, Panel 1, there is a high probability that it will become non-retrievable in a matter of months through lack of access, acceleration and closing of the room, or a major roof fall. (¶ 35).

AFFIDAVIT OF SHOSEI SERATA

Shosei Serata under penalty of perjury states as follows:

1. I am the President of Serata Geomechanics, Inc. (SGI), of Richmond, California, which is a research and consulting firm in the field of geomechanics and problems of mine stability.

2. I make this affidavit to show the court that the design of the Waste Isolation Pilot Plant ("WIPP") waste storage area disregards principles of geomechanics and is, for that reason, inherently unstable. There is a present risk that the roof of Room 1, of Panel 1, where tests are planned with radioactive waste, will collapse. In these circumstances it is highly inadvisable to introduce radioactive waste into that room, because of the risk that the waste may become non-retrievable. The risks of personal injury, radioactivity contamination, and other damage are grave and imminent for the following reasons:

a. Misunderstanding of basic mechanism of the roof failure

b. Lack of awareness of large lateral stresses already destroying the salt formations above the proposed anchor elevation

c. Inadequacy of the proposed support system

d. Imminence of roof fall in the near future in spite of the proposed roof support

e. Cover-up of acceleration of ground deterioration by the roof support system, resulting in sudden massive roof collapse.

3. First, I discuss my personal qualifications. I received a degree as M.S. in Civil Engineering, Structural Design, from Kyoto University in Japan in 1952. I came to the United States and received a degree as M.S. in Sanitary Engineering from the University of California at Berkeley in

1956. In 1959 I received my doctorate degree in Civil Engineering with a minor in Nuclear Physics from the University of Texas at Austin.

4. I investigated the feasibility of nuclear waste storage in underground salt openings by conducting laboratory testing of salt, underground measurement of salt openings, and theoretical analysis of opening stability with funding from the Atomic Energy Commission at the University of Texas, Austin, from 1956 to 1959. Based on results of this research, I wrote my Ph.D. dissertation on "Development of Design Principles for Disposal of Reactor Fuel Waste into Underground Salt Cavities" in 1959. I consulted for the Atomic Energy Commission in design and experiments for the nuclear waste storage mock-up test in a Kansas salt mine from 1959 to 1962.

5. In 1959 through 1966 I was an Assistant Professor and Associate Professor in the Department of Civil Engineering at Michigan State University. There I originated graduate programs in rock mechanics and nuclear engineering. I also conducted an active consulting practice in the field of rock mechanics, principally to the mining industry.

6. In 1966 I founded the firm of Serata Geomechanics, Inc. to conduct my research and consulting practice specializing in quantification of underground work by field adaptation of computer modeling and in situ measurements.

7. In 1968 through 1971 I taught as Lecturer in Geotechnical Engineering at the University of California at Berkeley.

8. In 1969-70 I taught rock mechanics at Stanford University as Visiting Professor in the Department of Mineral Engineering.

9. In the 1960s I developed, validated, and successfully implemented a

scientific and quantitative solution to underground mine stability questions which has come to be referred to as the stress control method. This method was originally brought into use in the Saskatchewan potash industry and successfully saved many mines from collapse. The bases of the method include (a) actual in situ measurement of stress state and material properties at the location of the problem, (b) time-dependent monitoring of ground deformation, and (c) construction of a site-specific computer model for design analysis by closely simulating the actual ground condition using the data from the field measurements. The computer program thus developed takes into account all of the following seven major behavioral components of the ground: elasticity, viscoelasticity, viscoplasticity, volume expansion, thermal expansion, brittle-ductile failure, and time-dependent strength deterioration. The simulation of brittle-ductile ground failure is made possible by this uniquely site-specific calibrated model of the ground.

10. Using such analytical techniques, we developed underground mine designs which resolve the problems of ground failure commonly encountered in underground mining. In brief, our designs typically avoid the use of massive pillars between rooms, which tend merely to concentrate underground stress to the roof and floor of adjacent rooms. Instead, our designs utilize yield (slender flexible) pillars to form a protective stress envelope which surrounds an entire group of rooms separated by the yield pillars. The stress envelope protects all the rooms inside the envelope, making them permanently stable. Solid abutment pillars are provided on both sides of the envelope to support it. The dimensions of the panel of rooms inside the stress envelope are determined mainly by the economics of

excavation and the scheme of utilization. All the loading is absorbed by the protective stress envelope, which acts like a stress arch extending from one abutment to the other.

11. The stress control method is the subject of one expired patent and three patent applications.

12. I have specific experience in applying these methods in underground operations involving salt and evaporite deposits. Instances are as follows:

a. In 1959-1964, working and consulting for the Atomic Energy Commission, I conducted field and laboratory tests in salt beds and domes, as possible locations for radioactive waste disposal in Texas and Kansas.

b. In 1963 through 1972 I performed mine design, surface subsidence analysis, flood recovery, and earthquake response studies for the Saskatchewan crown corporation (Potash Corporation of Saskatchewan) for their operations at Cory, Allan, Lanigan, and Rocanville mines, all in Saskatchewan.

c. From 1962 to date, I have been serving the private potash mines in Saskatchewan, including International Minerals and Chemical Corp., Central Canada Potash, and Cominco Fertilizers for improvement of their underground design and operation.

d. From 1971 to date I have been conducting cavern design analysis and field studies of various operations of underground cavern storage in salt formations in Alberta, Ontario, Louisiana, Texas, and Brazil for Dow Chemical Co.

e. In 1972-73 I designed caverns for petrochemical waste disposal in

salt formations for Akzo Zout Chemie, N.V. in the Netherlands.

f. In 1972-74 I analyzed the failing salt caverns used for natural gas storage and successfully redesigned them for permanently stable operation for Transcontinental Gas Pipeline Co. in the Eminence salt dome in Mississippi.

g. In 1973, I analyzed the failing condition of Cayuga salt mine at Lansing, New York, and recommended conversion from the conventional method to that of the stress control method. The recommendation was later successfully carried out not only saving the mine from major collapse, but also dramatically improving productivity.

h. In 1973 I conducted laboratory testing and computer modeling analysis of salt caverns which led to successful development of the compressed air energy storage method for the NWK Power Co. in Germany.

i. In 1973-82 I designed caverns in the Napoleonville salt dome in Louisiana for Shell Oil Development Co.

j. From 1973 to date I have been conducting computer simulation analysis and field stress measurement for development of criteria for design of underground cavern fields for the Solution Mining Research Institute (international trade organization of the industry).

k. In 1974 I designed Europe's first natural gas storage cavern in an underground salt dome for Ruhrgas A.G., Germany, by utilizing the finite element computer modeling technique.

l. In 1976-82 I did cavern analysis and design criteria development

for a compressed air energy storage project for General Electric Co. (U.S.), which was followed by computer software development for design of salt caverns used for compressed air energy storage for the Department of Energy (1978-82).

m. In 1976-82 I conducted material testing and computer modeling analysis for design, construction, and operation of the nation's first oil storage terminal in a salt dome for the Louisiana Offshore Oil Port (LOOP) in Clovelly, Louisiana.

n. From 1977 to the present, I have continued comprehensive studies building the computer model of the mining ground of Sifto Canada Inc. and converting the failing salt mine to successful operation of the stress control method of mining. The studies are still continuing for further improvement of the mining method.

o. In 1970-88 I adapted the stress control method of mining to multiple levels of salt and potash mining for the Lanigan Division of PCS, Seleine mine (Crown Corp. of Quebec), Diamond Crystal Salt of Louisiana, and Cargill mine of Louisiana.

p. In 1986-88 I constructed a computer model of the cavern field used for storage of LPG in the Barbers Hill salt dome for Warren Petroleum Co. of Texas (a subsidiary of Chevron Oil Co.), and analyzed for long-term future stability which was validated by the surface subsidence measurements.

q. In 1986-88 I developed a method of measurement and constructed the required instruments and carried out <u>in situ</u> measurements of the lateral stress field in the salt beds and surrounding strata in the Michigan salt basin at the Sifto Goderich (Ontario) mine at a

depth of 1800 ft for the Solution Mining Research Institute, detecting the presence of large lateral tectonic stress much greater than that of the geostatic state.

r. From 1986 to the present I conducted computer model analysis of long-term stability of the large cavern field and designed permanently stable caverns for the first U.S. compressed air energy storage (CAES) project for the Electric Power Research Institute (EPRI) at the McIntosh salt dome (Alabama). I further designed, constructed, and installed a surface subsidence monitoring system for validation of the design in situ.

s. From 1989 to date I have developed a stress control method of designing salt dome cavern fields for optimum utilization of deep salt domes at depths below 5000 ft for the Louisiana Land and Exploration Co.

t. In 1990-91 I analyzed and designed the expansion of a solution cavern field in the Michigan salt basin at Detroit for Marathon Oil Co.

13. I have written more than 50 scientific papers for professional journals and conferences. My resume and a list of publications are attached.

14. I have specific experience concerning the WIPP. In 1979 Bechtel Corporation ("Bechtel") entered into a contract to design the WIPP repository. Bechtel in turn retained Serata Geomechanics, Inc. as a consultant in matters of geomechanics and underground opening design. To analyze the issues of room stability I constructed a computer model of the behavior of the Salado formation salt beds, in which the WIPP underground

rooms were to be mined. Using that model, I designed a four-room entry system which I calculated to assure its stability for an infinite period of time, much more than 100 years. Such stability was considered desirable because for an extended period it would permit the waste to be retrieved after emplacement, in the event a preferable method of disposal were developed or any other unforeseen developments.

15. The DOE initially appeared receptive to my proposed design for the WIPP. The DOE accepted some of my suggestions, such as modifying the facility horizon to the present level to avoid an overlying clay seam.

16. I cautioned the DOE in 1979 that it would encounter serious problems if the stress control method were not used at the WIPP. I advised the DOE that it should use our computer modeling concept of the brittle-ductile duality of behavior of geological material in general and rock salt in particular, but to my knowledge it has not done so.

17. However, I failed to convince the DOE or Bechtel to adopt stress control methods for the design of the WIPP rooms. The DOE adopted instead a design employing massive (100 foot) pillars and a low (25%) extraction ratio. This traditional design is based on rules of thumb and mathematical idealization which defy scientific observation made in salt openings. I disapproved of this design. I was given the choice of either agreeing to the use of traditional mine design, which I believed would cause recurrent instability, or resigning the consultancy. I chose to resign.

18. I have now been retained as a consultant by the State of New Mexico to review the room instability problems which have been encountered at the WIPP.

19. In this current assignment I have reviewed (a) the Report of the

Geotechnical Panel on the Effective Life of Rooms in Panel 1, DOE/WIPP 91-023 (June 1991), (b) the report, Waste Isolation Pilot Plant Supplementary Roof Support Systems, Underground Storage Area, Room 1, Panel 1, DOE/WIPP 91-9230 (August 1991), and (c) the report, Room 1, Panel 1, Supplementary Roof Support External Design Review (September 19, 1991).

20. From a review of these materials, it is apparent that the room where it is proposed to emplace the radioactive waste is already in a state of progressive failure, demonstrating acceleration of closure--i.e., accelerated convergence between the roof and the floor--and will collapse in the near future. It is also apparent that the proposed supplemental support system can do little to prevent the failure of the room.

21. The failure of the room takes place as follows. When an underground room is excavated, the opening is immediately subjected to increased tangential stresses on the boundary of the opening. The increase of tangential stress associated with the loss of radial stress on the exposed boundary produces the maximum damaging stress, that is the shear stress, as a result of the excavation.

22. When the roof or floor includes weak sedimentary seams, such as the clay seams overlying the WIPP rooms located at the anhydrite "b" and anhydrite "a" layers, the concentrated tangential stresses will cause the strata to shear, first separately at these planes of weakness, followed by diagonal shearing failure.

23. The data concerning SPDV Test Room 2 at the WIPP show that four years after excavation, the lateral stresses over the roof caused substantial shear to take place in the formation between the anhydrites "a" and "b", which are 2.12 and 3.91 meters above the roof, respectively

(August 1991 report, Fig. 5.4). It is apparent that such roof failures have also progressed at Room 1, Panel 1, which is already in excess of five years old (Id. Table 5).

24. The roof stress state and associated failure will give rise to buckling and fracturing of the immediate roof formations of Room 1, Panel 1. Similar conditions caused the massive failure of the roof of SPDV Test Room 1 in February 1991. That room is now totally closed to access. Fracturing has already been observed in the roof of Room 1, Panel 1 (August 1991 report at A-6, Fig. 5.8). Progressive low-angle shear fractures are the endproducts of the above mechanism of roof failure (Id. A-6, A-7).

25. One indicator of forthcoming failure is a measurable acceleration in the rate of closure of a room. I note that SPDV Test Room 1 began to experience acceleration of closure in its sixth year, 1989 (August 1991 report, Table 5). In mid-1989, all routine activities in this room were suspended, presumably in response to this danger sign (Id., Fig. 5.1).

26. Room 1, Panel 1 has now shown a similar pattern of acceleration, with the rate of closure increasing from a rate of 3.24 inches per year to 3.57 inches per year (measured over only nine months (Id., Fig. 5.1). This is a clear danger signal and portends the failure of Room 1, Panel 1 in the near future. Activities should not take place in this room.

27. I have reviewed the proposed supplemental roof support system described in the August 1991 report. This system will not significantly postpone the failure of the roof of Room 1, Panel 1. The support system relies upon rock bolts 13 feet long, which are anchored in the overlying salt formation between the "a" and "b" seams. In other words, the entire support system depends upon the stability of the overlying salt formation

of 1.79 meter thickness. If this overlying salt formation is not reliable, the support system will not be useful.

28. Data already show that the overlying layer is failing. There is a large amount of fracture deformation being accumulated in the overlying formation (Id., Fig. 5.4). Indeed, the figure shows that lateral movement has been detected as deep as 15 meters above the roof of the facility (Id., A-6). The support system assumes that all the overlying formations above the "b" seam are competent (Id. 3-2, A-10), but actually they are not competent.

29. The designers of the support system have also assumed that the principal force they must contend with is gravity, so that the system need only bear the weight of the 2.12 meter roof formation (Id., 3-2, A-9), which is the stress equivalent of up to 7 psi. But this assumption ignores the major role of lateral stresses on the order of 4000 to 6000 psi, which are the real cause of the failure of the roof formations. The effort to restore the integrity of the immediate roof formation by bolting will only accelerate the failure of the deeper formations of the roof even beyond the "a" seam, as is already taking place. The result will be an acceleration of the roof failure extending much deeper into the roof formations.

30. It is certain that the overlying salt formations between the "a" and "b" seams will be failing over all the rooms in Panel 1. The designers assume that they will have to contend with only 1/2" per year of lateral movement in the roof (Id., 4-3). But the data show more movement than that (Id., Fig. 5.4), as do observation holes (June 1991 report, Parker report). This lateral movement is caused by the large lateral stresses which are currently destroying the roof steadily from the immediate to the overlying

formations, and further above with time. The result will be additional downward force upon the support, resulting in the destruction of the entire roof support system.

31. The designers have predicated their support system on a computer model, which they acknowledge does not include the brittle fracturing behavior which is the main mechanism of the present roof failure (Id., A-4, A-5, A-7). A design which omits consideration of the most important aspect of rock behavior cannot succeed.

32. The June 1991 expert panel report states that six months time is required to remove waste, even in emergency conditions (June 1991 report, at 3-3). There is no indication in the August 1991 report that warning systems have been developed which will provide six months of safe access after a decision is made to retrieve waste. The DOE apparently does not now choose to regard the acceleration of closure as a warning signal, because acceleration has been observed (August 1991 report, Table 5.1), but the DOE nevertheless desires to introduce radioactive waste into the room. In these circumstances, the burden is on the DOE to set forth another scientifically supported method of identifying forthcoming roof failure in Room 1, Panel 1, which provides six months of safe access after the danger signal is given. In the absence of such a method, to emplace radioactive waste in the room is irresponsible.

33. The DOE's costly monitoring system is not a reliable warning system at all, because it consists only of a data gathering activity with no quantitative analysis. Consequently, no specific ideas for establishing an action plan or danger thresholds are indicated. Moreover, I am unaware of any method of predicting roof failure in Room 1, Panel 1, other than

time-dependent monitoring of the three basic conditions of the roof formations: stress state (S), material properties (P), and ground deformation (D), with closely following brittle-ductile computer model analysis to reliably provide six months of safe access. The current SPD conditions estimated from the available data indicate that it is not now safe to introduce radioactive waste into that room.

34. It is also clear that the equipment access height required for Room 1, Panel 1, which is 3.45 meters (11' 4") (Id., 3-1), is almost certain to be lost in a very short time. The room is nominally 3.94 meters high (Id., Fig. 2.2), and the 18" (450 mm) rock bolt protrusions will reduce the available clearance to 3.49 meters. This clearance--if it truly exists today, given the irregularities of the WIPP rooms--will fall below 3.45 meters rapidly by reason of room closure.

35. If radioactive waste is introduced into Room 1, Panel 1, there is a high probability that it will become non-retrievable in a matter of months because of lack of essential equipment access, or such continued closure acceleration that the DOE itself concludes that the room is unsafe and must be closed to personnel, or a major roof fall that may cause personal injury or release of radioactivity and certainly will result in the room being closed to any further access.

I declare under penalty of perjury that the foregoing is true and correct. Executed on October 23, 1991.

SHOSEI SERATA, Ph.D.

EXHIBIT A

SERATA GEOMECHANICS, INC.

SHOSEI SERATA, Ph.D.

President and Principal Investigator

Dr. Serata, founder and president of Serata Geomechanics, Inc., directs the firm's activities in research and development of advanced techniques for in situ stress/property determination, solution cavern design, and underground mine design. He specializes in the design of underground and near-surface earth structures through the integration of three proprietary techniques: 1) instrument development, manufacturing, and field application; 2) computer simulation analysis of earth structures; and 3) advanced laboratory testing of complex earth materials.

Education

Postdoctoral studies:
- Geophysics, California Institute of Technology, Pasadena, 1966
- Advanced Nuclear Reactor Physics and Reactor Experimentation, Stanford University, 1961
- Radiation Effects on Materials, University of Michigan, Ann Arbor, 1960

Ph.D. Civil Engineering, University of Texas, Austin, 1959
Dissertation: "Development of Design Principle for Disposal of Reactor Fuel Waste into Underground Salt Cavities"

M.S. Sanitary Engineering, University of California, Berkeley, 1955

M.S. Civil Engineering, Kyoto University, Kyoto, Japan, 1952

Professional Experience

1966-present President and Founder, Serata Geomechanics, Inc., Richmond, California
Directs project work on design and analysis of underground and near-surface earth structures; supervises laboratory testing and finite element program development; directs instrument hardware/software development and manufacturing

1961-1966 Principal Investigator, "Stress Field in Underground Formations," sponsored by the National Science Foundation at Michigan State University, East Lansing

1959-1966 Assistant and Associate Professor, Dept. of Civil Engineering, Michigan State University, East Lansing
Specialized in rock mechanics, nuclear engineering, and instrumentation

1956-1959 Research Assistant (Acting Director), Reactor Fuel Waste Disposal project, sponsored by the Atomic Energy Commission at the University of Texas, Austin

1952-1953 Bridge Engineer, Prefectural Government of Hiroshima, Japan
Designed various civil engineering structures

Publications

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