Department of Energy
Carlsbad Field Office
P. O. Box 3090
Carlsbad, New Mexico 88221
December 13, 2001

Mr. Frank Marcinowski, Director
Office of Radiation and Indoor Air
U.S. Environmental Protection Agency
401 M. Street, S. W.
Washington, DC 20460

RE: Majorana Project

Dear Mr. Marcinowski:

The purpose of this correspondence is to provide the Environmental Protection Agency (EPA) with information regarding the Majorana Project, and to request approval to allow phase 1 and phase 2 of this astrophysics experiment to be performed in the Q Room Alcove of the Waste Isolation Pilot Plant (WIPP) underground. The Department of Energy's (DOE) acceptance of this project is based on a comprehensive assessment of the potential environmental, industrial hygiene, safety, and operational impacts developed during WIPP's routine project review and approval process.

The Majorana Project is a three-phase experiment being advanced by a collaboration of scientists, led by Dr. Harry Miley of Pacific Northwest National Laboratory (PNNL), Dr. Werner Tornow of Duke University, and Dr. Frank Avignone of the University of South Carolina. The purpose of this project is to investigate double-beta decay and develop a precise double-beta decay detector prototype. The results from these initial experiments (phase 1 and phase 2) will be used to design future double-beta decay experiments, such as the third phase of the Majorana Project. Details of the design, installation, potential hazards, and required mitigating controls associated with the first two phases of the project are provided in Enclosure 1. Enclosure 2 provides a completed EPA WIPP Experiment Review Checklist. Enclosures 3 through 10 provide a record of our review of the Majorana Project's potential impacts.

The DOE has determined that the facilities and infrastructure at WIPP can provide support for this project without interfering with WIPP's primary mission, to safely manage and dispose of transuranic wastes. The enclosed information is intended to provide the EPA with an understanding of both the project and the scope of DOE's review. The enclosed analyses and assurance that all materials and equipment will be removed from the WIPP underground at the end of the experiment support the DOE conclusion that this project will not adversely impact the on-going waste disposal operations or the long-term performance of the disposal system.

Your timely response to this proposal would be appreciated. If you have additional questions regarding this matter, please contact Mr. Roger Nelson at (505) 234-7213.

Sincerely,

Inés Triay

Dr. Inés R. Triay
Manager

Enclosure

cc: w/ enclosure
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Majorana

EPA Submittal

Carlsbad Field Office
US Department of Energy
Carlsbad, New Mexico

Table of Contents

Majorana EPA Submittal

Enclosure 1

Majorana EPA

Project

Description

Majorana Project - Project Description

1.) Experiment Description

The Majorana Project is a multi-faceted experiment whose purpose is to investigate double-beta decay, an extremely rare type of nuclear decay. The experiment is currently conceived of as occurring in three phases with increasingly complex science goals and experimental equipment:

Phase 1. The experimental apparatus for Phase 1 of the Majorana Project will consist of a single germanium detector operated within a modest lead shield. Phase 1 is expected to last about one year.

Phase 2. The experimental apparatus for the second phase will consist of a single detector array containing 14 germanium detector crystals. One of the detectors will be an enriched germanium-76 detector, surrounded by a unique liquid nitrogen cryostat containing additional high purity germanium (HPGe) detectors. This apparatus is under development by the members of the Majorana collaboration. After appropriate development and testing, Phase 2 will run for a period of four to five years during which a number of research and development issues surrounding the next phase of the experiment are settled.

Phase 3 of the Majorana Project involves an array of 210-segmented germanium-76 detectors, similar to the segmented detector used in the Phase 2 apparatus. The array will be made from 10 super-cryostats, each consisting of 21 segmented germanium-76 crystals. Each crystal weighs approximately 2.4 kilograms. In all, there will be 500 kilograms of enriched germanium-76. The production of enriched germanium-76 requires the use of centrifuges located in Krasnoyarsk, Russia. These centrifuges are currently capable of producing 50 kilograms of material per year but could be upgraded to produce 100 kilograms per year. The design of the Phase 3 apparatus is modular, so that the experiment can begin with the completion of the first super-cryostat. The completion of the first super-cryostat and hence the starting time of Phase 3 depends entirely on funding needed to support the Russian scientists who work with the centrifuges. Once such funding has been obtained, the construction of the first super-cryostat can be completed in approximately two year's time. The deployment period during which germanium is being enriched will span seven years. The expected overall running time for Phase 3 is ten years, mostly after the completion of the entire apparatus.

Table 1 Experimental goals:

Experiment Phase	Phase 1	Phase 2	Phase 3
Approximate Nt (mass-time product)	2.4 kg @ 85% Ge-76 x 1 •year	2.4 kg @ 85% Ge-76 x 5 years, plus 13 kg natural Ge x 5 years	500 kg @ 85% Ge-76 x 10 years
Technology Goals	Segmentation and pulse shape analysis development Determination of neutron background	Cooling test of 12 detectors in 1 cryostat High density pre-amp signal conditioning test	
	Qualification of preamplifier electronics Materials screening	Materials screening	
Science Goals	Dark matter limit	Ge-76 decay to the excited state Other isotopes decay to excited state Dark matter limit	Neutrino mass detection Dark matter impact: annual modulations

2.) Location

Phase 1 and 2 of this project will be located in the WIPP underground in the S90 drift at approximately W850 in the Room Q alcove. The southern half of the alcove will be allocated to this experiment. Phase 3 will have special siting requirements that will be addressed in a separate submittal and by an additional analysis package if it is determined it should be sited at WIPP. It is possible that the phases may actually occur out of order such that the Phase 1 apparatus may be added to the Phase 2 apparatus. Alternately, the Phase 2 apparatus may incorporate the Phase 1 apparatus.

3.) Configuration

The basic components of the experiment (both Phase 1 and Phase 2) will consist of a detector array, associated lead and cadmium (Cd) shielding, liquid nitrogen cooling system, data acquisition system, and support equipment (power supply, connex buildings, etc.). The experiment will be housed within two connex buildings. An eight-foot by eight-foot connex will house the electronic equipment and a twenty-foot by eight-foot connex will house the shielded detector array, cooling system, and data acquisition system equipment. Both connex units will be air-conditioned and will be provided with a High Efficiency Particulate Air (HEPA) filter system. A preliminary floor plan for Phase 2 of the experiment, showing the basic equipment layout, is presented in Figure 1.

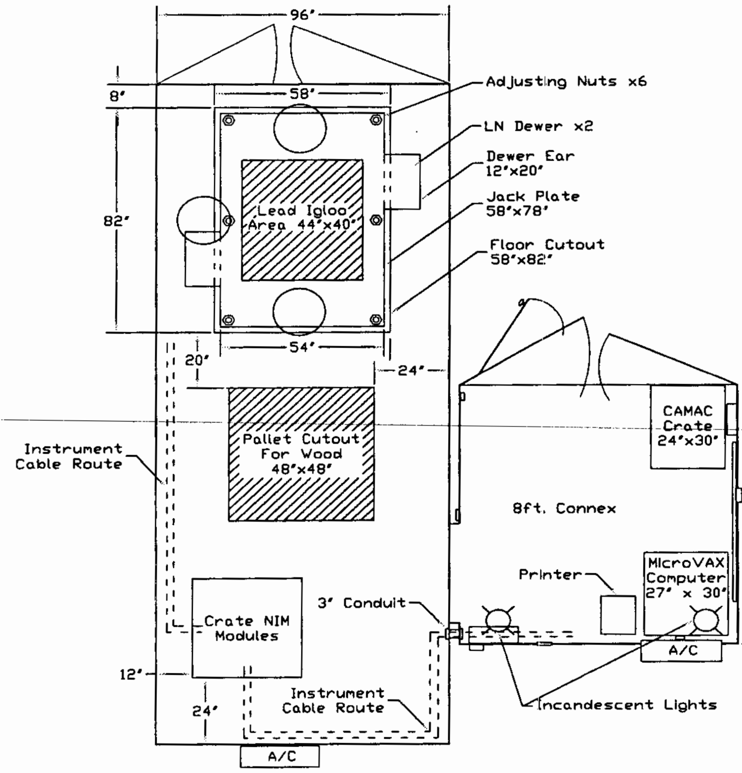


Figure 1: Preliminary floor-plan for Phase 2 of the experiment

The Phase 1 detector array will be a HPGe encased in a modest lead shield with a thin copper inner liner. The HPGe detector operates at liquid nitrogen (LN_2) temperature by cryostat contact with a 30-liter liquid nitrogen Dewar. The lead brick enclosure will be manually built from approximately 850 ~25-pound lead bricks (8-inch by 4-inch by 2-inch). The exterior dimensions of the lead enclosure are: 32-inch width, 32-inch length and 40-inch height. The dimensions of the interior of this enclosure will be approximately 8-inch width, 8-inch length and 14-inch height. Outside the lead shielding there will be a thin (~1mm) Cd jacket constructed using sheets between 30 cm and 45 cm in width with waterproof duct tape to provide a seal between the sheets. The purpose of the Cd jacket is to absorb thermal neutrons and provide a positive barrier to radon daughter intrusion. Finally, a layer of neutron moderator (plastic, paraffin, or containers of water) may be temporarily placed as an outer shield to determine the effects of neutrons on the system. The LN_2 Dewar will be located external to the lead enclosure within the large connex unit and will have a height of 24 inches and a diameter of 17.38 inches. A cut-away view of the Phase 1 apparatus is presented in Figure 2.

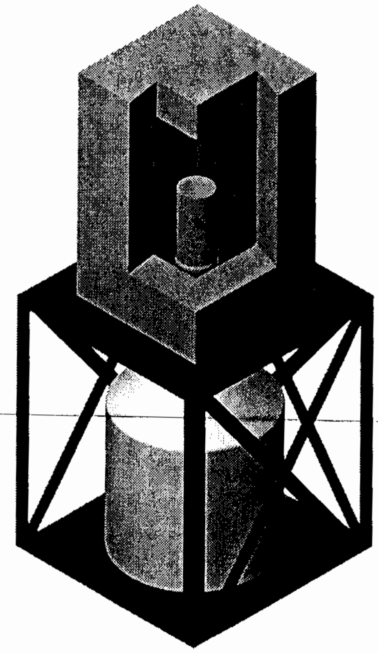


Figure 2: Cut-away view of the Phase 1 apparatus.

The configuration of the detector array for Phase 2 appears more complicated because of the necessity of having several LN_2 Dewars to cool the many Ge crystals in the system. The heart of the system is a toroidal (doughnut-shaped) cryostat holding several (12-16) germanium crystals. This unusual detector system is designed to surround one or two germanium detectors under special test. The detector from Phase 1 may be incorporated as one of the two inner detectors within the central hole in the toroidal detector. The lead shield will be constructed from a larger number of lead bricks and employ the same external Cd shielding jacket as used in Phase 1. The configuration of the shielded Phase 2 detector array is shown in Figure 3.

To provide replenishment for the LN_2 Dewars, a supply system will be configured out of three-eighths inch copper tubing with Swagelock fittings. In this fashion, the LN_2 Dewars can be replenished from outside the large connex building. They will need to be refilled approximately once per week (maximum of ten days between refillings). For safety, the connex units will be outfitted with an oxygen detection system to prevent personnel from entering an oxygen-deficient area, which could arise from excess gaseous nitrogen due to LN_2 boil-off during Dewar refilling. The boil-off gas will be directed into the inner chamber of the detector apparatus to provide a slight positive pressure and prevent radon gas buildup, if present.

Signals from the HPGe detectors of Phase 1 and 2 will be routed to a Computer Automated Measurement And Control (CAMAC) crate equipped with appropriate signal conditioning and acquisition modules. Experimental high-voltage requirements will be supplied by a Lecroy HV power supply. The electronics will be located external to the

lead enclosure and connected to it by 50-Ohm cables. HV cable connections will be made with SHV or equivalent safe connectors.

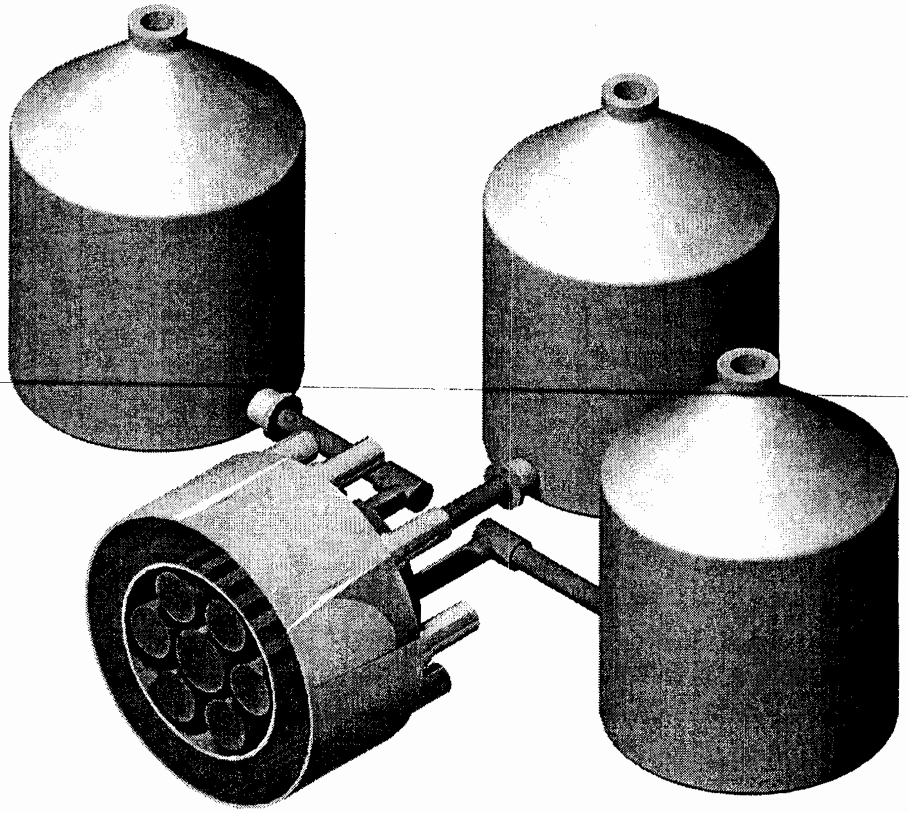


Figure 3. Phase 2 apparatus

Electrical power is supplied from U/G Switching Station #4 to a switchrack located in Q-Room. From the switchrack, power is fed to the connexes through 15KVA Mini Power Centers mounted on each connex. The Mini Power Centers house the transformers and distribution panels. The distribution panels provide circuit protection for the loads. The small connex loads include the air conditioning, incandescent lighting and two 20 amp receptacle circuits. The large connex loads include the air conditioning, incandescent and fluorescent lighting and two 20 amp receptacle circuits. The remaining 120-volt circuits (one in the small connex unit and two in the large connex unit) will supply electrical power for the computer system, the data acquisition system electronics, the high-voltage power supply and the communications systems associated with this experiment. These three circuits will be sustained by an 8 KVA un-interruptable power supply (UPS) capable of supporting the experiment for twelve hours in the event of an unplanned power outage. The fluorescent lighting must be separably switchable such that electronic noise can be minimized.

The detector instrumentation will generate electrical pulses whose output signals are sent to the CAMAC modules, where they are converted to digital signals via a 14-bit ADC system. The data are fed through the CAMAC dataway (data highway) to a computer

with local buffering and network connections. Data will be routed to computers behind the Pacific Northwest National Laboratory security firewall for data hosting for the collaboration members throughout the US and the world. Local operators of the experiment will also require nominal access to email, FTP, TELNET and other common network protocols and applications that are possible and commensurate with typical DOE security standards and local WIPP needs. The WIPP will provide a hub that will be connected to a fiber distribution device located on the Site Internet Backbone. A maximum of 2 IP addresses will be assigned to support network connectivity on the Internet. The WIPP network has a data bandwidth of 10 megabits per second. All systems on the network need to conform to C2 security standards. A complete system description and security plan needs to be submitted prior to any hardware or software installations. Telephone communications will be provided via one direct telephone line located within the small connex unit.

4.) Equipment/Materials

Detection System

Phase 1: One HPGe detector w/ 30-liter LN_2 Dewar
- Lead stand: (Bosch aluminum components with associated fittings)
- Aluminum plating (0.25 inch and 0.375 inch)

Phase 2: 2-3 Special HPGe detectors w/30-liter LN_2 Dewars
- Multiple detector stands (Bosch aluminum components with associated fittings)
- Lead support plating (seen in Figure 3)
- Lead bricks
- Nitrogen filling manifold: Cu tubing plus swagelock fittings
- Nitrogen gas purge system: Cu tubing plus swagelock fittings
- Inner shield: 0.25 inch Cd plating
- HV and signal cables

Instrumentation
- IBM PC or equivalent.
- Hewlett Packard LaserJet printer
- TBD High voltage system (0-5 kV, up to 0.1 mA source capability)
- CAMAC crate (CAMAC = Computer Automated Measurement And Control)

CAMAC modules:
- 2 each X-ray Instrumentation Associates Digital Gamma Finder (XIA DGF)
- Standard Engineering Corporation Dataway Display (DD-002)
- Power and signal cables

Chemicals and materials:

Alcohol, typically less than 1 liter (flammable storage cabinet required)
Dust-free medical gloves (vinyl), approximately 500, typically Oak Medical Supply
Chemical wipes (polyester), approximately 500
Duct tape, waterproof
10 mil plastic sheeting, approximately 50 yards
Dow-Corning clear RTV (silicone sealant with vinegar solvent), 16 oz.

5.) Hazards

- Liquid Nitrogen (LN_2)

Liquid nitrogen is necessary to maintain HPGe detectors at an optimal operating temperature. The LN_2 Dewars attached to the HPGe detectors have a 30-liter capacity, and at the expected rate of use must be refilled approximately once per week. This will be accomplished by using two standard 250-liter pressurized LN_2 tanks, with each tank capable of refilling the Dewars approximately six times. One of the tanks will be kept in the Room Q alcove outside of the connex, while the other will remain above ground and act as a spare when the tank in Room Q becomes empty. Then the two tanks can simply be switched, so that the empty tank can then be refilled above ground.

The 30-liter LN_2 Dewar will be located on the inside of the large connex unsealed, i.e., at atmospheric pressure, but not fully uncovered. To refill the Dewar with the pressurized LN_2 tanks, a feed-through system involving copper tubing and Swagelock fittings will be installed through one of the walls of the large connex. In this manner, the Dewars can be refilled safely by attaching the tank on the outside of the connex to the copper feed-through system without having to open the connex doors and someone being inside.

Liquid nitrogen is extremely cold (-196°C = -320°F at atmospheric pressure) and can cause severe frostbite. Therefore, the standard safety procedures, which include wearing insulated gloves and a face shield, will be used when transferring the liquid nitrogen from the tank to the Dewars. Also, gloves must be used anytime when touching any object cooled by liquid nitrogen. The gloves should be loose fitting so that they can be thrown off if liquid is somehow poured inside them. It is also important to realize that upon vaporization, liquid nitrogen expands by a factor of 700; one liter of liquid nitrogen becomes 24.6 cubic feet of nitrogen gas. This can cause explosion of a sealed container, or it can displace oxygen in the room and cause suffocation without warning. The Dewars are not sealed containers. To prevent a safety hazard in the case of insufficient oxygen, an oxygen detection system will be installed inside the large connex. This detection system will produce both an audible and visual warning when there is insufficient oxygen. Alarms will be noticeable both inside and outside the large connex. In this manner, one will not enter the connex when the alarm is on, and anyone on the inside of the large connex will immediately evacuate when the alarm sounds. Additionally, the connex atmosphere could become oxygen deficient not only from filling

the Dewars but also from routine usage of nitrogen if adequate ventilation is not maintained. It is important that the ventilation within the connex be kept on at all times and that the number of connex air changes per hour (3 or 4) be maintained. A minimal amount of the air shall be recirculated to prevent a buildup of nitrogen in the connex.

As stated above, one standard 250-liter pressurized LN_2 tank will be located outside the connex in the Q Room Alcove to refill the 30L Dewars through copper tubing. A catastrophic rupture of the large tank or feed piping could release enough nitrogen gas to make the alcove temporarily oxygen deficient. The tank and piping will be installed and protected from damage so that rupture or a broken pipe is not a credible event. The copper tubing will be insulated. The valve on the large tank should only be open during filling. To prevent any oxygen deficiency within the alcove, ventilation air will be drawn from the AIS, west through S90 and into the alcoves. Improvements to the ventilation system will extend ducting to within about five feet of the ends of the alcoves, in the upper west corners, and add joint seals to increase airflow in the alcove. Fresh air will sweep over the connexes and through the alcoves, then enter the ducting and be exhausted in S90 past the AIS to join the mining exhaust air in W170. Any swirling at the alcove corners at S90 will consist primarily of fresh air. The 15-20,000 cfm provided to the alcove will be sufficient to alleviate any possibility of nitrogen build-up.

Finally, care must be taken when transporting the pressurized LN_2 tanks to and from the Room Q alcove. Since transport from the underground to the above ground is via the elevator shaft, the tanks must be properly secured, i.e., chained to the wall in the elevator. The tanks will be transported on the materials deck of the hoist, not on the personnel deck, and always on trips separate from personnel trips.

- Lead (in the form of 2" by 4" by 8" bricks)

Prior to transportation of the lead bricks to the WIPP, they will be cleaned to remove poential lead particulate hazards, such as dust or oxide residues. Construction of the lead brick shielding will be performed using controls established by the Job Hazard Analysis, including personal protective clothing.

-Cadmium Sheet

The sheetwork will arrive safely encapsulated, be installed with gloves, will be covered after installation, and the gloves will be stored/disposed safely. The cadmium sheeting will be wrapped around the lead shielding and attached with duct tape. No particulate hazard is expected, since cadmium resists corosion/odixation and no particulate generating operations (drilling, sanding, grinding, etc.) will be required for installation.

6.) Training

General:

Use of electrical equipment and extension cords: Read WP-IS.01

GET 200B (16 hours) required for site access. (Required by all personnel)

SAF-501 (40 hours) Inexperienced Underground Miner. (Required by all unescorted underground workers).

Field Functions:

SAF-641 Fall Prevention (1 hour) Use of ladders and or scaffolding (Required by all underground workers using ladders and or scaffolding).
SAF-619 Compressed Gas Cylinder Safety (4 hours) (Required for workers handling compressed gasses like liquid nitrogen).
Electric Cart Operations (1 hour) (Required for operation of an electric golf cart).
ELC-103 Electrical Safety (4 hours) (Required for installation/operation of electrical equipment). CPR required for access around or near live electrical circuits.

7.) WIPP Procedures Applicable to Majorana (additional procedures may apply):

WP 04-AD3011	Equipment Tagout/Lockout
WP 09-CN3021	Component Indices
WP 10-WC3208	Work Change Notice
WP 12 IS.01	Industrial Safety Program
WP 14-TR.01	WIPP Training Program
WP 15-PS.2	Technical Procedure Writer's Guide

8.) Specifications

Temperature - inside connex 85F +/- 5F
Relative Humidity - inside connex 15 – 60 percent
Electrical Power - 110 volts +/- 5% at 20 amps per circuit
Network data rate - 10 megabits per second capicity
Telephone - Single voice/data circuit direct dial party line (with Los Alamos Dark Matter Experiment)
Q Room Alcove Ventilation – 60 fpm - Maintain compliance with WIPP Mine Ventilation Plan.

9.) Installation and Setup

Majorana collaborators, in particular, Pacific Northwest National Laboratory, will provide all equipment and components for this experiment. Installation of equipment used in the experiment will conducted in accordance with standard WIPP work authorization processes The lead bricks will be transported to the underground after the connex units are modified for air conditioning, HEPA filtration and basic infrastructure utilities. The two connex units will be transported to the South Q Room alcove area by WIPP Underground Facility Operations personnel. The two connex units will be modified to provide holes for the steel support assembly, holes for air conditioning, holes for HEPA filtration and holes for basic infrastructure utilities by WIPP Construction Engineering subcontractors. Wiring to support electrical power distribution, Internet network connection and basic telephone service will be provided by the WIPP

Construction Engineering subcontractors. Majorana Project collaborators will provide the assembly and setup of the experiment. Majorana contributors will generate a step by step experiment set up procedure to be reviewed and approved by WIPP Industrial Safety. All experimental collaborators will receive the required WIPP training to support their activities. The collaborators will abide by all applicable WIPP Operating procedures. All activities will be scheduled on the Plan Of The Day Schedule by the WIPP Technical Support Engineer. Use of the WIPP hoisting system and Underground Facility Operations personnel for experiment equipment and component hoisting and transport to Q Room will be coordinated with primary mission activities.

10.) Completion and Removal

Phases 1 and 2 of the Majorana Project are expected to be completed within five to seven years. Once the experiment is completed, the experimental equipment, materials, and wastes generated will be managed in accordance with applicable regulations and WIPP procedures for as long as they remain at WIPP. All equipment, materials, and wastes will be removed from the site prior to decommissioning of the WIPP as defined in the WIPP Hazardous Waste Facility Permit.

Enclosure 2

Majorana EPA

Review Checklist

Majorana Project - EPA WIPP Experiment Review Checklist

Primary interests and concerns related to placing individual experiments in the WIPP underground:

1. *Can the introduction of this experiment affect in any way the long-term integrity and viability of the WIPP as a disposal system for radioactive waste?*

   The potential for long-term impacts was considered during the project review process. Long-term impacts from this project are not anticipated because of the following:

   - the experiment will be conducted for 5 to 7 years, then be decommissioned,
   - the experiment will not change the repository footprint,
   - the experiment will not interfere with waste handling or emplacement,
   - the experiment utilizes materials with no potential for salt interactions, and all equipment, materials, and wastes will be removed from the site prior to decommissioning of the WIPP.

2. *Is there anything about the experiment that could alter the repository's design baseline from the terms of EPA's certification?*

   The design baseline of the repository will not be altered from the terms of EPA's certification by conducting the Majorana astrophysics experiment at WIPP. As discussed in the Majorana Project Description, the experiment will not interfere with waste disposal operations nor adversely impact the long-term performance of the repository.

3. *Could this experiment's interaction with other experiments create potential hazards during the short-term operational phase or the long-term performance of the disposal system? In other words, are there any potential synergistic effects that could result from an accident that affects multiple, unrelated experiments or operations?*

   Due to the location, configuration, construction, and scope of the experiment accidents involving the Majorana Project would have no potential synergistic effects on waste handling operations or other experiments. Since any accident would be immediately "cleaned-up", there would also be no impact on the long-term performance of the disposal system.

Majorana Project Summary

Plan and Description

The Majorana Project Description provides a comprehensive description of the experiment, including location, detailed drawings, hazard analysis and required mitigation measures, estimated duration, potential impact on waste disposal operations, and potential to impact long-term repository conditions.

The Majorana Project will consist of a series of passive experiments to measure double beta decay events where the interactions are captured by the detector array, converted to electronic signals, and routed into a computer data acquisition system. The sources that can cause these interactions include natural background radiation, cosmic rays, or a calibrated gamma-ray or neutron source, depending on the particular study being performed. Typical tasks that will be performed by the personnel operating the Majorana experiment consist of the following:

- Perform standard, daily, underground operation inspections (ground control, ventilation, electrical power, mine communications, etc.).
- Inspect experiment for evidence of leaks, spills, or off normal conditions.
- Perform electrical system checks of equipment.
- Collect data from study.
- Revise the layout of the experiment to measure a new parameter and repeat the above tasks.

The Carlsbad Field Office (CBFO) Chief Scientist and the Managing and Operating Contractor Environmental Safety and Health (ES&H) department will review and approve a test plan prior to the initiation of the experiment. As the experiment progresses, analysis of the results may be used to improve the design or alter specific portions of the test plan. Any time that the experiment is reconfigured, the appropriate industrial hygiene and safety procedures and controls will be utilized. These changes will be reviewed by the CBFO Chief Scientist and the E S & H department and approved prior to their implementation. Wastes generated during reconfiguration will be characterized and disposed of in accordance with applicable regulations and WIPP procedures.

Location

The experiment will be located in the Q Room Alcove (QRA), W850 and S90 of the WIPP underground, and utilize an area approximately 20 feet wide by 30 feet long in the south half of the QRA. This location was chosen for the experiment because in this location it will not impact or interfere with waste disposal operations. The S90 drift is physically isolated from the waste handling traffic pattern and the waste disposal areas of WIPP. In addition, the drift is within a separate air ventilation

circuit from the circuits used to service underground disposal operations.

Configuration and Organization

The Majorana Project is a passive cryogenic experiment designed to develop a precise double-beta decay detector. The primary components of the experiment will be a steel connex containing the lead shielded detector array and a second steel connex to house the electronic equipment. Both connex units will be air-conditioned and equipped with a high efficiency particulate air (HEPA) filter system. The detector array will consist of a cryostat containing germanium detector crystals immersed in liquid nitrogen and surrounded by lead brick shielding. The cooling fluid for the cryostat is provided by a series of 30-liter liquid nitrogen Dewars.

The potential for synergistic impacts from this experiment was examined during the review process and no potential impacts were identified. Due to the location and scope of the experiment there will be no synergistic effects to waste handling or other experiments. This experiment has no expected emissions or effluents that could impact existing experiments or waste disposal. The experiment is completely separated from the disposal areas of the mine, and from the ventilation circuits that service those areas. In the event a spill or minor fire were to occur in the QRA, there would be no impact to existing underground experiments or waste handling/disposal operations. In the unlikely event of a significant spill or fire, regardless of the location, all underground activities will be placed in a safe condition and personnel will be evacuated from the underground.

The Environmental Assessment (EA) for Conducting Astrophysics and Other Basic Science Experiments at the WIPP Site completed a bounding impact assessment of a series of proposed experiments at the WIPP. The EA committed to determining if additional NEPA documentation would be required to assess potential environmental impacts for future experiments, as details of those experiments became available. In keeping with this commitment, a NEPA compliance checklist, developed in accordance with the WIPP NEPA Compliance Procedure, will be used to initiate regulatory review and address the cumulative impacts of future experimental programs, including the Majorana Project.

Hazard Analysis

The planning, siting, and safety review processes required for conducting the Majorana experiment in the WIPP underground included a comprehensive assessment of the experiment's potential impact and hazards. The short operational duration, passive nature, and isolated location of the experiment preclude any short-term or long-term impact to waste emplacement operations in the repository. Because the experiment does not change the footprint of the repository, has no expected effluents other than nitrogen gas, requires no special utilities or unusual infrastructure requirements, and will be completely removed from the underground prior to

repository closure, it has no short term or long term impact on the repository design, operation, or long-term performance.

An Unreviewed Safety Question (USQ) screening was completed to determine if the impacts of conducting the experiment at WIPP would impact of the safety basis described in the WIPP Safety Analysis Report (SAR). The USQ process evaluated whether events associated with the experiment could result in an unplanned release of radioactive material, result in a new type of initiating event not previously identified, or be considered a new type of accident not bound by previous accidents evaluated in the SAR. An initiating event would be some event from the experiment that would cause a credible, new, radiological accident not previously considered by the SAR. This evaluation determined that potential accidents associated with the experiment can not affect the WIPP safety basis defined in the SAR and would not impact CH TRU waste disposal certification.

A Job Hazard Analysis (JHA) was performed during the review process to evaluate potential industrial safety accident scenarios, assist in the development of safety and industrial hygiene programs to control or mitigate potential personnel exposures, and address response to potential incidents. The JHA identifies hazards associated with the lead shielding, liquid nitrogen, and electrical power supply. In general, the identified hazards were:

- the intrinsic weight of the lead bricks and potential for airborne lead dust,
- the potential for frostbite burns from contact with cryogenic surfaces or spillage of liquid nitrogen,
- the potential for asphyxiation from oxygen displacement by nitrogen gas, and
- the possibility of fire due to the presence of combustible wood pallets and electrical power.

The JHA evaluated industrial safety and health hazards associated with the experiment to provide a response to proposed incidents and identify actions to control or mitigate potential personnel exposures. The JHA demonstrates that the WIPP facilities and infrastructure can provide support for this project without interfering with the primary mission of WIPP, to safely manage and dispose of transuranic wastes. The safety protocols and controls required to prevent injury or accidents and mitigate potential exposures from these hazards are described in detail in the JHA.

The experiment area will be supplied with approximately 18,000 cubic feet of air per minute from the air intake shaft using an exhausting system. Fresh air will be drawn from the air intake shaft westward through S90, circulated through the alcove and then enter an auxiliary ventilation duct that extends along the S90 drift. The auxiliary ventilation duct will transport the circulated air eastward past the air intake shaft and discharge into the W170 drift. The W170 drift carries exhaust air from the active

mining area and flows directly to the exhaust shaft without passing through any additional work areas (see Figure 1 below).

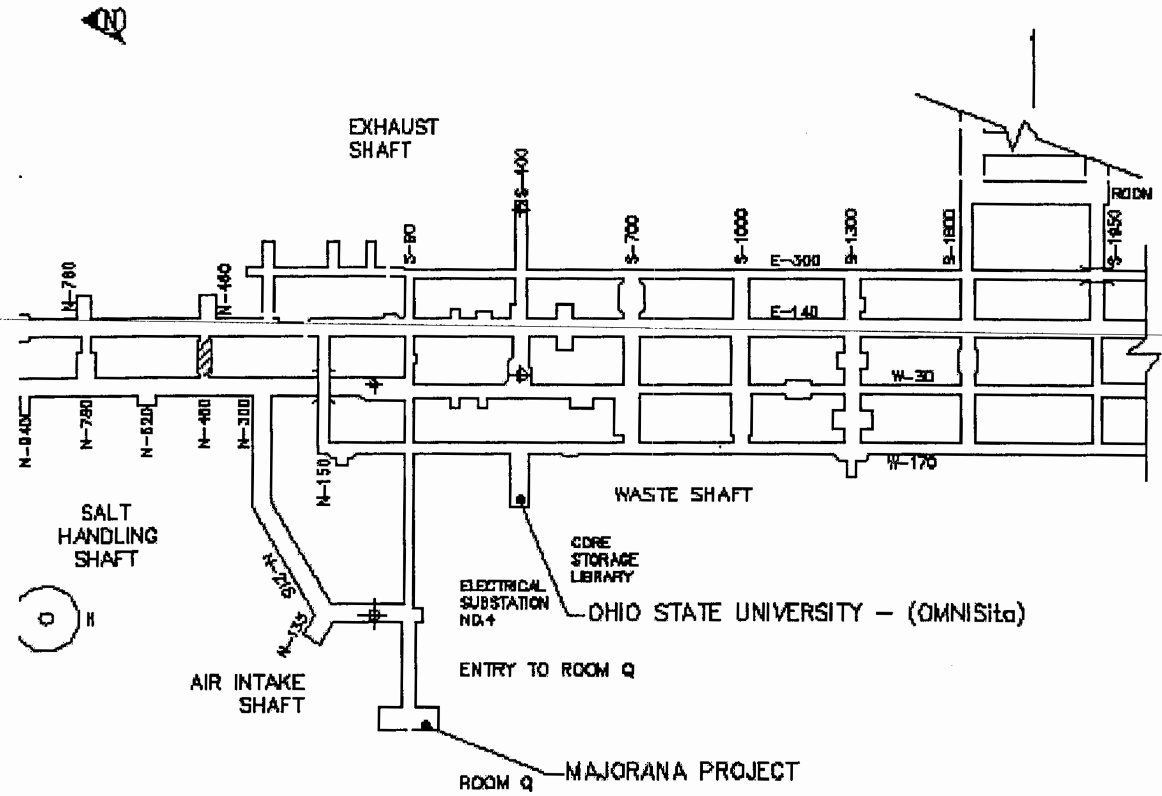


Figure 1 Location of Majorana Project

Experimental equipment and personnel will be transported underground so that their introduction will not interfere with waste disposal operations. Construction and experiment operational activities, including the movement of materials, will be coordinated with the Westinghouse TRU Solutions CH Waste Operations and Mine Operations Departments to ensure that equipment and personnel are available to support required tasks. Materials will be moved during the back shifts, as necessary, to avoid potential conflicts with TRU waste operations.

Both the USQ and JHA specifically addressed potential accident and failure scenarios. The USQ screening process evaluated the experiment to determine possible impact to the WIPP safety basis and determined that the experiment will not impact the safety basis of the CH waste process.

The potential for long-term impacts was considered during the project review process. Long-term impacts from this project are not anticipated because of the following:

- the experiment will be conducted for 5 to 7 years and then be decommissioned,

- the experiment will not change the repository footprint,
- the experiment will not interfere with waste handling or emplacement,
- the experiment utilizes materials with no potential for salt interactions,
- the location of the experiment will be actively managed for ground control,
- all equipment, materials, and wastes collected at WIPP before, during and after the operation of the experiment will be managed according to approved WIPP procedures, and
- all equipment, materials, and wastes will be removed from the site prior to decommissioning of the WIPP.

Installation of equipment used in the experiment will be conducted in accordance with standard WIPP work authorization processes to ensure engineered safety features and controls are implemented to prevent the occurrence of accidents. These processes require Engineering Change Proposals to be developed and standard environmental, safety, and regulatory compliance reviews of the proposals to be performed prior to implementation.

The hazards and safety protocols/controls identified in the JHA will not impact the approved certification design of the repository. The experiment will be built using inert materials. These materials include lead bricks and cadmium jacket forming the detector shielding, the solid-state germanium detectors, and a cryostat system containing liquid nitrogen. These materials will be removed from the site prior to repository closure and have no short-term potential for salt interaction. Details of protocols that will be followed to prevent and manage releases are described in the Project Description and Section 4(b)(ii) of the JHA.

Installation and Implementation

Installation of equipment used in the experiment will be conducted in accordance with standard WIPP work authorization processes. These processes require Engineering Change Proposals to be developed and standard environmental, safety, and regulatory compliance reviews of the proposals to be performed prior to implementation.

Construction of the Majorana experiment is estimated to require about 70 hoist trips for downloading of materials and equipment. Experimental equipment and personal will be transported underground so as to not interfere with waste disposal operations. Construction and experiment operational activities, including the movement of materials, will be coordinated with the Westinghouse TRU Solutions CH Waste Operations and Mine Operations Departments to ensure that equipment and personnel are available to support required tasks. Materials will be moved during the back shifts, if necessary, to avoid potential conflicts with TRU waste operations.

Review of the construction requirements and the operating plans indicate that not more than eight experimenters will be required to construct and operate the

experiment on a daily basis. Additional collaborators may visit the project from time to time.

Completion and Removal

All equipment, materials, and wastes will be removed from the site prior to decommissioning of the WIPP as defined in the WIPP Hazardous Waste Facility Permit. *See Section 10 of the Project Description.*

Enclosure 3

Majorana EPA Job Hazard Analysis

Majorana Project - Job Hazard Analysis

Contents:

Introduction

The Majorana double-beta decay Project (MP) involves the use of several potentially hazardous materials, as well as several potentially hazardous activities associated with its construction and operation. This Job Hazard Analysis covers those activities associated with the first two phases of the MP (see below). It identifies those areas that require special attention, and provides a detailed plan of the measures that will be used to minimize the hazards involved. Furthermore, it describes countermeasures that will be used in the unlikely event of an accident or spill of a potentially hazardous material. This document should be read in conjunction with the Majorana Project Description. It also describes the specific ground control inspections that the experimental team must conduct during normal operations of the MP.

2. Location

This project will be located in the WIPP underground in the S90 drift at approximately W850 in the Room Q alcove. The currently unoccupied southern half of the alcove will be allocated to the MP. A proposed floor plan of the experiment is shown in Figure 1.

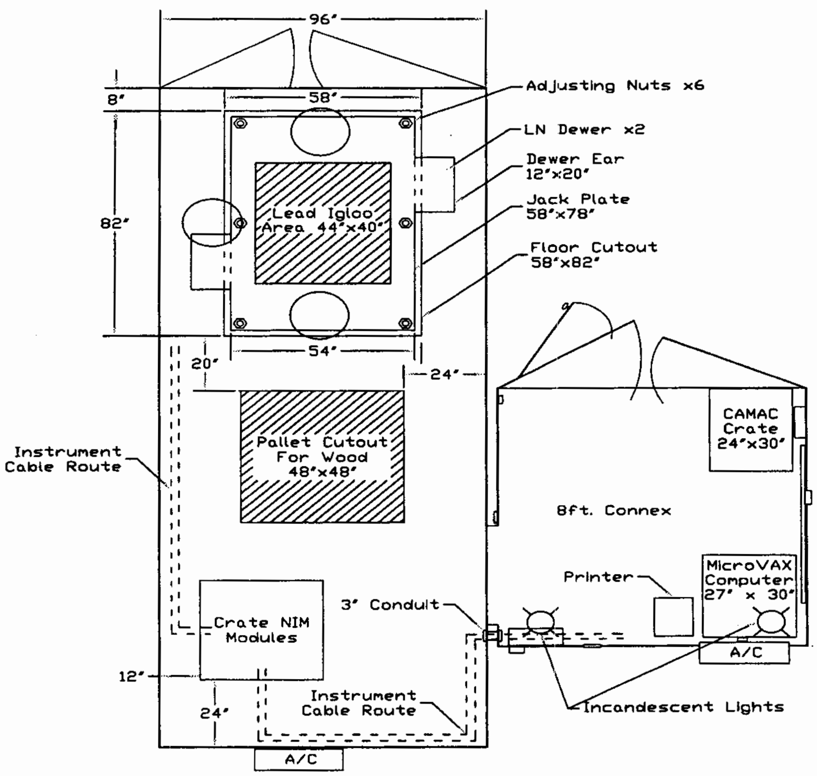


Figure 1

A map of the underground in Figure 2 shows the location of the experiment.

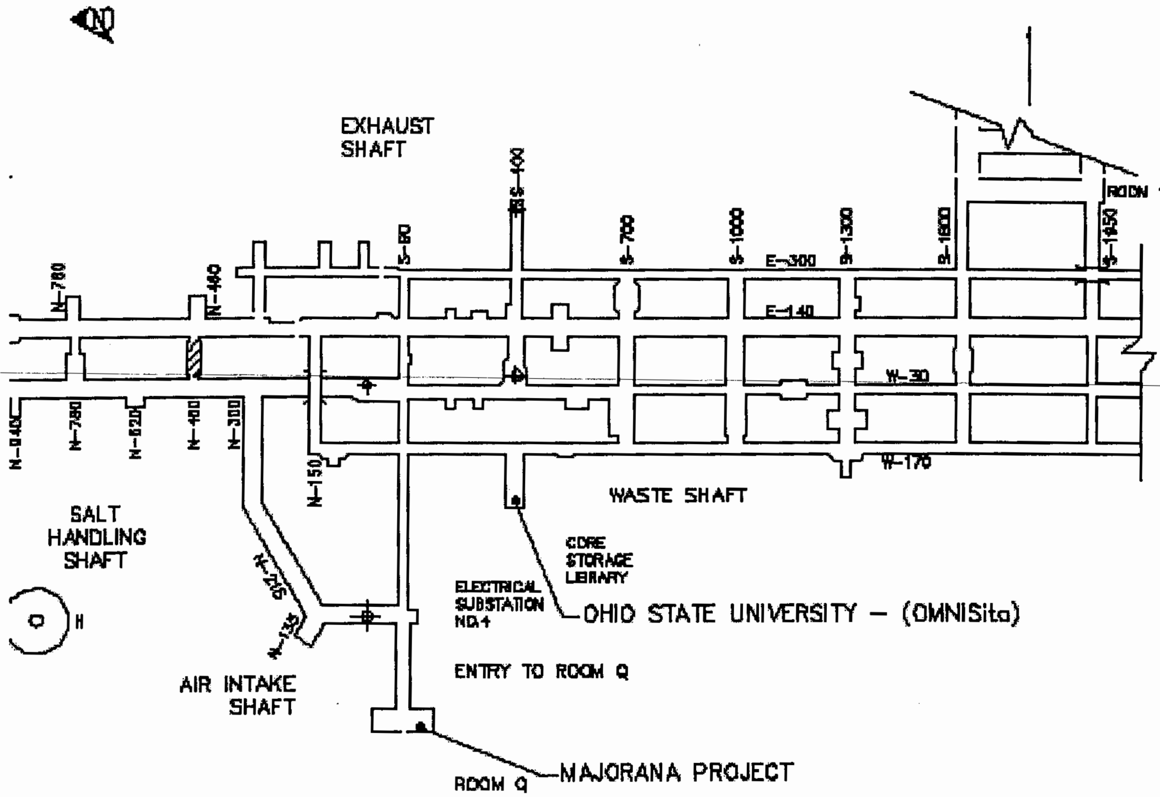


Figure 2 Majorana Location

3. Configuration of Majorana

The MP will be housed within two connex buildings. An eight-foot by eight-foot connex will house the computer equipment. A twenty-foot by eight-foot connex will house the experimental apparatus and the data acquisition system equipment (see Figure 1). The experimental apparatus will rest on a foundation of steel plates. Both connex units will be air-conditioned and will be ventilated through a High Efficiency Particulate Air (HEPA) filter system.

The MP is a multi-faceted experiment whose purpose is to investigate double-beta decay, an extremely rare type of nuclear decay. The experiment is currently conceived of as occurring in three phases with increasingly complex science goals and experimental equipment:

Phase 1.
The experimental apparatus for Phase 1 of the MP consists of a single germanium detector operated within a modest lead shield.

Phase 2.
The experimental apparatus for the second phase will include 14 germanium detector crystals. One of the detectors will be an enriched germanium-76 detector, surrounded by a unique cryostat containing multiple additional HPGe detectors. This apparatus is under development by the members of the Majorana collaboration. After appropriate development and testing, Phase 2 will run for a period of four to five years, during which a number of R&D issues surrounding the next phase of the experiment are settled.

Phase 1 and 2 of this project will be located in the southern half of the Room Q alcove. It is possible that the phases may actually occur out of order, such that the Phase 1 apparatus may be added to the Phase 2 apparatus. Alternately, the Phase 2 apparatus may incorporate the Phase 1 apparatus. The two phases, while radically different from the science and engineering perspectives, are essentially indistinguishable from the perspective of job safety, environmental impact, and impact on laboratory infrastructure and operations. The configuration of the Phase 1 instrument will be a high-purity germanium (HPGe) detector encased in about a 12-inch thick lead shield with a thin copper liner. The HPGe detectors operate at liquid nitrogen (LN_2) temperature by cryostat contact with a 30-liter liquid nitrogen Dewar. The lead brick enclosure will be manually built from approximately 850 ~25-pound lead bricks, each measuring 8-inch by 4-inch by 2-inch. The exterior dimensions of the lead enclosure are: 32-inch width, 32-inch length and 40-inch height. The interior dimensions will be approximately 8-inch width, 8-inch length and 14-inch height. Outside the lead shielding will be a thin (~1mm) cadmium jacket, constructed of sheets between 30 cm and 45 cm in width, with waterproof duct tape to provide a seal between the sheets. The jacket absorbs thermal neutrons and does double duty in providing a positive barrier to radon daughter intrusion. Outside this layer will be heavy plastic sheeting, simply to prevent human exposure to the cadmium. Finally, a layer of neutron moderator (plastic, paraffin, or containers of water) may be temporarily placed as an outer shield to determine the effects of neutrons on the system. The LN_2 Dewar will be located external to the lead enclosure within the large connex unit and have a height of 24 inches and a diameter of 17.38 inches.

The configuration of Phase 2 appears more complicated because of the necessity of having several LN_2 Dewars to cool the many germanium crystals in the system. The heart of the system is a toroidal (doughnut-shaped) cryostat holding several (12-16) germanium crystals. This unusual detector system is designed to surround one or two germanium detectors. The detector from Phase 1 may be incorporated as one of the two inner detectors within the central hole in the toroidial detector. The lead brick enclosure will be manually built from additional 25-pound lead bricks. The exterior dimensions of the lead enclosure are approximately: 44-inch width, 44-inch length and 56-inch height. The external layers will consist of the same materials as in Phase 1. The configuration of detectors and shielding is shown in Figure 3.

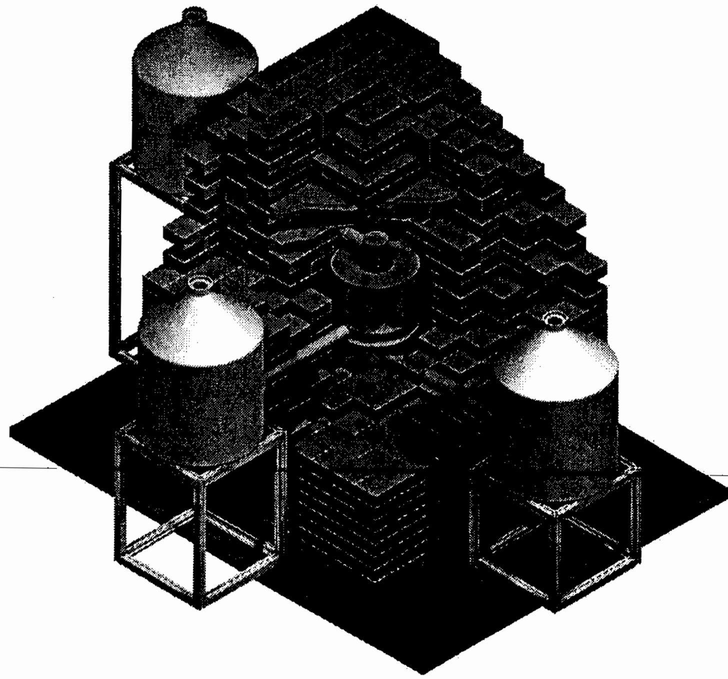


Figure 3: Cut-away view of the PNNL apparatus. The HPGe detectors are shown in copper.

4. Hazards

(a) Lead Bricks and Lead Particulate

The lead to be used as shielding comes in the form of bricks that measure 2" X 4" X 8" and weigh about 25lb each. The lead bricks have several hazards associated with them.

i) Their intrinsic weight means that during the construction of the MP several precautions must be followed.

   a. Steel-toed shoes will be worn at all times.

   b. NIOSH lifting procedures will be followed. The Occupational Health and Safety department at PNNL will train the designated Safety Officer in the correct lifting techniques. He will train other Majorana collaborators involved in the construction phase. The revised NIOSH lifting equation (DHHS, NIOSH Publication 94-110 1994) applied to the MP results in a lifting index of about 1.1, which while indicating no major issues, does recommend that only physically fit people should be involved. Mechanical aids will be used wherever possible; specifically, a cart will be used to move the bricks over any significant distances, such as from where a forklift deposits the bricks to where they are needed.

c. Before transportation, the lead bricks will be placed onto wooden pallets, approximately 55 bricks per pallet. A plywood sheet will be placed over the top of the bricks, and banded to the pallet. Additionally, shrink-wrap material will secure the bricks to the pallet. This will provide ample protection against bricks falling off.

ii) Lead dust is recognized as toxic with a federal 8-hour human exposure limit of 50 $\mu g/m^3$, and an action level of 25 $\mu g/m^3$. Therefore, several measures will be taken to minimize exposure to airborne particles.

a. Before entering the WIPP, each brick surface will be cleaned to remove surface carbonate and oxide layers. The used cloths will be designated as hazardous waste and disposed of appropriately.

b. Each pallet will be covered with plastic wrap to contain any lead dust that might be generated during transportation into the WIPP underground.

c. Upon arrival in the Q Room alcove, the pallets will only be placed on surfaces that protect the salt floor from becoming contaminated with dust, e.g., on a layer of heavy-duty plastic. The dust covers and bands will then be removed. Care must be taken and leather and nitrile gloves and safety glasses must be worn when removing the bands to protect against potential cutting and falling hazards.

Bricks will be installed in the experiment using controls established by the Industrial Hygiene Exposure Monitoring Plan. Personnel will wear disposable personal protective clothing (PPE), including gloves, and disposable coveralls. PPE will be doffed prior to leaving the work area. Whenever bricks are moved, they will be lifted, not dragged. A dust cover will be installed consisting of heavy-duty plastic sheeting. No eating, drinking, or smoking will be allowed during construction involving movement of lead bricks. Provisions shall be in place to allow for washing of hands at the time of doffing of PPE. Prior to disturbing the lead structure (testing of various configurations is one of the objectives of the MP) the plastic will be carefully removed and the structure vacuumed to remove any dust deposits. If the lead dust measurements indicate that there is a potential for exposure, administrative controls will be introduced to ensure that nobody could be exposed to a lead dust concentration above the action level.

(b) LN_2

Use of LN_2 presents hazards: frostbite burns from contact with cryogenic surfaces, and asphyxiation from oxygen displacement. Steps will be taken to ensure that the proper ventilation necessary to maintain oxygen levels above 19.5% (minimum for breathing air) exists during normal operation of the project. LN_2 is extremely cold (-196°C = -320°F at atmospheric pressure) and can cause severe frostbite. Therefore, the standard safety procedures, which include wearing insulated cryo-gloves and a face shield, will be used when transferring the liquid nitrogen from the tank to the Dewars. The gloves will be loose fitting so that they can be thrown off if liquid is accidentally poured inside them.

(c) Wooden Pallets

The wooden pallets add to the overall level of combustibles in the WIPP underground, and so their number will be minimized.

(i) Pallets will be taken to the Q Room alcove by forklift, and placed on a tarp to avoid possible contamination of the underlying salt with lead dust.

(ii) Once emptied, a minimum number of pallets will be stored in the underground (available in case the lead needs to be moved). The remaining pallets will be removed from the underground for storage at the surface. The total number of pallets in the underground is expected to be about ten (10).

(iii) It would be preferable for HDPE or steel pallets to be used. Wooden pallets will be replaced as needed.

(d) Electrical

(i) **110 V supply.** The MP will use many electronic modules for the data acquisition system, all of which are powered through 110V lines hooked up to Power Substation 4. Ground fault circuit breakers will be used. Extension cords will not be used except as a temporary measure. All extension cords will be GFCI protected.

(ii) **High Voltage.** Photo multiplier tubes (PMTs) typically are required for detector operation. PMTs operate at a voltage of 2000V to 5000V. Fusing and ground fault protection will be used.

(e) Steel Plates

The steel plates are heavy and require the use of steel-toed boots, appropriate lifting techniques, and mechanical lifting devices when necessary. Tripping hazard tape will be applied to the edge of the steel plates to identify potential hazards.

(i) Ground Control

We expect no ground control problems, because the WIPP has an excellent ground control program, and work areas are inspected daily. Title 30 CFR 57 requires that persons experienced in examining and testing for loose ground shall be designated by the mine operator. WIPP personnel are qualified for this task after completing a 40-hour miner-training course. Each person is required to examine, and, as applicable, test ground conditions in areas where work is to be performed, prior to commencing work. Requirements for ground control are provided in the Annual Ground Control Operating Plan.

5. Plans for response to an accident or an occurrence.

(a) Response to a spill of Ethanol used to clean equipment

Small amounts of ethanol may be used to wipe down materials/equipment during the operation of this experiment. If a spill occurs work will be stopped, the CMR shall be notified, and the fluid will be contained, absorbed, and managed in accordance with approved spill response and reporting procedures. Waste products will be characterized and properly managed and disposed of, using approved WIPP site generated waste management procedures.

(b) Response in the event of an underground fire

Response to fire in the underground will be in accordance with approved WIPP procedures. Personnel discovering a fire will notify the CMR by regular phone (8111) or the mine pager phone. Personnel may attempt to extinguish the fire using a portable fire extinguisher only if they feel capable and safe in doing so. If unable to extinguish the fire, they will evacuate to an egress hoist station. Personnel encountering smoke will don their self-rescuer immediately. NOTE: Self-rescuers are for emergency egress only and ARE NOT to be used for fire fighting purposes.

(c) Response to lead dust exposure

Potential for lead exposure during this project is a function of the presence of surface corrosion and oxides on the lead bricks. Aggressive measures are being taken at the front of this project to reduce lead exposure by cleaning and removing surface corrosion and oxidation from the bricks prior to their delivery to the WIPP. Oxidation should not be a problem in the underground. Individual exposure will be assessed, and mitigation measures (such as reduced lead handling time or additional PPE) will be taken in accordance with the Industrial Hygiene Exposure Monitoring Plan.

(d) Response to an injury, e.g., from dropping a brick

A first aid kit will be in the MP connex for immediate action; the CMR will be notified on the mine pager phone. Trained WIPP emergency response personnel will provide assistance.

(e) Response to a leak of LN_2

If a leak or spill occurs during the fluid transfer process to fill the LN_2 Dewars, work will be stopped, the CMR will be notified, and proper first aid will be administered if any LN_2 comes in contact with skin. The fluid will be contained by closing the main LN_2 supply valve. The incident will be managed in accordance with approved response and reporting procedures.

(f) Emergency evacuation routes

Primary route:

Exit the Q Room alcove to the east and proceed to the W30 drift, Turn left (north) at W30. Assemble/exit at Salt Handling Shaft.

Secondary route

Exit the Q Room alcove to the east and proceed to the W170 drift, turn to the left (north). Proceed along W170 to N150. Turn right at N150 and proceed east to the E0 drift. Turn right (south) at E0 and proceed to the assembly area /exit at the Salt Handling Shaft.

Majorana

JOB HAZARD ASSESSMENT WORKSHEET

Movement of Bricks to Underground and on to the Q Room Alcove

(Type of Work Performed)

Author:____________________ Date:_______ WIPP Safety Engineer Concurrence ________________ Date:

STEP	HAZARD	MITIGATING ACTIONS
1) Truck deliver to staging area	a) Shifting of load, bricks fall, damage equipment, injure personnel b) Failure of pallet, bricks fall, damage equipment, injure personnel c) Airborne lead dust inhalation	a) Load secured. b) Pallets inspected prior to being received at site. Defective pallets replaced. c) Bricks cleaned and wrapped in plastic prior to receipt. Bricks will be sampled for loose particulate prior to acceptance at the WIPP, and will not be accepted with excessive contamination.
2) Forklift stage bricks on surface	a) Pallet failure, bricks fall, damage equipment, injure personnel b) Misaligned forks, bricks fall, damage equipment, injure personnel c) Misaligned forks, plastic rips, airborne lead dust inhalation d) Bricks exposed to moisture, oxidize, lead dust inhalation	a) Qualified forklift operator. Pallets inspected. Faulty pallets replaced. b) Qualified forklift operator and spotter, bricks secured with plastic and straps. c) Qualified forklift operator and spotter. d) Delivery and staging will be allowed only during dry weather.
3) Forklift load bricks on cage	a) Pallet failure, bricks fall, damage equipment, injure personnel b) Misaligned forks, bricks fall, damage equipment, injure personnel c) Misaligned forks, plastic rips, airborne lead dust inhalation d) Plastic comes loose, lead dust inhalation	a) Qualified forklift operator. Pallets inspected. Faulty pallets replaced. b) Qualified forklift operator and spotter, bricks secured with plastic and straps. c) Qualified forklift operator and spotter d) Inspect. Repair with duct tape if necessary. Bricks rejected if excessively corroded or dusty.
4) Forklift remove bricks from cage	a) Pallet failure, bricks fall, damage equipment, injure personnel b) Misaligned forks, bricks fall, damage equipment, injure personnel c) Misaligned forks, plastic rips, airborne lead dust inhalation d) Plastic comes loose, lead dust inhalation	a) Qualified forklift operator. Pallets inspected. Faulty pallets replaced. b) Qualified forklift operator and spotter, bricks secured with plastic and straps. c) Qualified forklift operator and spotter d) Inspect. Repair with duct tape if necessary.
5) Forklift unload bricks at Q Room Alcove	a) Pallet failure, bricks fall, damage equipment, injure personnel b) Misaligned forks, bricks fall, damage equipment, injure personnel c) Misaligned forks, plastic rips, airborne lead dust inhalation d) Mine traffic causing accident.	a) Qualified forklift operator. Pallets inspected. Faulty pallets replaced. b) Qualified forklift operator and spotter bricks secured with plastic and straps. c) Qualified forklift operator and spotter d) Qualified operators.

- **Equipment:** (list any tools that may represent a hazard and all chemicals)
- PPE: (list all PPE required)
- Can pushing, pulling, lifting, bending or twisting cause strain?
- Is there a danger of striking against, being struck by, or otherwise making a harmful contact with an object?
- Is fall protection equipment required?
- Have MSDS been reviewed for chemicals used?
- Are there any environmental issues: heat, cold, lighting?
- ☐ Comments:

Majorana
JOB HAZARD ASSESSMENT WORKSHEET

Assembly of Detector
(Type of Work Performed)

Author:______________________ Date:________ WIPP Safety Engineer Concurrence _______________ Date:

STEP	HAZARD	MITIGATING ACTIONS
1) Placement of steel plate onto cribbing material that is placed on top of the lower steel plate	a) Lifting b) Drop or pinch point c) Sharp edges	a) Training in proper lifting. Using mechanical means where possible. Apply NIOSH lifting equation. b) Steel toed shoes required. Use mechanical lifting where possible. c) Examine sheet before manual lifting. Remove sharp edges with grinder. Use leather gloves to move.
2) Placement of lead bricks	a) Lifting b) Lead dust – inhalation c) Lead dust - ingestion d) Tripping on liner e) Dropping brick	a) Training in proper lifting. Using mechanical means where possible. Apply NIOSH lifting equation. b) DO NOT SLIDE BRICKS. Bricks will be cleaned before arrival at site. Remove plastic cover slowly. Perform initial air monitoring under limited lifting scenario. HEPA vacuum loose dust. Establish administrative controls based on monitoring results. c) Use impervious gloves and coveralls while moving brick. Remove PPE using contamination methods. Wash hands immediately after removing PPE. d) Training. Use caution bi-folds. e) Steel toed shoes required.
3) Assembly of N_2 Dewar system	a) Lifting	a) Training in proper lifting.
4) Filling of LN_2 system	a) Skin contact with fluid of cold metal b) Leak of LN_2 c) Eye contact with LN_2	a) Use of impervious cryo-gloves. Supply tubes will be inspected prior to use. b) Ensure proper ventilation prior to fluid transfer. Isolate LN_2 by closing valve. Inspect Swagelock fittings. c) Chemical goggles or a face shield will be used during transfer of the fluid.
5) Assembling detector	a) Electrical	a) Only qualified electricians will perform work following site procedures. GFCIs are required. Extension cords may not be used on a permanent basis.
6) Assembling background shield	a) Handling of cadmium sheeting b) Cadmium dust – inhalation c) Cadmium dust – ingestion (Since Cd resists corosion/odixation, no particulate hazard is expected)	a) Use impervious gloves and coveralls while handling. Remove PPE using contamination methods. Wash hands immediately after removing PPE. Ensure proper ventilation. Remove plastic cover slowly. b) Perform no drilling, sanding, welding, grinding or other particulate generating operations on material.

- **Equipment:** (list any tools that may represent a hazard and all chemicals)
- PPE: (list all PPE required)
- Can pushing, pulling, lifting, bending or twisting cause strain?
- Is there a danger of striking against, being struck by, or otherwise making a harmful contact with an object?
- Is fall protection equipment required?
- Have MSDS been reviewed for chemicals used?
- Are there any environmental issues: heat, cold, lighting?

☐ Comments:

Enclosure 4

Majorana EPA

Hazardous

Operations

Analysis-Nitrogen

Majorana Project - Hazardous Operations Analysis-Nitrogen

Ventilation needs in the Room Q area were calculated for the Majorana Project and the potential accidents related to the associated use of liquid nitrogen (LN_2). The project description states that the project consists of 3 phases. Each phase will use LN_2 to cool cylindrical High-Purity Germanium (HPGe) detectors. Phase 1 will use two detectors, each requiring a 30-liter open liquid nitrogen Dewar. The detectors and Dewars will be placed in a twenty-foot by eight-foot connex. The Dewars will be refilled every 7-10 days from a 250-liter pressurized LN_2 tank staged in the area. A spare tank will be kept on the surface. Phase 2 will use 14 detectors. It is assumed that this phase will also require a Dewar for each detector, or fourteen 30-liter Dewars. Just to weekly refill these would require the placement of two 250-liter tanks per week.

First to be considered was the ventilation necessary to maintain oxygen levels above 19.5% (minimum for breathing air) during normal operation of all three phases of the project. LN_2 expands by a factor of 700; therefore, one liter of LN_2 becomes 700 L or 24.6 cu. ft. of nitrogen gas. Therefore, for Phase 1, 60 L of LN_2 (30 L/Dewar for 2 Dewars) released over one week calculates to a release rate of 0.146 cfm N_2. This release rate would require a constant fresh air supply of 1.9 cfm (see attached calculations) into the connex with appropriate means for exhaust. Phase 2 would require 13.3 cfm constant fresh air.

For consideration of a catastrophic event, several scenarios were considered. All of these consider an immediate (1 minute) phase change from liquid to gas of the containers' contents, without allowing for the cooling effect that might slow down the evaporation rate. The complete immediate destruction of one Dewar of LN_2 would release 738 cu. ft. N_2. This release would require 9600 cfm of fresh air during the minute of release to maintain breathing air above 19.5% O_2. The destruction of both Dewars at the same instant would require twice that amount, or 19,200 cfm. The complete immediate destruction of the 250 L tank would require 79,950 cfm for the minute of release. The destruction of the fourteen Dewars of Phase 2 would require 134,000 cfm.

The question of credibility must now be considered. The project description states that the Dewars are used in an open mode, thus negating the concern of a valve being detached. As to the immediate complete release, either the Dewar would need to be tipped such that all the contents were released, or a gross puncture must occur. The project description states that the Dewars are physically attached to the detector inside the connex before being filled with LN_2. Whatever would cause the Dewar to be tipped would also have to tip the detector and possibly the lead bricks, assuming the attachment is substantial. Checks of the connection and assurances of the integrity of the juncture would control this event. For a puncture to occur, some device strong enough, large enough and long enough would have to be propelled with enough force to penetrate the Dewar while it was in the connex. No such credible event could be determined, other than actual sabotage or a roof collapse. Security checks upon entrance to the site and danger to the individual provide some limit to the former, while ground control limits the possibility of the latter. Without information on the detail configuration for Phase 2 and Phase 3, no credible spill scenarios can be evaluated yet, although roof collapse and sabotage would again appear to be the only possible causes.

Immediate release of the 250 L tank could occur due to operator error, tipping, sabotage, or roof collapse. The puncture of the 250 L tank due to operator error such as a forklift puncture is a credible event. However, the double stainless steel walls and cylindrical shape of the tank, combined with the round dullness of the forklift forks tend to reduce the probability and the severity of such an event. Whether or not this puncture would result in a complete immediate release would depend on the size and location of the puncture. It would also depend on whether the puncturing device was removed or allowed to remain in the puncture. The cage used to transport the tank is open in the front, with securing chains. This is the

normal approach used by the forklift.

The potential for forklift puncture will be eliminated by raising the floor of the cage approximately one inch with a spacer. Tipping is controlled by site requirement to substantially secure such containers. Sabotage and roof collapse are discussed in the previous paragraph.

In conclusion, the current plan calls for approximately 15,000-20,000 cfm of ventilation to be provided to the area. It also calls for the connex air system to be designed for 3 to 4 air changes per hour, which calculates to approximately 60 cfm of fresh air. In addition, oxygen sensors and an internal and external alarm system have been proposed. With these conditions and the controls suggested above, which include improvements to the tank transport cage and assurance of substantial securing of containers, this amount of ventilation should be more than adequate for the Majorana Project.

TITLE			PAGE
Ventilation Requirements for N_2 Release			OF
PROJECT: Majorana	AUTHOR: P. Hoffman DATE: 3/26/01	CHK'D. BY: P. Hoffman DATE: 3/26/01	CHK'D. BY DATE
S.O.	CALC. NO.	FILE NO.	GROUP

Phase 1: $\frac{30\text{ L LN}_2/\text{dewar} \times 24.6\text{ ft}^3\text{ N}_2/\text{L LN}_2 \times 2\text{ dewars}}{7\text{ days} \times 24\text{ hr/day} \times 60\text{ min/hr}} = 0.146\text{ cfm N}_2$

$\therefore\ 0.146\text{ ft}^3(0\%\text{O}_2) + X\text{ ft}^3(21\%\text{O}_2) = (0.146+x)\text{ ft}^3(19.5\%\text{O}_2)$

$X = 1.898\text{ ft}^3$ for two dewars

Phase 2: $= 13.29\text{ ft}^3$ for 14 dewars

Phase 3: $= 199.2\text{ ft}^3$ for 210 dewars.

Catastrophic:

$\frac{30\text{ L LN}_2/\text{dewar} \times 24.6\text{ ft}^3\text{ N}_2/\text{L LN}_2}{1\text{ min.}} = 738\text{ cfm N}_2/\text{dewar}$

$738\text{ ft}^3(0\%\text{O}_2) + X\text{ ft}^3(21\%\text{O}_2) = (738+X)\text{ ft}^3(19.5\%\text{O}_2)$

$X = 9594\text{ ft}^3$ for 1 dewar

$= 19188\text{ ft}^3$ for 2 dewars

$= 79,950\text{ ft}^3$ for 250 L tank.

REV. NO.	REV. DATE	AUTHOR DATE	CHK'D. BY DATE	CHK'D. BY DATE

Enclosure 5

Majorana EPA

Industrial Hygiene

Exposure

Monitoring Plan-

Lead

Majorana Project - Industrial Hygiene Exposure Monitoring Plan - Lead

CONTAMINANT:

Lead, Pb

EXPOSURE LIMIT:

OSHA PEL 0.050 mg/m^3 for an 8 hr. TWA; OSHA Action Level 0.030 mg/m3 for an 8 hr TWA; ACGIH TLV 0.050 mg/m3 for an 8 hr. TWA; WIPP Action Level 0.025 mg/m^3.

SAMPLING METHOD #:

NIOSH 7082 which replaces P&CAM 173 and S341.
Note: This is the only OSHA approved method for determination of personnel exposures.

TYPE SAMPLE:

Area and personal; full shift or length of exposure as appropriate; pre-activity (baseline); during activity; post activity. Note: Initial brick movement activity will be administratively limited to 2 hours, based on historical exposure data from the DOE complex. A duplicate sample will be taken at the brick movement area.

SAMPLES:

As determined by the cognizant ES&H professional overseeing this project.

EQUIPMENT:

Per NIOSH 7082

JOB TITLES/AREAS TO BE SAMPLED:

As determined by the cognizant ES&H professional overseeing this project, and the presence or absence of visible oxidation

ASSUMPTIONS:

Experimenters will be working to a WTS approved work package, which addresses concerns of the WTS ESH department.
Normal mine ventilation will be maintained.

ANALYSIS:

By an American Industrial Hygiene Association (AIHA) certified laboratory.

REFERENCES:

Busch, Kenneth and Leidel, Nelson. *NIOSH Occupational Exposure Sampling Strategy Manual*, National Institute of Occupational Safety and Health, Cincinnati, Ohio, January 1977.
Hawkins, Neil. *A Strategy for Occupational Exposure Assessment*, American Industrial Hygiene Association, Fairfax, Virginia, 1991.
DiNardi, Salvatore. *The Occupational Environment - Its Evaluation and Control*, American Industrial Hygiene Association, Fairfax, Virginia, 1997.
ACGIH, *Documentation of TLV's CD,* ACGIH, Cincinnati, Ohio, 1997.

Enclosure 6

Majorana EPA Annual Ground Control Operating Plan

ANNUAL GROUND CONTROL OPERATING PLAN
FOR THE WASTE ISOLATION PILOT PLANT

Westinghouse
Geotechnical Engineering
February 2001

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

TABLE

LIST OF FIGURES

FIGURE

1.0 INTRODUCTION

This Annual Ground Control Operating Plan (AGCOP) is an internal guidance document for short- and long-term planning for the Westinghouse Underground Operations and Engineering groups. The data collected for the plan and the evaluation of those data are most useful when used or considered immediately after collection. Use of the data becomes more difficult and less certain with time. Because of the dynamic nature of the underground openings and associated geotechnical activities, this plan is updated annually, and each successive document supersedes the previous document. The data, evaluations, and support plans may be updated more frequently. This document is not intended to be used as a final plan for construction. Detailed plans are developed specifically for that purpose. This plan is also a foundation document for development and revision of the more general and broad-based annual Long-Term Ground Control Plan (LTGCP).

1.1 Regulatory Compliance

This plan presents background information and a working guide to assist Underground Operations and Engineering in developing strategies for addressing ground control issues at the Waste Isolation Pilot Plant (WIPP). With the initial receipt of waste in March of 1999, this document provides additional detail to Panel 1 and Panel 2 activities and options.

1.1.1 Resource Conservation and Recovery Act Requirements

Both the AGCOP and the LTGCP serve to ensure that Resource Conservation and Recovery Act (RCRA) permit requirements specific to WIPP site ground control activities are met. The RCRA permit for the WIPP states that "The ground-control program at the WIPP facility will ensure that any room in a Hazardous Waste Disposal Unit (HWDU) in which waste will be placed will be sufficiently supported to assure compliance with the applicable portions of the Land Withdrawal Act (LWA). Which requires a regular review of roof-support plans and practices by the Bureau of Mines and the Mine Safety and Health Administration (MSHA). Support is installed to the requirements of 30 CFR Part 57 Subpart B". All ground control activities were examined for compliance with RCRA permit requirements and no deficiencies were noted. This report documents that examination and is submitted, when necessary, to support permit compliance. The United States Bureau of Mines no longer exists.

1.1.2 Mine Safety and Health Administration Requirements

Support systems at the WIPP are installed to the requirements of Code of Federal Regulations (CFR) 30 Part 57 Subpart B. Quality assurance/quality control personnel conduct random and as-requested checks as each system is installed. In addition, roof-support plans and practices are regularly reviewed and inspected by the Mine Safety and Health Administration and the New Mexico Bureau of Mine Inspection.

1.1.3 Environmental Protection Agency Requirements

Insofar as ground control activities may influence long-term repository performance and performance assessment calculations, no changes in ground control practices and ground control system behavior and performance were noted.

1.2 Scope

Chapter 2.0 documents the current status of all underground excavations with respect to location, geology, geometry, age, ground support, operational use, projected life, and physical conditions. Chapter 3.0 presents the methods used to evaluate ground conditions, including visual observations of the roof, ribs, and floor; inspection of observation holes; and review of geomechanical instrumentation data. Chapter 4.0 lists several ground-support options and specific applications of each. Chapter 5.0 presents projections and recommendations for ground control actions based on the information in Chapters 2.0 through 4.0 of this plan and on a rating of the critical nature of each specific area. Chapter 6.0 presents a summary statement, and Chapter 7.0 provides references.

1.3 Background

Underground excavation at WIPP began in 1982. Since that time, approximately 8 miles of drifts, rooms, and alcoves have been excavated with several areas now closed to access. The excavations vary in geometry, geology, age, and operational use. These parameters affect the selection of ground control measures, but the ability of the salt to creep or flow with time, and the related fracture process, has the greatest impact on selection of ground control systems. All ground control mechanisms are subjected to the salt-creep forces.

The ground control program at WIPP consists of many aspects, including continuous visual inspections of the underground openings, extensive geomechanical monitoring, numerical modeling, tracking and analysis of rockbolt failures, implementation of selective

ground control procedures, and comprehensive in situ and laboratory testing and evaluation of ground control components and systems.

Plans for areas that involve waste handling/emplacement are based on the most current waste receipt schedules provided by the Department of Energy's Carlsbad Field Office (CBFO). An area designated for near-term waste emplacement is cleared from a ground control standpoint for a specific period of time. The ground control program at WIPP has produced a greater understanding of the failure mechanisms involved in the mine roof and the support systems installed in it. The database of information is a tool that aids the ability to preserve and maintain optimal ground conditions and to predict and/or mitigate hazardous conditions.

1.3.1 Summary of 2000 Ground Control Actions

The receipt of waste initiated additional activities that affected ground control actions in 2000. Mining of Panel 2 and its associated access drifts was completed. To ensure that salt disposal from Panel 2 excavation was not impeded by limitations of the salt handling shaft, reopening of selected areas of the north end of the facility was authorized by the DOE. Panel 1 was also monitored more closely as Panel 2 was mined to evaluate effects of the mining on the existing openings.

This plan addresses ground control issues on a contemporary basis. Major ground control measures implemented in Calendar Year 2000 include the following:

- Areas in the north portion of the facility that had previously been closed were inspected, supported as necessary (rockbolted), and cleared for salt storage to support excavation of Panel 2. One aspect of this process included installation of a row of threaded-bar bolts at each end of the Site and Preliminary Design Validation (SPDV) rooms that remain closed.
- Cable lacing was installed in South-1600 between Rooms 1 and 6 of Panel 1.
- Additional threaded-bar bolts were installed at the south end of Room 1.
- A system consisting of Geobrugg Mesh (a heavy cable mesh) was installed at the ventilation overcast at South-2520 and East-300. The system covers the entire overcast and extends around the brows.
- Limited spot bolting to address isolated drummy areas was performed in newly excavated areas associated with Panel 2.

- Existing ground control was maintained as appropriate. Broken bolts in active patterns were replaced. Scaling, adding mesh, and bolting were performed on an as-needed basis in localized areas not actively supported.
- Floor milling activities were performed as required.

1.3.2 Projected Ground Control Measures for 2001

Panel 1 conditions are scrutinized carefully to ascertain suitability for waste disposal. All areas of the panel are reinforced with supplemental threaded-bar bolt installations. Current projections call for adding additional ground control only as needed and, preferably, immediately prior to waste emplacement in a specific area. With the waste disposal schedule being a controlling parameter, ground control projections for Panel 1 include:

- Replace broken bolts in most recent generation of support as necessary until near the time each room is required for waste disposal.
- Roof mats will be will be installed in the rooms selected for waste emplacement and their associated entry drifts as necessary prior to emplacement operations in those areas. The roof mats will be attached with a pattern of threaded-bar and mechanical-anchor rockbolts.
- If required, the floor in areas required for waste emplacement will be milled or mined to achieve operational clearance requirements.
- Room 7 is receiving waste and no additional ground control efforts are anticipated for 2001 with the exception of replacing accessible threaded-bar bolts that fail.

Detailed projections for Panel 1 are discussed in Section 5.2. If the rate of waste receipt is significantly slow, the economics of maintaining all of Panel 1 for waste emplacement may make the use of some areas of the panel less desirable then others.

Tentative projections for routine ground control actions in the remainder of the facility include the addition of mesh and supplemental pattern bolting with threaded-bar bolts, mechanical-anchor bolts, or yielding cable bolts as required. Ground control projections are tentative, based on evaluations of current conditions, and prioritized based on safety. Anticipated ground control actions that will or are scheduled to be performed in the next year include:

- Roof beam removal will be performed in the East-0 Drift from North-150 to North-1400, This activity is currently in progress. Following beam removal, a pattern of 6-foot-long mechanical-anchor rockbolts and chain-link mesh will be installed.
- Beam removal is also planned for the East-140 Drift from North-250 to North-1400 and the associated cross drifts between East-140 and East-0.
- Additional support may be added in the South-1300 crosscut between West-30 and West-170. This support may include splitting the existing bolt pattern with No. 7 threaded-bar bolts.
- In the West-30 Drift from South-90 to South-400, supplemental support will be installed.
- Supplemental support is planned for both brows at the Air Intake Shaft.
- Supplemental support will be installed on the both brows at the Waste Shaft Station and from the East-140 South-400 intersection to the Waste Shaft Station.

2.0 CURRENT STATUS AND CONDITIONS OF UNDERGROUND OPENINGS

The underground is divided into zones for ground control assessment purposes. The current status of the zones is constantly evaluated and documented. Figure 2-1 presents a layout of the facility with the numeric identification of each zone. Table 2-1 lists statistical information on each zone, such as area description, roof beam dimensions, opening geometry, excavation age, ground support, and operational use. This table also gives the projected life of the zone based on its operational use. Table 2-2 lists the current physical condition assessment of each zone based on field surveys performed in December and January of 2000 and 2001, respectively. The information provided in Table 2-2 is based on qualitative evaluations of roof, rib, and floor fracturing and related degradation of the opening. The data presented in Tables 2-1 and 2-2 are used for making ground control projections. A change in the conditions of an area may necessitate ground control actions not anticipated at this time.

2.1 <u>Geology</u>

The underground facility horizon lies within the Salado Formation. The basic constituents of the formation are near horizontal beds of clear halite (salt), argillaceous (clayey) halite, and polyhalitic halite. A detailed geologic discussion of the Salado Formation can be found in Holt and Powers [1984]. Two mining horizons are located within the facility horizon: (1) the disposal horizon and (2) the experimental horizon. Within these horizons

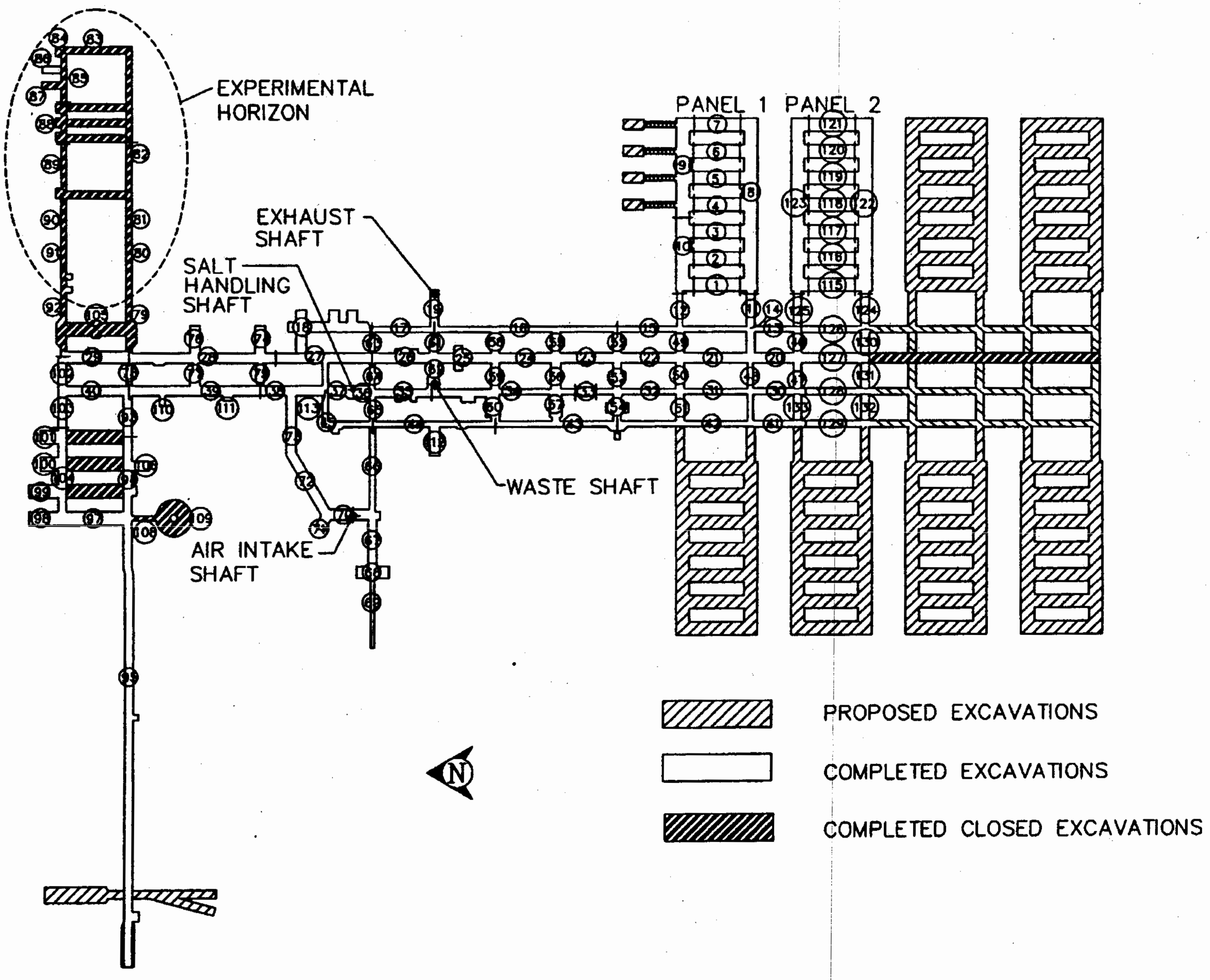


Figure 2-1. WIPP Underground Assessment Zones

Table 2-1. Underground Assessment Zones — Statistical Information (Page 1 of 4)

Zone Number	Area Description	Opening Dimensions (ft.)	Use	Age (yr.)	Est. Life	Bolt Length (ft.)	Bolt Diam. (in.)	Bolt Type	Bolt Spacing (ft.)	Roof Beam Dimensions (ft.)
1	ROOM 1 PANEL 1	13x33	WASTE DISP	14	ST	13	1.000	THRB	SPECIAL	7x33
2	ROOM 2 PANEL 1	13x33	WASTE DISP	13	ST	99	9.999	VARY	VARIOUS	7x33
3	ROOM 3 PANEL 1	13x33	WASTE DISP	13	ST	12	0.875	THRB	4.5SQ	7x33
4	ROOM 4 PANEL 1(N/2)	13x33	WASTE DISP	12	ST	12	0.875	THRB	4.5SQ	7x33
4	ROOM 4 PANEL 1(S/2)	13x33	WASTE DISP	12	ST	13	0.875	THRB	4.5SQ	7x33
5	ROOM 5 PANEL 1	13x33	WASTE DISP	12	ST	12	0.875	THRB	4.5SQ	7x33
6	ROOM 6 PANEL 1	13x33	WASTE DISP	12	ST	12	0.875	THRB	4.5SQ	7x33
7	ROOM 7 PANEL 1	13x33	WASTE DISP	12	ST	12	0.875	THRB	5x3.8TRI	7x33
8	S1950 PANEL 1	13x33	WASTE DISP	13	ST	13	0.750	THRB	4.5SQ	7x33
9	S1600 R4-R7 PANEL 1	13x33	WASTE DISP	12	ST	13	0.875	THRB	4.5SQ	7x33
10	S1600 R1-R4 PANEL 1	13x33	WASTE DISP	13	ST	13	0.875	THRB	4.5SQ	7x33
11	S1950P1 ENT E140-300	13x20	HAULAGE	14	ST	6	0.625	MECH	5x2.5TRI	7x20
11	S1950P1 ENT E300-520	13x20	HAULAGE	14	ST	6	0.625	MECH	5x2.5TRI	7x20
12	S1600 PANEL 1 ENTRY	12x14	VENTILATE	14	ST	6	0.625	MECH	5x2.5TRI	8x14
13	E300 S1950-S2180	12x14	VENTILATE	14	LT	10	0.750	MECH	4x2TRI	8x14
14	E300 OVERCAST-S1950	15x19	VENTILATE	14	LT	0	0.000	NONE	NONE	5x19
15	E300 S1300-S1600	12x14	VENTILATE	14	LT	6	0.625	MECH	5x2.5TRI	8x14
15	E300 S1600-S1950	12x14	VENTILATE	14	LT	10	0.750	MECH	5x2.5TRI	8x14
16	E300 S400-S1300	12x14	VENTILATE	15	LT	10	0.750	MECH	5x2.5TRI	8x14
17	E300 S90-S400	12x14	VENTILATE	14	LT	10	0.750	MECH	6x3TRI	8x14
18	E300 S90-N250	15x25	SHOP	7	I	12	0.750	THRB	4.5SQ	5x25
19	EXHST DRIFT E OF 300	12x20	VENTILATE	16	LT	10	0.750	MECH	5x2.5TRI	8x20
20	E140 S OF 2520	8x25	CLOSED	17	CL	0	0.000	MECH	UNKNOWN	6x25
20	E140 S2050-S2180	15x25	HAULAGE	17	LT	8	0.750	MECH	12x3TRI	5x25
21	E140 S1600-S1950	20x25	HAULAGE	17	LT	4	0.625	MECH	5x5TRI	6x25
21	E140 S1950-S2050	15x25	HAULAGE	17	LT	8	0.750	MECH	12x3TRI	5x25
22	E140 S1300-S1600	20x25	HAULAGE	17	LT	5	0.625	MECH	5x5TRI	6x25
23	E140 S1000-S1300	20x25	HAULAGE	17	LT	5	0.625	MECH	5x5TRI	6x25
24	E140 S700-S1000	15x25	HAULAGE	17	LT	12	0.875	THRB	4.5SQ	5x25
25	E140 S400-S700	15x25	HAULAGE	17	LT	8	0.750	MECH	12x3TRI	5x25
26	E140 S90-S400	15x25	HAULAGE	17	LT	10	0.750	MECH	5x2.5TRI	5x25
27	E140 N250-N460	15x25	HAULAGE	17	LT	10	0.750	MECH	5x2.5TRI	5x25
27	E140 S90-N250	15x25	HAULAGE	17	LT	10	0.750	MECH	5x2.5TRI	5x25
28	E140 N460-N780	15x25	STORAGE	17	LT	99	9.999	VARY	VARIOUS	5x25
28	E140 N780-N1100	15x25	HAULAGE	17	ST	10	0.750	MECH	5x2.5TRI	5x25
29	E140 N1100-N1400	15x30	HAULAGE	17	ST	10	0.750	MECH	5x2.5TRI	5x30
30	W30 S1950-S2180	12x14	ACCESS	12	LT	10	0.750	MECH	5x2.5TRI	8x14
31	W30 S1600-S1950	12x14	ACCESS	14	LT	10	0.750	MECH	6x3TRI	8x14
32	W30 S1175-S1300	12x14	ACCESS	15	LT	10	0.750	MECH	5x2.5TRI	8x14
32	W30 S1300-S1600	12x14	ACCESS	15	LT	6	0.625	MECH	5x3TRI	8x14
33	W30 S1150 BOOST FAN	20x25	VENTILATE	15	LT	6	0.750	MECH	4x6SQ	6x25
34	W30 S400-S700	12x20	ACCESS	15	LT	10	0.750	MECH	5x3TRI	8x20
34	W30 S700-S1000	12x14	ACCESS	15	LT	10	0.750	MECH	5x3TRI	8x14
34	W30 S1000-1125	12x14	ACCESS	15	LT	10	0.750	MECH	5x3TRI	8x14
35	W30 S90-S400	12x20	HAULAGE	17	LT	10	0.750	MECH	5x2.5TRI	8x20
36	SALT SHAFT STATION	20x33	STATION	18	LT	5	0.625	MECH	8x5TRI	6x33
37	E0 SALT STA-N150	12x25	HAULAGE	17	LT	6	0.625	MECH	5x3TRI	8x25
38	E0 N150-N460	12x25	HAULAGE	17	LT	10	0.750	MECH	5x2.5TRI	8x25

Table 2-1. Underground Assessment Zones — Statistical Information (Page 2 of 4)

Zone Number	Area Description	Opening Dimensions (ft.)	Use	Age (yr.)	Est. Life	Bolt Length (ft.)	Bolt Diam. (in.)	Bolt Type	Bolt Spacing (ft.)	Roof Beam Dimensions (ft.)
39	E0 N460-N780	12X25	HAULAGE	17	LT	10	0.750	MECH	5X2.5TRI	8X25
39	E0 N780-N1100	12x25	HAULAGE	17	ST	10	0.750	MECH	5x2.5TRI	8x25
40	E0 N1100-N1400	12x25	HAULAGE	17	ST	10	0.750	MECH	5X2.5TRI	8X25
41	W170 S1950-S2180	12x14	HAULAGE	11	LT	10	0.750	MECH	5x2.5TRI	8x14
42	W170 S1300-S1600	12x14	HAULAGE	15	LT	10	0.750	MECH	5x2.5TRI	8x14
42	W170 S1600-S1950	12x14	HAULAGE	15	LT	10	0.750	MECH	5x2.5TRI	8x14
43	W170 S1000-S1300	12x14	HAULAGE	15	LT	10	0.750	MECH	6x3TRI	8x14
43	W170 S700-S1000	12x14	HAULAGE	15	LT	10	0.750	MECH	6x3TRI	8x14
44	W170 S90-S700	12x14	HAULAGE	15	LT	10	0.750	MECH	6x3TRI	8x14
45	W170/N150 S90/E0	12x14	HAULAGE	15	LT	10	0.750	MECH	6x3TRI	8x14
46	S2180 E140-E300	13x20	CROSS	14	I	10	0.750	MECH	5x2.5TRI	7x20
47	S2180 W30-E140	13x20	CROSS	12	I	10	0.750	MECH	5x2.5TRI	7x20
47	S2180 W30-W170	13x20	CROSS	11	I	10	0.750	MECH	5x2.5TRI	7x20
48	S1950 W30-E140	12x14	CROSS	14	I	10	0.750	MECH	5x2.5TRI	8x14
48	S1950 W30-W170	12x14	CROSS	13	I	10	0.750	MECH	5x2.5TRI	8x14
49	S1600 E140-E300	12x20	CROSS	14	I	10	0.750	MECH	6x4TRI	8x20
50	S1600 E140-W30	12x20/27	WASHBAY	16	I	10	0.750	MECH	5x3TRI	8x20/27
51	S1600 W30-W170	12x20	CROSS	12	I	10	0.750	MECH	5x2.5TRI	8x20
52	S1300 E140-E300	12x25	VENTILATE	16	I	10	0.750	MECH	5x3TRI	8x25
53	S1300 E140-W30	12x20	OFFICES	15	I	6	0.625	MECH	6x3TRI	8x20
54	S1300 W30-W170	14x20	SHOP	15	I	99	9.999	MECH	4x2TRI	6x20
55	S1000 E140-E300	12x20	CROSS	14	I	10	0.750	MECH	5x5TRI	8x20
56	S1000 E140-W30	12x25	CROSS/VEN	16	I	10	0.750	MECH	5x2.5TRI	8x25
57	S1000 W30-W170	12x33	OFFICES	14	I	10	0.750	MECH	5x2.5TRI	8x33
58	S700 E140-E300	14x33	SHOP	16	I	10	0.750	MECH	5x5TRI	6x33
59	S700 E140-W30	12x20	HAULAGE	14	I	10	0.750	MECH	6x3TRI	8x20
60	S700 W30-W170	12x32	OFFICES	15	I	6	0.625	MECH	5x2.5TRI	8x32
61	S400 E140-E300	VARIES	VENTILATE	16	LT	10	0.750	MECH	5x3TRI	VARIES
62	WASTE SHAFT STATION	16x22/	STATION	17	LT	10	0.750	MECH	5x5TRI	4x22
63	S90 E140-E300	12x12	ACCESS	14	LT	10	0.750	MECH	5x2.5TRI	8x12
64	S90 E0-E140	12x25	ELECT SUBS	14	I	0	0.000	NONE	NONE	8x25
65	S90 W30-W170	12x14	ACCESS	15	LT	10	0.750	MECH	5x2.5TRI	8x14
66	S90 W170-AIS	12x14	VENTILATE	12	I	10	0.750	MECH	6x3TRI	8x14
67	S90 AIS-Q	12x20	EXPERIMEN	11	ST	10	0.750	MECH	6x3TRI	8x20
68	Q ALCOVE	15x30	EXPERIMEN	11	ST	6	0.625	MECH	6x6TRI	5x30
69	Q ROOM	9.5RND	CLOSED	10	CL	0	0.000	MECH	NONE	N/A
70	AIS STATION @ SHAFT	20x25	STATION	12	LT	12	0.750	MECH	6x6TRI	6x25
70	AIS STATION LOW BRWS	12x25	STATION	12	LT	6	0.750	MECH	6x6TRI	8x25
71	ROOM V	12x25	EXPERIMEN	12	ST	4	0.750	MECH	5x2.5TRI	8x25
72	AIS ACCESS N215	13x25	VENTILATE	12	LT	10	0.750	MECH	5x2.5TRI	7x25
73	N300 0E-WEST	13x25	VENTILATE	12	LT	10	0.750	MECH	5x3TRI	7x25
74	E140 N460 ALCOVE	13x25	OFFICES	9	I	10	0.750	MECH	5x2.5TRI	7x25
75	N460 E0-E140	13x25	ACCESS	17	I	10	0.750	MECH	6x3TRI	7x25
76	E140 N780 ALCOVE	13x25	STORAGE	9	I	10	0.750	MECH	5x2.5TRI	7x25
77	N780 E0-E140 SHOP	13x25	SHOP	17	I	10	0.750	MECH	5x2.5TRI	7x25
78	N1100 E0-E140	12x14	CROSS	17	ST	10	0.750	MECH	4x5TRI	8x14
79	N1100 E140-E300	12x24	CLOSED	16	CL	6	0.750	MECH	5x2.5T	8x24
79	N1100 E300-RAMP	9x14	CLOSED	16	CL	10	0.625	MECH	5x5TRI	8x14
80	N1100 RAMP	9x14	CLOSED	16	CL	6	0.750	MECH	5x2.5TRI	VARIES

Table 2-1. Underground Assessment Zones — Statistical Information (Page 3 of 4)

Zone Number	Area Description	Opening Dimensions (ft.)	Use	Age (yr.)	Est. Life	Bolt Length (ft.)	Bolt Diam. (in.)	Bolt Type	Patt. Bolt Spacing (ft.)	Roof Beam Dimensions (ft.)
81	N1100 RAMP-ROOM B	9x14	CLOSED	16	CL	6	0.750	MECH	5x2.5TRI	8x14
82	N1100 ROOMS B-D	9x14	CLOSED	16	CL	6	0.750	MECH	5x2.5TRI	8x14
83	ROOM D	18x18	CLOSED	16	CL	10	0.875	THRB	5x5TRI	5x14
84	ROOM M	11x24	CLOSED	16	CL	4	0.625	MECH	5x5SQ	6x24
85	N1400 ROOMS A3-D	12x14	CLOSED	16	CL	6	0.750	MECH	4x3TRI	5x14
86	ROOM C-1	18x18	CLOSED	16	CL	10	0.750	MECH	5x2.5TRI	5x14
87	ROOM C-2	18x18	CLOSED	16	CL	10	0.750	MECH	5x3TRI	5x14
88	N1400 ROOMS A1-A3	12x14	CLOSED	16	CL	6	0.625	MECH	4x3TRI	5x14
89	N1400 ROOMS A1-B	12x14	CLOSED	16	CL	6	0.625	MECH	5x3TRI	5x14
90	N1400 RAMP-ROOM B	12x14	CLOSED	16	CL	6	0.625	MECH	4x3TRI	5x14
91	N1400 RAMP	12x14	CLOSED	16	CL	10	0.750	MECH	5x2.5TRI	VARIES
92	N1400 E140-RAMP	12x14	CLOSED	16	CL	10	0.625	MECH	5x2.5TRI	8x14
93	N1100 E0-SPDV RM1	12x20	HAULAGE	17	ST	10	0.750	MECH	5x5TRI	8x20
94	N1100 SPDV ROOMS 1-4	12x20	HAULAGE	17	ST	10	0.750	MECH	5x5TRI	8x20
95	ROOM G AND G ACCESS	10x20	SALT STORE	15	ST	10	0.750	MECH	VARIOS	10x20
97	SPDV ROOM 4	13x33	HAULAGE	17	ST	10 & 12	0.875	THRB	4x4SQ	7x33
98	ROOM L-4	13x33	SALT STORE	11	ST	10	0.750	MECH	5x2.5TRI	7x33
99	ROOM L-3	13x33	SALT STORE	11	CL	10	0.750	MECH	5x2.5TRI	7x33
100	ROOM L-2	13x33	SALT STORE	16	CL	10	0.750	MECH	4x2TRI	7x33
101	ROOM L-1	13x33	SALT STORE	16	CL	10	0.750	MECH	5x2.5TRI	7x33
102	N1400 E0-E140	12x20	HAULAGE	17	ST	10	0.750	MECH	5x2.5TRI	8x20
103	N1400 E0-ROOM L1	12x20	HAULAGE	17	ST	10	0.750	MECH	5x2.5TRI	8x20
104	N1400 ROOMS L1-L4	12x20	HAULAGE	17	ST	10	0.750	MECH	4x4TRI	8x20
105	E300 N1100-1400 SHOP	13x33	CLOSED	10	CL	10	0.750	MECH	5x2.5TRI	7x33
106	ROOM J	12x23	SALT STORE	16	CL;	10	0.750	MECH	4x4TRI	8x23
108	ROOM H ACCESS	10x11	CLOSED	16	CL	99	0.750	MECH	5x5TRI	10x11
109	ROOM H	10x36	CLOSED	15	CL	99	9.999	MECH	5x5TRI	10x36
110	N940 ALCOVE 0E	12x14	STORAGE	11	ST	10	0.750	MECH	6x3TRI	8x14
111	E0 N620 ALCOVE	12x25	STORAGE	11	I	10	0.625	MECH	5x2.5TRI	8x25
112	W170 S400 ALCOVE	13x25	STORAGE	11	ST	10	0.750	MECH	5x2.5TRI	7x25
113	E0 N150 OVERCAST	20x15	VENTILATE	13	LT	10	0.750	MECH	4x4SQ	7x15
114	N150 OVERCAST-E140	10x14	VENTILATE	17	LT	10	0.750	MECH	8x4.5TRI	10x14
115	ROOM 1 PANEL 2	13x33	WASTE DISP	1	ST	N/A	N/A	N/A	N/A	N/A
116	ROOM 2 PANEL 2	13x33	WASTE DISP	1	ST	N/A	N/A	N/A	N/A	N/A
117	ROOM 3 PANEL 2	13x33	WASTE DISP	1	ST	N/A	N/A	N/A	N/A	N/A
118	ROOM 4 PANEL 2	13x33	WASTE DISP	1	ST	N/A	N/A	N/A	N/A	N/A
119	ROOM 5 PANEL 2	13x33	WASTE DISP	1	ST	N/A	N/A	N/A	N/A	N/A
120	ROOM 6 PANEL 2	13x33	WASTE DISP	1	ST	N/A	N/A	N/A	N/A	N/A
121	ROOM 7 PANEL 2	13x33	WASTE DISP	1	ST	N/A	N/A	N/A	N/A	N/A
122	S2520 PANEL 2	13x33	WASTE DISP	1	ST	N/A	N/A	N/A	N/A	N/A
123	S2180 PANEL 2	13x33	WASTE DISP	1	ST	N/A	N/A	N/A	N/A	N/A
124	S2520 PANEL 2 ENTRY	13x20	HAULAGE	1	ST	N/A	N/A	N/A	N/A	N/A
125	S2180 PANEL 2 ENTRY	12x14	VENTILATE	1	ST	N/A	N/A	N/A	N/A	N/A
126	E300 S2180-S2520	13X16	VENTILATE	1	LT	N/A	N/A	N/A	N/A	N/A
127	E140 S2180-S2520	15x25	HAULAGE	1	LT	N/A	N/A	N/A	N/A	N/A
128	W30 S2180-S2520	13x16	ACCESS	1	LT	N/A	N/A	N/A	N/A	N/A
129	W170 S2180-S2520	13x16	HAULAGE	1	LT	N/A	N/A	N/A	N/A	N/A
130	S2520 E140-E300	13x20	HAULAGE	1	ST	N/A	N/A	N/A	N/A	N/A
131	S2520 W30-E140	13x20	CROSS	1	I	N/A	N/A	N/A	N/A	N/A

Table 2-1. Underground Assessment Zones — Statistical Information (Page 4 of 4)

Zone Number	Area Description	Opening Dimensions (ft.)	Use	Age (yr.)	Est. Life	Bolt Length (ft.)	Bolt Diam. (in.)	Bolt Type	Patt. Bolt Spacing (ft.)	Roof Beam Dimensions (ft.)
132	S2520 W30-W170	13x20	CROSS	1	I	N/A	N/A	N/A	N/A	N/A
133	S2180 W30-W170	13x20	CROSS	1	I	N/A	N/A	N/A	N/A	N/A

Notes: For evaluation purposes, Zone 96 was combined with Zone 95, and Zone 107 was combined with Zone 94.

Age is calculated using the date of this printing and the date of completion of the first excavation sequence. The date of printing is February 2001. Zones 115 through 133 are less than 1 year old.

Zeros (e.g., 0.000) in a numerical column indicate that no information is available.
Nines (e.g., 9.999) in a numerical column indicate multiple types or dimensions.

Key:

ST	- Short-term	THRB	- Threaded-Bar Bolt
I	- Intermediate	MECH	- Mechanical Anchor
LT	- Long-term	TRI	- Triangular
CL	- Closed	SQ	- Square
			-

(Refer to text for detailed definitions)

Table 2-2. Underground Inspection Survey Summary (Page 1 of 3)

Zone Number	Area Description	Low-Angle Fracturing		Horizontal Fracturing	Longitudinal Fracturing	Ribs Assessment		Floor Assessment		Increased Closure Rate	Long-Term Projection
1	ROOM 1 PANEL 1	E4	W3	2	3	E1	W1	E2	W2	Y	2
2	ROOM 2 PANEL 1	E2	W3	2	1	E1	W1	E1	W1	Y	2
3	ROOM 3 PANEL 1	E3	W2	1	3	E1	W1	E2	W2	Y	2
4	ROOM 4 PANEL 1(N/2)	E4	W3	2	4	E1	W1	E2	W2	Y	2
4	ROOM 4 PANEL 1(S/2)	E4	W3	2	4	E1	W1	E2	W2	Y	2
5	ROOM 5 PANEL 1	E4	W2	1	3	E1	W1	E1	W1	Y	2
6	ROOM 6 PANEL 1	E3	W2	1	3	E1	W1	E1	W1	Y	2
7	ROOM 7 PANEL 1	E4	W2	1	3	E1	W1	E1	W1	N	2
8	S1950 PANEL 1	N3	S3	1	3	N1	S1	N2	S2	Y	2
9	S1600 R4-R7 PANEL 1	N1	S3	1	2	N1	S1	N1	S1	Y	2
10	S1600 R1-R4 PANEL 1	N2	S3	1	2	N1	S1	N2	S1	Y	2
11	S1950P1 ENT E140-300	N3	S2	1	2	N1	S1	N1	S1	Y	2
11	S1950P1 ENT E300-520	N4	S4	1	1	N1	S1	N1	S1	Y	2
12	S1600 PANEL 1 ENTRY	N1	S1	1	1	N1	S1	N1	S1	Y	1
13	E300 S1950-S2180	E1	W1	1	1	E1	W1	E1	W1	Y	1
14	E300 OVERCAST-S1950	E1	W1	1	1	E1	W1	NA	NA	N	1
15	E300 S1300-S1600	E1	W1	1	1	E1	W1	E1	W1	Y	1
15	E300 S1600-S1950	E1	W1	1	1	E1	W1	E1	W1	N	1
16	E300 S400-S1300	E1	W1	1	1	E1	W1	E1	W1	N	1
17	E300 S90-S400	E1	W1	1	1	E1	W1	E1	W1	N	1
18	E300 S90-N250	E1	W1	1	1	E1	W1	E1	W1	Y	1
19	EXHST DRIFT E OF 300	N1	S1	1	1	N1	S1	N1	S1	N	1
20	E140 S2050-S2180	E3	W3	1	1	E1	W1	E1	W1	Y	2
21	E140 S1600-S1950	E1	W1	1	1	E1	W1	E1	W1	Y	1
21	E140 S1950-S2050	E3	W3	1	1	E1	W1	E1	W1	Y	2
22	E140 S1300-S1600	E1	W1	1	1	E1	W1	E1	W1	N	1
23	E140 S1000-S1300	E1	W1	1	1	E1	W1	E1	W1	Y	1
24	E140 S700-S1000	E2	W2	1	2	E1	W1	E1	W1	N	1
25	E140 S400-S700	E1	W1	1	1	E1	W1	E2	W2	N	1
26	E140 S90-S400	E2	W2	1	1	E1	W1	E1	W1	N	2
27	E140 N250-N460	E1	W5	1	1	E1	W1	E1	W2	N	2
27	E140 S90-N250	E1	W2	1	1	E1	W1	E1	W1	N	1
28	E140 N460-N780	N/A	W5	1	1	E1	W1	E1	W1	N	2
30	W30 S1950-S2180	E1	W1	1	1	E1	W1	E1	W1	Y	1
31	W30 S1600-S1950	E1	W1	1	1	E1	W1	E1	W1	Y	1
32	W30 S1175-S1300	E1	W1	1	1	E1	W1	E1	W1	N	1
32	W30 S1300-S1600	E1	W1	1	1	E1	W1	E1	W1	Y	1
33	W30 S1150 BOOST FAN	E1	W1	2	1	E1	W1	NA	NA	Y	2
34	W30 S1000-S1125	E1	W1	1	1	E1	W1	E1	W1	Y	1
34	W30 S400-S700	E1	W1	1	1	E1	W1	E1	W1	N	1
34	W30 S700-S1000	E1	W1	1	1	E1	W1	E1	W1	Y	1
35	W30 S90-S400	E3	W2	2	2	E1	W1	E1	W1	N	2
36	SALT SHAFT STATION	E1	W1	2	2	E1	W1	E1	W1	N	2
37	E0 SALT STA-N150	E3	W2	3	1	E2	W2	E1	W1	N	2
38	E0 N150-N300	E3	W3	4	4	E1	W1	E1	W1	Y	2
38	E0 N300-N460	E3	W3	1	2	E1	W1	E1	W1	N	2
39	E0 N460-N780	E4	W3	1	3	E1	W1	E3	W1	N	2
41	W170 S1950-S2180	E1	W1	1	1	E1	W1	E1	W1	Y	1
42	W170 S1300-S1600	E1	W1	1	1	E1	W1	E1	W1	N	1
42	W170 S1600-S1950	E1	W1	1	1	E1	W1	E1	W1	N	1

Table 2-2. Underground Inspection Survey Summary (Page 2 of 3)

Zone Number	Area Description	Low-Angle Fracturing		Horizontal Fracturing	Longitudinal Fracturing	Ribs Assessment		Floor Assessment		Increased Closure Rate	Long-Term Projection
43	W170 S1000-S1300	E1	W1	1	1	E1	W1	E1	W1	N	1
43	W170 S700-S1000	E1	W1	1	1	E1	W1	E1	W1	N	1
44	W170 S90-S700	E1	W1	1	1	E1	W1	E1	W1	N	1
45	W170/N150 S90/E0	E1	W1	1	1	E1	W1	E1	W1	N	1
46	S2180 E140-E300	N1	S1	1	1	N1	S1	N1	S1	Y	1
47	S2180 W30-E140	N1	S1	1	1	N1	S1	N1	S1	Y	1
47	S2180 W30-W170	N1	S3	1	1	N1	S1	N1	S1	Y	2
48	S1950 W30-E140	N1	S1	1	1	N1	S1	N1	S1	Y	1
48	S1950 W30-W170	N1	S1	1	1	N1	S1	N1	S1	Y	1
49	S1600 E140-E300	N1	S1	1	1	N1	S1	N1	S1	Y	1
50	S1600 E140-W30	N1	S1	1	1	N1	S1	N1	S1	Y	1
51	S1600 W30-W170	N1	S2	1	1	N1	S1	N1	S1	N/A	1
52	S1300 E140-E300	N1	S1	1	1	N1	S1	N1	S1	N	1
53	S1300 E140-W30	N1	S1	2	1	N1	S1	N1	S1	N	1
54	S1300 W30-W170	N3	S3	1	3	N1	S1	N1	S1	N	2
55	S1000 E140-E300	N1	S1	1	1	N1	S1	N1	S1	N	1
56	S1000 E140-W30	N2	S2	1	1	N1	S1	N1	S1	N	1
57	S1000 W30-W170	N1	S1	1	1	N2	S2	N1	S1	N	1
58	S700 E140-E300	N1	S1	1	1	N1	S1	N1	S1	N	1
59	S700 E140-W30	N1	S1	1	1	N1	S1	N1	S1	Y	1
60	S700 W30-W170	N2	S2	1	1	N1	S1	N1	S1	N	1
61	S400 E140-E300	N1	S1	1	1	N1	S1	N1	S1	N	1
62	WASTE SHAFT STATION	N1	S1	2	1	N1	S1	N1	S1	Y	2
63	S90 E140-E300	N1	S1	1	1	N1	S1	N1	S1	N	1
64	S90 E0-E140	N1	S1	1	1	N1	S1	N1	S1	N	1
65	S90 W30-W170	N1	S1	1	1	N1	S1	N1	S1	N	1
66	S90 W170-AIS	N1	S1	1	1	N1	S1	N1	S1	N	1
67	S90 AIS-Q	N1	S2	1	1	N1	S1	N1	S1	N	1
68	Q ALCOVE	N1	S1	1	1	N1	S1	N1	S1	N	1
70	AIS STATION @ SHAFT	E1	W1	3	1	E1	W1	E1	W1	N	2
70	AIS STATION LOW BRWS	E1	W1	3	1	E1	W1	E1	W1	N	1
71	ROOM V	N1	S1	1	1	N1	S1	N1	S1	N	1
72	AIS ACCESS N215	N2	S2	2	2	N1	S1	N1	S1	N	1
73	N300 0E-WEST	N3	S3	1	2	N2	S1	N1	S1	N	2
74	E140 N460 ALCOVE	N1	S3	1	1	N1	S1	N1	S1	N	2
75	N460 E0-E140	N1	S2	1	1	N1	S1	N1	S1	N	3
76	E140 N780 ALCOVE	N1	S2	1	1	N1	S1	N2	S1	N	1
77	N780 E0-E140 SHOP	N1	S1	1	1	N1	S1	N1	S1	N	1
111	E0 N620 ALCOVE	N1	S1	1	1	N1	S1	N1	S1	N	1
112	W170 CORE STORAGE	N1	S1	1	1	N1	S1	N1	S1	N	1
113	E0 N150 OVERCAST	N1	S1	1	1	NA	NA	NA	NA	N	1
114	N150 OVERCAST-E140	N1	S1	1	1	N1	S1	N1	S1	N	1
115	ROOM 1 PANEL 2	E1	W1	1	1	E1	W1	E2	W1	NA	1
116	ROOM 2 PANEL 2	E1	W1	1	1	E1	W1	E1	W1	NA	1
117	ROOM 3 PANEL 2	E1	W1	1	1	E1	W1	E1	W1	NA	1

Table 2-2. Underground Inspection Survey Summary (Page 3 of 3)

Zone Number	Area Description	Low-Angle Fracturing		Horizontal Fracturing	Longitudinal Fracturing	Ribs Assessment		Floor Assessment		Increased Closure Rate	Long-Term Projection
118	ROOM 4 PANEL 2	E1	W1	1	1	E1	W1	E1	W1	NA	1
119	ROOM 5 PANEL 2	E1	W1	1	1	E1	W1	E1	W1	NA	1
120	ROOM 6 PANEL 2	E1	W1	1	1	E1	W1	E1	W1	NA	1
121	ROOM 7 PANEL 2	E1	W1	1	1	E1	W1	E2	W2	NA	1
122	S2520 PANEL 2	N1	S1	1	1	N1	S1	N1	S1	NA	1
123	S2180 PANEL 2	N1	S1	1	1	N1	S1	N1	S1	NA	1
124	S2520 PANEL 2 ENTRY	N1	S1	1	1	N1	S1	N1	S1	NA	1
125	S2180 PANEL 2 ENTRY	N1	S1	1	1	N1	S1	N1	S1	NA	1
126	E300 S2180-S2520	E1	W1	1	1	E1	W1	E1	W1	NA	1
127	E140 S2180-S2520	E1	W1	1	1	E1	W1	E1	W1	NA	1
128	W30 S2180-S2520	E1	W1	1	1	E1	W1	E1	W1	NA	1
129	W170 S2180-S2520	E1	W1	1	1	E1	W1	E1	W1	NA	1
130	S2520 E140-E300	N1	S1	1	1	N1	S1	N1	S1	NA	1
131	S2520 W30-E140	N1	S1	1	1	N1	S1	N1	S1	NA	1
132	S2520 W30-W170	N1	S1	1	1	N1	S1	N1	S1	NA	1
133	S2180 W30-W170	N1	S1	1	1	N1	S1	N1	S1	NA	1

Notes: All accessible zones were assessed from December 2000 to January 2001.

Areas north of North-780 were reopened to support salt disposal. These areas were assessed for ground conditions, and scaling and bolting was performed as required.

The roof is assessed on a scale from 1 to 5, "1" being no low-angle fracturing noted, and "5" being low-angle fracturing extending the full length of the zone, with separation or pull away in evidence.

Vertical fracturing (horizontal and longitudinal) is rated from 1 to 5, with "1" being none observed, and "5" being close bolt-to-bolt fracturing.

Ribs are assessed on a scale of 1 to 3, with "1" being good intact ribs, and "3" showing uncontrolled (no mesh or bolts) spalling or sloughing of the surface.

The floor is assessed on a scale of 1 to 3, with "1" being a good intact floor with no fracturing or floor heave Present. A "3" represents a badly fractured or heaving floor.

Under the heading "Increased Closure Rate," a "Y" indicates that the measured closure rate at any Convergence point within the area has increased more than 5 percent for the annual period ending October 1, 2000, as compared to the annual period ending October 1, 1999.

Long-term projections are rated on a scale of 1 to 3. At a minimum, areas with a rating of "3" are formally reviewed quarterly, those with a "2" are reviewed semiannually, and those rated as "1" are reviewed annually.

Key:
- N - North half of zone
- S - South half of zone
- NA - Not applicable or not available
- E - East half of zone
- W - West half of zone

are seams of anhydrite and clay that have a significant impact on the stability of openings and the selection of ground control systems. All openings in the experimental horizon are closed and no longer accessible; therefore, any reference relative to this horizon is limited to historical perspective. Figure 2-2 shows the typical stratigraphy at the WIPP facility horizon.

It is recognized that localized geologic conditions can have a considerable impact on the stability of an opening. Fracture development at a specific location (e.g., within a roof beam) may be influenced by the clay content or other seemingly minor factors.

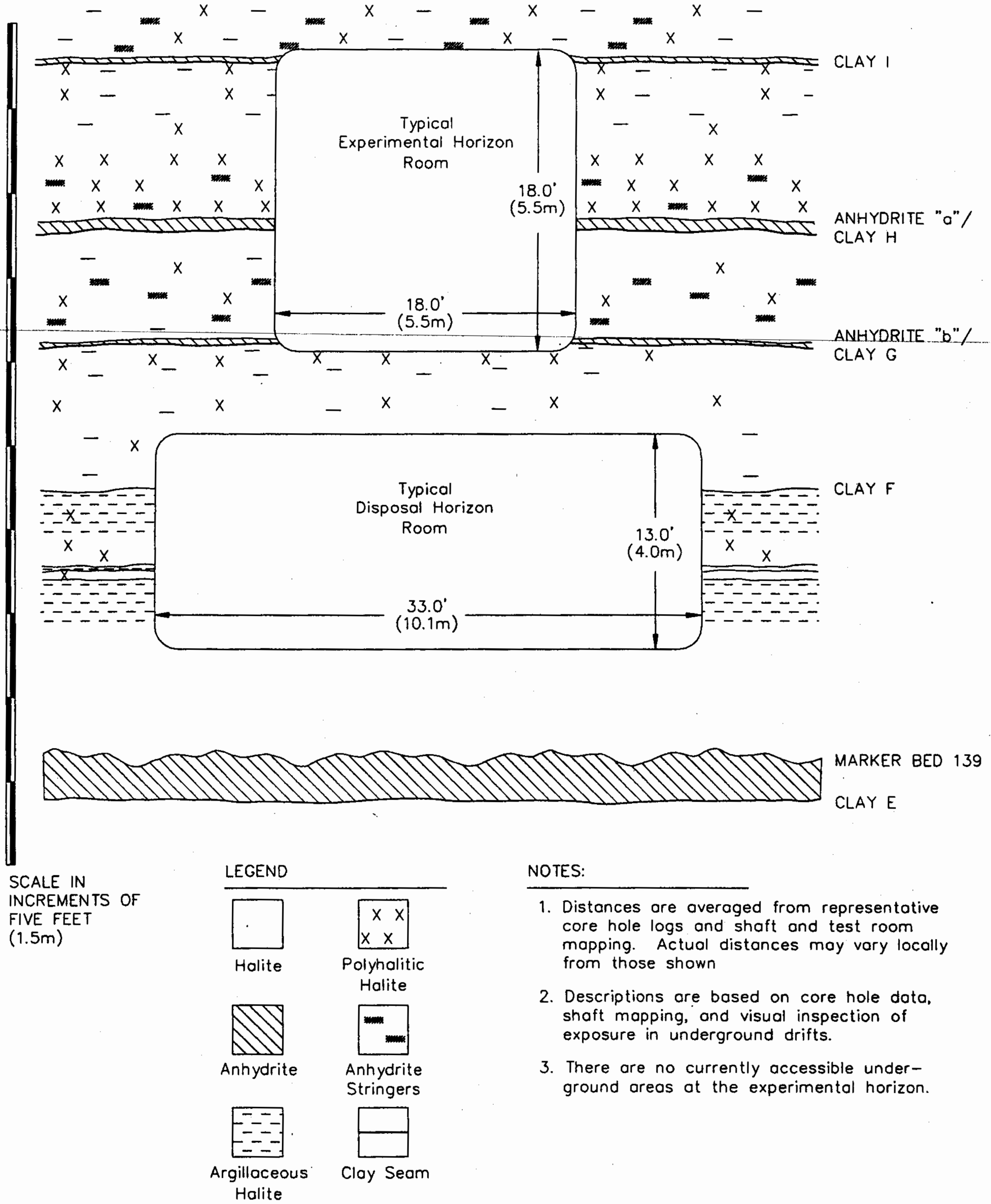
The stratigraphic location of the disposal rooms is within the disposal horizon. Over 90 percent of the underground openings are located within this horizon, and all ground control projections presented in this AGCOP are related to this level.

In relationship to Panels 1 and 2 with a 13-foot excavation height, Anhydrite "a" is located approximately 13 feet above the roof and is underlain by clay H, while Anhydrite "b" is located approximately 6.5 feet above the roof and is underlain by clay G. The clay layers provide surfaces along which movement can occur; whereas, the anhydrite layers are stiff units that do not creep. A 20-inch-thick to 32-inch-thick persistent bed of anhydrite, identified as Marker Bed 139 (MB 139), lies about 5 feet below the floor throughout Panels 1 and 2. Lateral variability in composition and thickness exists within this anhydrite bed at both repository and regional scales. MB 139 is underlain by clay E. The undulating top of MB 139 resists shear movement along the interface with the overlying salt [U.S. Department of Energy, 1993].

Current plans call for moving future disposal rooms up approximately 6.5 feet so the roof of a disposal room terminates at clay G. Figure 2-3 shows the new location of future storage rooms with respect to stratigraphy. The slip that occurs along the clay seam will allow the ribs of the excavation to creep inward without creating as much stress in the roof beam. Moving the disposal horizon up will also result in a greater barrier of salt between the floor of the room and MB 139. Panel 3 will be the first panel affected excavated at the new level. Ramping up to the new level beginning in the access drifts is required.

2.2 Opening Dimensions

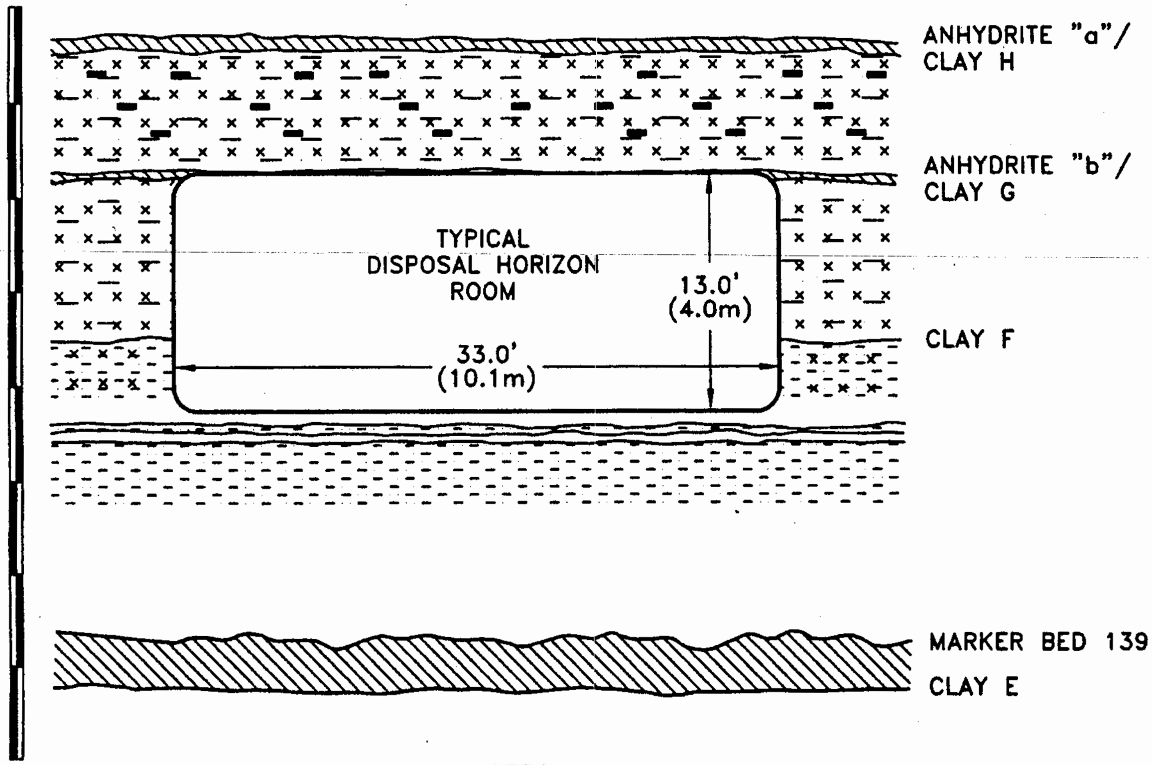
Most of the underground openings are rectangular in shape. The dimensions or cross-sectional areas of the various drifts, rooms, and alcoves in the underground differ, primarily, as a function of use. The geometry of an opening, the stratigraphic location of the opening, and the layout and geometry of surrounding excavations each play a role in

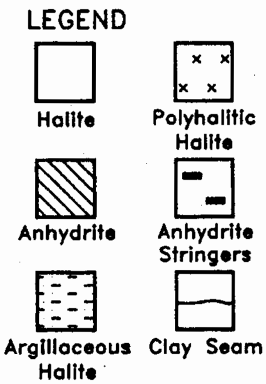


NOTES:

1. Distances are averaged from representative core hole logs and shaft and test room mapping. Actual distances may vary locally from those shown
2. Descriptions are based on core hole data, shaft mapping, and visual inspection of exposure in underground drifts.
3. There are no currently accessible underground areas at the experimental horizon.

Figure 2-2. Typical Stratigraphy at the WIPP Facility Horizon





NOTES:

1. Distances are averaged from representative core hole logs and shaft and test room mapping. Actual distances may vary locally from these shown.
2. Descriptions are based on core hole data, shaft mapping, and visual inspection of exposure in underground drifts.
3. There are no currently accessible under-ground areas at the experimental horizon.

Figure 2-3. Planned Stratigraphic Location of Future Waste Disposal Rooms.

the stability of that area. The opening dimensions of each zone are provided in Table 2-1. The dimensions listed are generally "as mined" and will vary slightly because of original mining tolerance; closure from the creep process; and maintenance activities, such as scaling and milling. Major changes to geometry, such as the roof beam removal in the East-140 Drift, are represented in annual updates to the tables.

A beam of salt is present between the roof of an excavation and the nearest anhydrite or clay seam above it. The height and stratigraphic location of the excavation determine the thickness of the beam. The structural relationship between the thickness of this beam and its width, its width being equal to the opening width, was evaluated. In general, the thicker and shorter a beam is, the more structurally competent it is.

It may be possible to mine some excavations to geometries that enhance their stability. However, localized geologic conditions will always be a factor in opening stability, and the future use of an area must be considered when designing its geometry.

2.3 Operational Use

Ground control plans are area specific and are influenced by operational as well as geotechnical requirements. The projected life of an area is also directly related to its use. Some areas may have to be supported for only a few years; other areas may require support for decades. In areas that require support for long periods of time, for example, the life of the facility, the support system will probably undergo several changes during that time. Table 2-1 lists the current use of each ground control zone.

2.4 Excavation Age

Excavation of the underground facility began in 1982, and over 60 percent of the existing openings were completed by the end of 1984. The average age of an opening is 15.5 years, with some openings being over 18 years old. Panel 2 and the associated haulage and ventilation drifts were recently completed and are less then 1 year old. Table 2-1 lists the age of each ground control area. The age of an excavation is important with respect to ground control because of the amount of deformation that has already occurred and the amount that is anticipated to occur during its projected life.

Some underground openings at WIPP (e.g., the main entries) must remain accessible for 50 years or longer. This life expectancy is based on 18 years since excavation and a 35-year operational life after receipt of waste. With this time frame in mind, support systems must be designed to accommodate creep-related deformation and to support the beam (if it becomes detached). Beam removal is also an option for long-life areas. The age of an

excavation at the time a support system is installed and the age of systems in place are factors that are considered when evaluating the long-term effectiveness of those systems.

2.5 Projected Life

Based primarily on its operational use and projections for receipt of waste, an estimated life was assigned to each underground zone. Three categories, short-term, intermediate, and long-term, were established for this purpose. These projections are an additional tool used in the ground control selection process. The criteria for these designations are:

- Short-Term (ST) — A projected life of less than 10 years. This designation includes waste disposal rooms.
- Intermediate (I) — A projected life of 10 to 15 years. Special use areas such as maintenance shops are included here. Shops will be required for the life of the facility, but because of creep-related closure, it is assumed that they may be relocated periodically.
- Long-Term (LT) — A projected life of up to 50 years or the life of the facility. This designation covers all areas critical to the long-term operation of the facility. Shaft stations, main ventilation drifts, and main access and haulage routes fall in this category.

These projections use the excavation date as a start time. If the current use of an area changes or receipt of waste is delayed significantly, designations for specific zones may be adjusted (e.g., a short-term area may change to an intermediate). Areas closed to access are designated as such and have no projected life. The closed areas can and have been reopened. These projections are unofficial and are used solely for the purposes set forth in this plan, primarily ground control planning. Table 2-1 lists the projected life of each zone.

2.6 Ground Conditions

Because salt is a rock that creeps when subjected to load, once an opening is made, a continuous process of deformation and associated fracturing is initiated that is the primary parameter affecting the condition of an excavation. The ground condition in turn is the primary parameter dictating the type of ground control measures that will be employed.

2.6.1 General Roof Beam Failure Mechanisms and Patterns

Roof beam conditions in general follow a predictable path of deterioration over time with the degree of degradation varying widely throughout the facility. Many areas have

remained very stable since their excavation, while low-angle fracturing and bed separation are observed in other areas. The strata interfaces (clay and anhydrite seams) do not provide much, if any, shear resistance, resulting in differential stresses and related strains developing above and below the seams. This differential movement concentrates the stresses in the beam and, with time, produces a stratigraphic offset in boreholes penetrating the seams, including rockbolt holes. Low-angle fractures develop from the ribs upward over the center of the room. They terminate where they reach a discontinuity in the stratigraphy, such as a clay seam. This fracture pattern is common in salt and potash mines and is illustrated in the *Long-Term Ground Control Plan* [Westinghouse Electric Corporation, 2000] and in the *Geotechnical Analysis Report for July 1996 — June 1997* [U.S. Department of Energy, 1998].

Once low-angle fractures on one side of a room are fully developed, movement of the beam may be primarily toward the low-angle fracture because it is the point of least resistance. A cantilever is formed that is wedged downward as it moves horizontally. Installed rockbolts have a tendency to cause a tensile fracture to develop along the thin edge of the wedge. As one end of the cantilever is forced down, tensile fractures may also develop along the top of the beam on the opposite side of the room. Observations made during the beam-removal activities in the East-140 Drift indicate that if separation at clay G occurs, that separation may be located near the upper terminus of the low-angle fracture as opposed to in the center of the drift.

The fracture mechanisms have proven to be consistent in areas experiencing advanced degradation of the roof beam. The monitored roof falls in SPDV Rooms 1 and 2 indicate that a detached section of a roof beam will be somewhat of a wedge shape. Observations of the fracture patterns exposed during the beam-removal process in the East-140 Drift confirm this mode of failure. Knowledge of the type of failure that can be expected in the roof beam aids in the design of ground support systems. For example, support systems designed to support the entire cross-sectional area of the roof beam are considered conservative based on a wedge-type failure. By following the installation procedure of ending the resin column approximately 1 foot above the clay seam as opposed to flush with the seam, it is anticipated that the bolts will be subjected to a less severe bend as a result of offset.

2.6.2 Panel 1

The ground conditions in Panel 1 follow a pattern similar to that observed in the areas of the East-140 Drift where the roof beam was removed. Low-angle fractures of varying degrees are observed in most areas. The installation of rockbolts has, in many instances,

resulted in the thin edge of the wedge associated with a cantilevered beam breaking with an associated vertical fracture that runs roughly parallel to the rib.

Table 2-3 depicts the total vertical and horizontal convergence at room center points for the Panel 1 rooms since their dates of excavation. As is illustrated in the table, total vertical convergence is over 3 feet in all of the panel rooms (over 4 feet in Room 1), and horizontal convergence is near 2 feet in all rooms. Because ground control measures have little or no effect on the creep process, convergence of this type will continue unabated until the openings are completely closed.

Table 2-3. Panel 1 — Total Vertical and Horizontal Closure

Room	Date of Excavation at Instrument	Excavation Completed to Final Dimensions	Total Vertical Closure as of Reporting Period[a] (in)	Total Horizontal Closure as of Reporting Period[a] (in)
Room 1	June 1986	August 1986	53.5	26.8
Room 2	January 1987	March 1988	38.6	23.4
Room 3	February 1987	March 1988	42.0	29.3
Room 4	February 1988	March 1988	41.0	30.9
Room 5	February 1988	March 1988	36.7	26.6
Room 6	February 1988	May 1988	39.1	23.8
Room 7[b]	March 1988	March 1988	39.0	22.3

(a) Data represents room center convergence points current though December 2000. Data compiled by MINEPLOT.EXE software [Westinghouse Geotechnical Engineering, 1998].

(b) Readings were taken as of October 16, 2000. Center points are no longer accessible because of waste emplacement.

As was expected, deformation rates in Panel 1 increased as a result of Panel 2 excavation. The greatest influence from Panel 2 mining has been observed in the southern half of the Panel 1 rooms and in the 1950 drift. Deformation rates in these areas initially increased; however, the rates are currently decreasing and are expected to level off at a rate above the pre-mining rate.

2.7 Support System Conditions

2.7.1 General

The ground support in most of the accessible areas underground consists of a combination of mechanical-anchor and threaded-bar rockbolts anchored above the first clay seam. Other than bolts that have noticeably failed, it is difficult, if not impossible, to tell what condition the remaining bolts are in. However, based on measured deformation and observed offset since their installation date, it can be surmised that a significant

number of the mechanical-anchor rockbolts of the original patterns are probably in material yield, are experiencing anchor slippage, or have failed. Bolts are replaced as they fail if determined necessary.

2.7.2 Panel 1

Various support systems have been installed in Panel 1 over a several-year time span. The types of systems and their installation dates are specified in Section 4.1.2 of this report. As in the other areas of the facility, it is difficult, if not impossible, to tell what condition the in-place bolts are in. However, based on measured deformation and observed offset since their installation date, a significant number of the rockbolts in the original patterns installed in Rooms 1 through 6 are probably in material yield, are experiencing anchor slippage, or have failed. Since the mechanical-anchor bolts installed in Room 7, South-1600, and South-1950 do not penetrate the first clay seam, they have not been exposed to the same degree of lateral and axial deformation as the bolts that do penetrate the clay seam.

The entire panel has been re-bolted with resin-anchored, threaded-bar bolts. The condition of these bolts will vary dependent on their date of installation, location, and method of installation. Excluding the mechanical bolts, the threaded bar installed in Room 1 is the oldest system in place in the panel. The yielding systems in Rooms 1 and 2 are no longer being de-tensioned and are behaving similar to non-yielding systems in other rooms of the panel. Bolts are being replaced as they fail as deemed necessary.

The bolts recently installed in Room 7 in conjunction with the cable lacing are the second pattern of threaded-bar bolts installed in the room. The rockbolt boreholes were oversized below the clay seam to allow for a larger amount of offset before the bolts are affected by lateral loading. In addition, the latest installations have the resin column terminated approximately 1 foot above the clay seam to allow for a less severe bend in the bolts once lateral loading begins.

Bolts will fail and require replacement as the panel ages. The rate of failure will increase dependent on the installation dates of the support systems. Based on the latest projected schedule and sequence for waste emplacement in the panel, many of the bolt failures will occur in areas that are filled and closed to access. No bolt replacement will be performed in those areas.

3.0 MONITORING AND EVALUATION

The RCRA permit for the WIPP states that "the geomechanical monitoring program at the WIPP facility is an integral part of the ground-control program. HWDUs, drifts, and geomechanical test rooms will be monitored to provide confirmation of structural integrity. Geomechanical data on the performance of the repository shafts and excavated areas will be collected as part of the geotechnical field-monitoring program. The results of the geotechnical investigations will be reported annually. The report will describe monitoring programs and the geomechanical data collected during the previous year."

The assessment and evaluation of the condition of WIPP excavations is an interactive, continuing process involving a wide variety of data. These evaluations can be as simple as the required daily visual site checks by personnel working in an area or as complex as the expert review of Room 1, Panel 1 [U.S. Department of Energy, 1991a]. The Geotechnical Engineering group gathers and evaluates data from various sources on a daily and weekly basis. A bimonthly underground geotechnical assessment report is prepared, as is the annual Geotechnical Analysis Report. An in-depth evaluation of all of the accessible underground is performed on an annual basis as part of the preparation of this plan. These evaluations are based on visual observations by Geotechnical Engineering personnel, analyses of instrumentation data, observation borehole data, and rockbolt failure patterns.

Special assessments are performed as needed. For example, assessments are performed to "clear" waste disposal areas for operations prior to emplacement. When this is done, limited areas are examined and evaluated and, if appropriate, approved for emplacement operations to proceed for a specific time period.

Remote monitoring of geotechnical conditions and ground support systems in selected closed locations (e.g., Room D) is also being performed. The monitoring continues to assist in evaluation of systems as they age and trend toward failure. It is intended that data from these zones will provide predictive information on ground falls in areas with installed roof-support systems. To date, there have been no roof falls or accelerations in closure rates in these areas.

3.1 Overall Geotechnical Evaluation Process

The RCRA permit further states that "the stability of an open panel excavation is generally determined by the rock deformation rate. The excavation may be unstable when there is a continuous increase in the deformation rate that cannot be controlled by the installed support system. The permittees will evaluate the performance of the excavation. These

evaluations assess the effectiveness of the roof-support system and estimate the stand-up time of the excavation. If an open panel shows the trend is toward adverse (unstable) conditions, the results will be reported to determine if it is necessary to terminate waste disposal activities in the open panel. This report of the trend toward adverse conditions in an open HWDU will also be provided to the Secretary of the New Mexico Environmental Department (NMED) within 5 working days of issuance of the report."

One of the more difficult aspects of ground control is determining and evaluating the criteria that dictate when ground control actions should be initiated. The identification of potential instabilities is essential to maintaining a safe underground environment. Ground control can be expensive and, in some instances, ground control measures can actually have an adverse effect on the in situ conditions (e.g., the breakup of a beam associated with installation of rigid bolts). Therefore, it is prudent to be as rigorous as possible in determining when to initiate ground control actions and what those actions should be. The process followed at WIPP includes evaluation of general categories of information. These categories include:

- Collection and analysis of geomechanical instrumentation data.
- Evaluation of the performance of installed ground support systems.
- Evaluation of physical observations.
- WIPP-specific experience.

Each category is evaluated independently and comparatively to the other categories. With respect to Panel 1 and the waste haulage routes leading to the panel, emplacement schedules must also be considered for logistic purposes. Criteria for corrective action are continually reevaluated and reassessed based on total performance to date. Actions taken are based on these analyses and planned use of the excavation.

Collection and Analyses of Geomechanical Instrumentation Data

Instrumentation data provide quantitative information on rock movement in and around an opening. Convergence and extensometer data are collected on a continuing basis. This information is plotted as displacement versus time and as rate of displacement versus time. These data are analyzed concentrating on trends in rates and changes in patterns as predictors of instability. For example, long-term data may indicate a consistent closure rate in a particular area of approximately 0.5 inch per year. A significant acceleration in this rate may be a warning sign of developing instability.

Evaluation of the Performance of Installed Ground Support Systems

Installed support systems are monitored for performance through various means. Visual inspections are performed on a regular, periodic basis. In most cases, one component of a system will show evidence of strain before failures are seen in a system. For example, it is typical to observe dimpling or cracking of bearing plates as support systems age before bolt or component failures. In addition, select support components may have instrumentation installed on them to assist in monitoring system integrity. When bolt or component failures occur, these are closely tracked, and the failed bolt or component is replaced when it is an active part of the installed ground support system in the area.

Bolt or component failures alone do not necessarily indicate an unstable situation. Because of the deformation process associated with creep, it is known that bolts will fail through time. The age of the in-place ground support, as well as the roof beam expansion rates and relative stratigraphic offset rates for the area of interest, must be considered when evaluating system performance. Knowledge of the mechanical properties of support system components and experience with the systems in the WIPP environment allows projection of how the system should perform under specific conditions. When a ground support system is performing in a manner inconsistent with what is expected, attention is increased.

Evaluation of Physical Observations

Physical observations generally include surface fractures, fractures within boreholes, offset in boreholes, spalling, and any other visually detectable behavior of the ground condition. Similar to the other data, anomalous behavior, such as accelerations in fracture development or increased slabbing, is an indicator of potential instability.

WIPP-Specific Experience

With 18 years of site-specific experience at the WIPP facility, many of the ground conditions observed are familiar. When such things as low-angle fracturing are first noticed, the geotechnical team knows what to expect in the future in that area. What ground control systems work well and how ground control affects ground conditions are also lessons learned that aid in the evaluation of current conditions.

3.2 Waste Disposal Area Evaluation And Acceptability

The process of determining acceptability of an area for waste emplacement operations and disposal involves an evaluation of projected geotechnical stability for an area for a specific period of time. As in other areas of the facility, roof stability is of primary interest, while rib and floor stability is secondary. Each determination considers performance of the underground excavation, the geomechanical instrument data, performance of any installed ground support, and physical observations. Expected overhead clearance and floor stability are also documented.

Acceptability of an area for waste emplacement is determined upon completion of the evaluation process. If the area is found to be acceptable, a time period is determined during which emplacement operations may proceed before another detailed, specific area acceptability evaluation is required. Present plans assume no more than two areas at a time will be cleared for emplacement and that acceptability periods will not exceed 1 year. Waste receipt rates will affect the size of the areas cleared (i.e., low waste receipt rates will result in smaller areas being cleared as acceptable for emplacement).

Geomechanical monitoring, support system monitoring, and physical observations will continue as long as physically possible during the waste emplacement operation. A reevaluation of an acceptable area will immediately be performed should conditions or data show unexpected behavior of the ground.

This evaluation process is common at the WIPP site. It supports planning and integration of operations processes relating to waste emplacement and room closure. This process is detailed in the document *Operational Guidance For Waste Disposal Area Acceptability And Closure* [Garcia, 1997].

3.3 Surface Observations by Geotechnical Engineering

A two-person team from Geotechnical Engineering performed a visual assessment of the underground facility during December and January of 2000 and 2001, respectively. The conditions of the roof, ribs, and floor were assessed in each ground control zone and were graded on a scale basis. For the purpose of these evaluations, lower numbers represent better conditions (i.e., "1" is better than "2"). The roof was evaluated with respect to low-angle fractures, scaling, and longitudinal or transverse vertical fractures, and then graded on a scale of 1 to 5. The ribs were evaluated on a scale of 1 to 3 based on their general condition, and it was noted if they had been mechanically scaled. The floor was evaluated with respect to heaving and fracturing and graded on a scale of 1 to 3. It was also noted if the floor had been milled. As a general rule, scaling and milling

activities remove small amounts of ground and are unlikely to have a significant effect on closure rates and the overall stability of the area.

For evaluation of the ribs, floor, and low-angle fractures in the roof, each zone was divided in half down its length. If an area was north-south running, an assessment of the east side and the west side was performed. An east-west running zone was evaluated on its north and south sides. A summary of these evaluations is given in Table 2-2.

The roof of an area was taken as a whole with regard to longitudinal or vertical fractures. A few vertical fractures may be an indicator of advancing deterioration, but they do not constitute reason for immediate remediation. Areas containing vertical fractures are closely monitored both mechanically and visually. The type and extent of these fractures will affect the ground control system chosen for a given area. An area with only a few longitudinal fractures could probably be supported with a standard bolt system; whereas, an area with extensive, connected fracturing, suggesting a breakup of the beam, might require a more extensive supplemental support system. The ratings of each zone with respect to fracturing are presented in Table 2-2.

Areas receiving higher numbers, based on the visual assessments, warrant closer monitoring. In these cases, the ground conditions are monitored more frequently, and additional instrumentation is installed when appropriate. At a minimum, areas with a long-term projection rating of "3" are formally reviewed quarterly, those with a "2" are reviewed semiannually, and those rated as "1" are reviewed annually. When it is determined that ground conditions have reached a point where a safety hazard could develop in the short term, mitigation actions are implemented.

3.4 Observation Borehole Data

The presence of horizontal offsetting (visible in boreholes) confirms lateral movements in the roof beam. Horizontal offsets occur in association with low-angle fractures and at clay seams. The greatest rate and magnitude of the observed offsets is near the ribs, and they generally decrease toward the longitudinal centerline of the room. Initially, the portion of the borehole from the collar to the offset moves toward the center of the excavation. It is not unusual for a highly fractured area to exhibit significant asymmetric lateral movement. For example, if low-angle fracturing on one side of the room extends to the first clay seam, the entire beam may move toward that side of the room.

A majority of rockbolt failures are related to the lateral movement of the roof beam. Most of the rockbolts at WIPP penetrate the first clay seam above the roof. Analysis of data

from observation holes, offset-load testing of rockbolts, borehole camera investigations, and overcoring of failed rockbolts assists in understanding the relationship of stratigraphic offsetting with rockbolt failure.

3.5 Geotechnical Instrumentation Data

The purpose of the geomechanical monitoring program is to provide in situ data to support continuing assessments of the behavior of the underground facilities. Specifically, the program provides:

- Early detection of conditions that could compromise operational safety.
- Evaluation of room closure that could affect operational performance.
- Guidance for design modifications and remedial actions.
- Data for interpreting the actual behavior of underground openings, in comparison with established design criteria.
- Data on which to base an accurate assessment of the mechanisms of deformation and fracturing that is taking place.
- Compliance requirements as specified in the Regulatory Permit Application.

Geotechnical data collected from each specific ground control zone are evaluated to determine if conditions exist which would warrant closer attention or possibly immediate attention from a ground control standpoint. For the long term, roof expansion rates, along with the expected life of a zone, are important criteria to be considered when selecting ground control measures for that area.

Manual and remote measurements of roof-to-floor and rib-to-rib closure are taken throughout the underground on a routine basis. In addition to closure data, extensometer data are also collected. Extensometer data, combined with information from observation holes, assist in the analyses of separations at clay seams and within salt beams (beam expansion). For the purpose of this document, a comparison of closure rates is performed annually. An increase in the closure rate does not necessarily indicate a problem but draws attention to that area and provides an additional data point for evaluation. A summary of this assessment is presented in Table 2-2; a "Y" (yes) indicates that the measured closure rate at any convergence point within the area has increased more than 5 percent for the annual period ending October 31, 2000, as compared to the annual period ending October 31, 1999.

3.6 Rockbolt Failure Data

Rockbolt failures have occurred throughout the underground facility. Initially, many of the failures were bolt head failures. The majority of current bolt failures are shaft failures associated with lateral movement at clay G in conjunction with tensile loading. In addition, the majority of the bolt failures previous to this year involved mechanical-anchor rockbolts, which were primarily related to their age, quantity, and date of installation with respect to date of excavation. However, systems employing threaded-bar bolts, particularly in Panel 1, are aging, and failures of these bolt types have increased and were involved in the majority of failures this year.

Observable rockbolt failures are recorded, and a database on failure locations and modes of failure is maintained. Much has already been learned from the analysis of past bolt failures, and as the information base increases, so does understanding of the failure mechanisms involved. Documentation and tracking of these failure patterns assist in short- and long-term ground control planning by highlighting problem areas. This system also provides a means by which to identify trends of bolt failures that may be correlated with installation methods, geometry, mining sequence, and other variables. Figure 3-1 presents a graphical representation of rockbolt failures by type. The overall reduction in bolt failures from 1995 to 1996 represented by the graph is primarily a function of area closures. The increase in total failures in Calendar Year 2000 is a function of age of installed systems, increased closure rate in Panel 1 as a result of Panel 2 excavation, and failed bolts that were included from newly reopened areas in the north end of the facility.

In addition to tracking the rockbolt failures, a limited rockbolt failure investigation program was implemented. Studies have also been undertaken to address corrosion and loading effects on the premature failure of support system components.

Extensive testing has been performed on the types of rockbolts and rockbolt material used at WIPP [Lucas, 1984; Deoras, 1992; Chua and Lovato, 1994; Stoller Corporation, 1995]. These tests were conducted to determine the failure mechanisms associated with premature bolt failures and conditions that contributed to those failures.

Testing was performed to evaluate the effects of corrosion and its relationship to premature failures. The test results indicated that corrosion did not play a major role in the early failure of bolts (e.g., bolts with a life span of 5 years or less). However, the mechanical-cyclic stress loads the bolts are exposed to while they are under high tensile load (that load sometimes being in excess of the bolts yield limit) result in fatigue failure.

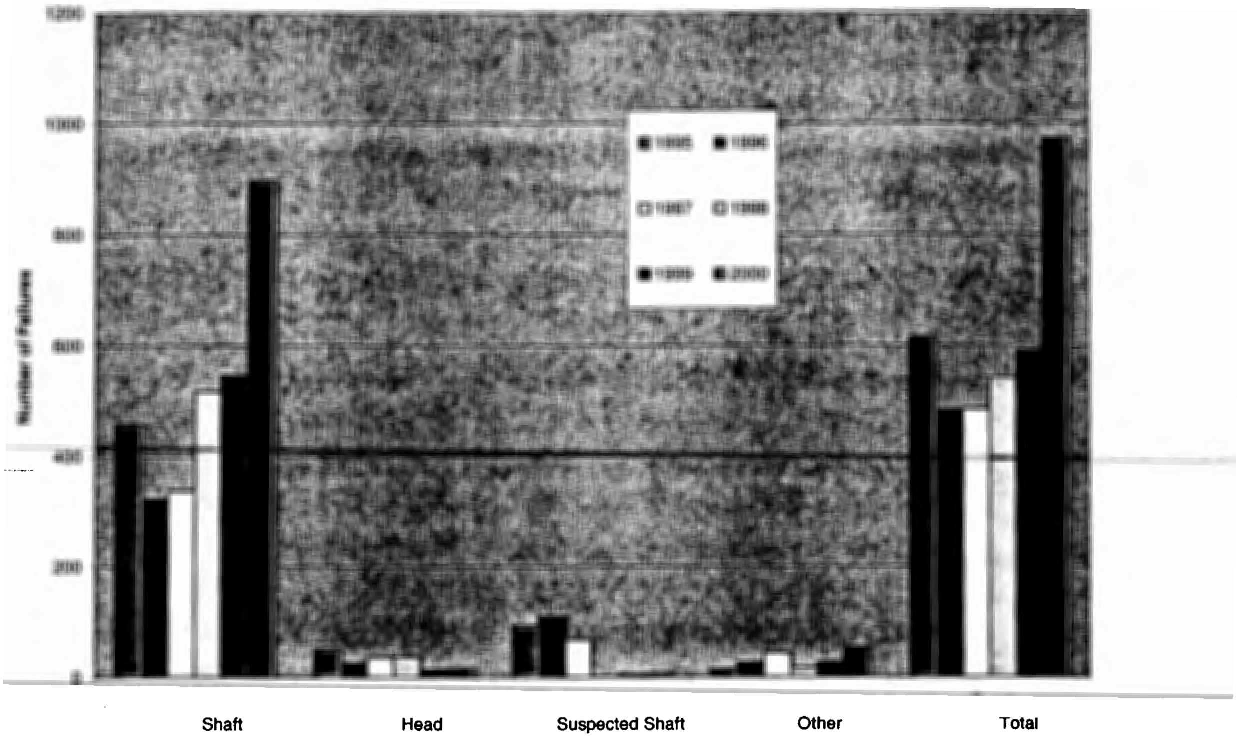


Figure 3-1. Rockbolt Failures by Type

A materials evaluation of the mechanical-anchor-type rockbolts and the threaded-bar rockbolts used at WIPP revealed that there was considerable variation in content; for example, carbon content, from bolt to bolt. The variability in content is within design specifications; however, each bolt may respond differently, to some degree, under similar loading conditions.

3.7 <u>Ground Support System Monitoring</u>

Instrument monitoring of ground support systems is also an integral aspect of the ground control program. Typical ground control instrumentation in use includes load cells, strain gages, and joint meters. Yielding components, such as load indicators, slipnuts, pipe collars, and yielding rockbolts, provide additional monitoring capabilities.

3.7.1 Load Cells

Load cells provide a quantitative measurement of the axial load on individual rockbolts or individual components of a ground support system. Load cells are installed on cable systems used to support brow areas at the Waste Shaft and Air Intake Shaft (AIS) Station areas and the East-0 overcast. Load cells are also installed on rockbolt support systems

in other areas of Panel 1, East-140, and in Room D. Load cells included in yielding support systems, such as the yielding cable bolt installations, monitor whether the systems are performing as intended (e.g., yielding at their designed loads).

3.7.2 Strain Gages

Supplemental bolt patterns were installed that incorporated systematic arrays of rockbolts equipped with strain gages. The strain gage data provide a variety of valuable information that includes evaluation of areal effects of creep-related closure loading on the ground control system, the ability to determine when the bolts reach their yield point, and comparison of strain gage data to load cell data.

3.7.3 Yielding Components

Yielding components, such as slipnuts, load indicators, pipe collars, and yielding cable bolts, are incorporated into several of the ground support systems in the facility. The primary purpose of these components is generally to allow for the system to yield with the creep-related deformation of the formation. However, because the components are designed to yield within specific load ranges, they also serve the function of providing an indication of the load on the system. These components are visually monitored to determine the rate and degree of yield on the system.

3.7.4 Joint Meters

The joint meters used at WIPP serve primarily as a geotechnical tool (i.e., to monitor fracture growth). However, a couple of meters have been incorporated into cable mesh support systems to monitor strain in the cables.

4.0 GROUND CONTROL OPTIONS

The end objective of each ground control option is to provide safe, geotechnically stable access for personnel and equipment. The options available to meet this objective involve providing internal support (e.g., bolts of various kinds), external support (e.g., cribs), or removing the roof beam. Closure of selected areas is an administrative choice in lieu of ground control options. Simply stated, these options are:

- Support the ground
- Remove the ground
- Close the area.

When evaluating these options, the criteria by which each option is judged include: the degree of safety provided, the support capacity of the system, ease of implementation, "life expectancy" of both the system and the area in which it is being implemented, economics, the impact of the chosen method on waste emplacement, and the waste emplacement schedule. It is important to appreciate the complexity of weighing these criteria relative to the differing conditions experienced throughout the facility. It is also important to understand that, although some of the options have no resource constraints, others may be difficult to implement at given times. (For example, current beam-removal activities were scheduled to follow excavation of Panel 2.)

The ground control program has produced an extensive database of information on ground control systems that are related directly to WIPP. Monitoring of installed supplemental systems continues to provide useful information for ground control system selection. In addition to in situ testing, laboratory testing is employed, as required, to evaluate alternative options for ground support.

4.1 Support Systems

With a few exceptions, all of the ground support in currently accessible areas of the underground is provided by internal systems. In general, internal support systems consist of pattern rockbolting. External support systems, such as cribs, have limited application at WIPP because of their operational constraints.

All normally accessible areas of the underground, except the South-90 electrical substation area, are currently rockbolted. Beginning in 1989, the entire facility was pattern bolted with mechanical-anchor rockbolts. Bolts 10 feet in length predominate, although some areas have been bolted with 5-foot, 6-foot, or 8-foot bolts. Within the mechanical rockbolt systems, a 5-foot × 2.5-foot triangular pattern is the most common in the WIPP underground.

More recent support system designs have focused on alternative types of rockbolts, primarily resin-anchored, threaded bar. Resin-anchored, threaded-bar bolts provide superior load-bearing capacity and ductility than the previously discussed mechanically anchored bolts. The threaded bars are anchored above the first clay seam to provide direct support of the roof beam and are commonly used in conjunction with mesh to contain smaller pieces of rock that may detach from the roof. The threaded-bar bolts may also be incorporated into a supplemental system of cable lacing or roof mats.

The primary purpose of pattern bolting is to support the roof beam or, more accurately, a portion of the roof beam, should it become detached as a result of fracturing. A variety of rockbolt patterns exists throughout the underground at WIPP. The design of the patterns is based on the width of the opening and the thickness of the roof beam. The effect of rock creep-related deformation on rockbolts creates a problem that is not common to standard ground support design practice.

Normally, a rockbolt pattern is designed so that the dead weight of the rock, with a factor of safety included, does not exceed the yield limit of the bolts. In rock such as halite, the mechanism of creep-related closure may put the bolts into yield as soon as 1 year after installation, regardless of the number of bolts installed. This may happen sooner if bolts are installed immediately after excavation, as the highest strain rates around a new opening are recorded immediately after the opening is excavated. These rates taper off to near steady state after approximately 1 year.

Creep also produces an offset of the strata at the first clay seam above the roof. The clay seam, with no inherent tensile strength, facilitates a separation between the roof beam and the strata above it. Different stress conditions above and below the seam produce differential strain rates, which result in an offset at the stratigraphic boundary. This offset eventually places a non-axial load on the bolts that reduce their axial load capacity. The creep-related parameter in support system design complicates the selection process. In addition to the dead weight of the material to be supported, roof expansion rates, installation time with respect to excavation date, offset, and bolt load/elongation properties must be considered in any support design.

Several types and combinations of specialized support systems are incorporated at specific locations within the underground. Some systems are monitored and provide performance information and some systems are designed for specific ground control applications. A variety of yielding systems are in place in the underground as small-scale and full-scale test emplacements. Cribs have been used to a limited extent in areas currently closed to access. Cribs have been placed at the perimeter of closed zones to limit the extent of a roof fall that may occur in areas where continued ground control activities are no longer being performed.

4.1.1 Brows

Brows throughout the facility are provided with supplemental support when there is visual evidence of separation. Wooden cribbing has been used in areas where access was not a problem. Roof mats and wire-rope cable systems are installed on some brows at shaft

stations and overcasts to provide additional support. Closure stations are installed on several brows to detect any acceleration in movement that may indicate a need for additional support.

4.1.2 Control of Broken Bolts

In high-use areas and areas where bolt breaking is being observed, Underground Operations provides a secondary attachment of the rockbolts to the roof. A lanyard (safety wire, cable, or chain) is installed on the rockbolt to prevent it from falling to the floor should it fail. Geotechnical Engineering is assisting Underground Operations in evaluating different techniques to secure broken bolts.

The failure of rockbolts in the underground is a common experience, averaging two to three a day. Because of the safety factor calculated into the ground support design, a substantial number of bolts would have to fail before the integrity of the system would come into question. Therefore, the failure of a rockbolt does not pose a hazard from a ground control standpoint. However, there is a potential hazard associated with personnel or equipment being struck by a falling bolt. Over the years, several different methods of controlling the falling bolts have been employed, with varying degrees of success. Methods used have included expanded metal wire mesh to hold the bolt in place and various lanyards made of wire, chain, or steel cable to catch a broken bolt. The wire mesh method made it difficult or impossible to identify when a bolt had failed. In most cases, the lanyards appear to work well and make identification and removal of a broken bolt relatively easy. A test matrix was developed to evaluate and document the performance characteristics of various lanyard systems. This test matrix included:

- Classification of installed lanyard systems according to physical characteristics (e.g., cable length and diameter).
- Classification of installed lanyard systems according to method of attachment (e.g., nailed to roof or attached to wire mesh).
- Performance tracking of in-place systems.

As a result of the field testing process, a lanyard system has been identified that produces excellent results for the control of broken bolts. The system consists of stainless steel wire rope, 7×19 strand core, 1/8 inch in diameter. The wire rope is configured to a length of approximately 18 inches with loops at each end that will snugly fit on a bolt head. The wire rope is passed through a cable thimble in the existing wire mesh and both loops are attached to the head of the bolt.

4.1.3 Panel 1

Rockbolt support was installed in Panel 1 in 1988 using a design based on the requirements for the demonstration program then prescribed. The original plan consisted of the storage of drums of contact-handled transuranic (CH TRU) waste in rooms for a period of 5 years. During this time and immediately following, the rooms were to be inaccessible, but the option to reenter was to be maintained so that the waste could be removed, if required. To assist with the possible reentry and to enhance stability, mechanically anchored rockbolts were installed. Ten-foot-long rockbolts were installed in Rooms 1 through 6, and 6-foot rockbolts were installed in Room 7, South-1600, and South-1950.

In 1991, a supplementary roof-support system was designed and installed in Room 1 to facilitate a planned bin-scale test program. A detailed description of the supplementary system is presented in *the Waste Isolation Pilot Plant Supplementary Roof Support System Underground Storage Area Room 1, Panel 1* [U.S. Department of Energy, 1991b]. Subsequently, additional ground support was installed in all of the Panel 1 rooms and drifts. Primary ground control activities in Panel 1 in the past year has been replacement of failed rockbolts. The roof-support history of Panel 1 is important because information on the age of the openings and when ground support was installed is vital to making predictions about future ground support requirements. A chronology of additional support systems and year of installation in Panel 1 is presented in Table 4-1.

Floor preparation is a planned activity in support of waste emplacement. Floors will be trimmed to provide a flat smooth working surface and to reestablish the appropriate working clearances. As an example, in the case of Room 7, more than 2 feet of floor was removed using the continuous miner. Removing this amount of material required a transition ramp down into the room.

4.2 Removal of the Roof Beam

The removal of the roof beam is not a support system but a mining alternative to ground support. The removal of the beam up to the next competent layer is considered when adequate support cannot be provided in a cost-effective manner or if removal of the beam will result in a safer working environment. In existing drifts with anticipated long lives, creep closure may ultimately require additional excavation to maintain operational clearance. Field results of the beam removal in the East-140 Drift proved this to be a viable alternative in areas of advanced beam deterioration. Observations, in the form of displacement measurements and fracture mapping, support the concept of removing the roof beam to enhance stability.

Table 4-1. Chronology of Panel 1 Ground Support

Year of System Installation	System Description	Area of Installation
1988	Ten-foot-long mechanical-anchor rockbolts	Rooms 1, 2, 3, 4, 5, and 6
1988	Six-foot-long mechanical-anchor rockbolts	Room 7, South-1600, and South-1950
1991	A layered support structure of welded wire mesh, expanded metal, channel steel, and threaded-bar bolts	All of Room 1
1992	Variation of Room 1 system	Parts of Room 2
1994	Supplemental system of 13-foot-long No. 7 threaded bar with full-load nuts	All of Room 7 and the South-1600 Drift
1994	Supplemental system of 13-foot-long No. 7 threaded bar with slip nuts	North half of Room 4
1994	Supplemental System of 12-foot-long No. 7 threaded bar with full-load nuts	All of Room 5
1995	Supplemental System of 12-foot-long No. 7 threaded bar with full-load nuts	South half of Room 4 and all of Room 6
1996	Supplemental system of 13-foot-long No. 7 threaded bar with full-load nuts	All of Room 3
1997	Cable slings (wire rope cables run from rib to rib)	Room 6 and Room 7
1997	Supplemental system of 13-foot-long No. 7 threaded bar with full-load nuts	South 1950 (except between Room 6 and 7)
1998	Wire rope lacing in conjunction with 13-foot-long No. 7 threaded bar with full-load nuts	Room 7 and South 1600 and 1950 between Rooms 6 and 7
1998	Cable slings	Center half of Room 5
1998	Cable slings	Center half of Room 4
1999	Cable slings	South 1600 Between Rooms 3 and 4
2000	Supplemental system of 12-foot-long No. 7 threaded bar with full-load nuts	South entry to Room 1
2000	Cable slings	Remaining areas of South 1600 between Rooms 1 and 6

Beam-removal actions at WIPP have been very successful in accomplishing their prime objective of removing highly fractured ground resulting in a competent roof requiring significantly less ground control maintenance activities. Monitoring results during beam removal in the East-140 Drift indicate that the newly created roof was geotechnically

stable and essentially fracture free. In addition, the beam-removal actions provided for operations and geotechnical opportunities that included the following:

- Documentation of removal techniques that prove that the roadheader can mine through threaded bars, bolts, and cable bolts without major difficulty.
- Mapping of roof-beam fracture patterns that confirmed failure modes and mechanisms.
- Observation and evaluation of in-place ground support as it was exposed, showing the reaction of various components to beam expansion and stratigraphic offset.
- Evaluation of the inherent stability of the fractured beam after support systems were removed, indicated by the fact no that roof falls were encountered during mining activity.
- Creation of a competent roof verified by extensometer data and physical observations.

Beam-removal operations are currently in progress in the East-0 Drift north of the salt-handling shaft.

4.3 Area Closure

Exercising the option to close an area instead of providing ground support involves administrative decisions as opposed to engineering solutions and, therefore, involves minimal labor and material costs relating to ground control. This option generally applies to areas that have reached the end of their useful life, or that, from an economical and/or safety standpoint, it is more prudent to close than to maintain. Closure of areas of the facility has been exercised in the past (e.g., all areas north of North-780). The option to close select areas of Panel 1 if safety becomes a concern was first formally noted in the *1994 Panel 1 Utilization Plan* [Westinghouse Electric Corporation, 1994] and remains viable.

Consideration must also be given to the logistics of reopening an area if reopening is anticipated. For example, areas north of North-780 were reopened to facilitate salt disposal during mining of Panel 2.

5.0 SUPPORT PROJECTIONS

Based on the opening assessments and projections made in Chapter 2.0, areas of concern are identified. They include areas that are operationally critical or exhibiting advanced deterioration as compared to other areas. Panel 1 is given special attention in

these projections because of its unique requirements with respect to waste emplacement and the waste emplacement schedule. Table 2-2 lists time projections for support requirements. (A "3" indicates that work is projected to be necessary within 1 year; a "2" indicates that work may be necessary within 5 years; and a "1" indicates that no work beyond normal maintenance is anticipated in the foreseeable future – within 5 years.)

In general terms, where reinforcing of existing support is required, a point-anchored, threaded-bar bolt pattern with full-load anchor nuts will be used to supplement the existing pattern. However, cable bolts may be used where the headroom or clearance in a drift is reduced to the point where bending or coupling of threaded bars would be required for installation. In critical areas where cantilevering or fracturing of the beam is observed, a roof mat system may be used, generally in conjunction with the roof-bolt system. If an opening is projected to be closed to access within a short time, mechanical bolts may be used to reinforce the existing support. New excavations will probably be pattern bolted after the initial high creep response has passed (usually 1 to 3 years after excavation, depending on the opening geometry and nearby excavation). Specific plans and layouts will be prepared and will be based on a detailed evaluation of each area.

5.1 Area Projections (Excluding Panel 1)

Following are tentative support projections for specific locations in the underground. These projections are intended to provide planning guidelines for future work. Detailed designs will be prepared as necessary for construction. These support recommendations are based on a continued need to access these areas (i.e., unused rooms will not be abandoned or backfilled).

5.1.1 East-0 and East-140 — North-150 to North-1400

This area was excavated over 15 years ago and has deteriorated to the point where it became necessary to install supplementary support, remove the highly fractured roof beam, or close portions of the area. From a technical standpoint, each option was acceptable to provide long-term safety. Removal of the roof beam in these areas has been approved and is in progress.

The beam is being removed up to and including Anhydrite "b" using a continuous mining machine. Based on current plans, the crosscuts at North-460, North-620, North-780, North-1100, and North-1400 will also have the beam removed.

5.1.2 Air Intake Shaft Station

The inspection of this area indicates that the upper brow appears to be stable at this time. The lower brow is developing separation fractures. Because the rockbolts in place are only 6 feet in length and do not penetrate the first clay seam, it may be necessary to provide additional support in the station area in the form of a supplemental bolt pattern that does penetrate the clay seam. This will probably be necessary within the next 1 to 3 years. Details include:

Bolts: Yielding cable bolts rated to yield at 45,000 pounds, 14 feet in length, in 1 3/8-inch × 14-foot holes.

Pattern: Split existing pattern

5.1.3 Air Intake North Access (North-300 and North-215)

Because of the development of low-angle fracturing in these drifts, it is projected that it may be necessary to re-bolt the area within 5 years. Projected details for the re-bolting project follow:

Bolts: No. 7 threaded bar with full-load nuts, 12 feet long, in 1 3/8-inch × 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch × 14-foot borehole.

Pattern: Split existing pattern

5.1.4 East-140 — North (North From the Waste Shaft Station)

<u>South-90 to South-400</u>

Increased fracturing in this area may require some supplemental support in the next 1 to 3 years. Projected details follow:

Bolts: No. 7 threaded bar with full-load nuts, 12 feet long, in 1 3/8-inch × 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch × 14-foot borehole.

Pattern: 5-foot × 5-foot nominal square pattern

Mesh: Chain link

South-90 to North-150

Increased fracturing in this area may require some supplemental support in the next 3 to 5 years. Projected details follow:

Bolts: No. 7 threaded bar with full-load nuts, 13 feet long, in 1 3/8-inch × 12.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch × 14-foot borehole.

Pattern: 5-foot × 5-foot nominal square pattern

Mesh: Chain link

5.1.5 East-140 — South (Access to Disposal Panels)

Roof beam removal was completed from South-1000 to South-1950 and the new roof remains in excellent condition.

South-400 to South-700

Increased fracturing in this area may require installation of supplemental support in the next 3 to 5 years. Projected details follow:

Bolts: No. 7 threaded bar with full-load nuts, 12 feet long, in 1 3/8-inch × 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch × 14-foot borehole.

Pattern: 5-foot × 5-foot nominal square pattern

Mesh: Chain link

South-1950 to South-2050

This area was re-bolted in 1998 using threaded bars concentrated in the drift center. However, fracturing in the area coupled with the load transfer resulting from mining in

Panel 2 and its entries may require some added supplemental support in the next 1 to 3 years. Projected details follow:

Bolts: No. 7 threaded bar with full-load nuts, 12 feet long, in 1 3/8-inch × 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam (installed in 1998 and to be maintained as primary support).

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch × 14-foot borehole.

Supplemental support as follows:

Mesh: Chain link

Strapping: Roof mats or cable slings on 5-foot to 6-foot intervals running from rib to rib

South-2050 to South-2180

This area may require some supplemental support in the next 1 to 3 years based on conditions and history in the adjacent areas as well as the potential for load transfer from the mining activities in Panel 2 and its entries. Projected details follow:

Bolts: No. 7 threaded bar with full-load nuts, 12 feet long, in 1 3/8-inch × 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch × 14-foot borehole.

Pattern: 5-foot × 5-foot nominal pattern concentrated along the drift center

South-2180 to South-2520

This area may require some supplemental support in the next 1 to 3 years based on conditions and history in the adjacent areas as well as the potential for load transfer from the mining activities in Panel 2 and its entries. Projected details follow:

Bolts: Mechanical-anchor rockbolts, 10 feet long.

Pattern: 5-foot × 5-foot nominal square pattern

Mesh: Chain link

A similar system of mechanical-anchor rockbolts may be used in the areas of East-300, West-30, and West-170 between South-2180 and South-2520.

5.1.6 Waste Shaft Station (East-140 to Waste Shaft)

Because of salt creep and loss of pattern bolts in this area, it is anticipated that the support system in place will need to be augmented within 1 to 3 years. A supplemental system consisting of pattern bolting with threaded-bar bolts may be employed. Details follow:

Bolts: No. 7 threaded bar with full-load nuts, 12 feet long, in 1-inch × 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Pattern: Split existing pattern

Mesh: None beyond the chain link already in place

5.1.7 Salt Shaft Station

The Salt Shaft Station had the roof beam removed approximately 12 years ago. The geotechnical monitoring in this area indicates that the roof has remained stable since that time. However, small vertical fractures have been observed and the current in-place rockbolts do not penetrate the existing roof beam. Because this is a high-use area, it may be prudent to install some additional bolts as a preventative maintenance measure within 3 to 5 years. The most likely supplemental support alternative would be to install No. 7 threaded-bar bolts through the existing chain link mesh.

5.1.8 West-30, South-1300 to South-1600

Because the pattern bolts in this area do not penetrate the beam, re-bolting of this area may be, but is not anticipated to be, necessary within 5 years. Support, if required, will be provided by splitting the existing pattern with threaded-bar bolts or yielding cable bolts. At the present time, continued observation is recommended.

5.1.9 West-30, South-90 to South-400

It is anticipated that some supplementary support will be necessary in this drift within a couple of years because of fracturing observed in the area. Projected details follow:

Bolts: No. 7 threaded bar with full-load nuts, 12 feet long, in 1 3/8-inch × 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch × 14-foot borehole.

Pattern: 5-foot × 5-foot nominal square pattern

Mesh: Chain link

5.1.10 West-30, South-1150 Booster Fan Area

Removal of the booster fans is planned for this area. The angled brows created during the installation of the fans are not typical of most brows at WIPP. It is planned that the brows will be reshaped with a mechanical scaler as necessary to form a more stable configuration. Rockbolts will be installed in the new brow and roof as required following removal of the booster fans.

5.1.11 South-1000 Crosscut Between West-30 and West-170

This is a high-use area and may require some supplemental support within 5 years. Projected details follow:

Bolts: No. 7 threaded bar, 12 feet long, in 1 3/8-inch × 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch × 14-foot borehole.

Pattern: 5-foot × 5-foot nominal square pattern

Mesh: Chain link

5.1.12 South-1300 Crosscut Between West-30 and West-170

This area was re-bolted with threaded-bar bolts approximately 1 year ago. However, this area is used as a mechanical shop and creep closure is limiting hoisting capabilities and overhead clearance. Beam removal for this area is being considered to eliminate these problems. The schedule for beam removal in this area is dependent on the schedule of ongoing beam removal operations.

5.1.13 South-1600 Crosscut Between West-30 and West-170

This area may require some supplemental support within the next 5 years. Projected details follow:

Bolts: No. 7 threaded bar, 12 feet long, in 1 3/8-inch × 11.5-foot holes reamed to 3 inches in diameter to approximately 1 foot beyond the first clay seam.

Alternatively: Use yielding cable bolts rated to 45,000 pounds, 14 feet long, in a 1 3/8-inch × 14-foot borehole.

Pattern: 5-foot × 5-foot nominal square pattern

Mesh: Chain link

5.2 Panel 1 Support Options and Plans

The schedule for the sustained rate of receipt, is a crucial parameter in making ground control decisions relative to Panel 1. Because of the age of the panel and the continuing deformation taking place, the timing of waste emplacement will affect the support requirements relative to each room. Ground control plans remain flexible with a long-term, conservative focus. The plans presented in this document are based on the most recent schedule and budget assumptions provided by the Department of Energy Carlsbad Field Office. Significant deviations in the anticipated schedule for receipt of waste can affect ground control preparation and other pre-disposal activities in two basic ways: (1) if the waste receipt schedule is accelerated, there may not be adequate time to install ground support systems as planned and (2) if the schedule is delayed, the ground control methods planned may not be adequate to sustain the ground without additional measures relative to the new time frame.

From a purely technical standpoint, the ability exists to maintain Panel 1 for waste emplacement for an indefinite period of time. However, the economics and potential operational impacts of this scenario may make it less desirable over time.

5.2.1 Panel 1 Support Options

With receipt of waste, ground control activities are integrally related to waste receipt schedules and related operational considerations. This section provides options for panel usage and the ground control alternatives required to implement those options. Evaluation of specific areas and recommendations for remedial ground control procedures must be made in a time frame that allows for implementation of those procedures prior to waste emplacement. Under all options, general maintenance activities, such as scaling down small pieces of rock and replacing identified broken bolts, would continue in all accessible areas. The identified options are:

- Use all of Panel 1.
- Use as much of the Panel 1 as possible.
- Move to Panel 2 as soon as possible.

In the case of several of the options and alternatives, significant overlap exists. For example, the current plan, consistent with the *1994 Panel 1 Utilization Plan* [Westinghouse Electric Corporation, 1994] and the subsequent 1996 update of that plan [Garcia, 1996] is to receive waste in Panel 1 and use as much of the area as possible. Portions of the panel may not be used or substantial efforts may be necessary to maintain the required ground control. A detailed description of options and alternatives can be found in the *Long-Term Ground Control Plan for the Waste Isolation Pilot Plant* [Westinghouse Electric Corporation, 1998].

5.2.2 Panel 1 Support Plans

Supplementary support is installed in most locations of Panel 1. (The now closed test alcoves and the entries to the panel are excluded.) The active support system in Room 7, including those portions of South-1600 and South-1950 east of Room 6, is a pattern of threaded bars installed through wire ropes laced together and covering a welded wire mesh grid. Similarly Rooms 3 through 6 and the South-1600 and South-1950 Drifts have patterns of threaded bars installed through welded wire mesh panels. Wire rope slings are installed in parts of Rooms 4 through 6. Most areas in Rooms 1 and 2 are bolted with threaded bars through steel channels with cable and mesh.

Numerous scenarios relating to ground response and waste receipt and emplacement rates have been considered to allow better planning and response to conditions that may be encountered. With some flexibility, it is believed that any developing instability or ground control problem can be addressed and safe operations maintained. Detailed plans address expected ground response, emplacement rates that allow filling of the panel by May 2002, as well as the possibility of schedule delays. By necessity these plans are specific, but remain flexible to better accommodate response to changing ground conditions, time constraints, resource availability, economics, and ground support technology improvements.

Room 7 Detailed Plans: This area is prepared to and is receiving waste. The floor was milled and the active support system was installed to provide maximum life with minimal maintenance during the waste disposal sequence. Given the current waste disposal schedule, no further support is planned for this area. The existing system should provide safe and adequate support for several years. However, if waste receipt is delayed or emplacement rate is slow, the existing system may be maintained by replacing broken bolts and adjusting the lacing. There are no plans to replace this system with another system. If delays are long or the waste emplacement rate slow, the system may be

further augmented by installing additional bolts through the cable lacing (e.g., cable bolts anchored above anhydrite "a"). If maintenance must be performed after waste is present, radiological safety will be a prime consideration in the operation.

Rooms 3 through 6 Detailed Plans: The existing systems will be maintained by replacing broken pattern bolts as necessary until near the time that a room is needed for waste disposal. In the months immediately prior to waste disposal in each room, the floor will be milled or mined to meet operational height requirements and a new bolt and roof mat support system will be constructed. The new system will incorporate existing components already in place (i.e., mesh and wire ropes) and new bolts. The roof mats will be run perpendicular to the room's longitudinal axis. It is planned that the roof mats will be supported with five threaded-bar bolts in the center and one mechanical-anchor bolt on each end. Timing of the construction is a function of waste receipt date and emplacement rates. If disposal rates proceed as expected, no further construction or maintenance should be necessary. If first receipt of waste is delayed substantially or if waste emplacement rates are retarded, it may be necessary to install some additional support prior to preparation for disposal or to consider mining the roof beam or closure of the room.

Rooms 1 and 2 Detailed Plans: The existing systems will be maintained by replacing broken bolts as necessary. This will continue until the room is needed for disposal. In the months preceding commencement of disposal operations in the room, the floor will be milled or mined; areas where a supplementary support system has not yet been installed will have a system similar to that described for Rooms 3 through 6, and excessively long bolt tails will be trimmed. A supplemental system may be installed to ensure stability with minimal maintenance during emplacement operations. As with other rooms, if first receipt of waste is delayed substantially or if waste emplacement rates are retarded, it may be necessary to install some additional support prior to preparation for disposal or to consider mining the roof beam or closure of the room.

5.3 Panel 2 Plans

At normal operating (waste throughput) rates, rock bolting in Panel 2 may only be required locally. Spot bolting using shorter mechanically anchored bolts will be used as necessary if spalls or loose ground are encountered during and after the mining process. Mesh may be used in conjunction with these bolts to secure any loose ground encountered during normal inspection processes. These bolts will not penetrate through to the next clay/anhydrite interface and will be anchored within the beam formed by the

mine roof and the clay/anhydrite interface above. This is the primary or initial support that will be used in Panels 2 through 8.

As deteriorating ground conditions require, pattern bolting may commence at any time after excavation. However, based on experience with the SPDV rooms and the rooms in Panel 1, pattern bolting is not expected to be required until 2 to 5 years after excavation. Disposal rooms may be pattern bolted prior to waste emplacement. Pattern bolting will be designed using the best support technology available at the time. This may include the use of yielding systems or other systems not currently available.

Supplemental support systems are not expected to be necessary in Panel 2. However, should a supplemental system be required, it is anticipated that its design may be similar to those installed and planned for Panel 1.

5.4 Long-Term, Low-Maintenance Areas

In general, the remaining areas of the underground facility are in good condition, and it is anticipated that only routine maintenance, which includes scaling and spot bolting, will be necessary to maintain them over the next 5 years.

6.0 SUMMARY STATEMENT

This document is used for planning purposes only. Ground conditions at WIPP are dynamic and, as such, projections for ground control actions as presented in this plan may change. The schedule for receipt of waste also affects the projections as presented. Significant delays in the receipt schedule would most likely result in significant changes to current ground control plans. Geotechnical Engineering evaluates a wide variety of current and historical geomechanical and observational data to formulate these projections.

7.0 REFERENCES

Chua, K. M. and J. M. Lovato, 1994. *Performance of Rock Bolts in Rock Salt: A Laboratory Evaluation*, Department of Civil Engineering, University of New Mexico, Albuquerque, NM.

Deoras, B. R., 1992. *Metallurgical Evaluation of Rock Bolts From the Waste Isolation Pilot Plant — WIPP Project*, Professional Service Industries, Pittsburgh Testing Laboratory Division, Pittsburgh, PA.

Garcia, J. J., 1996. *Transmittal of the 1996 Update to the 1994 Panel 1 Utilization Plan, WD:96:02147, Attachment: Panel 1 Utilization Plan 1996 Update*, Letter to E. K. Hunter, Department of Energy, Carlsbad Area Office, Carlsbad, NM, October 31.

Garcia, J. J., 1997. Garcia to Conway, *Operational Guidance For Waste Disposal Area Acceptability and Closure*, HA:97:2529, Waste Isolation Pilot Plant, Carlsbad, NM.

Holt, R. M. and D. W. Powers, 1984. *Geotechnical Activities in the Waste Handling Shaft, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico*, Westinghouse Electric Corporation, Waste Isolation Pilot Plant, Carlsbad, NM.

Lucas, J. P., 1984. *Analysis of Rock Bolt Material Failures at the WIPP Site*, SAND84-0224, Sandia National Laboratories, Albuquerque, New Mexico.

Stoller Corporation, 1995. *Corrosion Test Plans*, Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

U.S. Department of Energy, 1991a. *Report of the Geotechnical Panel on the Effective Life of Rooms in Panel 1*, DOE/WIPP 91-023, Waste Isolation Pilot Plant, Carlsbad, NM.

U.S. Department of Energy, 1991b. *Waste Isolation Pilot Plant Supplementary Roof Support System Underground Storage Area Room 1, Panel 1,* DOE/WIPP 91-057, Waste Isolation Pilot Plant, Carlsbad, NM.

U.S. Department of Energy, 1993. *Geotechnical Field Data and Analysis Report,* DOE/WIPP 93-019, Waste Isolation Pilot Plant, Carlsbad, NM.

U.S. Department of Energy, 1998. *Geotechnical Analysis Report for July 1996 — June 1997*, DOE/WIPP 98-3118, Waste Isolation Pilot Plant, Carlsbad, NM.

Westinghouse Electric Corporation, 1994. *1994 Panel 1 Utilization Plan,* WIPP/WID-94-2027, Waste Isolation Division, Carlsbad, NM.

Westinghouse Electric Corporation, 2000. *Long-Term Ground Control Plan for the Waste Isolation Pilot Plant*, WIPP/WID-96-2180/REV 4, Waste Isolation Division, Carlsbad, NM.

Westinghouse Geotechnical Engineering, 1998. MINEPLOT.EXE, Westinghouse Geotechnical Engineering Software Files, Waste Isolation Pilot Plant, Carlsbad, NM.

Enclosure 7

Majorana EPA

USQ Evaluation

Attachment 4 - USQ Safety Evaluation Worksheet

1. IDENTIFICATION

USQ Evaluation Log Number: **01-027**

Proposed Activity Number and Title (e.g., procedure number/title, ECP number/title, etc.)

Majorana Prototype Neutrino Detector (MPND) Double Beta Decay Experiment

Proposed Activity or Issue Description:

See Attached Project Description

Entry Condition: (More than one may be checked)

_____Facility Modification
_____Procedure Change
__X__ New Operation (Test or Experiment)
_____Potential Inadequate Safety Analyses (Discovery)
_____As-found Discrepancy Between Physical Configuration and TSRs (Discovery)
_____Other (Specify) ____________________

2. REFERENCE INFORMATION

(Provide detailed answers to the following and attach to this completed worksheet.)

A. Identify Systems, Structures, and Components (SSC) or process involved.
B. Identify the SAR and revision number used for the evaluation.
C. Where is the process or SSC described in the SAR?
D. Reference location of other information used for the USQ Determination (Drawing, ECOs, TSR references, procedures, etc.

USQ SAFETY EVALUATION

3. IMPACT ON THE ACCIDENTS EVALUATED IN THE SAFETY ANALYSIS REPORT

(Provide detailed answers to the following and attach to this completed worksheet.)

A. Identify the applicable SAR accidents reviewed for potential impact by the change. (SAR Chapter 5 accidents)
B. Identify the applicable SAR event trees in Appendix D, "Determination of Frequency for Selected Accidents" corresponding to the identified accidents.
C. Discuss the impact of the change on the probability of occurrence of these accidents. (Change to basic event logic, initiating event logic, fault tree probability, life cycle estimates, etc.)
D. Identify the applicable SAR tables in Appendix E, "Source Term/Dose Calculations," corresponding to the identified accidents
E. Discuss how the parameters and SSC affected by the change impact the consequences of these accidents (change the waste volume, magnitude of accident, material at risk, damage ratio, different release point, etc.).

Safety Evaluation Log Number __01-027____

4. IMPACT ON EQUIPMENT IMPORTANT TO SAFETY

(Provide detailed answers to the following and attach to this completed worksheet.)

A. Determine if the proposed change or issue impacts the Waste Hoist Brake System (If this answer is no question 4B is not applicable).
B. Determine if the proposed change or issue creates a failure mode not previously evaluated in the SAR (SAR Appendix C and DOE/WID-96-2178).

5. POTENTIAL FOR CREATION OF A NEW TYPE OF UNANALYZED ACCIDENT

(Provide detailed answers to the following and attach to this completed worksheet.)

A. Identify potential initiating events resulting from the change which could result in the release of radioactive material. (Will the change or activity be in the proximity of the waste container? Does it affect the waste handling process? Consider changes which may indirectly affect the waste (e.g, placing compressed gas cylinders in waste handling areas which could become missiles).
B. Determine if the impact of this change could result in a new type of initiating event not previously identified (review the "hazard analyses" - SAR Chapter 5, SAR Appendix C, and FHA).
C. Determine whether the hazards resulting from the impact of the change could be considered a new type of accident. (What would the hazard rank of the event be? Could the new event be bound by the existing accidents? What is the probability of the event occurrence?)

SUMMARY QUESTIONS
(Indicate yes, no, or n/a for each)

YES	**NO**		Based on 3C above, does the change increase the probability of a SAR accident?
YES	**NO**		Based on 3E above, does the change increase the consequences of a SAR accident?
YES	NO	**N/A**	Based on 4B above, does the change create the possibility for a different type malfunction of equipment important to safety than previously in the SAR?
YES	**NO**		Based on 5C above, does the change create the possibility for a new type of accident not previously evaluated in the SAR?
YES	**NO**		Does the change require a TSR Change?

EVALUATION RESULTS

YES	**NO**	Does the proposed activity/issue result in a USQ or TSR change? (If the answer to any of the above summary questions is "yes," the change requires DOE approval)

Attachment 4 - USQ Safety Evaluation Worksheet

Safety Evaluation Log Number __01-027____

COMPLETION		
Evaluator: Dennis A. Hofer	On file	10/4/01
Printed Name	Signature	Date
Safety Analysis Independent Review: Concurrence Yes X☐	No ☐	
Justification:		
Mike Carter 10/08/01	On file	
Printed Name	Signature	Date
Safety Analysis Manager: Approval X☐	Disapproval ☐	
Carl Ortiz 10/08/01	On file	
Printed Name	Signature	Date
NRB: Concur ☐	Nonconcur ☐	
Describe Action Required:		
Printed Name	Signature	Date

Enclosure 8

Majorana EPA

USQ Attachment

Attachment to USQ Safety Evaluation Number: 01-027

1. Proposed Activity or Issue Description:

The Pacific Northwest National Laboratory (PNNL) proposes to assemble a small Neutrino double beta decay detection experiment at the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico called Majorana. Such measurement will provide important input for our understanding of neutrino transformation and neutrino properties such as rest mass and particle/antiparticle relationship. See attached Project Description.

2. Reference Information:

1. The SSC involved is the underground Q Room Alcove off of the West 170 drift in the S90 drift at approximately W850, the Room Q south alcove area.
2. This is a new experiment not related to the Waste Handling process and is therefore not described in the SAR.
3. SAR Chapter 5 and Appendix C Hazop Session Summary.

3. Impact on the Accidents Evaluated in the Safety Analysis Report:

A Reviewed Chapter 5 and Appendix C Hazop Session Summary. Chapter 5 accidents in the SAR (reviewed section 5.2.3) relate to the waste handling process and this experiment is not related to this process and has no potential impact to SAR Chapter 5 accidents.

B. SAR Appendix D Because this experiment is not related to the CH waste processes it has no potential impact on SAR Chapter 5 accidents.

C. This experiment will be performed in one location, in the Underground Q Room Alcove at S90/W850 which is about 3000 feet from the waste. Additionally, the experiment will be located in the return Mine Operations ventilation split which is separated from the waste ventilation. Therefore, the proposed activity will not increase the probability of occurrence of SAR Chapter 5 accidents.

D. This experiment will not alter any source term or dose calculations as it is not related to waste handling and does not have any radioactive components other than small (1 inch) encapsulated calibration sources.

E. This experiment can not impact the consequences of these accidents (change the waste volume, magnitude of accident, material at risk, damage ratio, different release point, etc.) because it is not related to or located near the waste handling process.

5. Potential for Creation of a New Type of Unanalyzed Accident

A. There are no potential initiating events resulting from this experiment which could result in the release of radioactive material. This is because the experiment has no radioactive material involved. .This experiment will be performed in one location, in the Underground Q Room Alcove at S90/W850 which is about 3000 feet from the waste and will not be in the proximity of any waste container. It does not affect the waste handling process. Nothing about this experiment may indirectly affect the waste (e.g, placing compressed gas cylinders in waste handling areas which could become missiles).

B. This experiment can not result in a new type of initiating event not previously identified because it is unrelated to the waste handling process and contains no radioactive material other than small (1 inch) encapsulated calibration sources.

C. There are no hazards resulting from the impact of the change which could be considered a new type of accident. The standard industrial hazards associated with handling of lead bricks and liquid nitrogen are discussed and mitigated in section five of the attached project description.

Enclosure 9

Majorana EPA

NEPA Checklist

Environmental Review

DOCUMENT NAME: Project Description for the TUNL Majorana Project (Test Plan, Engineering Document, Etc.)	DOCUMENT No. N/A (If available)

DESCRIPTION: (Identify the type of work or action required, location, schedule, justification. Use separate attachment if necessary)

The Triangle Universities Nuclear Laboratory (TUNL) Phase 1 of the Majorana Project is a multi-faceted experiment whose purpose is to investigate double-beta decay using two High-Purity Germanium (HPGe) detectors. Phase 1, to be continued at WIPP over the next two years, continues the study of Molybdenum-100 and eventually beginning the study of another isotope (Selenium-82, Zirconium-96, Tellurium-130, Xenon-136, or Neodymium-150). See attached Project Description.

ENVIRONMENTAL CONCERNS: Will the project/activity, either during construction or operations result in changes and/or disturbances in the following areas? Check "YES" of the proposed project/activity represents a commitment to a course of actions that would ultimately require a positive response to one or more of the questions below. Provide explanations for "YES" responses using the guidelines for completion of the Environmental Review Form contained in Attachment 3.

		YES	NO			YES	NO
1.	Air emissions	[ ]	[x]	12.	Outside property protection area	[ ]	[x]
2.	Liquid effluents	[ ]	[x]	13.	Archaeological/cultural resources	[ ] ~~[x]~~	[X] 8/30/00 DAH
3.	Solid waste	[x]	[ ]	14.	Noticeable increase in noise	[ ]	[x]
4.	Hazardous constituents	[x]	[ ]	15.	Radiation/toxic chemical exposures	[ ]	[x]
5.	Radioactive waste	[ ]	[x]	16.	Pesticide/herbicide use	[ ]	[x]
6.	Mixed waste (rad. & haz.)	[ ]	[x]	17.	High energy source/explosives	[x]	[ ]
7.	Chemical storage/use	[ ]	[x]	18.	Transportation issues	[ ]	[x]
8.	Petroleum use/storage	[ ]	[x]	19.	Special status species/environment	[ ]	[x]
9.	Asbestos materials	[ ]	[x]	20.	Environment restoration site	[ ]	[x]
10.	Utility system	[ ]	[x]	21.	Other (specify)	[ ]	[x]
11.	Clearing or excavation	[ ]	[x]				

No.	Explanation and qualification of specific "YES" responses. Use a separate attachment if necessary to explain responses.
3	Copper wire ends, wire insulation and scraps of metal and cable. Proper disposal and containment is required. Scraps will be sent to an approved land fill. or be recycled per WIP procedure DLR 9/11/00
4	Methanol. Ethanol or lead contaminated rags. Request the creation of a Satellite Accumulation Area for this type of waste stream. Proper disposal and containment is required.
17	Liquid Nitrogen Canisters. Trained personnel will follow proper handling procedures in accordance with section 3.0 of WP 12-IS.01.

Are any waste minimization measures planned for this action? If "YES", provide brief description of the measures planned.

DENNIS A Hofer	Dennis A. Hofer	8/30/00
CI Printed Name	Signature	Date
D.C. ROBERTSON	[signature]	9/11/00
WID NEPA Coordinator	Signature	Date
Land Use Coordinator Printed Name (Required only if items 12, 13, and/or 20 are checked "YES")	Signature	Date

PER DISCUSSIONS WITH HAROLD JOHNSON THE CAO NEPA COMPLIANCE OFFICER, PHASE I OF TUNL MAJORANA PROJECT IS COVERED BY A CX. CX DOCUMENTATION IS ATTACHED

Enclosure 10

Majorana EPA

Record of Categorical Exclusion Determination

RECORD OF CATEGORICAL EXCLUSION DETERMINATION

The proposed action is construction of a prototype unit for detecting double beta decay of molybdnum using two germanium detectors, cooled by liquid nitrogen, and housed in an enclosure constructed of lead bricks. The experiment would be located in the S90 drift at approximately W850 in the Room Q alcove. Additional description of the project is contained in the attached USQ safety evaluation sheet.

B3.6 Siting/construction/operation/decommissioning of facilities for small scale research and development and pilot projects

Regulatory Requirements in 10 CFR 1021.410(b): (See full text in regulation)

(1) The proposed action fits within a class of actions that is listed in Appendix A or B to Subpart D

For classes of actions listed in Appendix B, the following conditions are integral elements: i.e., to fit within a class, the proposal must not:

(1) Threaten a violation of statutory, regulatory, or permit requirements for environment, safety and health, including DOE and/or Executive Orders
(2) Require siting, construction or major expansion of waste storage, disposal, recovery, or treatment facilities, but may include such categorically excluded facilities;
(3) Disturb hazardous substances, pollutants, contaminants, or CERCLA-excluded petroleum/natural gas products that pre-exist in the environment such that there would be uncontrolled or unpermitted releases; or
(4) Adversely affect enivornmentally sensitive resources (including but not limited to those listed in paragraph B.(4).[2]

(2) There are no extraordinary circumstances related to the proposal that may affect the significance of the environmental effects of the proposal; and
(3) The proposal is not "connected" to other actions with potentially significant impacts, is not related to other actions with cimulatively significant impacts, and is not precluded by 40 CRF 1506.1 or 10 CFR 1021.211

Determination:

Based on my review of information conveyed to me and in my possession concerning the proposed action, as NEPA Compliance Officer (as authorized under DOE Order 451.1A), I have determined that the proposed action fits within the specified class of actions, the other regulatory requirements set forth above are met, and the proposed action is hereby categorically excluded from further NEPA review-

Harold Johnson 9/18/2000

Signature Date

NEPA Compliance Officer, Carlsbad Area Office

Attachment:

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[1] May be incorporated in its entirety into other enviromental review records.
[2] All reviews and discusssions supporting the "not adversely affect" determination have been completed.