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**RENEWAL APPLICATION
APPENDIX I1**

**DETAILED DESIGN REPORT FOR AN OPERATION PHASE PANEL CLOSURE
SYSTEM**

Adapted from DOE/WIPP 96-2150

Waste Isolation Pilot Plant
Hazardous Waste Facility Permit
Draft Renewal Application
May 2009

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**RENEWAL APPLICATION
APPENDIX I1**

**DETAILED DESIGN REPORT FOR AN OPERATION PHASE PANEL CLOSURE
SYSTEM**

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List of Abbreviations/Acronyms

| | | |
|----|--------|---|
| 1 | | |
| 2 | | |
| 3 | ACI | American Concrete Institute |
| 4 | AISC | American Institute for Steel Construction |
| 5 | *CFR | Code of Federal Regulations |
| 6 | cm | centimeter |
| 7 | °C | degrees celsius |
| 8 | °F | degrees Fahrenheit |
| 9 | DOE | U.S. Department of Energy |
| 10 | DRZ | disturbed rock zone |
| 11 | EEP | Excavation Effects Program |
| 12 | ESC | expansive salt-saturated concrete |
| 13 | FLAC | Fast Lagrangian Analysis of Continua |
| 14 | ft | foot (feet) |
| 15 | GPR | ground-penetrating radar |
| 16 | Kips | 1,000 pounds |
| 17 | m | meter(s) |
| 18 | MB 139 | Marker Bed 139 |
| 19 | MOC | Management and Operating Contractor (Permit Condition I.D.3) |
| 20 | MPa | megapascal(s) |
| 21 | MSHA | Mine Safety and Health Administration |
| 22 | NMAC | New Mexico Administrative Code |
| 23 | NMED | New Mexico Environment Department |
| 24 | NaCl | sodium chloride |
| 25 | NMVP | no-migration variance petition |
| 26 | psi | pound(s) per square inch |
| 27 | RCRA | Resource Conservation and Recovery Act |
| 28 | SMC | Salado Mass Concrete |
| 29 | TRU | transuranic |
| 30 | VOC | volatile organic compound(s) |
| 31 | WIPP | Waste Isolation Pilot Plant |

1 **RENEWAL APPLICATION**
2 **APPENDIX I1**

3
4 **DETAILED DESIGN REPORT FOR AN OPERATION PHASE PANEL CLOSURE**
5 **SYSTEM**

6
7
8 Executive Summary

9 **Scope.** Under contract to the Management and Operating Contractor (**MOC**), IT Corporation
10 has prepared a detailed design of a panel-closure system for the Waste Isolation Pilot Plant
11 (**WIPP**). Preparation of this detailed design of an operational-phase closure system is required
12 to support a Resource Conservation and Recovery Act (**RCRA**) Part B permit application. This
13 report describes the detailed design for a panel-closure system specific to the WIPP site. The
14 recommended panel-closure system will adequately isolate the waste-emplacement panels for at
15 least 35 years.

16
17 The report was modified to make it a part of the RCRA Permit issued by the New Mexico
18 Environment Department (**NMED**) on October 27, 1999. The primary change required in the
19 original report was to specify that Panel Closure Design Options A, B, C and E are not approved
20 as part of the facility Permit. Option D is the most robust of the original group of options, and it
21 was specified in the Permit as the design to be constructed for all panel closures. The concrete to
22 be used for panel closures is salt-saturated Salado Mass Concrete as specified in Renewal
23 Application Appendix I1G, instead of the proposed plain concrete. The Permittees may submit
24 proposals to modify the Permit (Module II), the Closure Plan (Renewal Application Chapter I)
25 and this Appendix (identified as Renewal Application Appendix I1) in the future, as specified in
26 20.4.1.900 NMAC (incorporating 40 CFR §270.42).

27
28 Other changes included in this version of the report revised for the permit are minor edits to
29 regulatory citations, deletion of references to the No Migration Variance Petition (no longer
30 required under 40 CFR 268.6), and movement of all figures to the end of the document.
31 Appendices A through F in the original document are not included in this Renewal Application
32 Appendix. ~~Although those Appendices were important in demonstrating that the panel closures~~
33 ~~will meet the performance standards in the hazardous waste regulations, they do not provide~~
34 ~~design details or plans to be implemented as Permit requirements. References to these original~~
35 ~~Appendices were modified to indicate that they were part of the Permit application, but are not~~
36 ~~included in the Permit. In contrast, Appendix G (Technical Specifications) and, Appendix H~~
37 ~~(Design Drawings) are necessary components of future activities and are retained as parts of this~~
38 ~~Renewal Application Appendix.~~

39
40 **Purpose.** This report provides detailed design and material engineering specifications for the
41 construction, emplacement, and interface-grouting associated with a panel-closure system at the
42 WIPP repository, which would ensure that an effective panel-closure system is in place for at
43 least 35 years. The panel-closure system provides assurance that the limit for the migration of
44 volatile organic compounds (**VOC**) will be met at the point of compliance, the WIPP site

1 boundary. This assurance is obtained through the inherent flexibility of the panel-closure
2 system. The panel-closure system will be located in the air-intake and air-exhaust drifts (Figure
3 I1-1). The system components have been designed to maintain their intended functional
4 requirements under loads generated from salt creep, internal pressure, and a postulated methane
5 explosion. The design complies with regulatory requirements for a panel-closure system
6 promulgated by RCRA and the Mine Health and Safety Administration (**MSHA**). The design
7 uses common construction practices according to existing standards.
8

9 **Background.** The engineering design considers a range of expected subsurface conditions at the
10 location of a panel-closure system. The geology is predominantly halite with interbedded
11 anhydrite at the repository horizon. During the operational period, the panel-closure system
12 would be subject to creep from the surrounding host rock that contains trace amounts of brine.
13

14 During the conceptual design stage, two air-flow models were evaluated: (1) unrestricted flow
15 and (2) restricted flow through the panel-closure system. The "unrestricted" air flow model is
16 defined as a model in which the gas pressure that develops is at or very near atmospheric
17 pressure such that there exists no back pressure in the disposal areas. Flow is unrestricted in this
18 model. The "restricted" air flow model is defined as a model in which the back pressure in the
19 waste emplacement panels develops due to the restriction of flow through the barrier, and the
20 surrounding disturbed rock zone. The analysis was based on an assumed gas generation rate of
21 8,200 moles per panel per year (0.1 moles per drum per year) due to microbial degradation, an
22 expected volumetric closure rate of 28,000 cubic feet (800 cubic meters) per year due to salt
23 creep, the expected headspace concentration for a series of nine VOCs, and the expected air
24 dispersion from the exhaust shaft to the WIPP site boundary. The analysis indicated that the
25 panel-closure system would limit the concentration of each VOC at the WIPP site boundary to a
26 small fraction of the health-based exposure limits during the operational period.
27

28 **Alternate Designs.** Various options were evaluated considering active systems, passive
29 systems, and composite systems. Consideration of the aforementioned factors led to the
30 selection of a passive panel-closure system consisting of an enlarged tapered concrete barrier
31 which will be grouted at the interface and an explosion-isolation wall. This system provides
32 flexibility for a range of ground conditions likely to be encountered in the underground
33 repository. No other special requirements for engineered components beyond the normal
34 requirements for fire suppression and methane explosion or deflagration containment exist for
35 the panel-closure system during the operational period.
36

37 The panel-closure system design incorporates mitigative measures to address the treatment of
38 fractures and therefore minimizes the potential migration of contaminants. The design includes
39 excavating the disturbed rock zone (**DRZ**) and emplacing an enlarged concrete barrier.
40

41 To be effective, the excavation and installation of the panel-closure system must be completed
42 within a short time frame to minimize disturbance to the surrounding salt. A rigid concrete
43 barrier will promote interface stress buildup, as fractures are expected to heal with time. For this
44 purpose, the main concrete barrier would be tapered to reduce shear stress and to increase
45 compressive stress along the interface zone.

1
2 **Design Classification.** Procedure WP 09-CN3023 (Westinghouse, 1995a) was used to establish
3 a design classification for the panel-closure system. It uses a decision-flow-logic process to
4 designate the panel-closure system as a Class IIIB structure. This is because during the methane
5 explosion the concrete barrier would not fail.

6
7 **Design Evaluations.** To investigate several key design issues, design evaluations were
8 performed. These design evaluations can be divided into those that satisfy (1) the operational
9 requirements of the system and (2) the structural and material requirements of the system.

10
11 The conclusions reached from the evaluations addressing the operational requirements are as
12 follows:

- 13
14 • Based on an air-flow model used to predict the mass flow rate of carbon tetrachloride
15 through the panel-closure system for the alternatives, the air-flow analysis suggests that
16 the fully enlarged barrier provides the highest protection for restricting VOCs during the
17 operational period of 35 years.
- 18
19 • Results of the Fast Lagrangian Analysis of Continua (**FLAC**) analyses show that the
20 recommended enlarged configuration is a circular rib-segment excavated to Clay G and
21 under MB 139. Interface grouting would be performed at the upper boundary of the
concrete barrier.
- 22
23 • The results of the transverse plane-strain models show that higher stresses would form in
24 MB 139 following excavation, but that after installation of the panel-closure system, the
25 barrier confinement will result in an increase in barrier-confining stress and a reduction in
26 shear stress. The main concrete barrier would provide substantial uniform confining
stresses as the barrier is subjected to secondary salt creep.
- 27
28 • The removal of the fractured salt prior to installation of the main concrete barrier would
29 reduce the potential for flexure. The fracturing of MB 139 and the attendant fracturing of
30 the floor could reduce structural load resistance (structural stiffness), which could
31 initially result in barrier flexure and shear. With the removal of MB 139, the fractured
32 salt stiffens the surrounding rock and results in the development of more uniform
compression.
- 33
34 • The trade-off study also showed that a panel-closure system with an enlarged concrete
35 barrier with the removal of the fractured salt roof and anhydrite in the floor was found to
be the most protective.

36 The conclusions reached from the design evaluations addressing the structural and material
37 requirements of the panel-closure system are as follows:

- 38
39 • Existing information on the heat of hydration of the concrete supports placing concrete
40 with a low cement content to reduce the temperature rise associated with hydration.

1 Plasticizers might be used to achieve the required slump at the required strength. A
2 thermal analysis, coupled with a salt creep analysis, suggests installation of the enlarged
3 barrier at or below ambient temperatures to adequately control hydration temperatures.

- 4 • In addition to installation at or below ambient temperatures, the concrete used in the main
5 barrier would exhibit the following:

- 6 – An 8 inch (0.2 meter) slump after 3 hours of intermittent mixing
7 – A less-than-25-degree Fahrenheit heat rise prior to installation
8 – An unconfined compressive strength of 4,000 pounds per square inch (psi) (28
9 megapascals [MPa]) after 28 days
10 – Volume stability
11 – Minimal entrained air

- 12
13 • The trace amounts of brine from the salt at the repository horizon will not degrade the
14 main concrete barrier for at least 35 years.

- 15 • In 20 years, the open passage above the waste stack would be reduced in size. Further,
16 rooms with bulkheads at each end would be isolated in the panel. It is unlikely that a
17 long passage with an open geometry would exist; therefore, the dynamic analysis
18 considered a deflagration with a peak explosive pressure of 240 psi (1.7 MPa).

- 19 • The heat-transfer analysis shows that elevated temperatures would occur within the salt
20 and the explosion-isolation wall; however, the elevated temperatures will be isolated by
21 the panel-closure system. Temperature gradients will not significantly affect the stability
22 of the wall.

- 23 • The fractures in the roof and floor could be affected by expanding gas products reaching
24 pressures on the order of 240 psi (1.7 MPa). Because the peak internal pressure from the
25 deflagration is only one fifth of the pressure, fractures could not propagate beyond the
26 barrier.

27 A composite system is selected for the design with various components to provide flexibility.
28 These design options are described below.

29
30 **Design Options.** Figure I1-2 illustrates the options developed to satisfy the requirements for the
31 panel-closure system. The basis for selecting an option depends on conditions at the panel-
32 closure system locations as would be documented by future subsurface investigations. ~~As noted
33 earlier, Option D is the only option approved for construction as part of the facility permit issued
34 by the NMED.~~

35
36 While no specific requirements exist for barricading inactive waste areas under the MSHA, their
37 intent is to safely isolate these abandoned areas from active workings using barricades of
38 "substantial construction." A previous analysis (DOE, 1995) examined the issue of methane gas
39 generation from transuranic waste and the potential consequence in closed areas. The principal

1 concern is whether an explosive mixture of methane with an ignition source would result in
2 deflagration. A concrete block wall of sufficient thickness will be used to resist dynamic and salt
3 creep loads.

4
5 It was shown (DOE, 1995) that an explosive atmosphere may exist after approximately 20 years.

6
7 **Design Components.** The enlarged concrete barrier location within the air-intake and air-
8 exhaust drifts will be determined following observation of subsurface conditions. The enlarged
9 concrete barrier will be composed of salt-saturated Salado Mass Concrete with sufficient
10 unconfined compressive strength. The barrier will consist of a circular rib segment excavated
11 into the surrounding salt where the central portion of the barrier will extend just beyond Clay G
12 and MB 139. FLAC analyses showed that plain concrete will develop adequate confined
13 compressive strength.

14
15 The enlarged concrete barrier will be placed in four cells, with construction joints formed
16 perpendicular to the direction of potential air flow. The concrete will be placed through 6-inch
17 (15.2 centimeter) diameter steel pipes and will be vibrated from outside the formwork. The
18 formwork is designed to withstand the hydrostatic loads that would occur during installation with
19 minimal bracing onto exposed salt surfaces. This will be accomplished by a series of steel plates
20 that are stiffened by angle iron, with load reactions carried by spacer rods. Some exterior
21 bracing will be required when the concrete is poured into the first cell at the location for the
22 enlarged concrete barrier. All structural steel will be American Society of Testing and Materials
23 [grade] A36 in conformance with the latest standards specified by the American Institute for
24 Steel Construction. After concrete placement, the formwork will be left in place and will stiffen
25 the enlarged concrete barrier if nonuniform reactive loadings should occur after panel closure.

26
27 After completion of the enlarged concrete barrier installation, it will be grouted through a series
28 of grout supply and air return lines that terminate in grout boxes. The boxes will be mounted
29 near the top of the barrier. The grout will be injected through one set of lines and returned
30 through a second set of air lines.

31
32 An explosion-isolation wall, constructed with concrete-blocks, will mitigate the effects of a
33 methane explosion. The explosion-isolation wall would consist of 3,500 psi (24 MPa) concrete
34 blocks mortared together with a bonding agent. The concrete-block wall design complies with
35 MSHA requirements, because it consists of noncombustible materials of "substantial
36 construction." The concrete-block walls will be keyed into the salt. For the WIPP, an explosion-
37 isolation wall is designed to resist loading from salt creep.

38
39 The compliance of the detailed design was evaluated against the design requirements established
40 for the panel-closure system. The design complies with all aspects of the design basis
41 established for the panel-closure system.

1 1.0 Introduction

2 The Waste Isolation Pilot Plant (**WIPP**) repository, a U.S. Department of Energy (**DOE**)
3 research facility located near Carlsbad, New Mexico, is approximately 2,150 feet (ft) (655 meters
4 [m]) below the surface, in the Salado Formation. The WIPP facility consists of a northern
5 experimental area, a shaft-pillar area, and a waste-emplacment area. The WIPP facility will be
6 used to dispose transuranic (**TRU**) mixed waste.

7
8 One important aspect of future repository operations at the WIPP is the activities associated with
9 closure of waste-emplacment panels. Each panel consists of air-intake and air-exhaust drifts,
10 panel-access drifts, and seven rooms (Figure I1-1). After completion of waste-emplacment
11 activities, each panel will be closed, while waste emplacment may be occurring in the other
12 panel(s). The closure of individual panels during the operational period will be conducted in
13 compliance with project-specific health, safety, and environmental performance criteria.

14
15 1.1 Scope

16 This report provides information on the detailed design and material engineering specifications
17 for the construction, installation, and interface grouting associated with a panel-closure system
18 for a minimum operational period of 35 years. The panel-closure system design provides
19 assurance that the limit for the migration of volatile organic compounds (**VOC**) will be met at
20 the point of compliance, the WIPP site boundary. This assurance is obtained through the
21 inherent flexibility of the panel closure system. The panel-closure system will be located in the
22 air-intake and air-exhaust drifts to each panel (Figure I1-1). The panel-closure system design
23 maintains its intended functional requirements under loads generated from salt creep, internal
24 panel pressure, and a postulated methane explosion. The design complies with regulatory
25 requirements for a panel-closure system promulgated by the Resource Conservation and
26 Recovery Act (**RCRA**) and Mine Safety and Health Administration (**MSHA**) (see citations in
27 Section 1.3 below).

28
29 Figure I1-3 illustrates the design process used for preparing the detailed design. The design
30 process commenced with the evaluation of the performance requirements of the panel-closure
31 system through review of the work performed in developing the conceptual design and the
32 "Underground Hazardous Waste Management Unit Closure Criteria for the Waste Isolation Pilot
33 Plant Operation Phase" (Westinghouse, 1995b). The various design evaluations were performed
34 to address specific design-implementation issues identified by the project. The results of these
35 design evaluations are presented in this report.

36
37 1.2 Design Classification

38 Procedure WP 09-CN3023 (Westinghouse, 1995a) was used to establish a design classification
39 for the panel-closure system. The design classification for the panel-closure system evolved
40 from addressing the short-term operational issues regarding the reduction of VOC migration.
41 Figure I1-4 shows the decision flow logic process used to designate the panel-closure system as a
42 Class IIIB structure.

1 1.3 Regulatory Requirements

2 The following subsections discuss the regulatory requirements specified in RCRA and MSHA
3 for the panel-closure system.

4
5 1.3.1 Resource Conservation and Recovery Act (40 CFR 264 and 270)

6 In accordance with 20.4.1.500 NMAC, incorporating Title 40, Code of Federal Regulations
7 (CFR), Part 264, Subpart X (40 CFR 264, Subpart X), "Miscellaneous Units," and 20.4.1.900
8 NMAC, incorporating 40 CFR 270.23, "Specific Part B Information Requirements for
9 Miscellaneous Units," information required for miscellaneous units is submitted in permit
10 applications and renewal applications. ~~a RCRA Part B permit application has been submitted for~~
11 ~~the WIPP facility.~~

12
13 1.3.2 Protection of the Environment and Human Health

14 ~~The WIPP RCRA Part B permit application indicates that VOCs~~ Volatile Organic Compounds
15 ~~must not exceed health-based~~ environmental performance standards established in Renewal
16 Application Chapter N. ~~beyond the WIPP site boundary. Worker exposure to VOCs, and VOC~~
17 ~~emissions to non-waste workers or to the nearest resident will not pose greater than a 10⁻⁶-excess~~
18 ~~cancer risk in order to meet health-based standards.~~ The panel-closure system design
19 incorporates measures to mitigate VOC migration for compliance with these standards.

20
21 1.3.3 Closure Requirements (20 New Mexico Administrative Code 4.1, Subpart V)

22 The Permittees will notify the Secretary of the New Mexico Environment Department in writing
23 at least 60 days prior to the date on which partial and final closure activities are scheduled to
24 begin.

25
26 1.3.4 Mining Safety and Health Administration

27 The significance of small natural-gas occurrences within the WIPP repository is within the
28 classification of Category IV for natural gas under the MSHA (30 CFR 57, Subpart T) ~~(MSHA,~~
29 ~~1987)~~. These regulations include the hazards of methane gas and volatile dust. Category IV
30 "applies to mines in which non-combustible ore is extracted and which liberate a concentration
31 of methane that is not explosive nor capable of forming explosive mixtures with air based on the
32 history of the mine or the geological area in which the mine is located." For "barriers and
33 stoppings," the regulations provide for noncombustible materials (where appropriate) for the
34 specific mine category and require that "barriers and stoppings" be of "substantial construction."
35 Substantial construction implies construction of such strength, material, and workmanship that
36 the barrier could withstand air blasts, methane detonation or deflagration, blasting shock, and
37 ground movement expected in the mining environment.

38

1 1.4 Report Organization

2 This report presents the engineering package for the detailed design of the panel-closure system.
3 Chapter 2.0 presents the design evaluations. Chapter 3.0 describes the design and Chapter 4.0
4 presents the Constructability Design Calculations Index. Chapter 5.0 shows the technical
5 specifications. Chapter 6.0 presents the design drawings. The conclusions are presented in
6 Chapter 7.0 and the references presented in Chapter 8.0. Appendices to this report provide
7 detailed information to support the information contained in Chapters 2.0 through 7.0 of this
8 report.

9
10 2.0 Design Evaluations

11 This chapter in the Part B permit application presented the results of the various design
12 evaluations that support the panel-closure system ~~(i.e., (1) analyses addressing the operational~~
13 ~~requirements, and (2) analyses addressing the structural and material requirements)~~ are. ~~These~~
14 ~~evaluations were~~ important in demonstrating that the panel closures will adequately restrict
15 releases of VOCs and will be structurally stable during the operations phase of the WIPP.
16 ~~However, these evaluations are not necessary as part of the facility permit and have been deleted~~
17 ~~from this edited document.~~

18
19 3.0 Design Description

20 This chapter presents the final design selected from the evaluations performed in the previous
21 chapter. It presents design modifications to cover a range of conditions that may be encountered
22 in the underground and describes the design components for the panel-closure system. Finally,
23 information is presented on the proposed construction for the panel-closure system.

24
25 3.1 Design Concept

26 The composite panel-closure system proposed in the permit application included (1) a standard
27 concrete barrier, rectangular in shape, or (2) an enlarged tapered concrete barrier. Options (1)
28 and (2) were both proposed to be grouted along the interface and may contain explosion- or
29 construction-isolation walls. Figure I1-2 illustrates these design components. The construction
30 methods and materials to be used to implement the design have been proven in previous mining
31 and construction projects. The standard concrete barrier without DRZ removal was intended to
32 apply to future panel air-intake and air-exhaust drifts where the time duration between
33 excavation and barrier emplacement is short. The enlarged concrete barrier with DRZ removal
34 and explosion-isolation wall is the only option approved in the RCRA facility Permit. The
35 design concept for the enlarged concrete barrier incorporates:

- 36
37
 - 38 • A concrete barrier that is tapered to promote the rapid stress buildup on the host rock.
39 The stiffness was selected to provide rapid buildup of compressive stress and reduction in
 shear stress in the host rock.

- 1 • The enlarged barrier requires DRZ removal just beyond Clay G and MB 139, and to a
2 corresponding distance in the ribs to keep the tapered shape approximately spherical.
3 The design includes DRZ removal and thereby limits VOC flow through the panel-
4 closure system.
- 5 • The design of the approved panel-closure system includes an explosion-isolation wall
6 designed to provide strength and deformational serviceability during the operational
7 period. The length was selected to assure that uniform compression develops over a
8 substantial portion of the structure and that end-shear loading that might result in
9 fracturing of salt into the back is reduced.

10 3.2 Design Summary Options

11 The design options consists of the following:

- 12 ~~• An enlarged concrete barrier with the DRZ removed and a construction isolation wall~~
- 13 ~~• An an enlarged concrete barrier with the DRZ removed and an explosion-isolation wall.~~
14 (This is the only option approved in the RCRA facility Permit.)
- 15 ~~• A rectangular concrete barrier without the DRZ removed and a construction isolation~~
16 ~~wall~~
- 17 ~~• A rectangular concrete barrier without the DRZ removed and an explosion isolation wall.~~

18
19 In each case, interface Interface grouting will be used for the upper barrier/salt interface to
20 compensate for any void space between the top of the barrier and the salt. The process for
21 selecting these options was proposed to depend on the subsurface conditions at the panel-closure
22 system locations described in the following subsections.

23
24 Observation boreholes will be drilled into the roof or floor of the new air intake and air exhaust
25 drifts and will be used for observation of fractures and bed separation. Observations can be
26 made in the boreholes using a small video camera, or a scratch rod. A scratch rod survey will be
27 performed in accordance with the current Excavation Effects Program (EEP) procedure.

28
29 The EEP was initiated in 1986 with the occurrence of fractures in Site and Preliminary Design
30 Validation Room 3. The purpose of the EEP is to study fractures that develop as a result of
31 underground excavation at the WIPP and to monitor those fractures. Borehole inspections have
32 been successful for determining the fracturing and bed separation in the host rock. These
33 inspections have been performed since 1983 (Francke and Terrill, 1993). This technique in
34 addition to the above will be used to determine the optimum location for the panel-closure
35 system.

36
37 Since the enlarged barrier is required to be constructed for all panel closures, the proposed DRZ
38 investigations are not required as part of the RCRA facility Permit.

1 3.3 Design Components

2 The following subsections present system and components design features.

3
4 3.3.1 Concrete Barrier

5 The enlarged concrete barrier consists of Salado Mass Concrete, with sufficient unconfined
6 compressive strength and with an approximately circular cross-section excavated into the salt
7 over the central portion of the barrier (Figure I1-5). The enlarged concrete barrier will be located
8 at the optimum locations in the air-intake and air-exhaust drifts with the central portion
9 extending just beyond Clay G and MB 139.

10
11 The enlarged concrete barrier will be placed in four cells, with construction joints perpendicular
12 to the direction of potential air flow. The concrete strength will be selected according to the
13 standards specified by the latest edition of the ACI code for plain concrete. The concrete will be
14 placed through 6-inch- (15-cm)-diameter steel pipes and vibrated from outside the formwork.
15 The formwork is designed to withstand the hydrostatic loads during construction, with minimal
16 bracing onto exposed salt surfaces. This will be accomplished by placing a series of steel plates
17 that are stiffened by angle iron, with load reactions carried by spacer rods. The spacer rods will
18 be staggered to reduce potential flow along the rod surfaces through the barrier. Some exterior
19 bracing will be required when the first cell is poured. All structural steel will be ASTM A36,
20 with detailing, fabrication, and erection of structural steel in conformance with the latest edition
21 of the AISC steel manual (~~AISC, 1989~~). After concrete placement, the formwork will be left in
22 place.

23
24 The above design is for the most severe conditions expected to be encountered at the WIPP.

25
26 3.3.2 Explosion- and Construction-Isolation Walls

27 An explosion-isolation wall, consisting of concrete-blocks, will mitigate the effects of a
28 postulated methane explosion. The explosion-isolation wall consists of 3,500-psi (24-MPa)
29 concrete blocks mortared together with cement (Figure I1-6).

30
31 The concrete block wall design complies with MSHA requirements (30 CFR 57) (~~MSHA, 1987~~)
32 because it uses incombustible materials of substantial construction. The explosion-isolation wall
33 will be placed into the salt for support. The explosion-isolation walls are designed to resist creep
34 loading from salt deformation. In the absence of the postulated methane explosion, the design
35 was proposed to be simplified to a construction-isolation wall. The construction-isolation wall
36 design provides temporary isolation during the time the main concrete barrier is being
37 constructed. The construction-isolation wall was not approved as part of the RCRA facility
38 Permit.

39
40 3.3.3 Interface Grouting

41 After construction of the main concrete barrier, the interface between the main concrete barrier
42 and the salt will be grouted through a series of grout-supply and air-return lines that will

1 terminate in grout distribution collection boxes. The openings in these boxes will be protected
2 during concrete placement (Figure I1-7). The grout boxes will be mounted near the top of the
3 barrier. The grout will be injected through one distribution system, with air and return grout
4 flowing through a second distribution system.
5

6 3.4 Panel-Closure System Construction

7 The construction methods and materials to be used to implement the design have been proven in
8 previous mining and construction projects. The design uses common construction practices
9 according to existing standards. The proposed construction sequence follows completion of the
10 waste-emplacement activities in each panel: (1) Perform subsurface exploration to determine the
11 optimum location for the panel closure system, (2) ~~select the appropriate design option for the~~
12 ~~location,~~ (3) prepare surfaces for the construction- or explosion-isolation walls, (4) ~~install these~~
13 walls, (5) ~~excavate for the enlarged concrete barrier (if required),~~ (6) ~~install concrete~~
14 formwork, (7) ~~emplace concrete for the first cell,~~ (8) ~~grout the completed cell,~~ and (9) ~~install~~
15 subsequent formwork, concrete and grout until completion of the enlarged concrete barrier.
16 ~~(Step 2 above is not required as part of the RCRA facility Permit, because there are no design~~
17 ~~options to choose between.)~~
18

19 The explosion-isolation wall will be located approximately 30 feet from the main concrete
20 barrier. The host rock will be excavated 6 inches (15 cms) around the entire perimeter prior to
21 installing the explosion-isolation wall. The surface preparation will produce a level surface for
22 placing the first layer of concrete blocks. Excavation may be performed by either mechanical or
23 manual means.
24

25 Excavation for the enlarged concrete barrier will be performed using mechanical means, such as
26 a cutting head on a suitable boom. The existing roadheader at the main barrier location in each
27 drift is capable of excavating the back and the portions of the ribs above the floor level. Some
28 manual excavation may be required in this situation as well. If mechanical means are not
29 available, drilling boreholes and an expansive agent can be used to fragment the rock (Fernandez
30 et al., 1989). Excavation will follow the lines and grades established for the design. The roof
31 will be excavated to just above Clay G and then the floor to just below MB 139 to remove the
32 DRZ. The tolerances for the enlarged concrete-barrier excavation are +6 to 0 inches (+15 to
33 0 cm). In addition, loose or spalling rock from the excavation surface will be removed to
34 provide an appropriate surface abutting the enlarged concrete barrier. The excavations will be
35 performed according to approved ground control plans.
36

37 Following completion of the roof excavation for the enlarged barrier, the floor will be excavated.
38 If mechanical means are not available, drilling boreholes and using an expansive agent to
39 fragment the rock (Fernandez et al., 1989) is a method that can be used. Expansive agents would
40 load the rock salt and anhydrite, producing localized tensile fracturing in a controlled manner, to
41 produce a sound surface.
42

43 A batch plant at the surface or underground will be prepared for batching, mixing, and delivering
44 the concrete to the underground in sufficient quantity to complete placement of the concrete

1 within one form cell. The placement of concrete will be continuous until completion, with a time
2 for completing one section not to exceed 10 hours, allowing an additional 2 hours for cleanup of
3 equipment.

4
5 Pumping equipment suitable for placing the concrete into the forms will be provided at the main
6 concrete barrier location. After transporting, and prior to pumping, the concrete will be remixed
7 to compensate for segregation of aggregate during transport. Batch concrete will be checked at
8 the surface at the time of mixing and again at the point of transfer to the pump for slump and
9 temperature. Admixtures may be added at the remix stage in accordance with the batch design.

10
11 **4.0 Design Calculations**

12 Table I1-1 summarizes calculations to support the construction details for an explosion-isolation
13 wall, construction-isolation wall, and structural steel formwork for concrete barriers up to 29-ft
14 high. The codes for the explosion-isolation and construction-isolation wall are specified by the
15 Uniform Building Code (~~International Conference of Building Officials, 1994~~), with related
16 seismic design requirements. The external loads for the solid block wall are as developed in the
17 methane-explosion and fracture propagation design evaluations.

18
19 **TABLE I1-1**
20 **CONSTRUCTABILITY DESIGN CALCULATIONS INDEX**
21

| Section | Design Area | Category |
|---------|--|----------|
| 1.0 | Explosion-isolation wall | W |
| 2.0 | Explosion-isolation wall seismic check | S |
| 3.0 | Formwork design | F |

22
23 The structural formwork for all cells is designed in accordance with the AISC guidelines on
24 allowable stress (~~AISC, 1989~~). Lateral pressures are developed using ACI 347R-88, using a
25 standard concrete weighing 150 pounds per cubic foot (2,410 kg/m³) with a slump of 8 inches
26 (20 cm) or less. Design loadings reflect full hydrostatic head of concrete, with lifts spaced at 4 ft
27 (1.2 m) intervals from bottom to top through portals, with no external vibration. All forms will
28 remain in place.

1 5.0 Technical Specifications

2 The specifications are in the engineering file room at the WIPP and are the property of the MOC.
 3 These specifications are included as an attachment in Appendix G and summarized in Table I1-2.

4
 5
 6
 7

**TABLE I1-2
 TECHNICAL SPECIFICATIONS FOR THE WIPP PANEL-CLOSURE SYSTEM**

| | |
|--|---------------------------------|
| Division 1 - General Requirements | |
| Section 01010 | Summary of Work |
| Section 01090 | Reference Standards |
| Section 01400 | Contractor Quality Control |
| Section 01600 | Material and Equipment |
| Division 2 - Site Work | |
| Section 02010 | Mobilization and Demobilization |
| Section 02222 | Excavation |
| Section 02722 | Grouting |
| Division 3 - Concrete | |
| Section 03100 | Concrete Formwork |
| Section 03300 | Cast-in-Place Concrete |
| Division 4 - Masonry | |
| Section 04100 | Mortar |
| Section 04300 | Unit Masonry System |

1 6.0 Drawings

2 The drawings (~~Appendix H~~) are in the engineering file room at the WIPP and are the property of
3 the MOC and summarized in Table I1-3 are in Renewal Application Appendix I1H.

4
5 **TABLE I1-3**
6 **PANEL-CLOSURE SYSTEM DRAWINGS**
7

| Drawing Number | Title |
|----------------|---|
| 762447-E1 | Title Sheet |
| 762447-E2 | Underground Waste Disposal Plan |
| 762447-E3 | Air Intake Drift Construction Details |
| 762447-E4 | Air Exhaust Drift Construction Details |
| 762447-E5 | Construction and Explosion Barrier Construction Details |
| 762447-E6 | Grouting and Miscellaneous Details |

1 7.0 Conclusions

2 This chapter presents the conclusions for the detailed design activities of the panel-closure
3 system. A design basis, including the operational requirements, the structural and material
4 requirements, and the construction requirements, was developed that addresses the governing
5 regulations for the panel-closure system. Table I1-4 summarizes the design basis for the panel-
6 closure system and the compliance with the design basis. The panel-closure system design
7 incorporates mitigative measures to address the treatment of fractures and therefore counter the
8 potential migration of VOCs. Several alternatives were evaluated for the treatment of fractures.
9 These included excavation and emplacement of a fully enlarged barrier with removal of the
10 DRZ, excavation of the roof and emplacement of a partially enlarged barrier, and emplacement
11 of a standard barrier with formation grouting.
12

13 To investigate several key design issues and to implement the design, design evaluations were
14 performed. These design evaluations can be divided into evaluations satisfying the operational
15 requirements of the system and evaluations satisfying the structural and materials requirements
16 of the system. The conclusions reached from the evaluations addressing the operational
17 requirements are as follows:
18

- 19 • Based on an air-flow model used to predict the mass flow rate of carbon tetrachloride
20 through the panel-closure system for the alternatives, the air-flow analysis suggests that
21 the fully enlarged barrier is the most protective for restricting VOCs for at least during
22 ~~the operational period~~ of 35 years.
- 23 • Results of the FLAC analyses show that the recommended enlarged configuration is a
24 circular rib-segment excavated to Clay G and under MB 139. Interface grouting would
25 be performed at the upper boundary of the concrete barrier.
- 26 • The results of the transverse plane-strain models show that high stresses would form in
27 MB 139 following excavation, but that after installation of the panel-closure system, an
28 increase in barrier-confining stress and a reduction in shear stress would result. The
29 concrete barrier would provide substantial uniform confining stresses as the barrier is
30 subjected to secondary salt creep.
- 31 • The removal of the fractured salt prior to installation of the main concrete barrier would
32 reduce the potential for flexure. With the removal of MB 139, the fractured salt stiffens
33 the surrounding rock and results in the development of more uniform compression.

1
 2
 3

**TABLE I1-4
 COMPLIANCE OF THE DESIGN WITH THE DESIGN REQUIREMENTS**

| Type of Requirement | Requirement | Section | Compliance with Requirement | Notes on Compliance |
|---------------------|---|-------------------------|-----------------------------|--|
| Operational | Individual panels shall be closed in accordance with the schedule of actual waste emplacement. | 2.1.1 | Complies | Gas-flow models used for design are based on the waste-emplacement operational schedule. |
| | The panel-closure system shall provide assurance that the limit for the migration of volatile organic compounds (VOC) of concern will be met at the point of compliance. To achieve this assurance, the design shall consider the potential flow of VOCs through the several components of the disturbed rock zone and the panel-closure system. | 2.1.1, 2.1.2 | Complies | Gas-flow modeling shows that the VOC flow is less than the design migration limit. |
| | The panel-closure system shall comply with its intended functional requirements under loads generated from creep closure and any internal pressure that might develop in the disposal panel under reasonably anticipated conditions. | 2.1.2, 4.0 | Complies | Stress analyses and design calculations show that the panel-closure system performs as intended. |
| | The panel-closure system shall comply with its intended functional requirements under a postulated methane explosion. | 2.2.3, 2.2.4, 4.0 | Complies | The methane explosion studies, fracture propagation studies, and supporting design calculations show that the panel-closure system performs as intended. |

| Type of Requirement | Requirement | Section | Compliance with Requirement | Notes on Compliance |
|---|--|-----------------------|-----------------------------|---|
| Operational (continued) | The operational life of the panel-closure system shall be at least 35 years. | 2.1.1 | Complies | Gas-flow modeling and analyses shows satisfactory performance for at least 35 years. |
| | The panel-closure system for each individual panel shall not require routine maintenance during its operational life. | 3.2 | Complies | Passive design components require no routine maintenance. |
| | The panel-closure system shall address the most severe ground conditions expected in the panel entries. If actual conditions are found to be more favorable, this design can be simplified and still satisfy the operational requirements of the system. | 2.1.1 2.1.3 3.2 | Complies | Design is based upon flow and structural analyses for the most severe expected ground conditions. If conditions are less severe, simpler design options are used. The various design options accommodate all expected conditions. |
| Design configuration and essential features | The panel-closure system shall be emplaced in the air-intake and air-exhaust drifts <u>as illustrated in Renewal Application Appendix M3, identified by Westinghouse (1995c)</u> | 3.2 | Complies | The design shows placement in the designated areas for panel closure. |
| | The panel-closure system shall consist of a concrete barrier and construction-isolation and explosion-isolation walls with dimensions to satisfy the operational requirements of the system. | 3.2, 3.3 | Complies | The panel-closure system design uses the identified components with dimensions to satisfy the operational requirements of the system. |

| Type of Requirement | Requirement | Section | Compliance with Requirement | Notes on Compliance |
|-------------------------|---|---------|-----------------------------|---|
| Safety | The design class for the panel-closure system shall be IIIb. Design and construction shall follow conventional mining and construction practices. | 3.4 | Complies | Components are designed according to Class IIIb. The construction sequence for the design followed conventional mining practices. |
| | The structural analysis for the underground shall use the empirical data acquired from the WIPP Excavation Effects Program. | 2.1.2 | Complies | The structural analysis uses properties that model creep closure for stress analyses from data acquired in the WIPP Excavation Effects Program. |
| Structural and material | The panel-closure system materials shall be compatible with their emplacement environment and function. Surface treatment between the host rock and the panel-closure system shall be considered in the design. | 2.2.1 | Complies | The material compatibility studies showed no degradation of materials and no need for surface treatment. |
| | The selection and placement of concrete in the concrete barrier shall address potential thermal cracking due to the heat of hydration. | 2.2.2 | Complies | The heat generation studies show that hydration temperatures are controlled by appropriate selection of cement type and placement temperature. |

| Type of Requirement | Requirement | Section | Compliance with Requirement | Notes on Compliance |
|--|---|-------------------------|-----------------------------|---|
| Structural and material (continued) | The panel-closure system shall sustain the dynamic pressure and subsequent temperature generated by a postulated methane explosion. | 2.2.3, 2.2.4, 4.0 | Complies | The methane explosion study shows that the explosion-isolation wall protects the concrete barrier from pressure loading and thermal loading. The fracture propagation study shows that the system performs as intended. |
| Construction | The panel-closure system shall use to the extent possible normal construction practices according to existing standards. | 3.4 | Complies | The specifications include normal construction practices used in the underground at WIPP and according to the most current steel and concrete specifications. |
| | During construction of the panel-closure system, a quality assurance/quality control program shall be established to verify material properties and construction practices. | 3.4 | Complies | The specifications include materials testing to verify material properties and construction practices. |
| | The construction specification shall take into account the shaft and underground access capacities and services for materials handling. | 3.4 | Complies | The specifications allow construction within the capacities of underground access. |

- 1 • The trade-off study also showed that a panel-closure system with an enlarged concrete
2 barrier with the removal of the fractured salt roof and anhydrite in the floor was found to
3 be the most protective.

4 The conclusions reached from the design evaluations addressing the structural and material
5 requirements of the panel-closure system are as follows:
6

- 7 • Existing information on the heat of hydration of the concrete supports placing concrete
8 with a low cement content to reduce the temperature rise associated with hydration. The
9 slump at the required strength would be achieved through the use of plasticizers. A
10 thermal analysis coupled with a salt creep analysis suggest installation of the enlarged
11 barrier at or below ambient temperatures to adequately control hydration temperatures.
- 12 • In addition to installation at or below ambient temperatures, the concrete used in the main
13 concrete barrier would exhibit the following:
- 14 – An 8 inch (0.2 meter) slump after 3 hours of intermittent mixing
15 – A less-than-25-degree Fahrenheit heat rise prior to installation
16 – An unconfined compressive strength of 4,000 psi (28 MPa) after 28 days
17 – Volume stability
18 – Minimal entrained air
- 19
- 20 • The trace amounts of brine from the salt at the repository horizon should not degrade the
21 main concrete barrier for at least 35 years.
- 22 • In 20 years, the open passage above the waste stack would be reduced in size. Further,
23 rooms with bulkheads at each end would be isolated in the panel. It is unlikely that a
24 long passage with an open geometry would exist; therefore, the dynamic analysis
25 considered a deflagration with a peak explosive pressure of 240 psi (1.7 MPa).
- 26 • The heat-transfer analysis shows that elevated temperatures would occur within the salt
27 and the explosion-isolation wall; however, the elevated temperatures will be isolated by
28 the panel-closure system. Temperature gradients will not significantly affect the stability
29 of the wall.
- 30 • The fractures in the roof and floor could be affected by expanding gas products reaching
31 pressures of the order of 240 psi (1.7 MPa). Because the peak internal pressure from the
32 deflagration is only one fifth of the pressure, fractures could not propagate beyond the
33 wall.

34 The design options proposed to satisfy the design requirements for the panel-closure system
35 include (1) a standard barrier, rectangular in shape, or (2) an enlarged concrete barrier,
36 approximately spherical in shape. Options (1) and (2) will be grouted at the interface and may
37 contain explosion- or construction-isolation walls. Only the enlarged barrier with an explosion-
38 isolation wall is approved as part of the RCRA facility Permit.
39

1 The design provides flexibility to satisfy the design migration limit for the flow of VOCs out of
2 the panels. An enlarged concrete barrier would be selected where the air-intake and air-exhaust
3 drifts have aged and where there is fracturing resulting in significant flow of VOCs. These
4 conditions apply to the most severe ground conditions in the air-intake and air-exhaust drifts of
5 Panel 1. If ground conditions are more favorable, such as might be the case for future panel
6 entries, the design was proposed to be simplified to a standard concrete barrier rectangular in
7 shape, with a construction isolation wall. GPRGround Penetrating Radar and observation
8 boreholes are available for detecting the location and extent of fractures in the DRZ. These
9 methods may be used to select the optimum location within each entry and exhaust drift for the
10 enlarged barrier panel-closure system.

11
12 The design is presented in this report as a series of calculations, engineering drawings, and
13 technical performance specifications. The drawings illustrate the construction details for the
14 system. The technical performance specifications cover the general requirements of the system,
15 site work, concrete, and masonry. Information on the proposed construction method is also
16 presented.

17
18 The design complies with all aspects of the design basis established for the WIPP panel-closure
19 system. The design can be constructed in the underground environment with no special
20 requirements at the WIPP.

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FIGURES

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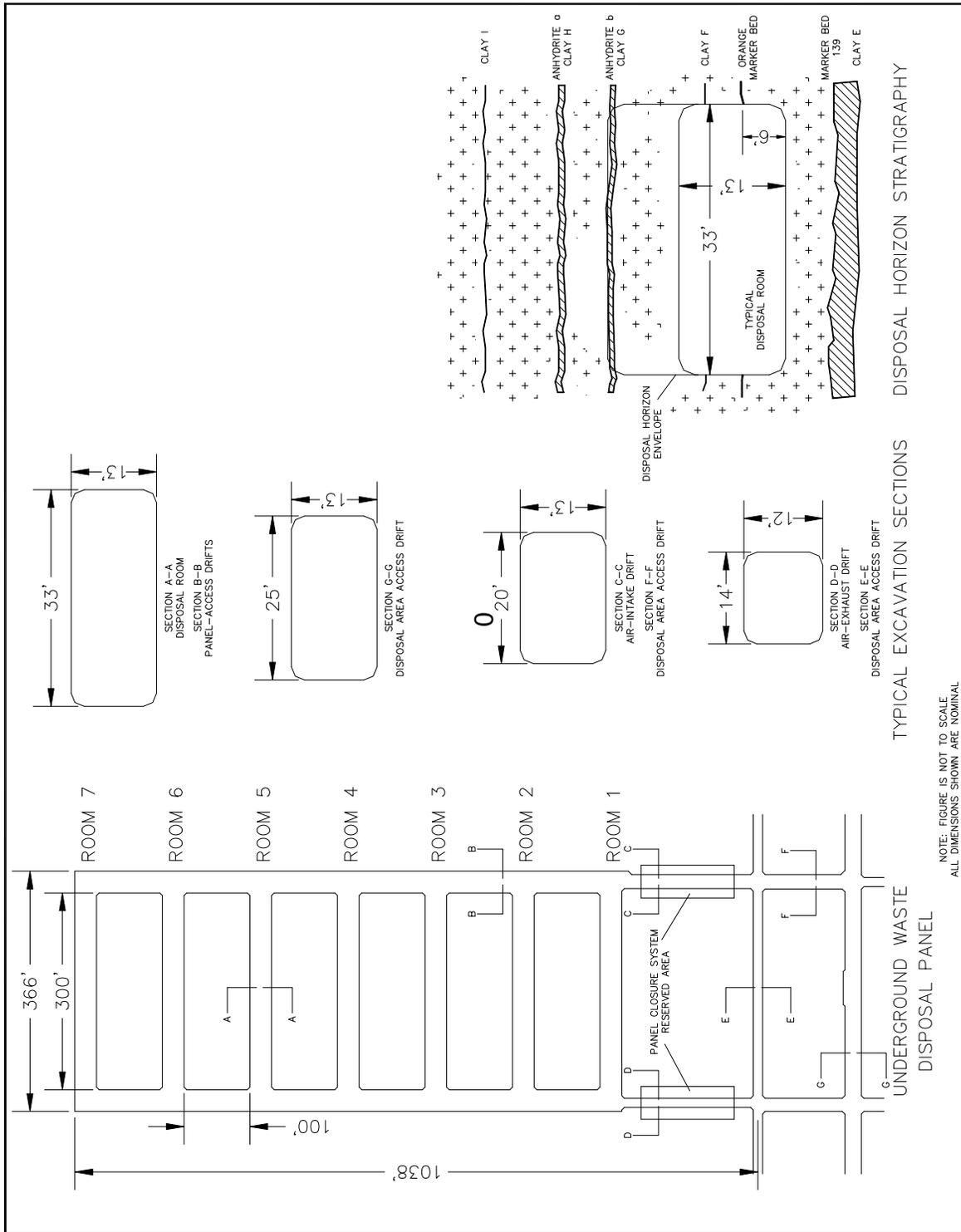


Figure I1-1
 Typical Facilities – Typical Disposal Panel

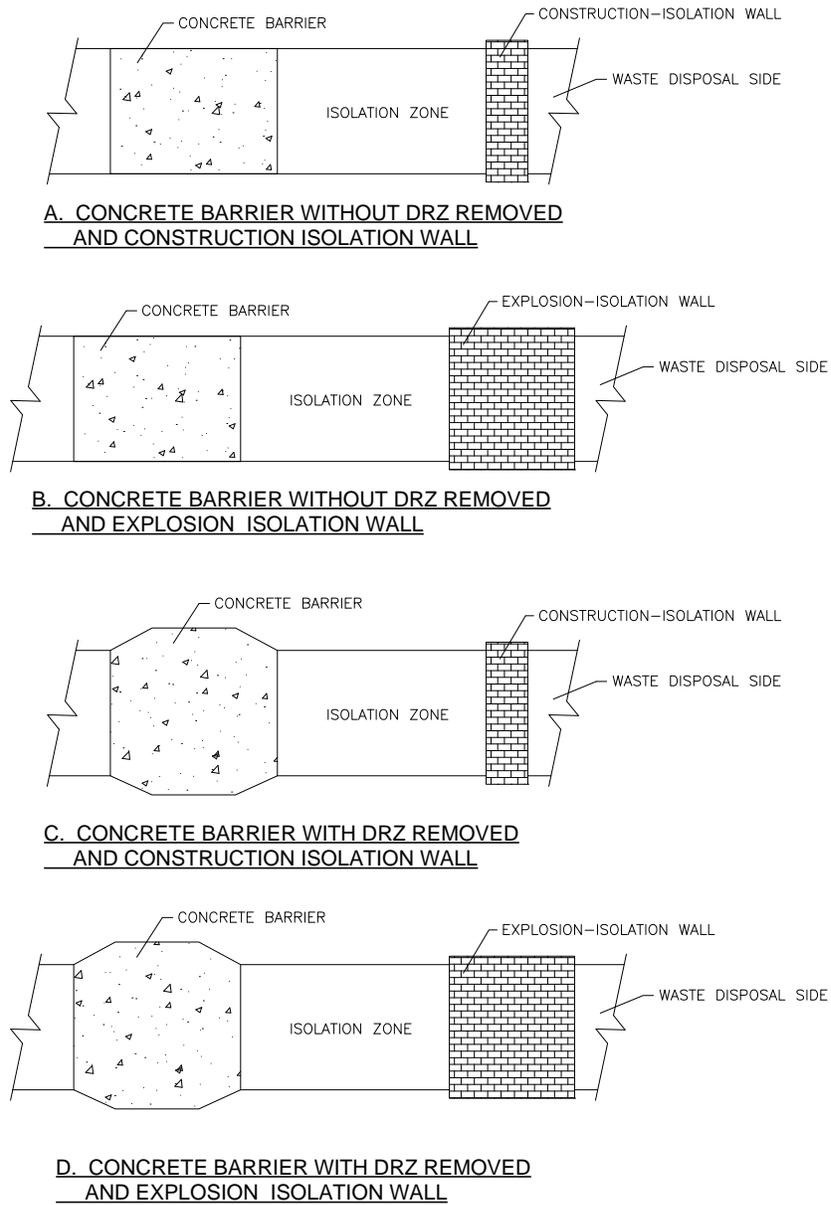


Figure I1-2
Main Barrier with Wall Combinations

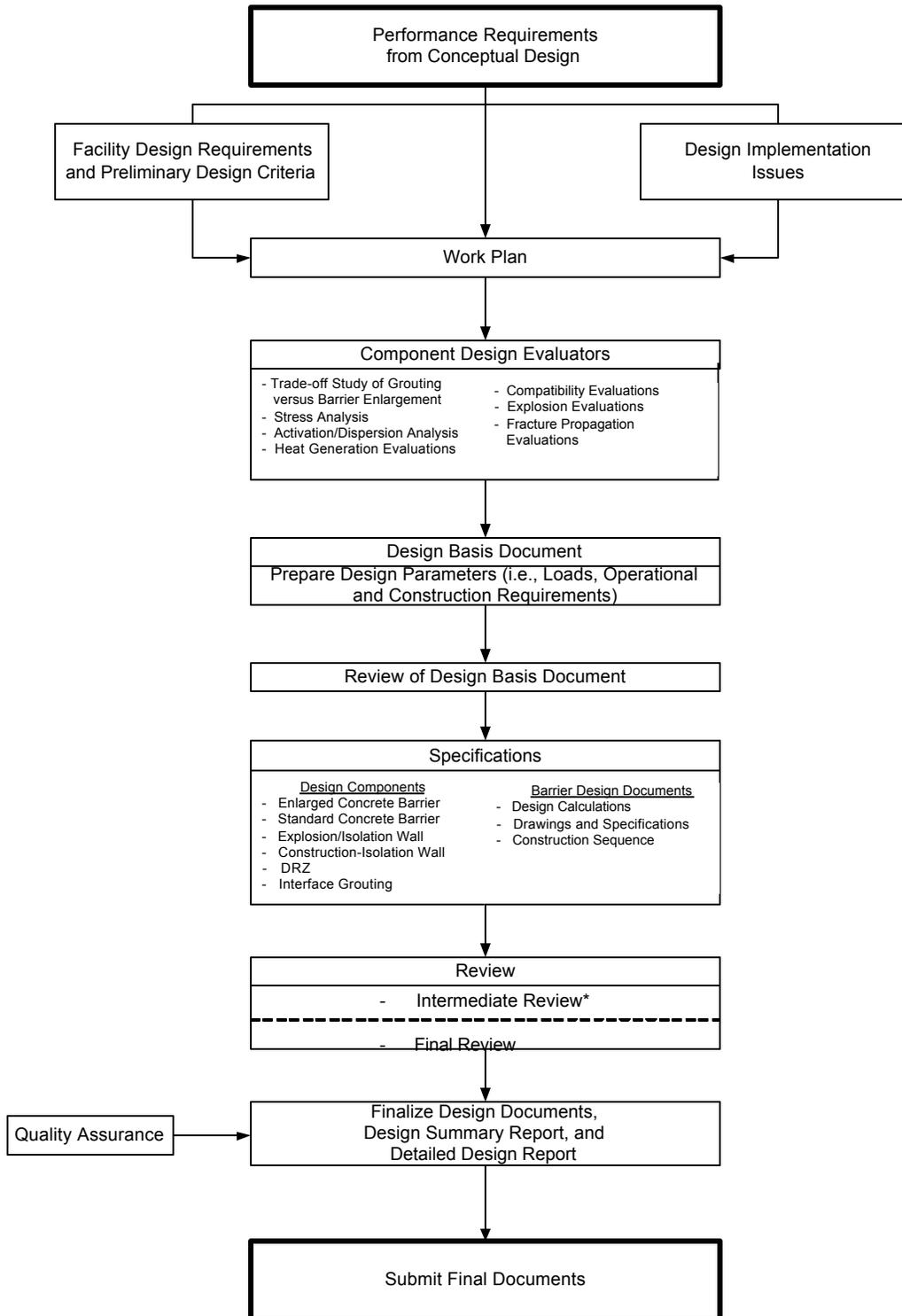


Figure I1-3
 Design Process for the Panel-Closure System

A. Select a system structure or component for classification. (Start with a mitigating item)

B. Is the system, structure, or component required to mitigate the consequences of an accident?

C. Would the system, structure or component failure result in loss of safety functions of a Design Class I components?

D. Does the system, structure, or component provide any function related to nuclear materials?

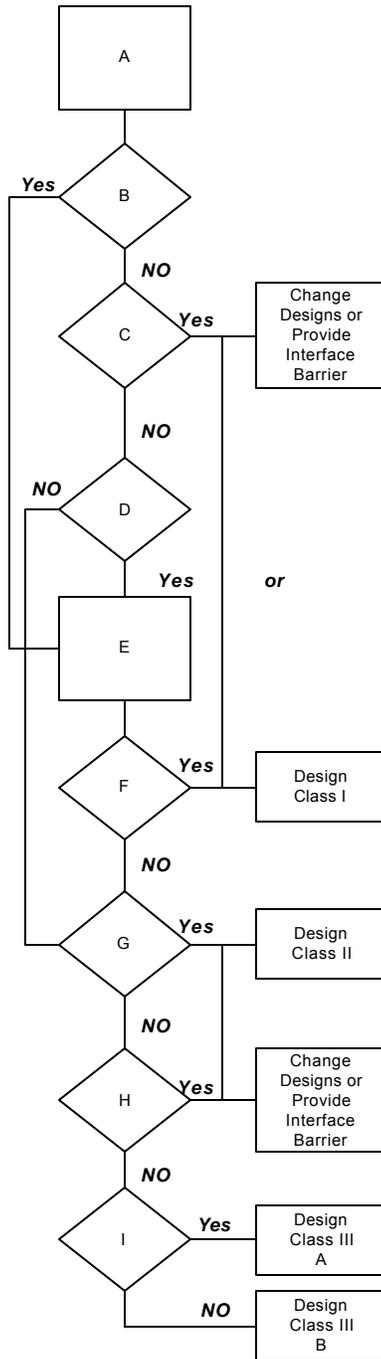
E. Select a conservative accident scenario and perform safety analysis.

F. Does the cumulative radiological consequences following the accident exceed 25 Rem whole body or 75 Rem organ dose commitment to individual at the Zone I boundary

G. Does the structure, system, operation or component conform to the Class II criteria as defined in Attachment 2?

H. Would the structure, system, operation or component failure result in loss of the required function of a Class II component?

I. Are special design requirements necessary to ensure that failure of the system, structure, or component will NOT result in a significant shutdown of the facility or inhibit accessibility or maintainability of required equipment or have special significance to health and safety of operations personnel?



B. _____ YES X NO
Describe requirement

C. _____ YES X NO
Failure mode and affected Class I component

D. _____ YES X NO
Describe function

E. _____ YES N/A NO
Attach safety analysis

F. _____ YES _____ NO
Calculate dose rates
N/A

G. _____ YES X NO
Criteria
N/A

H. _____ YES X NO
Failure mode and affected Class II component

I. _____ YES X NO
Requirements

Figure I1-4
 Design Classification of the Panel-Closure System

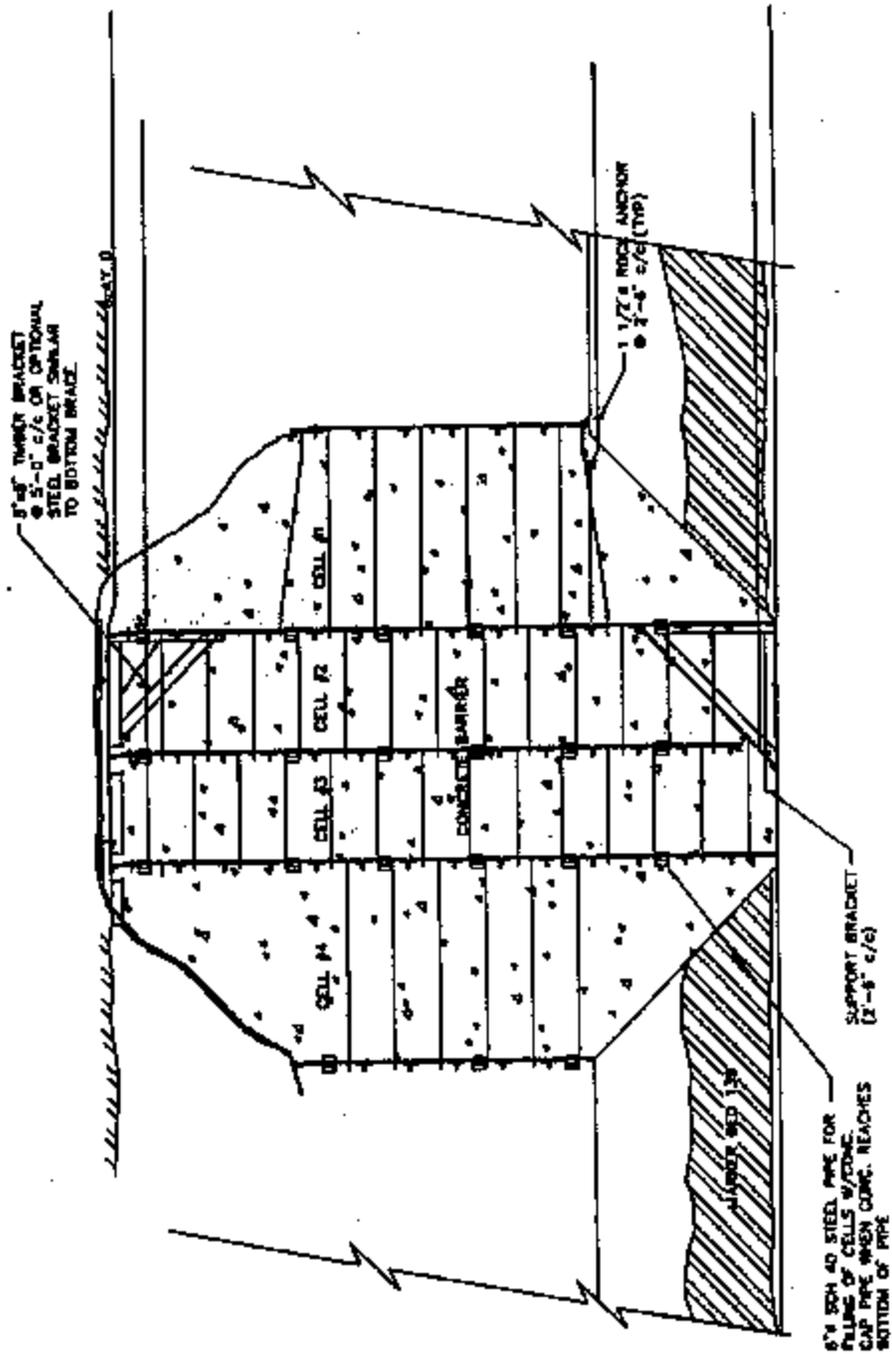


Figure I1-5
Concrete Barrier with DRZ Removal

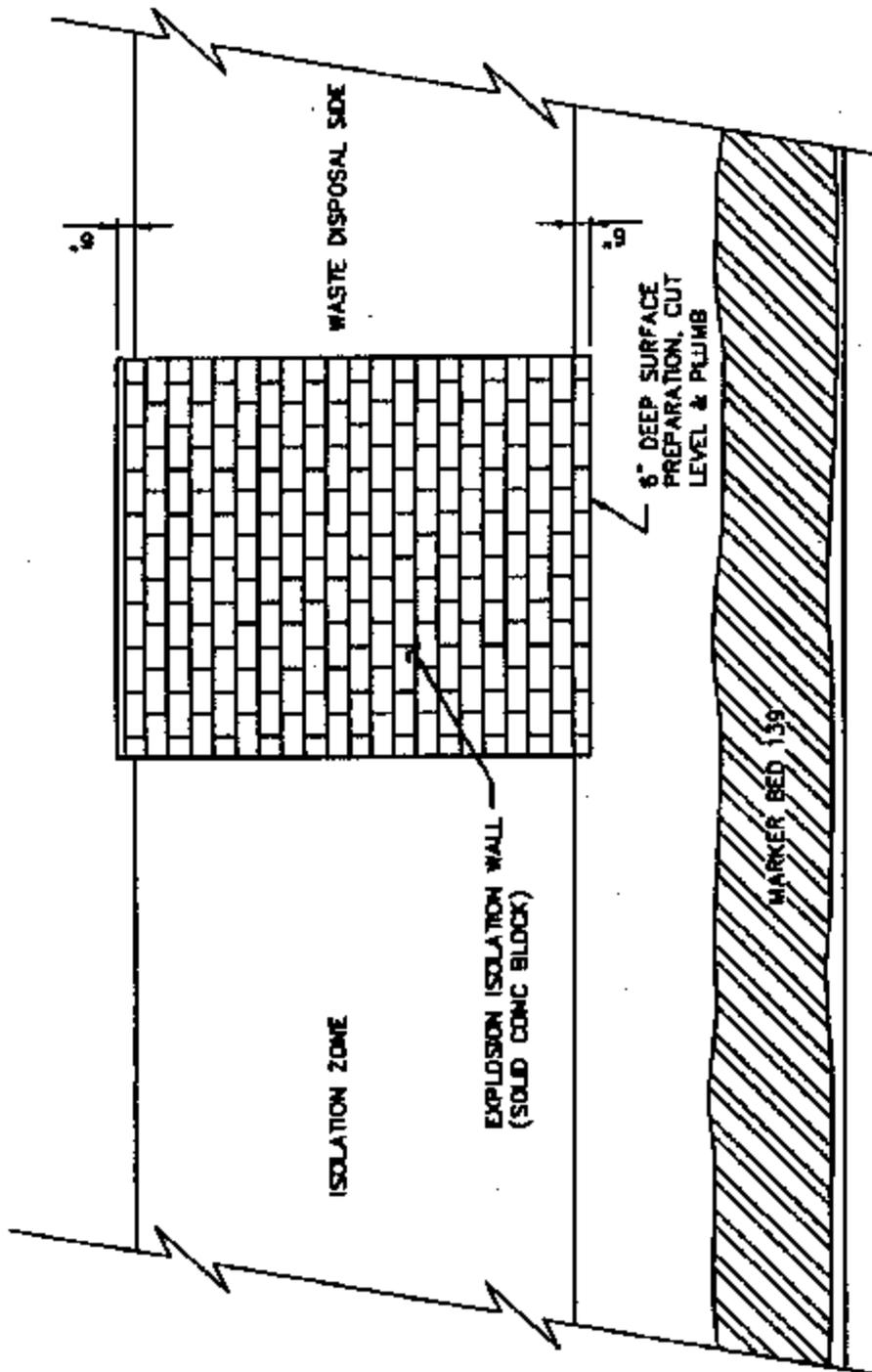


Figure I1-6
Explosion-Isolation Wall

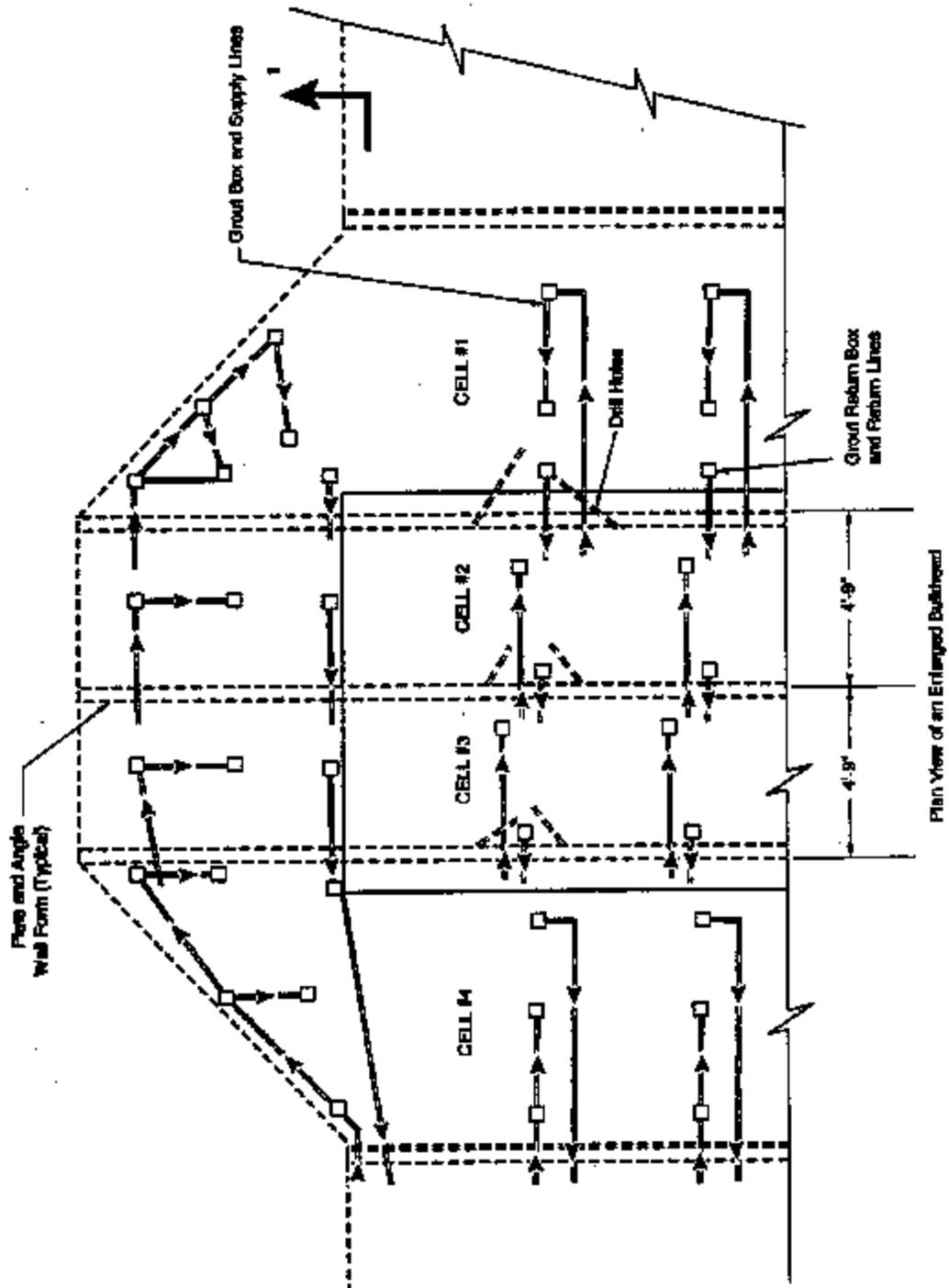


Figure II-7
Grouting Details