

**ATTACHMENT I2
APPENDIX B**

SHAFT SEALING CONSTRUCTION PROCEDURES

**SHAFT SEALING SYSTEM
COMPLIANCE SUBMITTAL DESIGN REPORT**

Waste Isolation Pilot Plant
Hazardous Waste Permit
October 27, 1999

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ATTACHMENT I2 APPENDIX B

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SHAFT SEALING SYSTEM COMPLIANCE SUBMITTAL DESIGN REPORT

Appendix B Abstract

This appendix describes equipment and procedures used to construct the shaft seals as specified in Permit Attachment I2. Existing or reasonably modified construction equipment is specified, standard mining practices are applied, and a general schedule is provided at the end of this appendix. This appendix describes the following activities:

- pre-sealing activities for the sub-surface and surface,
- construction and operation of a multi-deck stage,
- installation of special concrete (sumps, shaft station monoliths, and concrete plugs),
- installation of compacted clay columns,
- emplacement and dynamic compaction of WIPP salt,
- installation of neat asphalt and asphaltic mastic mix,
- grouting of concrete plugs and the country rock behind existing shaft liners,
- removal of portions of the existing shaft liners, and
- emplacement of compacted earthen fill.

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1 **B1. Introduction**

2 This appendix describes construction specifications for placement of shaft seal materials.
3 Flexibility is incorporated in construction specifications to facilitate placement of several different
4 material types. Engineering materials used to seal the full length of the shaft include earthen fill,
5 compacted clay, tamped crushed salt, asphalt, concrete, and a combination of concrete and
6 asphalt in concrete-asphalt waterstops. Appendix A of Permit Attachment I2 provides details of
7 the materials. A full-length shaft seal of this type has never before been constructed; however,
8 application of available technology and equipment, standard construction practices, and
9 common materials provides confidence that the system can be placed to satisfy the design
10 requirements.

11 A primary feature of the construction specification is development of a work platform from which
12 seal materials are placed. Although the proposed multi-deck stage (galloway) proposed here is
13 engineered specifically for shaft sealing operations, it is similar to stages used for construction
14 of shafts. Inherently flexible, the multi-deck stage facilitates several construction methods
15 required for the various materials specified for the shaft seal system. It provides an assembly of
16 a slickline and header for transport of flowable materials from the surface to the placement
17 horizon. A crane device is attached to the base of the stage to facilitate compaction, and an
18 avenue through the stage provides a means to transport bulk material. It is understood that
19 procedures specified here may change during the tens of years preceding construction as a
20 result of equipment development, additional testing, or design changes. Further, it is
21 acknowledged that the construction methods specified are not the only methods that could
22 place the seal materials successfully.

23 A few assumptions are made for purposes of evaluating construction activities. These
24 assumptions are not binding, but are included to assist discussion of general operational
25 scenarios. For example, four multi-deck stages are specified, one for each shaft. This
26 specification is based on shaft-sinking experience, which indicates that because of the wear
27 encountered, it is advisable to replace rather than rebuild stages. However, much of the
28 equipment on the multi-deck stage is reused. For scheduling purposes, it is assumed that
29 sealing operations are conducted in two of the four shafts simultaneously. The Air Intake and
30 Exhaust Shafts are sealed first, and the Waste and Salt Handling Shafts are sealed last. With
31 this approach, shaft sealing will require about six and a half years, excluding related work
32 undertaken by the WIPP Operating Contractor. Sealing the shafts sequentially would require
33 approximately eleven and a half years. To facilitate discussion of scheduling and
34 responsibilities, it is assumed that sealing operations will be conducted by a contractor other
35 than the WIPP Operating Contractor.

36 Years from now, when actual construction begins, it is probable that alternatives may be
37 favored. Therefore, construction procedures note alternative methods in recognition that
38 changes are likely and that the construction strategy is sufficiently robust to accommodate
39 alternatives. This appendix contains both general and very specific information. It begins with a
40 discussion of general mobilization in Section 2. Details of the multi-deck construction stage are
41 provided in Section 3. Section 4 contains descriptions of the construction activities. Information
42 presented here is supplemented by several engineering drawings and sketches contained in
43 Appendix E. The topical information and the level of provided detail substantiate the theory that
44 reliable shaft seal construction is possible using available technology and materials.

1 **B2. Project Mobilization**

2 The duty descriptions that follow are for discussion purposes. The discussions do not
3 presuppose contractual arrangements, but simply identify tasks necessary for shaft seal
4 construction.

5 **B2.1 Subsurface**

6 Prior to initiation of sealing activities, the WIPP Operating Contractor will remove installations
7 and equipment on the repository level. A determination of items removed will be made before
8 construction begins. Such removal would include, but is not limited to, gates and fences at the
9 shaft; equipment such as winches, ventilation fans, pipelines; and communication and power
10 cables. Additionally, the following items will be removed from the shafts:

- 11 ● cables, counterweights, and sheaves;
- 12 ● existing waterlines; and
- 13 ● electrical cables not required for sealing operations.

14 The following equipment will be stored near the shaft on the repository level by the Sealing
15 Contractor prior to initiation of sealing activities:

- 16 ● a concrete header, hopper, and pump;
- 17 ● a concrete pump line to distribute concrete; and
- 18 ● an auxiliary mine fan and sufficient flexible ventilation tubing to reach work areas
19 required for installation of the shaft station concrete monolith.

20 The subsurface will be prepared adequately for placement of the shaft station monolith.
21 Determination of other preparatory requirements may be necessary at the time of construction.

22 **B2.2 Surface**

23 The Operating Contractor will remove surface facilities such as headframes, hoists, and
24 buildings to provide clear space for the Sealing Contractor. Utilities required for sealing activities
25 (e.g., air compressors, water, electrical power and communication lines) will be preserved. The
26 Sealing Contractor will establish a site office and facilities required to support the construction
27 crews, including a change house, lamp room, warehouse, maintenance shop, and security
28 provisions. Locations will be selected and foundations constructed for headframes, multi-deck
29 stage winches, man/equipment hoist, and exhaust fan. A drawing in Appendix E (Sketch E-4)
30 depicts a typical headframe and associated surface facilities. The hoist and winches will be
31 enclosed in suitable buildings; utilities and ventilation ducting will be extended to the shaft collar.
32 The large ventilation fan located near the collar is designed to exhaust air through the rigid
33 ventilation duct, resulting in the movement of fresh air down the shaft. Air flow will be sufficient
34 to support eight workers to the depth of the repository level. The following facilities will be
35 procured and positioned near the shaft collar:

- 36 ● a concrete batch plant capable of weighing, batching, and mixing the concrete to
37 design specifications;
- 38 ● a crushing and screening plant to process WIPP salt and local soil;
- 39 ● an insulated and heated pug mill, asphalt pump, asphalt storage tank, and other
40 auxiliary equipment; and
- 41 ● pads, silos, and structures to protect sealing materials from the weather.

42 The Sealing Contractor will construct a temporary structural steel bulkhead over the shaft at the
43 surface. The bulkhead will be sufficiently strong to support the weight of the multi-deck stage,

1 which will be constructed on it. When the multi-deck stage is completed, the headframe will be
2 erected. The headframe (depicted in Appendix E, Sketch E-3) will be built around the multi-deck
3 stage, and a mobile crane will be required during fabrication. When the headframe is
4 completed, cables for hoisting and lowering the multi-deck stage will be installed. Cables will run
5 from the three winches, over the sheaves in the headframe, down and under the sheaves on the
6 multi-deck stage, and up to anchors in the headframe. The headframe will be sufficiently high to
7 permit the multi-deck stage to be hoisted until the lowest component is 3.05 m (10 ft) above
8 surface. This will facilitate slinging equipment below the multi-deck stage and lowering it to the
9 work surface, as well as activities required at the collar during asphalt emplacement.

10 The multi-deck stage will be lowered to clear the collar, allowing the installation of compressed-
11 air-activated steel shaft collar doors, which will serve as a safety device, permitting safe access
12 to the man cage and bucket, while preventing objects from falling down the shaft. Following
13 installation of these doors, workers will utilize the multi-deck stage to traverse the shaft from the
14 collar to the repository horizon, inspecting it for safety hazards and making any necessary
15 repairs. After this inspection, the multi-deck stage will return to the surface.

16 **B2.3 Installation of Utilities**

17 In preparation for placement of shaft seal materials, requisite utilities will be outfitted for
18 operations. The multi-deck stage will descend from the collar to the repository horizon. As
19 added assurance against unwanted water, a gathering system similar to the one currently in
20 place at the bottom of the concrete liner will be installed and moved upward as seal
21 emplacement proceeds. Water collected will be hoisted to the surface for disposal. Additionally,
22 any significant inflow will be located and minimized by grouting. After installation of the water
23 gathering system, the following utilities will be installed from surface to the repository horizon by
24 securely fastening them to the shaft wall:

- 25 ● 5.1-cm steel waterline with automatic shut-off valves every 60 m;
- 26 ● 10.2-cm steel compressed-air line;
- 27 ● power, signal, and communications cables;
- 28 ● 15.2 cm steel slickline and header; and
- 29 ● a rigid, cylindrical, ventilation duct, which would range from 107 cm in diameter in
30 the three largest shafts to 91 cm in diameter in the Salt Handling Shaft.

31 **B3. Multi-Deck Stage**

32 The multi-deck stage (galloway) provides a work platform from which all sealing operations
33 except placement of asphalt are conducted. The concept of using a multi-deck stage is derived
34 from similar equipment commonly employed during shaft sinking operations. Plan and section
35 views of conceptual multi-deck stages are shown in Appendix E, Sketches E-1 and E-2. The
36 construction decks specified here are modified from typical shaft sinking configurations in two
37 important ways to facilitate construction. Conceptual illustrations of these two modifications are
38 displayed in Figures I2B-1 and I2B-2. Figure I2B-1 illustrates the multi-deck performing dynamic
39 compaction of salt. Figure I2B-2 illustrates the multi-deck stage configured for excavation of the
40 kerf required for the asphalt waterstop in Salado salt.

41 A device called a polar crane mounted below the lower deck can be configured for either
42 dynamic compaction or salt excavation. The crane can rotate 360° horizontally by actuating its
43 geared track drive. Its maximum rotational speed will be approximately two revolutions per
44 minute. The crane can be controlled manually or by computer (computerized control will swiftly

1 position the tamper in the numerous drop positions required for dynamic compaction). When
2 excavation for the concrete-asphalt waterstops is required, the tamper, electromagnet, and
3 cable used for dynamic compaction will be removed, and a custom salt undercutter will be
4 mounted on the polar crane trolley. Geared drives on the crane, trolley, and undercutter will
5 supply the force required for excavation. In addition to the special features noted above and
6 shown in Figures I2B-1 and I2B-2, the multi-deck stage has the following equipment and
7 capabilities:

- 8 ● Maximum hoisting/lowering speed is approximately 4.6 m (15 ft) per minute.
- 9 ● A cable, electromagnet, and tamper will be attached to the polar crane during
10 dynamic compaction. The cylindrical tamper consists of A-36 carbon steel plates
11 bolted together with high-tensile-strength steel bolts. It is hoisted and dropped by
12 the polar crane using the electromagnet. The tamper will be mechanically
13 secured to the polar crane before personnel are allowed under it.
- 14 ● Range-finding lasers will facilitate the accurate positioning of the multi-deck
15 stage above the work surface and allow the operator to determine when the
16 surface is sufficiently level. The distance indicated by each laser will be displayed
17 on a monitor at the crane control station.
- 18 ● Flood lights and remotely controlled closed-circuit television equipment will
19 enable the crane operator to view operations below the multi-deck stage on a
20 monitor.
- 21 ● Fold-out floor extensions that accommodate the variance in shaft diameter
22 between the unlined and lined portions of the shaft will be provided for safety.
- 23 ● A cutout in each deck, combined with a removable section of the polar crane
24 track, will permit stage movement without removal of the rigid ventilation duct
25 (which is fastened to the shaft wall).

26 The multi-deck stage is equipped with many of the features found on conventional shaft sinking
27 stages, such as:

- 28 ● three independent hoisting/lowering cables,
- 29 ● man and material conveyances capable of passing through the multi-deck stage
30 and accessing the working surface below,
- 31 ● a jib crane that can be used to service the working surface below,
- 32 ● removable safety screens and railings, and
- 33 ● centering devices.

34 Three sets of double locking devices are provided to secure the multi-deck stage to the shaft
35 wall. A suitable factor of safety for these locking devices is judged to be 4. The area of the grips
36 securing the deck is calculated from static principles:

$$37 \quad FS = \mu (Co) (A)/W \quad (B-1)$$

38 where:

39 FS = factor of safety

40 μ = steel/salt friction coefficient = 0.15 (see Table 20.1 in McClintock and Aragon, 1966;
41 and Van Sambeek, 1988)

42 Co = compressive strength of WIPP salt, which varies from 172 kg/cm² to 262 kg/cm² (Van
43 Sambeek, 1988)

1 W = total vertical weight
2 A = total gripper pad surface area.

3 Manipulating the equation to solve for required area, applying a factor of safety of 4, selecting
4 the heaviest work stage (753,832 kg) and the minimum compressive strength value for salt
5 (assuming that the locking pressure equals the minimum compressive strength of salt), the
6 following gripper surface area (A) is:

7 $A = 4(753,832 \text{ kg})/0.15(172 \text{ kg/cm}^2) = 11,416.5 \text{ cm}^2$, and each of the six gripper pads would be
8 1902.8 cm^2 .

9 As designed, each gripper pad area is 2167.2 cm^2 , resulting in a factor of safety (FS) of 4.56.
10 Additionally, although tension in the hoisting cables is relaxed while the multi-deck stage is in
11 the locked configuration, the cables are still available to hold the work-deck, should the locking
12 devices fail.

13 **B4. Placement of Sealing Materials**

14 Construction activities include placement of materials in three basic ways: (1) by slickline (e.g.,
15 concrete and asphalt), (2) by compaction (e.g., salt and earthen fill), and (3) by physical
16 placement (e.g., clay blocks). Materials will be placed at various elevations using identical
17 procedures. Because placement procedures generally are identical regardless of elevation, they
18 will be described only once. Where differences occur, they will be identified and described. In
19 general, placement of shaft seal elements is described from bottom to top.

20 **B4.1 Concrete**

21 Concrete is used as a seal material for several different components, such as the existing
22 sumps in the Salt Handling Shaft and the Waste Shaft, the shaft station monoliths, concrete
23 plugs, and concrete-asphalt waterstops. Existing sumps are shown in Appendix E, Drawings
24 SNL-007, Sheets 6 and 21. Shaft station monoliths are shown in Drawings SNL-007, Sheets 6,
25 11, 16, and 21. Concrete plugs are depicted on Drawings SNL-007, Sheets 4, 5, 9, 10, 14, 15,
26 19, and 20. Lower, middle, and upper concrete-asphalt waterstops are shown in Drawing
27 SNL-007, Sheet 22. Construction material for all concrete members will be Salado Mass
28 Concrete (SMC).

29 As specified, all SMC will be mixed on surface to produce a product possessing the
30 characteristics defined in Appendix A. Concrete will be transferred to its placement location
31 within the shaft via slickline and header. The slickline (shown in Figure I2B-1) is a steel pipe
32 fastened to the shaft wall. Vertical drops as great as 656 m to the repository horizon are
33 required. Such concrete transport and construction are common in mining applications. For
34 example, a large copper mine in Arizona is placing concrete at a depth of 797 m using this
35 procedure. A header attached to the bottom of the slickline is designed to absorb kinetic energy
36 generated by the falling material. The header, a steel pipe slightly larger in diameter than the
37 slickline and made of thicker steel, diverts the flow 45° , absorbing most of the impact. Because
38 the drop generates considerable force, the header will be securely supported by a reinforced
39 steel shelf bolted to the shaft wall. A flexible hose, in sections approximately 3 m long and
40 joined by quick-connect fittings, will be attached to the header.

B4.1.1 Shaft Station Monolith

Construction of the shaft station monoliths is preceded by filling two existing sumps with SMC. Initially, sufficient hose will be used to convey the concrete to the bottom of the sump. The discharge will remain below the concrete surface during placement to minimize air entrainment. Sections of hose will be withdrawn and removed as the SMC rises to the floor of the repository horizon in a continuous pour. Subsequent to filling the sump, arrangements will be made to place the concrete monolith.

A small mine fan will be located above the rigid suction-duct inlet to ensure a fresh air base. Masonry block forms will be constructed at the extremities of the shaft station monolith in the drifts leading from the station. Temporary forms, partially filling the opening, will be erected at the shafts to facilitate the placement of the outermost concrete. These temporary forms will permit access necessary to ensure adequate concrete placement. SMC will be transported via the slickline to the header, which will discharge into a hopper feeding the concrete pump, and the pump will be attached to the pumpcrete line. The pumpcrete line, suspended in cable slings near the back of the drifts, will be extended to the outer forms. A flexible hose, attached to the end of the pumpcrete line, will be used by workers to direct emplacement. The pumpcrete line will be withdrawn as emplacement proceeds toward the shaft.

When the concrete has reached the top of the temporary forms, they will be extended to seal the openings completely, and two 5-cm-diameter polyvinyl chloride (PVC) pipes will be incorporated in the upper portion of each form. Both pipes will be situated in a vertical plane oriented on the long axis of the heading and inclined away from the station at approximately 70° to the horizontal. The upper end of the top pipe will extend to just below the back, and the upper end of the lower pipe will be located just below that of the top pipe. SMC will be injected through the lower pipe until return is obtained from the upper pipe, ensuring that the heading has been filled to the back. The header will then be moved to a position in the shaft above the designed elevation at the top of the shaft station monolith and supported by a bracket bolted to the shaft wall. After the outer concrete has achieved stability, the temporary interior forms may be removed. Equipment no longer required will be slung below the multi-deck stage and hoisted to surface for storage and later use. The station and shaft will be filled to design elevation with concrete via the slickline, header, and flexible hose. The slickline is cleaned with spherical, neoprene swabs ("pigs") that are pumped through the slickline, header, and hose.

B4.1.2 Concrete-Asphalt Waterstops

Lower, middle, and upper concrete-asphalt waterstops in a given shaft are identical and consist of two SMC sections separated by an asphalt waterstop. Before the bottom member of the lower concrete component is placed, the multi-deck stage will be raised into the headframe; the polar crane will be mounted below the lower deck; and the salt undercutter will be mounted on the crane trolley. The multi-deck stage will then return to the elevation of the concrete component. Two undercutter bars will be used to make the necessary excavations for upper, middle, and lower asphalt-concrete waterstops and the concrete plug above the Salado Formation. Notches for the plugs will be excavated using a short, rigid cutter bar (length less than half the radius). The kerf for the asphalt waterstop will be excavated using a long cutter bar that can excavate the walls to a depth of one shaft radius. These operations will be conducted as required as seal placement proceeds upward.

1 The lower concrete member (and all subsequent concrete entities) will be placed via the
2 slickline, header, and flexible hose, using the procedure outlined for the shaft station monolith.
3 Construction of vertical shaft seals provides the ideal situation for minimizing interface
4 permeability between the rock and seal materials. Concrete will flow under its own weight to
5 provide intimate contact. A tight cohesive interface was demonstrated for concrete in the small-
6 scale seal performance tests (SSSPTs). The SSSPT concrete plugs were nearly impermeable
7 without grouting. However, interface grouting is usually performed in similar construction, and it
8 will be done here in the appropriate locations.

9 **B4.1.3 Concrete Plugs**

10 An SMC plug, keyed into the shaft wall, is situated a few meters above the upper Salado
11 contact in the Rustler Formation. A final SMC plug is located a few meters below surface in the
12 Dewey Lake Redbeds. This plug is emplaced within the existing shaft liner using the same
13 construction technique employed for the concrete-asphalt waterstops.

14 **B4.2 Clay**

15 **B4.2.1 Salado and Rustler Compacted Clay Column**

16 Blocks of sodium bentonite clay, precompacted to a density of 1.8 to 2.0 g/cm³, will be the
17 sealing material. This density has been achieved at the WIPP using a compaction pressure of
18 492.2 kg/cm² in a machine designed to produce adobe blocks (Knowles and Howard, 1996).
19 Blocks are envisioned as cubes, 20.8 cm on the edge, weighing approximately 18 kg, a
20 reasonable weight for workers to handle. The bentonite blocks will be compacted at the WIPP in
21 a new custom block-compacting machine and will be stored in controlled humidity to prevent
22 desiccation cracking. Blocks will be transported from surface in the man cage, which will be
23 sized to fit through the circular "bucket hole" in the multi-deck stage. The conveyance will be
24 stacked with blocks to a height of approximately 1.8 m.

25 Installation will consist of manually stacking individual blocks so that all interfaces are in contact.
26 Block surfaces will be moistened with a spray of potable water as the blocks are placed to
27 initiate a minor amount of swelling, which will ensure a tight fit and a decrease in permeability.
28 Peripheral blocks will be trimmed to fit irregularities in the shaft wall and placed as close to the
29 wall as possible. Trimmed material will be manually removed with a vacuum. Dry bentonite will
30 be manually tamped into remaining voids in each layer of blocks. This procedure will be
31 repeated throughout the clay column. The multi-deck stage will, in all cases, be raised and
32 utilities removed to the surface as emplacement of sealing materials proceeds upward.

33 Dynamic compaction construction is an alternative method of clay emplacement that could be
34 considered in the detailed design. Dynamic compaction materials being considered are:

- 35 ● sodium bentonite/fine silica sand, and
- 36 ● highly compressed bentonite pellets.

37 Boonsinsuk et al. (1991) developed and tested a dynamic (drop hammer) method for a relatively
38 large diameter (0.5-m) hole, simulated with a steel cylinder, that gave very good results on 1 : 1
39 dry mass mixtures of sodium bentonite and sand, at a moisture content of 17% to 19%. The
40 alternatives have the advantages of simplifying emplacement.

1 **B4.3 Asphalt**

2 Asphalt, produced as a distillate of petroleum, is selected as the seal material because of its
3 longevity, extremely low permeability, history of successful use as a shaft lining material, and its
4 ability to heal if deformed. Shielded from ultraviolet radiation and mixed with hydrated lime to
5 inhibit microbial degradation, the longevity of the asphalt will be great. Emplaced by tremie line
6 at the temperature specified, the material will be fluid and self-leveling, ensuring complete
7 contact with the salt.

8 Construction of an asphalt column using heated asphalt will introduce heat to the surrounding
9 salt. The thermal shock and heat dissipation through the salt has not been studied in detail.
10 Performance of the asphalt column may be enhanced by the introduction of the heat that results
11 from acceleration of creep and healing of microfractures. If, upon further study, the
12 thermomechanical effects are deemed undesirable or if an alternative construction method is
13 preferred at a later date, asphalt can readily be placed as blocks. Asphalt can "cold flow" to fill
14 gaps, or the seams between blocks can be filled with low-viscosity material.

15 **B4.3.1 Concrete-Asphalt Waterstops**

16 Electrically insulated, steel grated flooring will be constructed over the shaft at the surface. A
17 second, similar flooring will be built in the shaft 3 m below the first. These floors will be used
18 only during the emplacement of asphalt and asphaltic mastic mix (AMM) and will be removed at
19 all other times. A 12.7-cm ID/14-cm OD, 4130 steel pipe (tremie line) in 3-m lengths will be
20 electrically equipped for impedance heating, then insulated and suspended in the shaft from
21 slips (pipe holding devices) situated on the upper floor. The tremie line cross-sectional area is
22 smallest at the shoulder of the top thread, where tensional yield is 50,000 kg; the line weight is
23 20.8 kg/m. Heavier weights are routinely suspended in this manner in the petroleum and mining
24 industries.

25 Neat, AR-4000-graded petroleum-based asphalt cement will be the sealing material for asphalt
26 waterstops. Neat asphalt from the refinery will be delivered to the WIPP at approximately 80°C
27 in conventional, insulated refinery trucks and pumped into a heated and insulated storage tank
28 located near the shaft. The multi-deck stage will be hoisted into the headframe and
29 mechanically secured for safety. Asphalt, heated to 180°C ±5°, will be pumped down the shaft to
30 the fill elevation through the heated tremie line. Viscosity of the neat asphalt for the waterstops
31 will be sufficiently low to allow limited penetration of the DRZ. Installation of asphalt in each of
32 the concrete-waterstops is identical.

33 As the pipe is lowered, workers on the lower deck will attach the wiring required for heating
34 circuits and apply insulation. Workers on the top deck will install flanged and electrically
35 insulated couplings as required (the opening in the slip bowl will be large enough to permit the
36 passage of these couplings). Properly equipping and lowering the pipe should progress at the
37 rate of one section every 10 minutes. The lower asphalt waterstop requires approximately 607
38 m of pipe for a casing weight of 12,700 kg. Additionally, electrical wire and insulation will weigh
39 about 7250 kg for a total equipped tremie line weight of 20,000 kg. Therefore, the safety factor
40 for the tremie line is 50,000 kg/20,000 kg, or 2.5.

41 To minimize air entrainment, the lower end of the tremie line will be immersed as much as 1 m
42 during hot asphalt emplacement. Therefore, the lower 3 m of casing will be left bare (to simplify
43 cleaning when emplacement has been completed).

1 Initially the tremie line will be lowered until it contacts the concrete plug (immediately underlying
2 the excavation for the waterstop) and then raised approximately 0.3 m. Asphalt emplacement
3 will proceed as follows:

- 4 ● The impedance heating system will be energized, heating the tremie line to
5 $180^{\circ}\text{C} \pm 5^{\circ}$, and the asphalt in the storage tank will be heated to approximately
6 $180^{\circ}\text{C} \pm 5^{\circ}$.
- 7 ● Heated, neat asphalt will be pumped down the tremie line at a rate approximating
8 13 L/min. This low rate will ensure that the asphalt flows across the plug from the
9 insertion point, completely filling the excavation and shaft to the design elevation.
- 10 ● The tremie line will be raised 3 m and cleaned by pumping a neoprene swab
11 through it with air pressure. Impedance heating will be stopped, and the line will
12 be allowed to cool. When cool, the line will be hoisted, stripped, cleaned,
13 disassembled, and stored for future use.

14 Sealing operations will be suspended until the air temperature at the top of the asphalt has
15 fallen to approximately 50°C for the comfort of the workers when they resume activity at the fill
16 horizon. Temperature will be determined by lowering a remotely read thermometer to an
17 elevation approximately 3 m above the asphalt at the center of the shaft. The temperature of the
18 asphalt at the center of the shaft will be 50°C in about a month, but active ventilation should
19 permit work to resume in about two weeks (see calculations in Appendix D of Appendix I2 in the
20 permit application, which is not included in the Permit).

21 When sufficient cooling has occurred, workers will descend in the multi-deck stage and cover
22 the hot asphalt with an insulating and structural material such as fiber-reinforced shotcrete, as
23 illustrated in Figure I2B-3. To accomplish this, they will spray cementitious shotcrete containing
24 fibrillated polypropylene fibers (for added tensional strength), attaining a minimum thickness of
25 approximately 0.6 m.

26 **B4.3.2 Asphaltic Mastic Mix Column**

27 Asphaltic mastic mix (AMM) for the column will be prepared on surface in a pug mill. Viscosity of
28 the AMM can be tailored to provide desired properties such as limited migration into large
29 fractures.

- 30 ● AMM will be prepared by mixing the ingredients in the pug mill, which has been
31 heated to $180^{\circ}\text{C} \pm 5^{\circ}$. The mix will be pumped from the pug mill through the
32 tremie line to the emplacement depth. AMM is self-leveling at this temperature,
33 and its hydrostatic head will ensure intimate contact with the shaft walls.
- 34 ● Pumping rate will be approximately 200 L/min for efficiency, because of the
35 larger volume (approximately 1,224,700 L in the Air Intake Shaft). To facilitate
36 efficient emplacement and avoid air entrainment, the tremie line will not be
37 shortened until the mix has filled 6 vertical meters of the shaft. Back pressure
38 (approximately 0.84 kg/cm^2) resulting from 6 m of AMM above the discharge
39 point will be easily overcome from surface by the hydraulic head.

40 After 6 vertical meters of AMM have been placed:

- 41 ● Impedance heating current will be turned off and locked out (the hot line will drain
42 completely).

- 1 ● To prevent excessive back pressure resulting from AMM above the insertion
2 point, the line will be disconnected from the pump and hoisted hot. Two sections
3 will be stripped, removed, cleaned with a "pig," and stacked near the shaft.
- 4 ● Electrical feed will be adjusted (because of the decreased resistance of the
5 shortened line).
- 6 ● The tremie line will be reconnected to the pump.
- 7 ● The impedance heating system will be energized.
- 8 ● When the temperature of the line has stabilized at $180^{\circ}\text{C} \pm 5^{\circ}$, pumping will
9 resume.

10 This procedure will be followed until the entire column, including the volume computed to
11 counteract 0.9 m of vertical shrinkage (calculations in Appendix D of Appendix I2 in the permit
12 application), has been placed. The line will be disconnected from the pump and cleaned by
13 pumping "pigs" through it with air pressure. It will then be hoisted, stripped, removed in 3-m
14 sections, and stacked on surface for reuse.

15 Sealing operations will be suspended following removal of the tremie line, and ventilation will be
16 continuous to speed cooling. The column will shrink vertically but maintain contact with the shaft
17 walls as it cools. When the air temperature at 3 m above the asphalt has cooled sufficiently,
18 workers will descend on the multi-deck stage and cover the hot asphalt with fibercrete as
19 described for the concrete-asphalt waterstop (Section B4.3.1) and illustrated in Figure I2B-3.

20 Note: Near the top of the Salado Formation, portions of the concrete liner key, chemical seal
21 rings, and concrete and steel shaft liners will be removed. Liner removal will occur before
22 emplacement of AMM. For safety, exposed rock will be secured with horizontal, radial rock bolts
23 and cyclone steel mesh. A range-finding device, fastened to the shaft wall approximately 3 m
24 above the proposed top of the asphaltic column, will indicate when the hot AMM reaches the
25 desired elevation. A remotely read thermometer, affixed to the shaft wall approximately 2 m
26 above the proposed top of the column, will show when the air temperature has fallen sufficiently
27 to resume operations. The intake of the rigid ventilation duct will be positioned approximately 3
28 m above the proposed top of the column, and ventilation will be continuous throughout
29 emplacement and cooling of the asphaltic column. After the multi-deck stage has been hoisted
30 into the headframe and mechanically secured for safety, emplacement of AMM will proceed.

31 **B4.4 Compacted Salt Column**

32 Crushed, mine-run salt, dynamically compacted against intact Salado salt, is the major long-
33 term shaft seal element. As-mined WIPP salt will be crushed and screened to a maximum
34 particle dimension of 5 mm. The salt will be transferred from surface to the fill elevation via the
35 slickline and header. A flexible hose attached to the header will be used to emplace the salt,
36 and a calculated weight of water will be added. After the salt has been nominally leveled, it will
37 be dynamically compacted. Dynamic compaction consists of compacting material by dropping a
38 tamper on it and delivering a specified amount of energy. The application of three times
39 Modified Procter Energy (MPE) to each lift (one MPE equals $2,700,000 \text{ Joules/m}^3$) will result in
40 compacting the salt to 90% of the density of in-place rock salt.

41 Approximately 170 vertical meters of salt will be dynamically compacted. Dynamic compaction
42 was validated in a large-scale demonstration at Sandia National Laboratories during 1995. As-
43 mined WIPP salt was dynamically compacted to 90% density of in-place rock salt in a cylindrical

1 steel chamber simulating the Salt Handling Shaft (Ahrens and Hansen, 1995). Depth of
2 compaction is greater than that achieved by most other methods, allowing the emplacement of
3 thicker lifts. For example, dropping the 4.69 metric ton tamper 18 m (as specified below) results
4 in a compaction depth of approximately 4.6 m, allowing emplacement of lifts 1.5-m high. Most
5 other compaction methods are limited to lifts of 0.3 m or less. Lift thickness will be increased
6 and drop height decreased for the initial lift above the concrete plug at the base of the salt
7 column to ensure that the concrete is not damaged. Drop height for the second and third lifts will
8 be decreased as well. Although the tamper impact is thereby reduced, three MPE will be
9 delivered to the entire salt column.

10 If lifts are 1.5-m thick, the third lift below the surface will receive additional densification during
11 compaction of overlying lifts, and this phenomenon will proceed up the shaft. Construction will
12 begin by hoisting the multi-deck stage to the surface and attaching the cable, electromagnet,
13 and tamper to the hoist on the polar crane. The multi-deck assembly will be lowered to the
14 placement elevation, and moisture content of the crushed and screened salt will be calibrated.
15 Then the salt will be conveyed at a measured rate via a weighbelt conveyor to a vibrator-
16 equipped hopper overlying the 15.2-cm ID slickline. The salt will pass down the slickline and exit
17 a flexible hose connected to the header. A worker will direct the discharge so that the upper
18 surface of the lift is nominally level and suitable for dynamic compaction. A second worker will
19 add potable water, in the form of a fine spray, to the salt as it exits the hose. Water volume will
20 be electronically controlled and coordinated with the weight of the salt to achieve the desired
21 moisture content.

22 The initial lift above the SMC will be 4.6 m, and drop height will be 6 m. This increased lift
23 thickness and reduced drop height are specified to protect the underlying SMC plug from
24 damage and/or displacement from tamper impact. Compaction depth for a drop height of 6 m is
25 approximately 3.7 m. Ultimately, the tamper will be dropped six times in each position, resulting
26 in a total of 132 drops per lift in the larger shafts. The drop pattern is shown in Figure I2B-4. A
27 salt lift 1.5 m high will then be placed and leveled. Following compaction of the initial lift, the
28 multi-deck stage will be positioned so the base of the hoisted tamper is 10 m above the surface
29 of the salt.

30 The multi-deck stage will then be secured to the shaft walls by activating hydraulically powered
31 locking devices. Hydraulic pressure will be maintained on these units when they are in the
32 locked position; in addition, a mechanical pawl and ratchet on each pair will prevent loosening.
33 The safety factor for the locking devices has been calculated to be approximately 4.5. After
34 locking, tension in the hoisting cables will be relaxed, and centering rams will be activated to
35 level the decks. Prior to positioning the stage, tension will be applied to the hoisting cables; the
36 centering rams will be retracted; and the locking devices will be disengaged.

37 The work deck will be hoisted until the base of the retracted tamper is 23 m above the surface
38 of the salt, where it will be locked into position and leveled as described above. This procedure,
39 repeated throughout the salt column, allows emplacement and compaction of three lifts (1.5-m
40 thick) per multi-deck stage move. Depth of compaction for a drop height of 18 m is
41 approximately 4.6 m. Therefore the third lift below the fill surface will receive a total of 9 MPE
42 ($274,560 \text{ m kg/m}^3$), matching the energy applied in the successful, large-scale demonstration.

1 The compactive effect expands laterally as it proceeds downward from the base of the tamper
2 and will effectively compact the salt into irregularities in the shaft wall, as demonstrated in the
3 large-scale demonstration. Although other techniques could be used, dynamic compaction was
4 selected because it is simple, can be used in the WIPP shafts, and has been demonstrated
5 (Hansen and Ahrens, 1996).

6 The tamper will be dropped from the hoisted position by turning off the power to the
7 electromagnet. Immediately upon release, the crane operator will "chase" the tamper by
8 lowering the electromagnet at twice hoisting speed; the magnet will engage the tamper, allowing
9 it to be hoisted for the subsequent drop. Initially, the tamper will be dropped in positions that
10 avoid impact craters caused by preceding drops. The surface will then be leveled manually and
11 the tamper dropped in positions omitted during the previous drop series.

12 Experience gained during the large-scale salt compaction demonstration indicated that a
13 considerable volume of dust is generated during the emplacement of the salt, but not during
14 dynamic compaction. However, because the intake of the rigid vent duct is below the multi-deck
15 stage, workers below the stage will wear respirators during emplacement. They will be the only
16 workers affected by dust during dynamic compaction.

17 The Air Intake Shaft will require 22 drop positions (Figure I2B-4). Application of one MPE
18 requires six drops in each position, for a total of 132 drops per lift. Three MPE, a total of 396
19 drops per lift, will be applied to all salt. After each compaction cycle, the salt surface will be
20 leveled manually and the tamper will be dropped in positions omitted in the preceding drop
21 series. Two lifts, each 1.8 m high, will then be sequentially placed, leveled, and compacted with
22 two MPE, using a 6-m drop height.

23 Dynamic compaction ensures a tight interface. Salt compacted during the large-scale dynamic
24 compaction demonstration adhered so tenaciously to the smooth interior walls of the steel
25 compaction chamber that grinders with stiff wire wheels were required for its removal.

26 **B4.5 Grout**

27 Ultrafine sulfate-resistant cementitious grout (Ahrens et al., 1996) is selected as the sealing
28 material. Specifically developed for use at the WIPP, and successfully demonstrated in an in
29 situ test, the hardened grout has a permeability of 1×10^{-21} m². It has the ability to penetrate
30 fractures smaller than 6 microns and is being used for the following purposes:

- 31 ● to seal many of the microfractures in the DRZ and ensure a tight interface
32 between SMC and the enclosing rock, and
- 33 ● to solidify fractured rock behind existing concrete shaft liners, prior to removal of
34 the liner (for worker safety).

35 The interface between concrete plugs in the Salado Formation (and one in the Rustler
36 Formation, a short distance above the Salado) will be grouted. A 45° downward-opening cone of
37 reverse circulation diamond drill holes will be collared in the top of the plugs, drilled in a spin
38 pattern (see Figure I2B-5), and stage grouted with ultrafine cementitious grout at 3.5 kg/cm²
39 below lithostatic pressure. Stage grouting consists of:

- 40 ● drilling and grouting primary holes, one at a time;
- 41 ● drilling and grouting secondary holes, one at a time, on either side of the primary
42 holes that accepted grout; and

- (if necessary) drilling and grouting tertiary holes on either side of secondary holes that accepted grout.

Note: For safety, all liner removal tasks will be accomplished from the bottom deck. In areas where the steel liner is removed, it will be cut into manageable pieces with a cutting torch and hoisted to the surface for disposal. Mechanical methods will be employed to clean and roughen the existing concrete shaft liner before placing the Dewey Lake SMC plug in the shafts.

The work sequence will start 3 m below the lower elevation of liner removal. A 45° upward-opening cone of grout injection holes, drilled in a “spin” pattern (Figure I2B-6), will be drilled to a depth subtending one shaft radius on a horizontal plane. These holes will be stage grouted as described in Section 4.5. Noncoring, reverse circulation, diamond drill equipment will be used to avoid plugging fractures with fine-grained diamond drill cuttings. Ultrafine cementitious grout will be mixed on the surface, transferred via the slickline to the upper deck of the multi-deck stage, and injected at 3.5 kg/cm² gage below lithostatic pressure to avoid hydrofracturing the rock. Grout will be transferred in batches, and after each transfer, a “pig” will be pumped through the slickline and header to clean them. Grouting will proceed upward from the lowest fan to the highest. Recent studies conducted in the Air Intake Shaft (Dale and Hurtado, 1996) show that this hole depth exceeds that required for complete penetration of the Disturbed Rock Zone (DRZ). Maximum horizontal spacing at the ends of the holes will be 3 m.

The multi-deck stage will then be raised 3 m and a second fan, identical to the first, will be drilled and grouted. This procedure will continue, with grout fans 3 m apart vertically, until the highest fan, located 3 m above the highest point of liner removal, has been drilled and grouted. Ultrafine cementitious grout was observed to penetrate more than 2 m in the underground grouting experiment conducted at the WIPP in Room L-3 (Ahrens and Onofrei, 1996).

When grouting is completed, the multi-deck stage will be lowered to the bottom of the liner removal section and a hole will be made through the concrete liner. This hole, approximately 30 cm in diameter, will serve as “free-face” to which the liner will be broken. Similar establishment and utilization of free face is a common practice in hard rock mining (e.g., the central drill hole in a series drilled into the rock to be blasted is left empty and used as free-face to which explosives in adjacent holes break the rock). Radial, horizontal percussion holes will be drilled on a 30-cm grid (or less, if required), covering the liner to be removed. Hydraulic wedges, activated in these holes, will then break out the liner, starting adjacent to the free face and progressing away from it, from the bottom up. Broken fragments of the concrete liner will fall to the fill surface below.

A mucking “claw,” suspended from the trolley of the polar crane, will collect the broken concrete and place it in the bucket for removal to the surface. As many as three buckets can be used to speed this work.

B4.6 Compacted Earthen Fill

Local soil, screened to a maximum particle dimension of 13 mm, will be placed and compacted to inhibit the migration of surficial water into the shaft cross section. Such movement is further decreased by a 12-m high SMC plug at the top of the Dewey Lake Redbeds.

B4.6.1 Lower Section

Emplacement of the compacted earthen fill will proceed as follows:

- Moisture content of the screened soil will be determined.
- The soil will then be transferred via the slickline, header, and flexible hose from surface to the fill elevation. The moisture content optimal for compaction will be achieved using the same procedure as described for compacted salt (Section B4.4). The soil will be emplaced in lifts 1.2 m high (depth of compaction is approximately 3.7 m) and dynamically compacted using a drop height of 18.3 m.
- The fill will be dynamically compacted until its hydraulic conductivity to water is nominally equivalent to that of the surrounding formation.

This procedure will continue until the lower section has been emplaced and compacted. Care will be exercised at the top of the column to ensure that all soil receives sufficient compaction.

B4.6.2 Upper Section

The upper section contains insufficient room to employ dynamic compaction. Therefore the screened soil, emplaced as described above, will be compacted by vibratory-impact sheepsfoot roller, vibratory sheepsfoot roller, or a walk-behind vibratory-plate compactor. Because of the limited compaction depth of this equipment, lifts will be 0.3 m high. The top of the fill will be coordinated with the WIPP Operating Contractor to accommodate plans for decommissioning surface facilities and placing markers.

B4.7 Schedule

Preliminary construction schedules are included on the following pages. The first schedule is a concise outline of the total construction schedule. It is followed by individual schedules for each shaft. The first schedule in each shaft series is a truncated schedule showing the major milestones. The truncated schedules are followed by detailed construction schedules for each shaft. These schedules indicate that it will take approximately six and a half years to complete the shaft sealing operations, assuming two shafts are simultaneously sealed.

1

SEALING SCHEDULE - ALL SHAFTS

1

SEALING SCHEDULE - AIR INTAKE SHAFT

ID	Task Name	Duration	Year 1				Year 2				Year 3							
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4				
1	Mobilization	4w	█															
3	Plant Set-up	12w	█	█														
5	Inspect & Scale Shaft-2151'	1w		█														
7	Install Construction Utilities	7.17w		█	█													
9	Drill & Grout Lining	11.5w		█	█	█												
11	Shaft Station Monolith-37'	4.78w			█	█												
15	Lower Salado Compacted Clay Column-93.5'	4.96w				█	█											
17	Lower Concrete-Asphalt Waterstop-50'	8.25w					█	█										
26	Compacted Salt Column-563.5'	23.58w						█	█									
28	Middle Concrete-Asphalt Waterstop-50'	8.25w							█	█								
37	Upper Salado Compacted Clay Column-344'	18.24w								█	█							
39	Upper Concrete-Asphalt Waterstop-50'	10.25w									█	█						
48	Asphalt Column-138.3'	19.41w										█	█					
56	Concrete Plug-20'	5.95w											█	█				
61	Remove Concrete Shaft Lining	5.71w												█	█			
63	Rustler Compacted Clay Column-234.7'	8.36w													█	█		
65	Compacted Earthen Fill-473'	7.69w														█	█	
67	Concrete Plug-40'	2.96w															█	
71	Compacted Earthen Fill-57'	0.85w																█
73	Demobilization	3.2w																█

Project: AIR INTAKE SHAFT SEALING SCHEDULE
 Date: Tue 7/9/96

Task Summary: █
 Progress: █
 Milestone: █

Summary: █
 Rolled Up Task: █
 Rolled Up Milestone: ◇

96 1

Waste Isolation Pilot Plant
 Hazardous Waste Permit
 October 27, 1999

ID	Task Name	Duration	Year 1				Year 2				Year 3						
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4			
1	Mobilization	4w	■														
2	Mobilize	4w	■														
3	Plant Set-up	12w		■	■												
4	Plant Set-up	12w		■	■												
5	Inspect & Scale Shaft-2161'	1w															
6	Inspect & Scale Shaft	1w															
7	Install Construction Utilities	7.17w			■	■											
8	Install Utilities	7.17w			■	■											
9	Drill & Grout Lining	11.5w					■	■									
10	Drill & Grout Lining	11.5w					■	■									
11	Shaft Station Monolith-37'	4.78w							■	■							
12	Construct Bulkheads	0.8w															
13	Pour Concrete (37' high)	0.98w															
14	Cure Concrete	3w															
15	Lower Salado Compacted Clay Column-93.5'	4.96w															
16	Emplace Bentonite Blocks (93.5' high)	4.96w															
17	Lower Concrete-Asphalt Waterstop-50'	8.25w															
18	Excavate for Lower Plug	1.67w															
19	Pour Concrete-Lower Plug (23' high typ.)	0.28w															
20	Excavate Waterstop	0.63w															
21	Place Asphalt (4' high typ.)	0.72w															
22	Cool-down Asphalt	1w															

Project: AIR INTAKE SHAFT SEALING SCHEDULE
 Date: Tue 7/9/96

Task Progress Milestone

Summary Rolled Up Task Rolled Up Milestone

Rolled Up Progress

ID	Task Name	Duration	Year 1				Year 2				Year 3									
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4						
23	Excavate for Upper Plug	1.67w																		
24	Pour Concrete-Upper Plug (23' high typ.)	0.28w																		
25	Cure Concrete	2w																		
26	Compacted Salt Column-563.5'	23.58w																		
27	Emplace & Compact Crushed/Screened Salt	23.58w																		
28	Middle Concrete-Asphalt Waterstop-50'	8.25w																		
29	Excavate for Lower Plug	1.67w																		
30	Pour Concrete-Lower Plug	0.28w																		
31	Excavate Waterstop	0.63w																		
32	Place Asphalt	0.72w																		
33	Cool-down Asphalt	1w																		
34	Excavate for Upper Plug	1.67w																		
35	Pour Concrete-Upper Plug	0.28w																		
36	Cure Concrete	2w																		
37	Upper Saiado Compacted Clay Column-344'	18.24w																		
38	Emplace Bentonite Blocks	18.24w																		
39	Upper Concrete-Asphalt Waterstop-50'	10.25w																		
40	Excavate for Lower Plug	1.67w																		
41	Pour Concrete-Lower Plug	0.28w																		
42	Excavate Waterstop	0.63w																		
43	Place Asphalt	0.72w																		
44	Cool-down Asphalt	1w																		

Project: AIR INTAKE SHAFT
 SEALING SCHEDULE
 Date: Tue 7/9/96

Task Progress Milestone
 Summary Rolled Up Task Rolled Up Milestone
 Rolled Up Progress

ID	Task Name	Duration	Year 1				Year 2				Year 3			
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4
45	Excavate for Upper Plug	1.67W												
46	Pour Concrete-Upper Plug	0.28W												
47	Cure Concrete	4W												
48	Asphalt Column-136.3'	19.41W												
49	Remove Lining in Key	3.76W												
50	Remove Chemical Seal Rings	0.6W												
51	Mobilize to Emplace Asphalt	0.3W												
52	Asphalt in Salt Section	3.62W												
53	Asphalt in Lower Lined Section	1.93W												
54	Complete Asphalt Emplacement	2.77W												
55	Cool-down Asphalt	6.43W												
56	Concrete Plug-20'	5.99W												
57	Remove Concrete Lining & Rock	1.65W												
58	Remove Liner Plate	0.13W												
59	Pour Concrete(20' high)	0.21W												
60	Cure Concrete	4W												
61	Remove Concrete Shaft Lining	5.71W												
62	Remove 86' of lining-4 zones	5.71W												
63	Rustler Compacted Clay Column-234.7'	8.36W												
64	Emplace & Compact Bentonite(234.7' high)	8.36W												
65	Compacted Earthen Fill-473'	7.59W												
66	Emplace & Compact Earthen Fill(473' high)	7.59W												

Project: AIR INTAKE SHAFT SEALING SCHEDULE
 Date: Tue 7/9/98

Task Progress Milestone

Summary Rolled Up Task Milestone

Rolled Up Progress

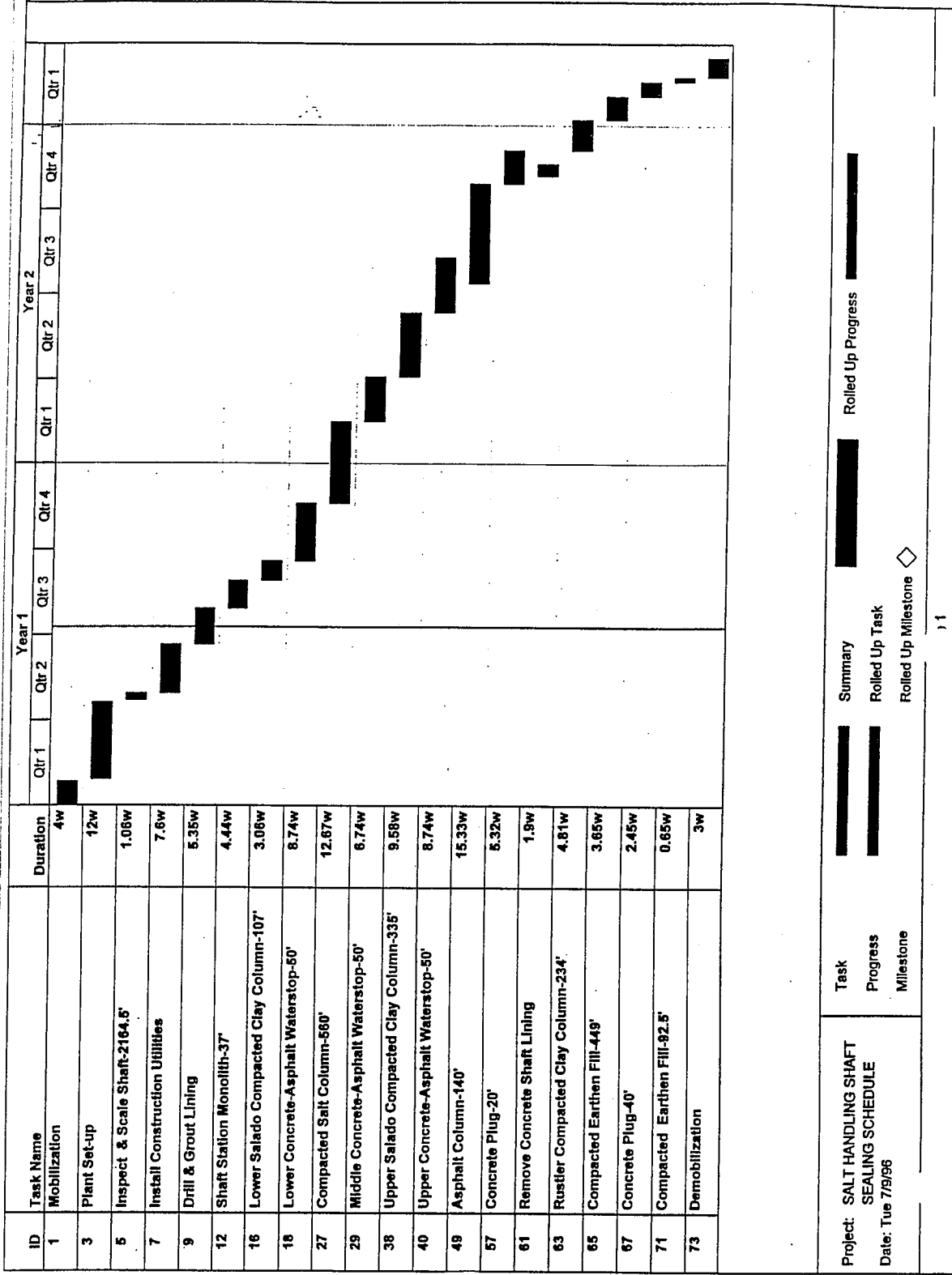
Page 3

ID	Task Name	Duration	Year 1				Year 2				Year 3			
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4
67	Concrete Plug-40'	2.96w												
68	Clean Existing Surface	0.6w												
69	Pour Concrete(40' high)	0.36w												
70	Cure Concrete	2w												
71	Compacted Earthen Fill-57'	0.65w												
72	Emplace & Compact Earthen Fill (57' high)	0.65w												
73	Demobilization	3.2w												
74	Demob	3.2w												

Project: AIR INTAKE SHAFT SEALING SCHEDULE	Task	Summary	Rolled Up Progress
Date: Tue 7/9/96	Progress	Rolled Up Task	
	Milestone	Rolled Up Milestone	

1

SEALING SCHEDULE - SALT HANDLING SHAFT



ID	Task Name	Duration	Year 1				Year 2						
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4			
1	Mobilization	4w	■										
2	Mobilize	4w	■										
3	Plant Set-up	12w	■	■									
4	Plant Set-up	12w	■	■									
5	Inspect & Scale Shaft-2164.5'	1.06w		■									
6	Inspect & Scale Shaft	1.06w		■									
7	Install Construction Utilities	7.6w		■	■								
8	Install Utilities	7.6w		■	■								
9	Drill & Grout Lining	5.35w			■	■							
10	Drill Grout Holes	2.14w			■								
11	Grout Lining	3.21w			■								
12	Shaft Station Monolith-37'	4.44w			■	■							
13	Construct Bulkheads	0.8w			■								
14	Pour Concrete (37' high)	0.64w			■								
15	Cure Concrete	3w			■								
16	Lower Salado Compacted Clay Column-107'	3.06w			■	■							
17	Emplace Bentonite Blocks (107.0' high)	3.06w			■	■							
18	Lower Concrete-Asphalt Waterstop-50'	8.74w			■	■	■	■					
19	Excavate for Lower Plug	1.36w			■								
20	Pour Concrete-Lower Plug (23' high-tyt)	0.17w			■								
21	Excavate Waterstop	0.34w			■								
22	Place Asphalt (4' high-tyt)	0.3w			■								

Project: SALT HANDLING SHAFT
 SEALING SCHEDULE
 Date: Tue 7/9/98

Task
 Progress
 Milestone

Summary
 Rolled Up Task
 Rolled Up Milestone

Rolled Up Progress

ID	Task Name	Duration	Year 1				Year 2						
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4			
23	Cool-down Asphalt	1w											
24	Excavate for Upper Plug	1.38w											
25	Pour Concrete-Upper Plug (23' high-tp)	0.17w											
26	Cure Concrete	4w											
27	Compacted Salt Column-560'	12.67w											
28	Emplace & Compact Crushed/Screened Salt	12.67w											
29	Middle Concrete-Asphalt Waterstop-50'	6.74w											
30	Excavate for Lower Plug	1.38w											
31	Pour Concrete-Lower Plug	0.17w											
32	Excavate Waterstop	0.34w											
33	Place Asphalt	0.3w											
34	Cool-down Asphalt	1w											
35	Excavate for Upper Plug	1.38w											
36	Pour Concrete-Upper Plug	0.17w											
37	Cure Concrete	2w											
38	Upper Salado Compacted Clay Column-335'	9.58w											
39	Emplace Bentonite Blocks	9.58w											
40	Upper Concrete-Asphalt Waterstop-50'	8.74w											
41	Excavate for Lower Plug	1.38w											
42	Pour Concrete-Lower Plug	0.17w											
43	Excavate Waterstop	0.34w											
44	Place Asphalt	0.3w											

Project: SALT HANDLING SHAFT
 SEALING SCHEDULE
 Date: Tue 7/9/96

Task
 Progress
 Milestone

Summary
 Rolled Up Task
 Rolled Up Milestone

Task
 Progress
 Milestone

Summary
 Rolled Up Task
 Rolled Up Milestone

ID	Task Name	Duration	Year 1				Year 2						
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4			
45	Cool-down Asphalt	1w											
46	Excavate for Upper Plug	1.38w											
47	Pour Concrete-Upper Plug	0.17w											
48	Cure Concrete	4w											
49	Asphalt Column-140'	15.33w											
50	Remove Lining In Key	2.02w											
51	Remove Chemical Seal Rings	0.4w											
52	Mobilize to emplace asphalt	2w											
53	Asphalt In Salt Section	2.73w											
54	Asphalt In Lower Lined Section	0.25w											
55	Complete Asphalt Emplacement	1.5w											
56	Cool-down Asphalt	6.43w											
57	Concrete Plug-20'	5.32w											
58	Remove Concrete Lining & Rock	1.11w											
59	Pour Concrete (20' high)	0.21w											
60	Cure Concrete	4w											
61	Remove Concrete Shaft Lining	1.9w											
62	Remove 72' of lining-4 zones	1.9w											
63	Rustler Compacted Clay Column-234'	4.81w											
64	Emplace & Compact Bentonite (234' high)	4.81w											
65	Compacted Earthen Fill-449'	3.65w											
66	Emplace & Compact Earthen Fill (449' high)	3.65w											

Project: SALT HANDLING SHAFT SEALING SCHEDULE	Task	Summary	Rolled Up Progress
Date: Tue 7/9/96	Progress	Rolled Up Task	
	Milestone	Rolled Up Milestone	

ID	Task Name	Duration	Year 1				Year 2													
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4										
67	Concrete Plug-40'	2.45w																		
68	Clean Existing Surface	0.34w																		
69	Pour Concrete	0.11w																		
70	Cure Concrete	2w																		
71	Compacted Earthen Fill-92.5'	0.85w																		
72	Emplace & Compact Earthen Fill (92.5'high)	0.65w																		
73	Demobilization	3w																		
74	Demob	3w																		

Project: SALT HANDLING SHAFT SEALING SCHEDULE Date: Tue 7/9/96	Task Progress Milestone	Summary Rolled Up Task Rolled Up Milestone \diamond	Rolled Up Progress Rolled Up Task Rolled Up Milestone
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1

SEALING SCHEDULE - EXHAUST SHAFT

ID	Task Name	Duration	Year 1				Year 2				Year			
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2		
1	Mobilization	4w	█											
3	Plant Set-up	12w	█	█										
5	Inspect & Scale Shaft-2169.5'	1w		█										
7	Install Construction Utilities	7.2w		█	█									
9	Drill & Grout Lining	8.26w		█	█									
12	Shaft Station Monolith-33'	3.69w			█									
16	Lower Salado Compacted Clay Column-98'	3.18w			█									
18	Lower Concrete-Asphalt Waterstop-50'	9.19w			█	█								
27	Compacted Salt Column-559'	14.37w			█	█								
29	Middle Concrete-Asphalt Waterstop-50'	7.19w			█	█								
38	Upper Salado Compacted Clay Column-340'	11.01w			█	█								
40	Upper Concrete-Asphalt Waterstop-50'	9.16w			█	█								
49	Asphalt Column-142.5'	18.43w			█	█								
57	Concrete Plug-20'	5.87w			█	█								
61	Remove Concrete Shaft Lining	3.23w			█	█								
63	Rustler Compacted Clay Column-234.5'	6.62w			█	█								
65	Compacted Earthen Fill-486.4'	5.44w			█	█								
67	Concrete Plug-40'	2.89w			█	█								
71	Compacted Earthen Fill-58.1'	0.44w			█	█								
73	Demobilization	3w												

Project: EXHAUST SHAFT
 SEALING SCHEDULE
 Date: Tue 7/9/98

Task
 Progress
 Milestone

Summary
 Rolled Up Task
 Rolled Up Milestone

Rolled Up Progress

ID	Task Name	Duration	Year 1				Year 2				Year		
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	
1	Mobilization	4w	■										
2	Mobilize	4w	■										
3	Plant Set-up	12w	■	■									
4	Plant Set-up	12w	■	■									
5	Inspect & Scale Shaft-2159.5'	1w		■									
6	Inspect & Scale Shaft	1w		■									
7	Install Construction Utilities	7.2w		■	■								
8	Install Utilities	7.2w		■	■								
9	Drill & Grout Lining	8.26w			■	■							
10	Drill Grout Holes	3.3w			■								
11	Grout Lining	4.96w			■	■							
12	Shaft Station Monolith-33'	3.69w			■	■							
13	Construct Bulkheads	0.4w			■								
14	Pour Concrete (33' high)	0.29w			■								
15	Cure Concrete	3w			■	■							
16	Lower Salado Compacted Clay Column-98'	3.18w			■	■							
17	Emplace Bentonite Blocks (98' high)	3.18w			■	■							
18	Lower Concrete-Asphalt Waterstop-50'	9.19w			■	■	■	■					
19	Excavate for Lower Plug	1.45w			■								
20	Pour Concrete-Lower Plug (23' high-ty)	0.22w			■								
21	Excavate Waterstop	0.47w			■								
22	Place Asphalt (4' high-ty)	0.38w			■								

Project: EXHAUST SHAFT
 SEALING SCHEDULE
 Date: Tue 7/9/98

Task
 Progress
 Milestone

Summary
 Rolled Up Task
 Rolled Up Milestone

Roll Up Progress

ID	Task Name	Duration	Year 1				Year 2				Year 3				
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2			
23	Cool-down Asphalt	1W													
24	Excavate for Upper Plug	1.45W													
25	Pour Concrete-Upper Plug (23' high-tp)	0.22W													
26	Cure Concrete	4W													
27	Compacted Salt Column-559'	14.37W													
28	Emplace & Compact Crushed/Screened Salt	14.37W													
29	Middle Concrete-Asphalt Waterstop-50'	7.19W													
30	Excavate for Lower Plug	1.45W													
31	Pour Concrete-Lower Plug	0.22W													
32	Excavate Waterstop	0.47W													
33	Place Asphalt	0.38W													
34	Cool-down Asphalt	1W													
35	Excavate for Upper Plug	1.45W													
36	Pour Concrete-Upper Plug	0.22W													
37	Cure Concrete	2W													
38	Upper Salado Compacted Clay Column-340'	11.01W													
39	Emplace Bentonite Blocks(340' high)	11.01W													
40	Upper Concrete-Asphalt Waterstop-50'	9.19W													
41	Excavate for Lower Plug	1.45W													
42	Pour Concrete-Lower Plug	0.22W													
43	Excavate Waterstop	0.47W													
44	Place Asphalt	0.38W													

Project: EXHAUST SHAFT
 SEALING SCHEDULE
 Date: Tue 7/9/99

Task: [Bar] Summary: [Bar] Rolled Up Progress: [Bar]
 Progress: [Bar] Rolled Up Task: [Bar]
 Milestone: [Diamond] Rolled Up Milestone: [Diamond]

ID	Task Name	Duration	Year 1				Year 2				Year				
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2			
45	Cool-down Asphalt	1w													
46	Excavate for Upper Plug	1.45w													
47	Pour Concrete-Upper Plug	0.22w													
48	Cure Concrete	4w													
49	Asphalt Column-142.5'	18.43w													
50	Remove Lining in Key	3.15w													
51	Remove Chemical Seal Rings	0.5w													
52	Mobilize to Emplace Asphalt	2w													
53	Asphalt in Silt Section	2.64w													
54	Asphalt in Lower Lined Section	1.44w													
55	Complete Asphalt Emplacement	2.27w													
56	Cool-down Asphalt	6.43w													
57	Concrete Plug-20'	5.87w													
58	Remove Concrete Lining & Rock	1.7w													
59	Pour Concrete (20' high)	0.17w													
60	Cure Concrete	4w													
61	Remove Concrete Shaft Lining	3.23w													
62	Remove 84' of lining-4 zones	3.23w													
63	Rustler Compacted Clay Column-234.5'	6.62w													
64	Emplace & Compact Bentonite(234.5' high)	6.62w													
65	Compacted Earthen Fill-486.4'	5.44w													
66	Emplace & Compact Earthen Fill(486.4' high)	5.44w													

Project: EXHAUST SHAFT
 SEALING SCHEDULE
 Date: Tue 7/9/96

Task
 Progress
 Milestone

Summary
 Rolled Up Task
 Rolled Up Milestone

Roll Up Progress

ID	Task Name	Duration	Year 1				Year 2				Year	
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2
67	Concrete Plug-40'	2.69w										
68	Clean Existing Surface	0.47w										
69	Pour Concrete	0.22w										
70	Cure Concrete	2w										
71	Compacted Earthen Fill-56.1'	0.44w										
72	Emplace & Compact Earthen Fill (56.1'high)	0.44w										
73	Demobilization	3w										
74	Demob	3w										

Project: EXHAUST SHAFT SEALING SCHEDULE Date: Tue 7/9/96	Task Progress Milestone	Summary Rolled Up Task Rolled Up Milestone	Rolled Up Progress Rolled Up Milestone
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1

SEALING SCHEDULE - WASTE SHAFT

ID	Task Name	Duration	Year 1				Year 2				Year 3				Ye		
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	
1	Mobilization	4w	■														
3	Plant Set-up	12w	■	■													
5	Inspect & Scale Shaft-2159.5'	1w		■													
7	Install Construction Utilities	7.2w		■	■												
9	Drill & Grout Lining	11.21w			■	■											
12	Shaft Station Monolith-37'	5.17w				■	■										
16	Lower Salado Compacted Clay Column-96'	5.01w					■	■									
18	Lower Concrete-Asphalt Waterstop-50'	12.57w						■	■								
27	Compacted Salt Column-555.5'	22.87w							■	■							
29	Middle Concrete-Asphalt Waterstop-50'	10.57w								■	■						
38	Upper Salado Compacted Clay Column-351.5'	17.86w									■	■					
40	Upper Concrete-Asphalt Waterstop-50'	12.57w										■	■				
49	Asphalt Column-142.3'	20.71w											■	■			
57	Concrete Plug-20'	5.98w												■	■		
61	Remove Concrete Shaft Lining	5.07w													■	■	
63	Rustler Compacted Clay Column-234.7'	10.99w														■	
65	Compacted Earthen Fill-447'	8.25w															■
67	Concrete Plug-40'	3.04w															■
71	Compacted Earthen Fill-61.5'	1.14w															■
73	Demobilization	3.5w															■

Project: WASTE HANDLING SHAFT
 SEALING SCHEDULE
 Date: Tue 7/9/96

Task
 Progress
 Milestone

Summary
 Rolled Up Task
 Rolled Up Milestone

Rollled Up Progress

ID	Task Name	Duration	Year 1				Year 2				Year 3				Year	
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2
1	Mobilization	4w	■													
2	Mobilize	4w	■													
3	Plant Set-up	12w	■	■												
4	Plant Set-up	12w	■	■												
5	Inspect & Scale Shaft-2159.5'	1w		■												
6	Inspect & Scale Shaft	1w		■												
7	Install Construction Utilities	7.2w		■	■											
8	Install Utilities	7.2w		■	■											
9	Drill & Grout Lining	11.21w		■	■	■										
10	Drill Grout Holes	4.48w		■	■											
11	Grout Lining	6.73w		■	■	■										
12	Shaft Station Monolith-37'	5.17w		■	■	■										
13	Construct Bulkheads	1w			■											
14	Pour Concrete (37' high)	1.17w			■											
15	Cure Concrete	3w			■											
16	Lower Salado Compacted Clay Column-96'	5.01w			■	■										
17	Emplace Bentonite Blocks (96' high)	5.01w			■	■										
18	Lower Concrete-Asphalt Waterstop-50'	12.57w			■	■	■	■	■	■	■	■	■	■	■	■
19	Excavate for Lower Plug	2.72w			■	■										
20	Pour Concrete-Lower Plug (23' high-typ)	0.27w			■											
21	Excavate Waterstop	0.84w			■											
22	Place Asphalt (4' high-typ)	0.75w			■											

Project: WASTE HANDLING SHAFT
 SEALING SCHEDULE
 Date: Tue 7/9/96

Task: ■
 Progress: ■
 Milestone: ◆

Summary: ■
 Rolled Up Task: ■
 Rolled Up Milestone: ◆

Rolled Up Progress: ■

ID	Task Name	Duration	Year 1				Year 2				Year 3				Year 4	
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2
23	Cool-down Asphalt	1w														
24	Excavate for Upper Plug	2.72w														
25	Pour Concrete-Upper Plug (23' high-tp)	0.27w														
26	Cure Concrete	4w														
27	Compacted Salt Column-555.5'	22.87w														
28	Emplace & Compact Crushed/Screened Salt	22.87w														
29	Middle Concrete-Asphalt Waterstop-50'	10.57w														
30	Excavate for Lower Plug	2.72w														
31	Pour Concrete-Lower Plug	0.27w														
32	Excavate Waterstop	0.84w														
33	Place Asphalt	0.75w														
34	Cool-down Asphalt	1w														
35	Excavate for Upper Plug	2.72w														
36	Pour Concrete-Upper Plug	0.27w														
37	Cure Concrete	2w														
38	Upper Salado Compacted Clay Column-351.5'	17.86w														
39	Emplace Bentonite Blocks(351.5' high)	17.86w														
40	Upper Concrete-Asphalt Waterstop-50'	12.57w														
41	Excavate for Lower Plug	2.72w														
42	Pour Concrete-Lower Plug	0.27w														
43	Excavate Waterstop	0.84w														
44	Place Asphalt	0.75w														

Project: WASTE HANDLING SHAFT
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 Date: Tue 7/9/96

Task
 Progress
 Milestone

Summary
 Rolled Up Task
 Rolled Up Milestone

Rollled Up Progress

ID	Task Name	Duration	Year 1				Year 2				Year 3				Year		
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	
45	Cool-down Asphalt	1w															
46	Excavate for Upper Plug	2.72w															
47	Pour Concrete-Upper Plug	0.27w															
48	Cure Concrete	4w															
49	Asphalt Column-142.3'	20.71w															
50	Remove Lining in Key	3.8w															
51	Remove Chemical Seal Rings	0.6w															
52	Mobilize to emplace asphalt	0.3w															
53	Asphalt in Salt Section	4.01w															
54	Asphalt in Lower Lined Section	2.33w															
55	Complete Asphalt Emplacement	3.24w															
56	Cool-down Asphalt	6.43w															
57	Concrete Plug-20'	5.98w															
58	Remove Concrete Lining & Rock	1.73w															
59	Pour Concrete (20' high)	0.25w															
60	Cure Concrete	4w															
61	Remove Concrete Shaft Lining	5.07w															
62	Remove 84' of lining—4 zones	5.07w															
63	Rustler Compacted Clay Column-234.7'	10.99w															
64	Emplace & Compact Bentonite (234.7' high)	10.99w															
65	Compacted Earthen Fill-447'	8.25w															
66	Emplace & Compact Earthen Fill (447' high)	8.25w															

Project: WASTE HANDLING SHAFT SEALING SCHEDULE
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Task: [Bar] Summary [Bar] Rolled Up Progress [Bar]
 Progress: [Bar] Rolled Up Task [Bar]
 Milestone: [Bar] Rolled Up Milestone [Diamond]

Page 3

ID	Task Name	Duration	Year 1				Year 2				Year 3				Ye	
			Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4		
67	Concrete Plug-40'	3.04w														
68	Clean Existing Surface	0.64w														
69	Pour Concrete	0.4w														
70	Cure Concrete	2w														
71	Compacted Earthen Fill-61.5'	1.14w														
72	Emplace & Compact Earthen Fill (61.5' high)	1.14w														
73	Demobilization	3.5w														
74	Demob	3.5w														

Task Progress Milestone	Summary Rolled Up Task Rolled Up Milestone	Rolled Up Progress Rolled Up Task Rolled Up Milestone
Project: WASTE HANDLING SHAFT SEALING SCHEDULE Date: Tue 7/9/99		
4		

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1

FIGURES

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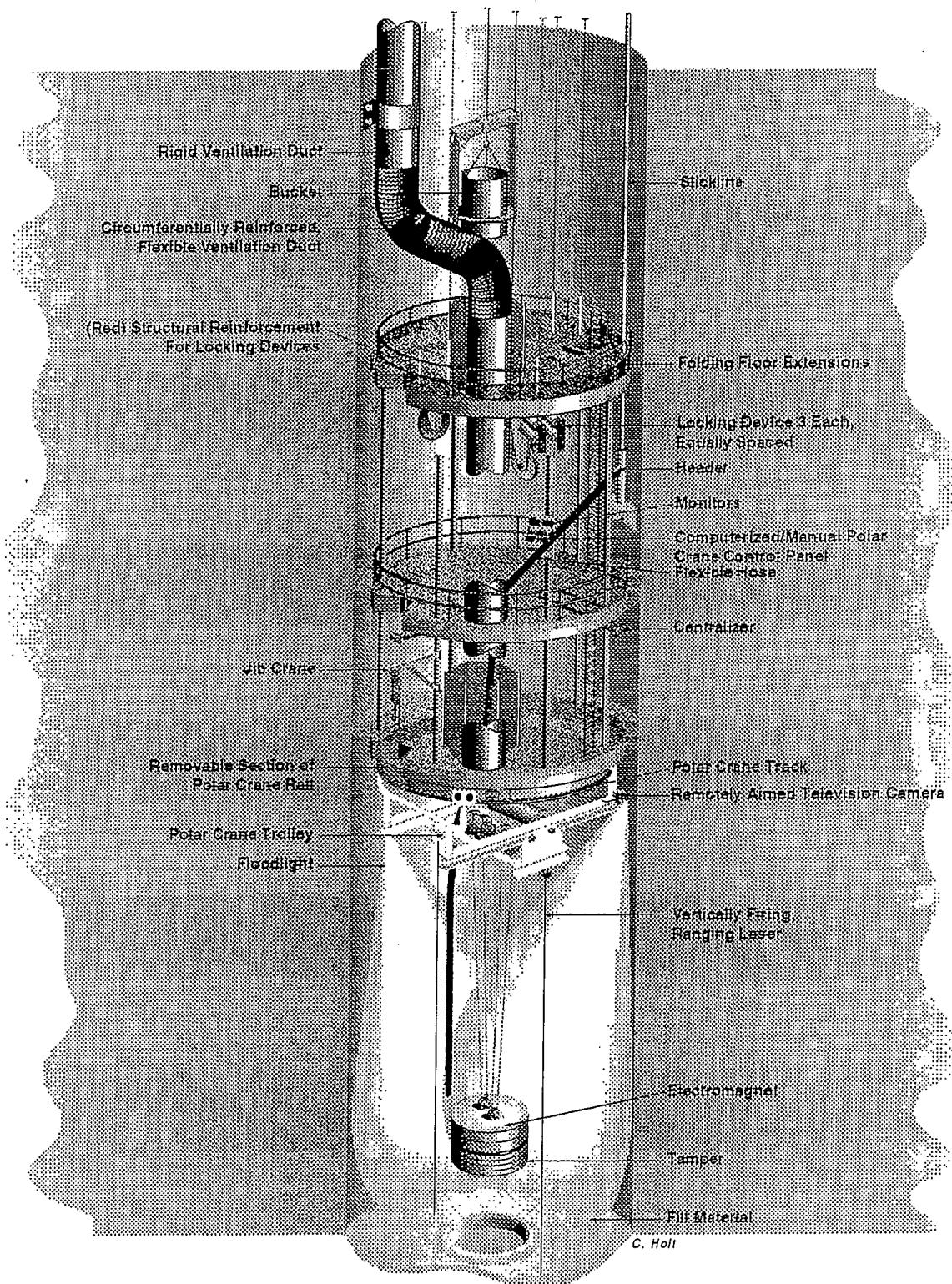


Figure I2B-1
Multi-deck stage illustrating dynamic compaction

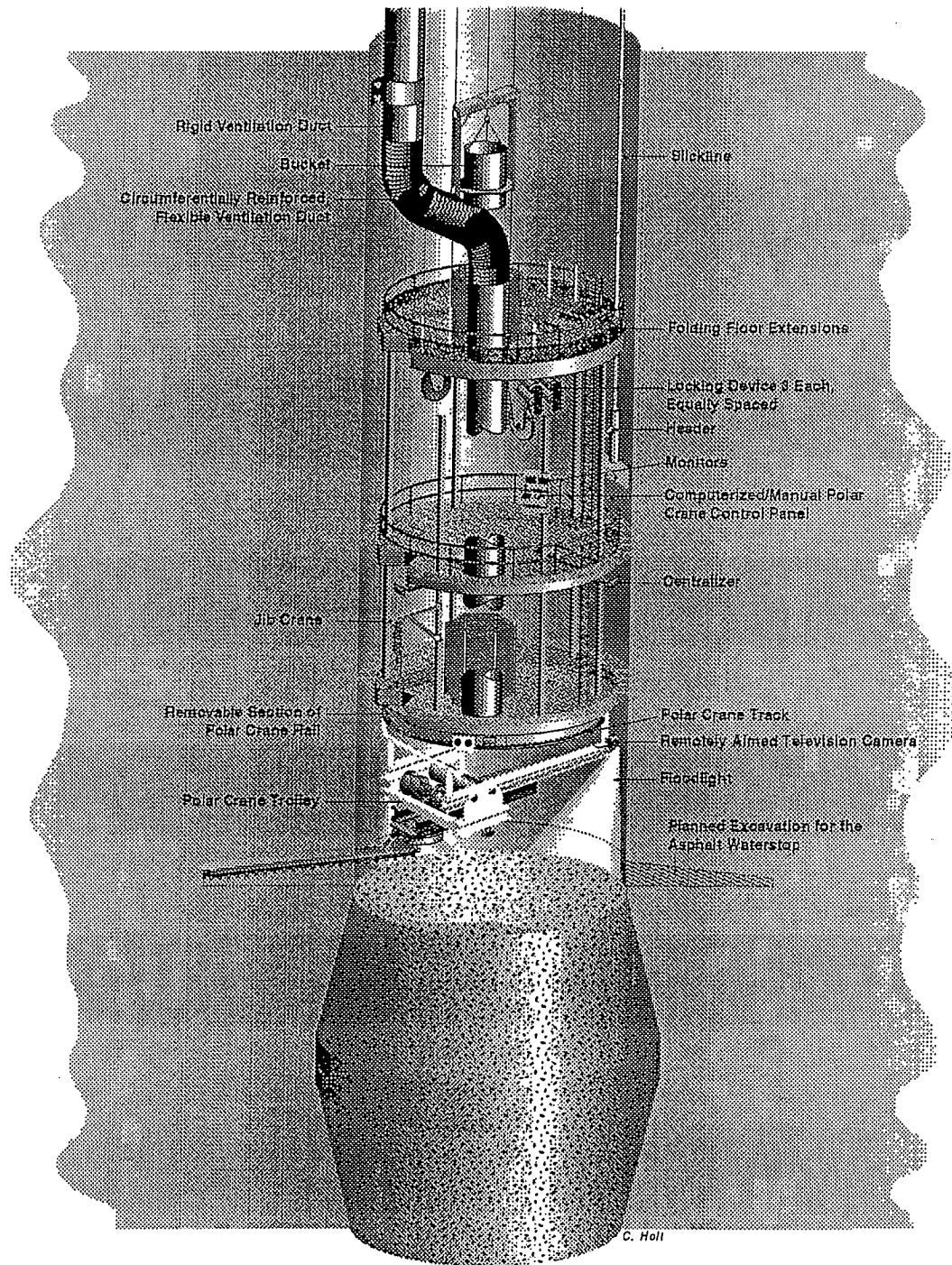
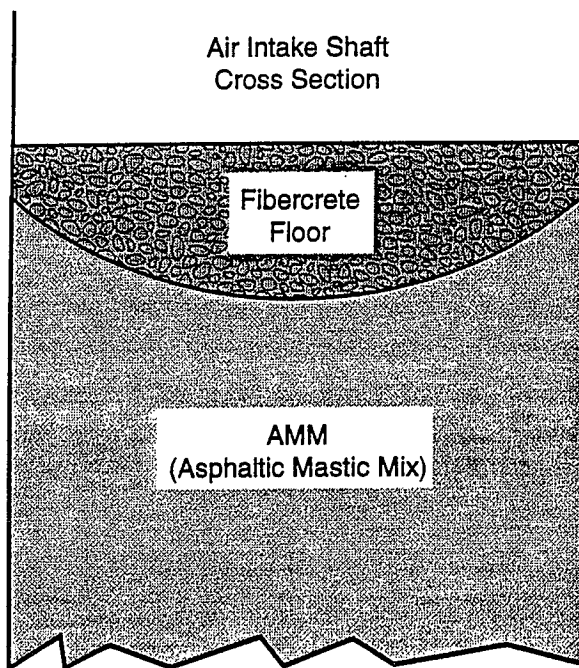
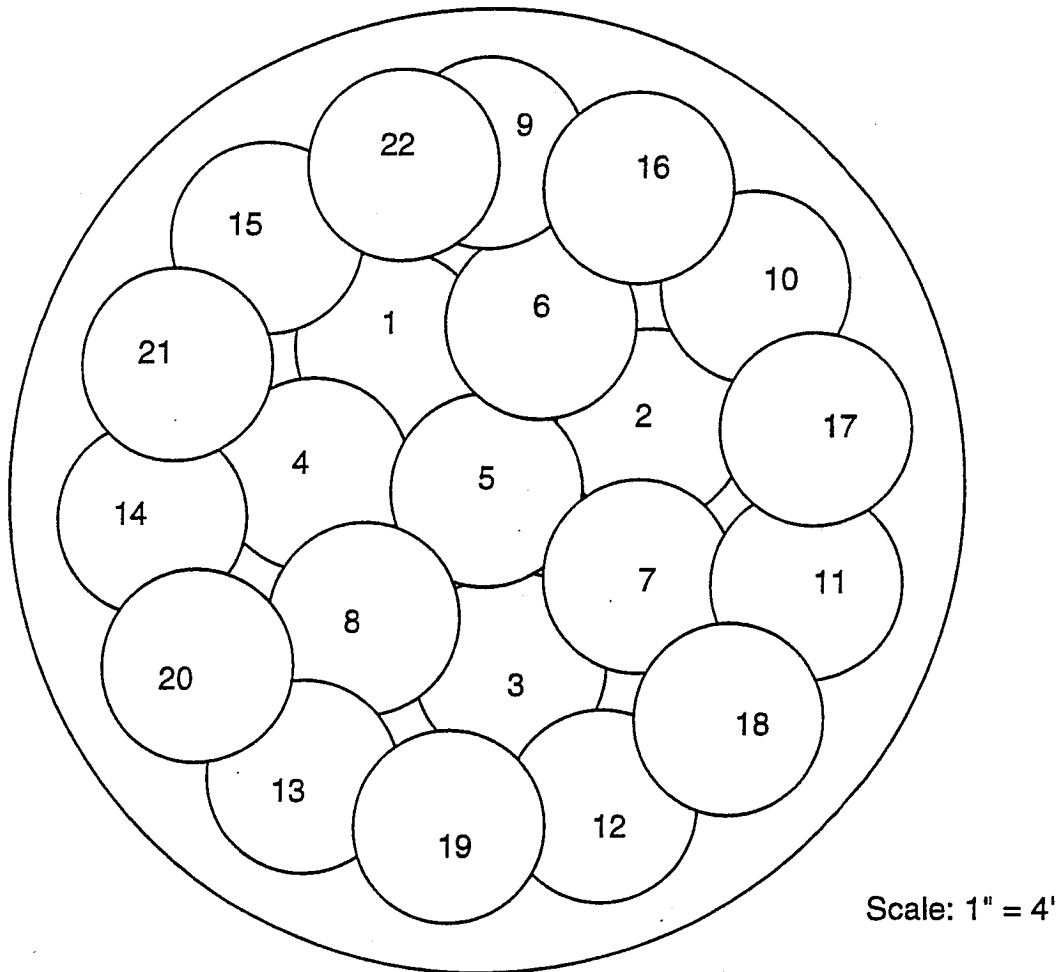


Figure I2B-2
Multi-deck stage illustrating excavation for asphalt waterstop



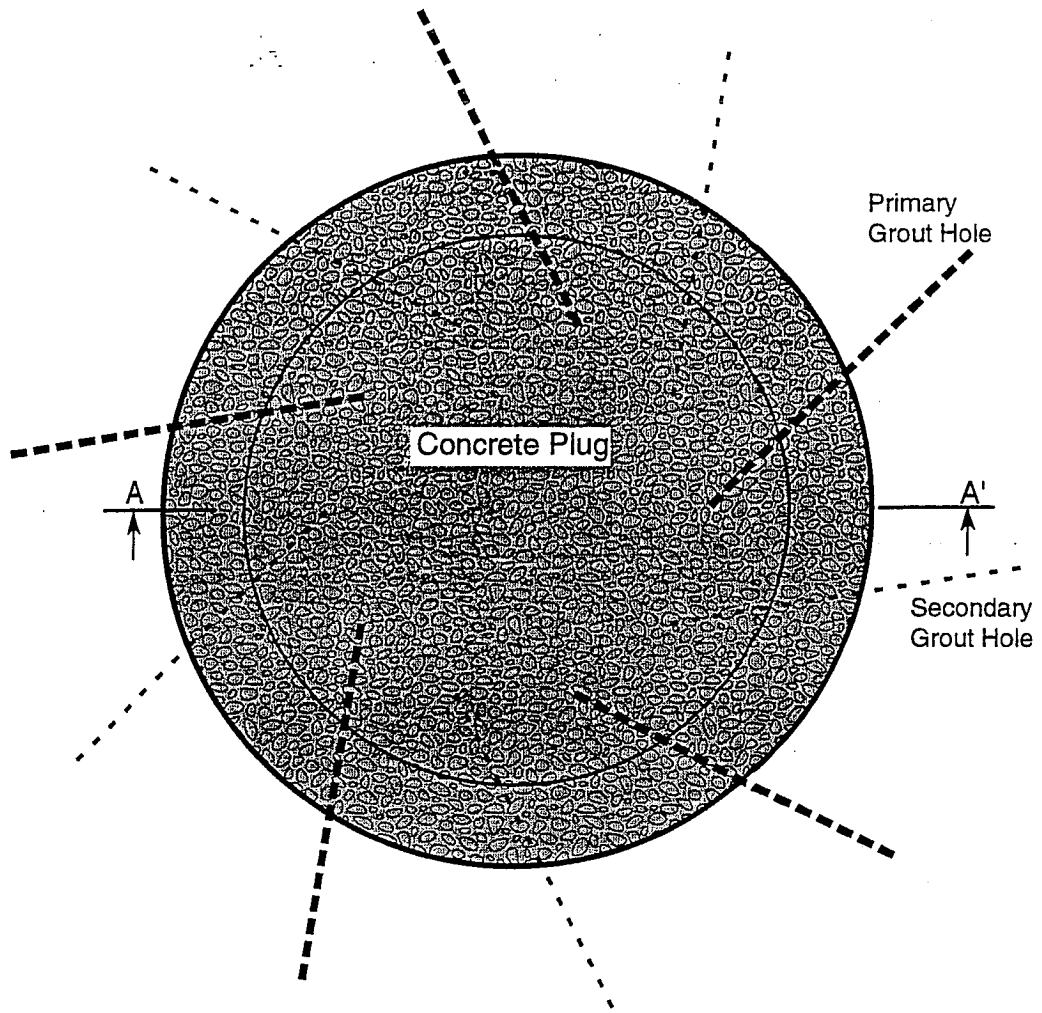
TRI-6121-375-0

Figure I2B-3
Typical fibercrete at top of asphalt

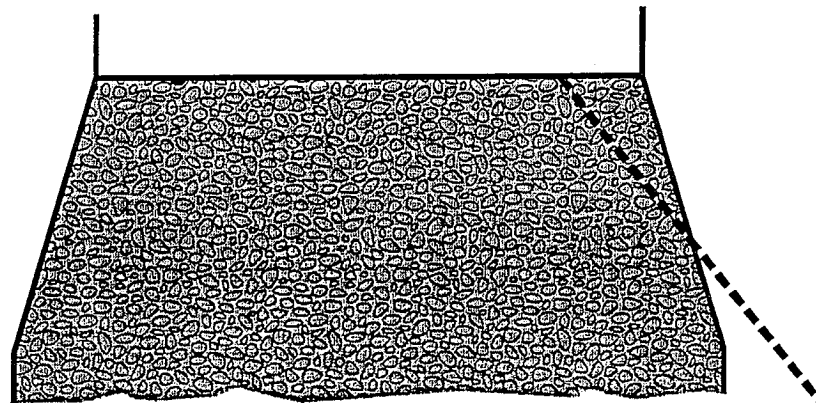


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Figure I2B-4
Drop pattern for 6-m-diameter shaft using a 1.2-m-diameter tamper



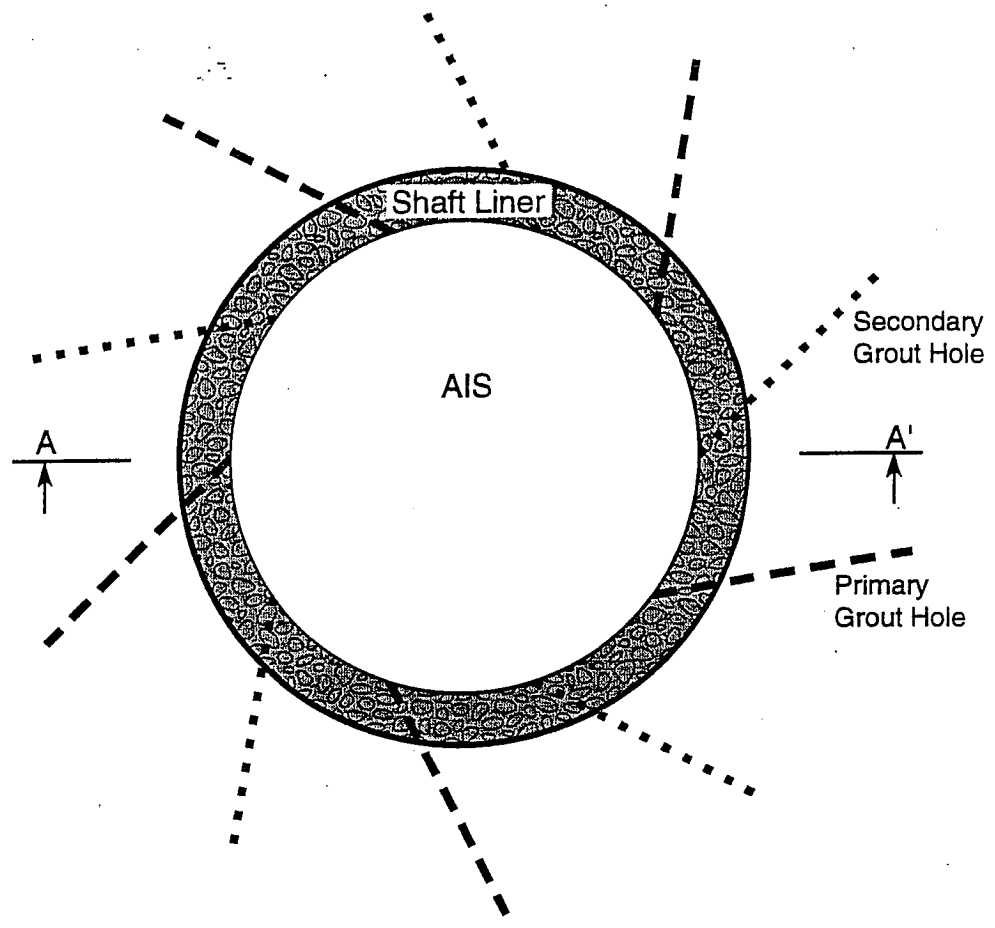
Plan View of Grout Holes in Spin Pattern



Section A - A'

TRI-6121-373-0

Figure I2B-5
Plan and section views of downward spin pattern of grout holes



Plan View of Grout Holes in Spin Pattern



Section A - A'

TRI-6121-374-0

Figure I2B-6
Plan and section views of upward spin pattern of grout holes