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QA: N/A
Project No. WM-00011

DEC 23 2003

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TRANSMITTAL OF *EXAMPLE OF LEVEL OF DESIGN DETAIL TO BE FOUND IN SECTIONS OF THE YUCCA MOUNTAIN REPOSITORY SAFETY ANALYSIS REPORT – EMPLACEMENT DRIFT GROUND SUPPORT,* REVISION C

Reference: Ltr, Ziegler to Chief, High-Level Waste Branch, dtd 9/19/03

In response to requests from the U.S. Nuclear Regulatory Commission (NRC) staff, the U.S. Department of Energy is providing additional example text, tables and figures representative of the type and amount of information to be included in sections of the Yucca Mountain Repository Safety Analysis Report (SAR). This is the second example of representative SAR text, tables and figures provided to the NRC. The first example of representative SAR text, tables and figures was provided to the NRC in the referenced letter. The example text, tables and figures contained in the enclosure below are characteristic of the SAR subsection for the Emplacement Drift Ground Support system. This example of text, tables and figures does not reflect a particular design solution; however, it is representative of the level of detail that would be in the SAR. This material is being provided for informational purposes only, not for NRC staff technical review.

There are no new regulatory commitments in this letter or its enclosure. Please direct any questions regarding this letter to Joe C. Price at (702) 794-1441 or Paul G. Harrington at (702) 794-5415.

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Office of License Application and Strategy

OLA&S:JCP-0287

Enclosure:
Example of Level of Design Detail to be Found in Sections of the Yucca Mountain Repository Safety Analysis Report – Emplacement Drift Ground Support, Revision C

NMSS07

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EXAMPLE OF LEVEL OF DESIGN DETAIL

1. EMPLACEMENT DRIFT GROUND SUPPORT

1.1 SYSTEM DESCRIPTION

System Functions–Maintaining stable repository openings assures operator safety, promotes operational efficiency throughout the preclosure period, and facilitates drip shield installation and inspections prior to closure. The ground support system functions to provide the stable repository openings by providing a surface that prevents loosening of rock. These functions are neither important to safety nor important to waste isolation (Section 1.3).

Temporary Support Description–The temporary ground support is used as necessary to provide worker safety until the permanent support system is installed. The temporary supports, consisting primarily of spot bolting, are minimal in nature, are of standard industry materials, and are not removed prior to permanent support installation.

Permanent Support Description–The permanent ground support is installed as the drifts are developed with utilities and invert structures. Frictional rock bolts will fasten overlapping Bernold-type perforated steel sheets with approximately 240° coverage around the tunnel periphery above the invert. Radially oriented rock bolts, with faceplates and of the length and diameter to provide the required holding capacity, are placed also in an approximately 240° coverage pattern around the drift periphery (Figure 1). Friction rock bolts are used to provide a shearing contact between the rock bolthole and the bolt surface. This is particularly important in the lithophysal rocks where the surface contact of the bolt to the borehole may not be continuous due to the lithophysal voids. The contact area and frictional resistance of the rock bolts, even in the highest lithophysal porosity areas, are sufficient to maintain drift stability.

The perforated steel sheeting is attached to the drift wall by the rock bolts and their faceplates. The steel sheeting provides a confinement to the rock surface around the top of the drift, limiting the initiation of loosening or raveling of the rock surface and any subsequent rockfall. This function is particularly important in the lithophysal rocks where rock block size is on the order of inches. The small perforations or slotting of the steel sheet are sufficient to allow air circulation and drying of the rock surface, but small enough that most rock particles in the lithophysal rock cannot pass.

Both the friction-type rock bolts and the perforated steel sheets are made of stainless steel, equivalent to 316. This material was chosen based on the potential corrosion mechanisms that are expected in the repository environment including dry oxidation, humid-air corrosion, aqueous corrosion, stress corrosion cracking, hydrogen embrittlement, and microbiologically influenced corrosion. The stainless steel rock bolts and perforated stainless steel sheets with a thickness of approximately 3 mm are not expected to experience widespread failure during the preclosure period.

1.2 INSTALLATION AND MAINTENANCE

1.2.1 Excavation Sequence and Support Installation

Figure 2 shows the basic excavation opening shapes for the emplacement drift. The temporary ground support is installed as the drifts are excavated.

The temporary support will consist of spot bolting with carbon steel, friction-type rock bolts, and light-gauge wire mesh or steel mats in the tunnel crown. The purpose of this support is to provide personnel with safety from loosened rock during the tunneling process, as well as for protection of the geologic mapping personnel that will follow behind the tunnel boring machine. The extent of the temporary ground support will be determined by field engineering, consistent with normal mining practice, as required.

1.2.2 Inspection and Maintenance Strategies

The ground supports for the emplacement drifts have been designed with the objective of minimal maintenance for the preclosure period. Benefits of repairs and replacements would be weighed against potential radiological exposures and other operational concerns specific to the situation. However, these repairs and replacements are only planned as contingencies and not as a normal activity for emplacement drift ground support.

1.2.2.1 Inspection Methodologies

During the preclosure period, observation and instrumentation will be used as a basis for assessing the performance of the ground support and opening stability and as a basis for maintenance decisions. The primary assessment method will be observation of ground support and tunnel conditions. Due to the environmental conditions (heat and radiation), observations will be done remotely after waste is emplaced in the drifts.

1.2.2.2 Maintenance

No preventative maintenance of ground support structures is anticipated. Repair maintenance of the ground support would involve standard procedures typical of mining or civil tunneling operations. The maintenance operation would typically involve removal of any failed ground support, scaling and removal of loosened rock, and reinstallation of support. It is possible that decisions not to emplace waste packages along a specific area of the emplacement drift could also be made.

1.2.2.3 Decision to Repair

Decisions about the need for ground support maintenance will be made based on visual and instrumentation records. If required, additional contingency emplacement drift space will be available.

1.3 CONSIDERATIONS IMPORTANT TO SAFETY OR WASTE ISOLATION

Engineering analyses discussed in Section XX demonstrate that the largest credible rockfall postulated without ground support will not breach the waste packages, so radioactive material will not be released due to rockfalls. Therefore, the ground support structures and components perform no function that is important to safety. Ground support is not credited in the total system performance assessment for protecting drip shields or waste packages from rockfall, so ground support structures and components are not important to waste isolation. The materials that comprise both the temporary and permanent ground support are accounted for in the postclosure analysis in Section XX. See Section XX for the important to safety and important to waste isolation classification.

1.4 DESIGN CONSIDERATIONS

Ground support is a static system interfacing with the natural and imposed environment. It is designed to perform its function in that environment for the entire preclosure period. The environmental conditions presented below are addressed in the design of the emplacement drift ground support.

1.4.1 Environmental Conditions

The most important environmental conditions in emplacement drifts related to corrosion of steel ground support components are temperature, relative humidity, and air and water chemistry.

1.4.1.1 Temperature

The drift wall temperature profiles show that the highest temperature at emplacement drift walls is less than 96°C (205°F), the upper bound temperature limit for the preclosure period. It varies from approximately 38°C (100°F) at 100 meters to approximately 73°C (163°F) at 600 meters along the emplacement drift, and generally decreases as a function of ventilation time. The rock bolts and perforated sheets are designed to support the rock over the temperature range from ambient to 96°C (205°F).

1.4.1.2 Relative Humidity

Ventilation will affect the relative humidity greatly. During the preclosure period the drifts will be normally ventilated with outside air. Consequently, the relative humidity inside the drift will remain low. In the event that ventilation is interrupted, the period of no ventilation and increased relative humidity will be short compared to the service life of the ground support and will not impact its performance. The relative humidity inside a bolt hole is expected to be higher, especially at the deeper portion near the end of the bolt hole, where the relative humidity value may be greater than 90 percent. This high relative humidity has a strong impact on corrosion of friction-type rock bolts. The ground support stainless steel wall and rock bolt thickness account for corrosion in the relative humidity environment and preserve performance for the service life of the system.

1.4.1.3 Groundwater Chemistry and Air in Emplacement Drifts

The most important characteristics of the infiltrating water related to steel corrosion are chloride, sulfate, bicarbonate, and pH. Sulfate and chloride ions are considered to be the most corrosive of the common ions found in naturally occurring waters, with sulfate generally regarded as the most corrosive, while bicarbonate and carbonate ions are considered corrosion inhibitors (Tilman et al. 1984, p. 16). Conservative values for the concentration of chloride, sulfate, and bicarbonate, and pH value in the initial fracture and matrix water were used to evaluate potential corrosion rates.

The chemistry of air in the emplacement drifts will be that of outside air drawn from various locations atop Yucca Mountain. The ventilation rate of approximately 15 m^3/s in each emplacement drift is the dominant air exchange. This ventilation air rate far exceeds the air exchange rate inside the rock mass. Therefore, emplacement drift air chemistry is nominally outside air, and ventilation air chemistry has no discernible impact on the corrosion of ground support components.

1.4.2 Geologic Conditions Relevant to Ground Support Function

Emplacement drifts are located in the two major Topopah Spring Tuff subunit categories that comprise the repository: lithophysal tuff (approximately 80 percent lower lithophysal unit and 5 percent upper lithophysal unit) and nonlithophysal tuff (approximately 10 percent middle nonlithophysal unit and 5 percent lower nonlithophysal unit). The lithophysal rocks are characterized by approximately 10 to 30 percent void porosity in the form of lithophysae. The lithophysae are of varying shape, distribution, and size. They average about 10 cm in diameter but can be as large as 1.8 m in diameter. Additionally, the lower lithophysal unit is highly fractured. The fractures are predominantly vertically oriented with spacing of a few centimeters and trace lengths averaging about 0.3 m. The impact of this structure results in compressive strength that varies as a function of porosity and sample size. The uniaxial compressive strength values vary from about 10 MPa at the low end to about 25 MPa at the upper end. These conditions are factored into the design of the ground control system as discussed in Section 1.5.

1.4.3 Design Criteria

Design criteria are specified for the ground support to provide worker safety and operational efficiency. These criteria do not imply functions either important to safety or important to waste isolation. The following criteria are applicable to the design of the ground support system in emplacement drifts:

- The ground support shall be designed to maintain adequate operating equipment envelopes through permanent closure for emplacement drifts.
- The ground support shall be designed to accommodate geologic mapping of emplacement drifts.
- The ground support shall be designed for the appropriate worst-case combination of in situ, thermal, seismic, construction, and operational loads for the preclosure period.
- The ground support for emplacement drifts shall consider the factors of safety margin in design as shown in Table 1.
- The ground support shall use materials (types and quantities) having acceptable long-term effects on waste isolation.
- The ground support shall be designed to withstand an earthquake with an exceedance frequency of 1×10^{-4}/year.
- The ground support for emplacement drifts shall be designed to function without planned maintenance during the operational life (100-year preclosure period), while

providing for the ability to perform unplanned maintenance in the emplacement drifts on an as-needed basis.

1.5 DESIGN METHODOLOGY

The design methodology employed in the development of the emplacement drift ground support was to select a ground support design based on industry experience. This was then followed by a detailed numerical analysis of the selected system under repository loading conditions for verification that the ground support selected maintained drift stability.

1.5.1 Choice of Support Method

The primary function of the ground support in nonlithophysal rock is simple retainment of relatively small key blocks under low stress conditions. The lithophysal rock also requires a retainment function under relatively low stress and strength conditions. However, due to the small rock block size, the potential failure mode in lithophysal rock would be raveling, wherein small rock particles loosen and detach, and the mechanism propagates until a stable opening shape is achieved. Thus, the primary function of the ground support in lithophysal rock is to limit raveling. It is important that, even under the action of in situ, thermal, and seismic preclosure stresses, the rock mass is under relatively low operating stresses. Thus, controlling this failure mode does not require heavy-load-bearing ground support methods but, primarily, a continuous surface to prevent initiation of loosening. Due to the operational time frame and desire to minimize maintenance, it is also important that the materials be compatible with the environmental conditions and that they be corrosion resistant.

1.5.2 Detailed Numerical and Empirical Analysis of Ground Support Methods

The ground support selected was analyzed via numerical modeling techniques. The use of numerical modeling techniques for ground support analysis is needed because of the nonstandard loading conditions that result from heat generated by the waste, seismic loading from potential earthquakes, and the limited applicability of empirical ground support design methods for lithophysal rocks.

1.5.2.1 Model Selection for Ground Support Analysis

A number of different numerical modeling methods are required for analysis of ground support issues depending on the particular rock type (i.e., lithophysal versus nonlithophysal) and the loading conditions (i.e., quasistatic versus dynamic) to be examined.

In general, two-dimensional equivalent continuum-based models are used for analysis of lithophysal rocks in which a standard Mohr-Coulomb plasticity material model is used to describe the mechanical response of the rock mass. The variability of rock mass quality and the associated elastic and strength properties are based primarily on lithophysal porosity. Parametric studies are conducted using a range of properties that reflect the range of rock mass porosities encountered in the Enhanced Characterization of the Repository Block excavations.

Both two- and three-dimensional equivalent continuum models are used for analysis of the nonlithophysal rock mass. Rock mass property estimates for the nonlithophysal rock were developed from in situ rock mass classifications using the Q method. A summary of the modeling methods used for the ground support studies is given in Table 2.

1.5.2.2 Initial and Boundary Conditions

The repository excavations are initially loaded by the in situ gravitational stresses. At Yucca Mountain, the vertical gravitational stress is the maximum component, while the principal horizontal components vary somewhat, depending on the topography (Section 1.5.2.3.1).

1.5.2.3 Loading Conditions

The stresses applied to the emplacement drifts that must be accounted for in the ground support design include three basic categories: in situ, seismic, and thermal stresses. Each of these applied stress sources is discussed below.

1.5.2.3.1 In Situ Stress

The in situ stress state has been measured at the site, showing the vertical component to be the maximum principal stress (σ_1), which is taken to be equal to the overburden load at that location. The minimum (σ_3) and intermediate (σ_2) principal stresses are subhorizontal and oriented at azimuths of N105E and N15E, respectively. The ratio of the minimum principal stress to maximum principal stress (σ_3/σ_1) is 0.36, and the ratio of the intermediate principal stress to the maximum principal stress (σ_2/σ_1) is 0.62.

1.5.2.3.2 Seismic Loads

The ground motions associated with an earthquake (an exceedance frequency of 1×10^{-4}/year) are used as a basis for determination of the impact of seismic shaking on emplacement drift stability. Repetitive seismic loading is also examined for applied ground motions with an annual exceedance frequency of 5×10^{-4}/year.

1.5.2.3.3 Thermally Induced Stress

Heat generated by the waste packages will result in preclosure heating of the rock mass surrounding the emplacement drifts. This temperature rise will result in thermal expansion of the rock mass surrounding the emplacement drifts and a resultant thermal stress increase that is proportional to the rock mass deformation modulus and thermally induced strain. The thermal stress at maximum temperature rise is included in the estimation of drift stability.

In addition to the base thermal loading, transient temperature increases due to ventilation interruption were considered. Ventilation shutdowns of 1 to 30 days were examined at 2, 5, and 10 years after initiation of forced ventilation. Ventilation shutdown could result in temporary temperature spikes to approximately 95°C, which is below the upper bound temperature limit for the preclosure period discussed in Section 1.4.1.1.

1.5.3 Ground Support for Emplacement Drifts

The analysis of the emplacement drift ground reaction curves and direct modeling of ground support using structural elements within the models has been performed and is summarized below.

Ground Reaction Curve Analysis– Evaluation of the excavation openings using ground reaction curve analysis show that the emplacement drifts equilibrate in a self-supporting mode; thus, the role of ground support is to maintain the surface condition and integrity of the rock mass against loosening or deterioration during the preclosure time period.

Rock Bolt Load Determination–A series of explicit calculations of the estimated loading of friction rock bolts and the associated deformations of the excavations is conducted for the rock mass strength and loading variations. The force-displacement characteristics of the rock bolt structural elements is derived and calibrated from pull tests on Swellex and Split Set rock bolts. Straining of the overlapped surface sheeting is derived from the circumferential strain on the opening surface due to predicted radial deformations. From these analyses, in the worst case, the loads are well below the anchorage capacity of the friction rock bolts in both the lithophysal and nonlithophysal rocks. These loads are a small percentage of the loading from in situ and thermal stresses.

1.5.4 Summary of Ground Support Analyses

The following general conclusions summarize the results of the analyses:

- The excavations arrive at self-supporting equilibrium with safety factors of 2 or greater against collapse modes for the rock mass quality conditions. Therefore, the primary role of ground support at Yucca Mountain is to prevent deterioration and loosening of the rock mass tunnel periphery. A primary issue is choice of ground support materials to ensure service life throughout the preclosure time frame.

- The friction rock bolts and overlapped surface sheeting are expected to perform satisfactorily under in situ, thermal, and seismic loads with a minimum factor of safety that exceeds required safety margins.

- The surface sheeting is structurally capable of supporting potentially loosened rock between rock bolts and has the deformation capacity to withstand deformation-induced strains during transient loading.

1.6 CODES AND STANDARDS

The following codes and standards are applicable:

- ASTM A 240/A 240M-03b, *Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications*

- ASTM A 276-03, *Standard Specification for Stainless Steel Bars and Shapes*

- ASTM F 432-95 (Reapproved 2001), *Standard Specification for Roof and Rock Bolts and Accessories*

1.7 REFERENCES

Hoek, E. 2000. *[Practical] Rock Engineering [2000 Edition].* Toronto, Canada. TIC: 253544.

Tilman, M.M.; Jolly, A.F., III.; and Neumeier, L.A. 1984. *Corrosion of Friction Rock Stabilizers in Selected Uranium and Copper Mine Waters.* Report of Investigations 8904. [Pittsburgh, Pennsylvania]: U.S. Department of the Interior, Bureau of Mines. TIC: 230626.

Table 1. Factors of Safety Margin in Design

Load Type	Factor of Safety
Static loads (in situ+thermal)	1.4 to 1.8
Static plus dynamic loads (in situ+thermal+seismic)	1.2 to 1.5

Table 2. Summary of Numerical Models Used for Emplacement and Nonemplacement Drift Ground Support Analyses

Rock Type	Comment	Model
Nonlithophysal	Rock mass behavior controlled by fracture geometry.	Three-dimensional continuum (FLAC3D) for equivalent continuum parameter studies of drift intersection problems.
		Two-dimensional continuum (FLAC) for equivalent continuum parameter studies for cross-sectional analysis of emplacement drifts.
Lithophysal	Rock mass behavior controlled by lithophysal porosity and dense fracturing.	Two-dimensional continuum (FLAC) for equivalent continuum parametric studies.

EXAMPLE OF LEVEL OF DESIGN DETAIL

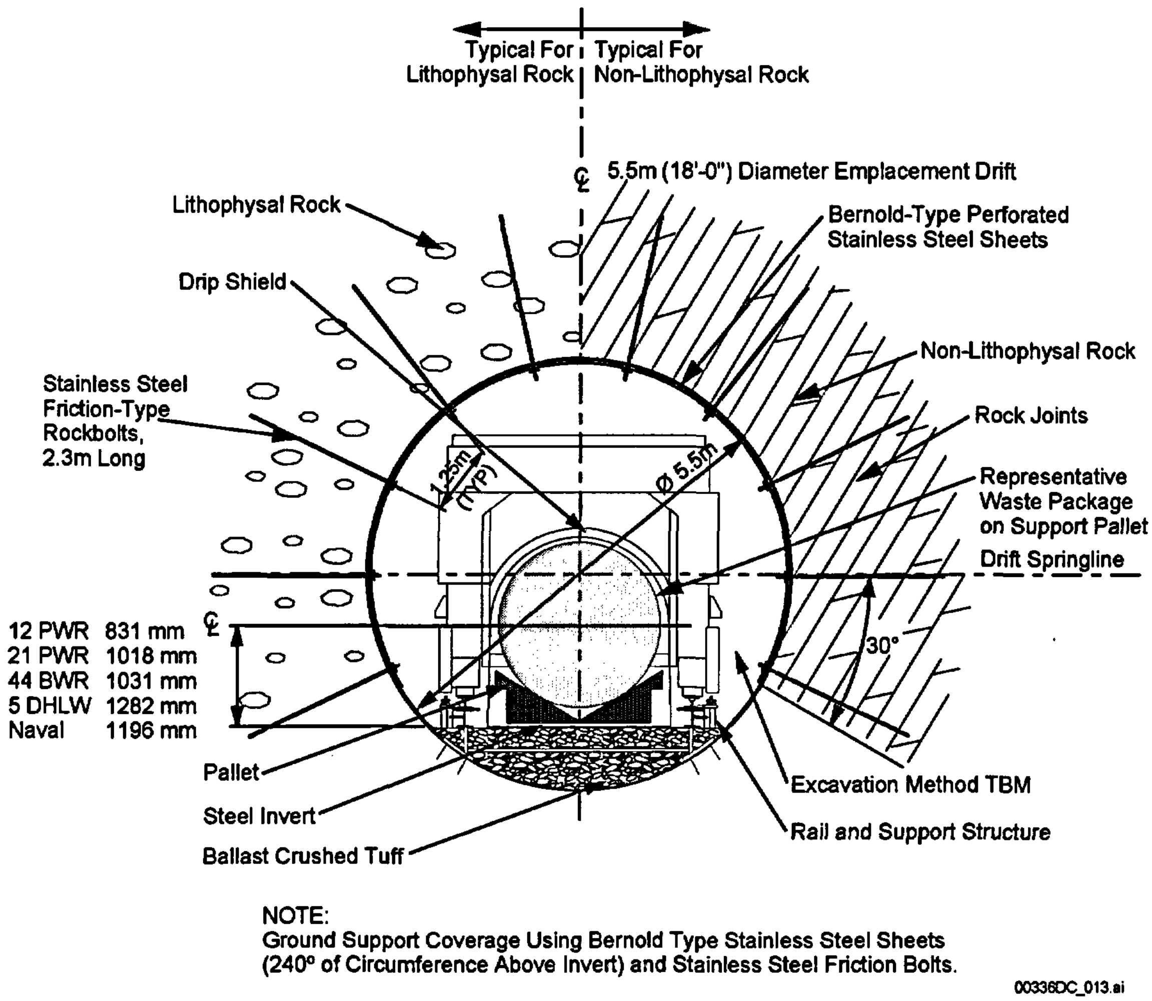

Figure 1. Schematic of Typical Emplacement Drift Permanent Ground Support

EXAMPLE OF LEVEL OF DESIGN DETAIL

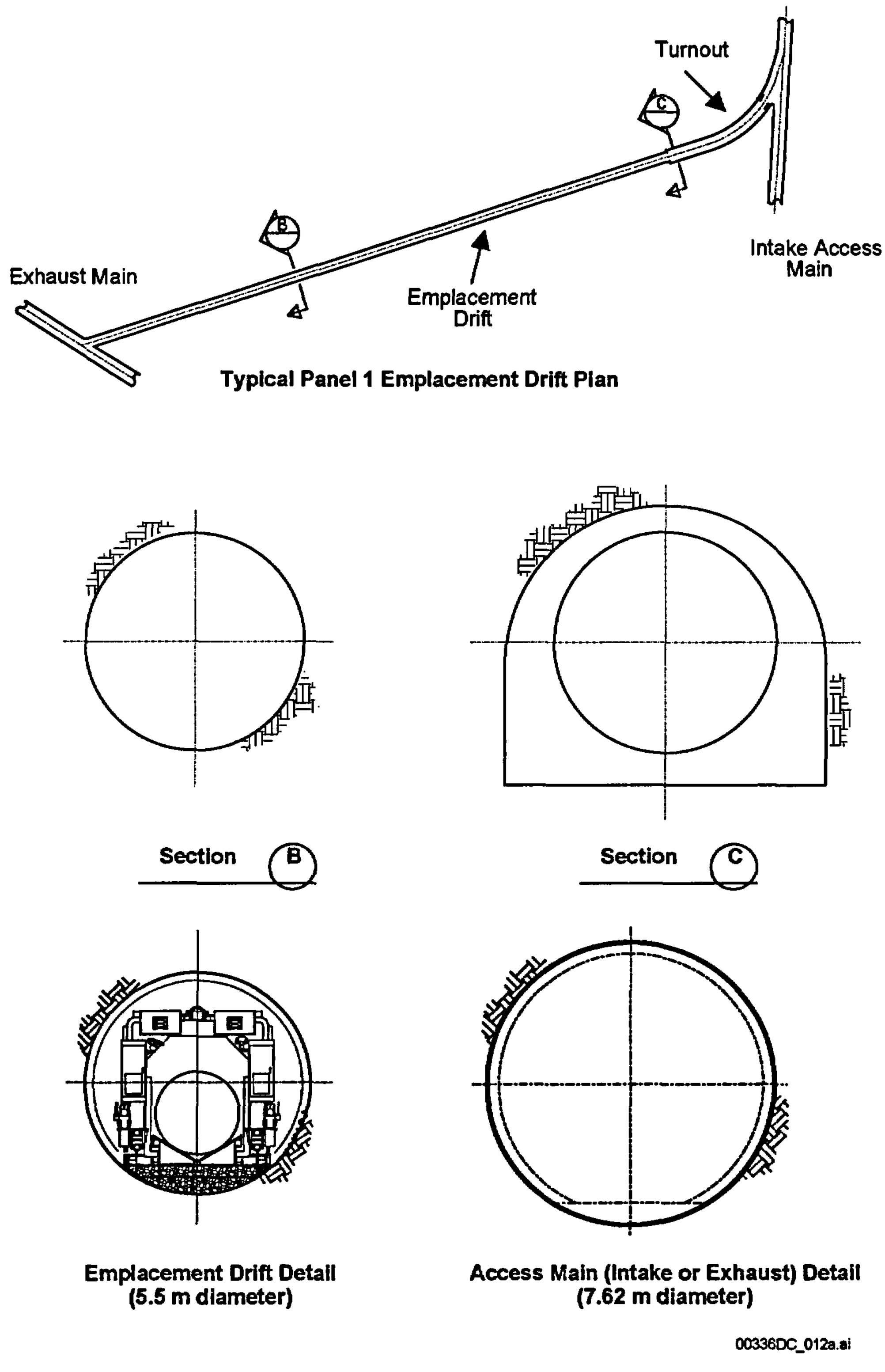

Figure 2. Plan View and Cross-Sectional Views of Primary Repository Excavations