**OFFICE OF CIVILIAN RADIOACTIVE WASTE
MANAGEMENT
ANALYSIS/MODEL COVER SHEET
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246	240
248	
253	
274	
342	
343	

**OFFICE OF CIVILIAN RADIOACTIVE WASTE
MANAGEMENT
ANALYSIS/MODEL REVISION RECORD**
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1. Page: 2 of: 25

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Initial Issue

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ACRONYMS AND ABBREVIATIONS

AAR	Association of American Railroads
AREA	American Railroad Engineering Association
ASCE	American Society of Civil Engineers
BES	Backfill Emplacement System
CMAA	Crane Manufacturers Association of America, Inc.
DOE	U.S. Department of Energy
GCS	Ground Control System
IEEE	Institute of Electrical and Electronics Engineers, Inc.
MGR	Monitored Geologic Repository
OMC	MGR Operations Monitoring and Control System
PCM	Performance Confirmation Drift Monitoring System
rem/hr	Roentgen equivalent man per hour
SDD	system description document
SED	Subsurface Electrical Distribution System
SET	Subsurface Emplacement Transportation System
SFR	Subsurface Fire Protection System
SFS	Subsurface Facility System
SSC	structure, system and component
TBD	to be determined
TBV	to be verified
UBC	Uniform Building Code
WES	Waste Emplacement System
WRS	Waste Retrieval System
XCS	Ex-container System

1. PURPOSE

The objective of this analysis is to identify issues and criteria that apply to the design of the Subsurface Emplacement Transportation System (SET). The SET consists of the track used by the waste package handling equipment, the conductors and related equipment used to supply electrical power to that equipment, and the instrumentation and controls used to monitor and operate those track and power supply systems.

Major considerations of this analysis include:

- Operational life of the SET
- Geometric constraints on the track layout
- Operating loads on the track
- Environmentally induced loads on the track
- Power supply (electrification) requirements
- Instrumentation and control requirements

This analysis will provide the basis for development of the system description document (SDD) for the SET.

This analysis also defines the interfaces that need to be considered in the design of the SET. These interfaces include, but are not limited to, the following:

- Waste handling building
- Monitored Geologic Repository (MGR) surface site layout
- Waste Emplacement System (WES)
- Waste Retrieval System (WRS)
- Ground Control System (GCS)
- Ex-Container System (XCS)
- Subsurface Electrical Distribution System (SED)
- MGR Operations Monitoring and Control System (OMC)
- Subsurface Facility System (SFS)
- Subsurface Fire Protection System (SFR)
- Performance Confirmation Emplacement Drift Monitoring System (PCM)
- Backfill Emplacement System (BES)

2. QUALITY ASSURANCE

The quality assurance classification of repository structures, systems, and components (SSCs) has been performed in accordance with QAP-2-3, *Classification of Permanent Items* (Reference 8.1). The SET has been classified as non-quality-affecting by *Classification of the Preliminary MGDS Repository Design* (Reference 8.2).

This design activity has been evaluated in accordance with QAP-2-0, *Conduct of Activities* (Reference 8.3), and has been determined to be quality-affecting and, therefore, is subject to the

requirements of the *Quality Assurance Requirements and Description* (Reference 8.4). This analysis is also subject to quality assurance controls in accordance with AP-3.10Q, *Analyses and Models* (Reference 8.5).

The input data used in this analysis require verification; therefore, the outputs are unqualified. The outputs from this document cannot be used for procurement, fabrication, or construction. The formal to-be-verified (TBV) and to-be-determined (TBD) tracking system described in NLP-3-15 (Reference 8.6) apply to this analysis.

3. COMPUTER SOFTWARE AND MODEL USAGE

No engineering or scientific design computer software programs were used in the preparation of this analysis.

4. INPUTS

The SET supports other systems that actively perform the waste handling, performance confirmation, and other MGR operating functions. The criteria that define the requirements of and limitations on the SET are necessarily derived from those supported systems, as set forth in the SDD for each of those systems. Those defining criteria are identified in this section.

4.1 DATA AND PARAMETERS

- 4.1.1 The WRS shall have an operational life of 134 years after the start of emplacement.
(used in Section 6.1.1) [Reference 8.15, Paragraph 1.2.1.1]
- 4.1.2 The WES shall transport and emplace waste packages over a maximum grade of ± 2.5 percent between the surface and the emplacement drift and a maximum grade of ± 1 percent within the emplacement drifts.
(used in Sections 6.1.2 and 6.1.3) [Reference 8.7, Paragraph 1.2.1.4]
- 4.1.3 The WES shall be capable of transporting and emplacing waste packages with the characteristics defined in Table 1.

Table 1. Waste Package Characteristics

Length	3.7 to 6.2 m
Diameter	1.25 to 2.0 m
Weight	83,000 kilograms maximum

(used in Section 6.1.1) [Reference 8.7, Paragraph 1.2.1.7] (TBV-246)

- 4.1.4 The WES shall be designed to support MGR operations during and after exposure to the natural environments at the MGR surface as identified in Table 2.

Table 2. Natural Surface Environments

Surface Environment	Range
Temperature	–15 to 47 degrees Centigrade (C)
Maximum Daily Precipitation	5 inches maximum in 24-hour period
Humidity	TBD
Wind Speeds	40 meters per second (m/s) maximum 1-minute wind speed 53 m/s maximum 1-second-gust wind speed at 10 meters (m) above ground level at North Portal area
Snowfall	Maximum daily snowfall of 10 inches Maximum monthly snowfall of 17 inches Maximum annual snowfall of 31 inches

(used in Section 6.1.2) [Reference 8.7, Paragraph 1.2.3.1] (TBD-240)

- 4.1.5 The WES, WRS, PCM, and BES shall be designed to operate during and after exposure to the subsurface environments identified in Table 3.

Table 3. Subsurface Operating Environments

Environmental Characteristic	Waste Emplacement Phase ⁽¹⁾	Monitoring Phase ⁽²⁾
Temperature		
• Ramps, Main Access Drifts, and Emplacement Drift Turnouts	10°C to 50°C ⁽³⁾	10°C to 27°C
• Emplacement Drifts	10°C to 50°C ⁽³⁾	220°C (max.)
Humidity - All Locations	10% to 100%	10% to 100%

Notes:

1. All data for waste emplacement phase from Reference 8.16, Section 1.2.3.1 (TBV-342) except as noted.
2. All data for the monitoring phase from Reference 8.16, Section 1.2.3.2 (TBV-343).
3. Maximum temperature for waste emplacement phase from Reference 8.7, Section 1.2.3.2.
(used in Sections 6.1.2, 6.1.3, and 6.8)

- 4.1.6 The WES shall operate within the SFS radii shown in Table 4.

Table 4. Radius/Turnouts

Location	Minimum Radius (Measured at the Track and Drift Centerlines)
North Ramp Curvature	305 m
Emplacement Drift Turnout Curvature	20 m

(used in Section 6.1.2) [Reference 8.7, Paragraph 1.2.4.2] (TBV-253)

- 4.1.7 The long-term radiation levels of the waste packages are 370 Roentgen equivalent man per hour (rem/hr) or less.
(used in Section 6.9) [Reference 8.22, Section 1.2.4.1] (TBV-248)
- 4.1.8 The maximum grade of the surface pathways used by the WES shall be ± 2.5 percent.
(used in Section 6.1.2) [Reference 8.20, Section 1.2.4.9]
- 4.1.9 The maximum grade of the surface pathway used by the WRS shall be ± 2.7 percent.
(used in Section 6.1.2) [Reference 8.20, Section 1.2.4.10]

4.2 CRITERIA

- 4.2.1 The MGR shall comply with the applicable provisions of 29 CFR 1910, Occupational Safety and Health Standards.
(used in Section 6.1.1) [Reference 8.19, Section 3.1.E]
- 4.2.2 The MGR shall comply with other laws, statutes, U.S. Codes, treaties, CFRs, executive orders, NUREGS, state and local codes and regulations, U.S. Department of Energy (DOE) Orders, and other directives applicable to the geologic disposal of spent nuclear fuel and high-level waste, including those related to environmental protection and radiological health and safety, as identified through analyses of the MGR.
(used in Section 6.1.1) [Reference 8.19, Section 3.1.G]
- 4.2.3 The MGR shall be capable of receiving, packaging, emplacing, and isolating commercial spent nuclear fuel, DOE spent nuclear fuel, vitrified defense high-level waste, vitrified commercial high-level waste, and immobilized plutonium waste-form, in accordance with the National Waste Policy Act and implementing regulations at the annual rates specified in Table 3-2 of the *Monitored Geologic Repository Requirements Document* (Reference 8.19) (used in Section 6.11.4) [Reference 8.19, Section 3.2.C]
- 4.2.4 The MGR shall allow the repository to be closed as early as 10 years after emplacement of the last waste package or to be kept open for at least 100 years from initiation of waste emplacement. The MGR shall include provisions that support a deferral of closure for up to 300 years from initiation of waste emplacement, with appropriate monitoring and maintenance. (used in Section 6.1.1) [Reference 8.19, Section 3.2.H]
- 4.2.5 The MGR shall have the capability of retrieving all emplaced waste packages within 34 years.
(used in Section 6.1.1) [Reference 8.19, Section 3.2.J]
- 4.2.6 Because of the uncertainty about the possible start time for retrieval operations, transportation capabilities and architecture shall not be maintained for post-retrieval waste transport.
(used in Section 6.1.1) [Reference 8.19, Section 3.2.K]
- 4.2.7 All MGR SSCs shall be designed and fabricated in accordance with applicable industry codes, standards, and engineering principles and practices, with particular attention given to those requirements that incorporate system safety, human factors, reliability, availability, maintainability, and habitability standards.
(used in Section 6.1.1) [Reference 8.19, Section 3.3.A]

4.3 CODES AND STANDARDS

4.3.1 American Institute of Steel Construction

1. AISC M016-89 *Manual of Steel Construction*, Allowable Stress Design, Ninth Edition, 1989. TIC: 205770.

4.3.2 Not used.

4.3.3 Crane Manufacturers Association of America Inc. (CMAA)

1. CMAA No. 70, *Specification for Top-Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes*, Revised 1994. TIC: 248767.

4.3.4 American Railroad Engineering Association (AREA)

1. *Manual for Railway Engineering*, 1997. TIC: 233847.

4.3.5 Association of American Railroads (AAR)

1. *Manual of Standards and Recommended Practices*, Section C - Part II, Specifications for Design, Fabrication, and Construction of Freight Cars, M-1001, Volume I, Standard, Issue of 1993. TIC: 10188.

4.3.6 American National Standard Institute (ANSI)/American Society of Civil Engineers (ASCE)

1. ANSI/ASCE 7-95, *Minimum Design Loads for Buildings and Other Structures* (Revision of ANSI/ASCE 7-93), June 6, 1996. TIC: 236611.

4.3.7 Code of Federal Regulations (CFR)

1. 10 CFR 1910. Labor: Occupational Safety and Health Standards. Readily available.

4.3.8 Uniform Building Code (UBC)

1. *Structural Engineering Design Provisions*, Volume 2, 1997. TIC: 233818.

4.3.9 U.S. Nuclear Regulatory Commission (NCR)

1. Regulatory Guide 1.12, *Nuclear Power Plant Instrumentation for Earthquakes*, Rev 2, March 1997.
2. Regulatory Guide 1.166, *Pre-earthquake Planning and Intermediate Nuclear Power Plant Operator Post-earthquake Actions*, Rev 0, March 1997.

4.3.10 The Institute of Electrical and Electronics Engineers, Inc. (IEEE)

1. IEEE-C2, National Electrical Safety Code, 1987. TIC: 231575.

4.3.11 Interim Guidance Documents

1. Dyer, J.R., 1999. "Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain." Letter from J.R. Dyer (DOE/YMSCO) to D.R. Wilkins (CRWMS M&O), OL&RC:AVG:1436, June 18, 1999, with enclosure. ACC: MOL.19990623.0026; MOL.19990623.0027.

5. ASSUMPTIONS

No assumptions were used in the preparation of this analysis.

6. ANALYSIS

6.1 SYSTEM REQUIREMENTS

6.1.1 General

The SET includes:

- Track and turnouts for supporting and guiding rail-mounted mobile equipment that transport the waste packages.
- Transformers, rectifiers, conductors, and related equipment for providing electrical power to that mobile equipment.
- Instrumentation and control equipment required to monitor and operate the tracks, turnouts, and power supply equipment.

The SET shall be used by or with other systems for the transport of waste packages from the waste handling building to the emplacement drifts. Additionally, portions of the SET will support other systems to monitor the emplaced waste packages, to perform routine operations and maintenance tasks, and to react to abnormal conditions. The SET shall support backfill operations as part of closure, as well as operations involving the transportation, emplacement, retrieval (as required), and performance confirmation monitoring of all waste packages. The range in size and weight of these waste packages are as indicated in Table 1 (Parameter 4.1.3).

The operational life of the SET is determined by the operational lives of the other systems whose mobile equipment uses the SET. Those systems must be designed such that the repository can remain open for at least 100 years after initial waste emplacement (Criterion 4.2.3) and all of the emplaced waste can be retrieved within 34 years after notice is given to initiate a retrieval action (Criterion 4.2.5). The 134-year operational life of the WRS (Parameter 4.1.1) is based on the previous revision to Criterion 4.2.5 that had the retrieval action being initiated at the end of the initial 100-year period. The current version of Criterion 4.2.5 requires the 34-year retrieval period to be part of the 100 years.

Whenever it is determined that no more retrieval actions are required, those systems that are needed to conduct retrieval operations will no longer be maintained (Criterion 4.2.6). However, the actual closure of the repository can be deferred for up to 300 years after initial waste emplacement (Criterion 4.2.3). Furthermore, performance confirmation monitoring must continue until closure [Code/Standard 4.3.11, Sections 63.131(b) and 63.134(d)], and a retrieval capability maintained until performance confirmation monitoring is completed [Code/Standard 4.3.11, Section 63.111(e)(1)].

Based on these requirements, the operational life of the SET for waste handling operations shall be 100 years after initial waste emplacement, with the exception that it shall be capable of being restored or repaired as necessary to support retrieval operations for up to 300 years after initial waste emplacement. The operational life of the SET to support performance confirmation monitoring operations shall be 300 years after initial waste emplacement.

As an SSC of the MGR, the SET shall comply with the applicable provisions of 29 CFR 1910 (Criterion 4.2.1), as well as with other laws, statutes, U.S. Codes, treaties, federal regulations, executive orders, NUREGS, state and local codes and regulations, and DOE Orders. The SET shall also comply with other directives that apply to the geological disposal of spent nuclear fuel and high-level waste, including those identified throughout analyses of the MGR as being related to environmental protection and radiological health and safety (Criterion 4.2.2). There is a TBV associated with Criterion 4.2.2 because that criterion makes a broad requirement without citing specific laws, codes, etc. That TBV is not carried to the output of this analysis because the laws and codes specific to the SET are cited in Section 4.3.

Additionally, as an SSC of the MGR, the SET shall be designed and fabricated in accordance with applicable industry codes, standards, and engineering principles and practices, with particular attention given to those requirements that incorporate system safety, human factors, reliability, availability, maintainability, and habitability standards (Criterion 4.2.7). Those industry codes and standards are also listed in Section 4.3.

6.1.2 Surface, Ramps, Main Drifts, and Emplacement Drift Turnouts

The SET track gauge shall accommodate the Waste Emplacement System (WES) and WRS rail-mounted mobile equipment that will operate on the surface and within the underground ramps, main access drifts, and emplacement drift turnouts. WES equipment operating in these sections requires a track gauge of 1.44 m (Reference 8.8, Section 4.3.3) (TBV-274). On the surface, the portion of the SET track used by the WES will have grades not exceeding ± 2.5 percent (Parameter 4.1.8). The surface portion of the SET track that is used only by the WRS will have grades not exceeding ± 2.7 percent. Underground, the track grade shall not exceed ± 1.0 percent in the emplacement drift turnouts or ± 2.5 percent between the North Portal and the emplacement drift turnouts (Parameter 4.1.2). The surface layout of the SET (Reference 8.21, Figure 8) indicates that there are no track curves with centerline radii less than 30 m (100 feet). Additionally, the portion of the SET inside the waste handling building is expected to be straight. For underground sections of track, the centerline of the track will generally coincide with the centerline of the opening. The minimum track radii, measured at the track centerline, shall be 20 m in the emplacement drift turnouts and 305 m between the North Portal and the emplacement drift turnouts (Parameter 4.1.6). Therefore, the SET horizontal track geometry is bounded by the

subsurface curve radii minimums. The surface portion of the SET shall be designed operate within the MGR's natural surface environment, as indicated on Table 2 (Parameter 4.1.4). The portion of the SET in the ramps, main access drifts, and emplacement drift turnouts shall be designed to operate under controlled environment conditions expected for those areas, as indicated on Table 3 (Parameter 4.1.5).

6.1.3 Emplacement Drifts

The SET track gauge shall accommodate the WES, WRS, and PCM rail-mounted mobile equipment that will operate within the emplacement drifts. Based on preliminary designs, the WES equipment operating within the emplacement drift requires a track gauge of 2.58 m (Reference 8.9, Section 4.3.23), but that information is unqualified and is subject to change. The centerline of the track will coincide with the centerline of the emplacement drift. The track grade shall not exceed ± 1.0 percent in the emplacement drifts (Parameter 4.1.2). The portion of the SET within the emplacement drifts shall be designed to operate under the environmental conditions expected in those areas during the emplacement and monitoring phases of the Project as indicated in Table 3 (Parameter 4.1.5).

6.2 RAIL ELECTRIFICATION

6.2.1 General

The current definition of the SET rail electrification system is based on the *Repository Rail Electrification Analysis* (Reference 8.12), which is an unqualified document. Information from *Repository Rail Electrification Analysis* (Reference 8.12) is subject to change and is presented here for information only.

The SET will provide 750-volt DC electrical power to operate the subsurface mobile equipment (Reference 8.12, Section 8.1). The SET will obtain AC power from the SED and convert it to DC power using transformers and rectifiers.

To the greatest extent practical, the SET electrification system will incorporate engineered safety features such as ground fault interrupters, lockable isolation switches, and safety guards to protect personnel from accidental electrocution.

6.2.2 Overhead Trolley System

An overhead wire or trolley system will be used to power rail-mounted equipment operating on SET tracks on the surface and within the underground ramps, main access drifts, and emplacement drift turnouts (Reference 8.12, Section 8.2). The system will transfer electrical power to the rail-mounted vehicles through a conductor or contact wire that is normally suspended above and parallel to the centerline of the track. Current will be returned through the track rails to complete the circuit.

6.2.3 Third-Rail System

A third-rail system will be used to power rail-mounted equipment operating within the emplacement drifts. The system will transfer electrical power to the rail-mounted vehicle

through a conductor located beside, parallel to, and at approximately the same level as one of the track rails (Reference 8.12, Section 8.2). Current will be returned through the track rails to complete the circuit. The joints and fasteners of the third-rail system will be able to accommodate expansions and contractions in the rail caused by large temperature changes.

One problem with a third-rail system is that its location close to the track presents a hazard to personnel working in an emplacement drift. To mitigate this concern, personnel will not be permitted in the emplacement drift when waste packages are present (Reference 8.11, CPA 020). However, the design shall provide positive means to de-energize the third-rail system and provide temporary or permanent safety guards as necessary to ensure that personnel working in the emplacement drifts prior to waste emplacement are adequately protected.

6.2.4 Monitoring and Controls

The following SET subsystems will monitor and control various parts of the system:

- The track monitoring system will provide input to the OMC regarding the location of mobile equipment on the tracks. The same system will also provide information regarding rail continuity.
- The turnout monitoring and control system will provide input to the OMC regarding switch position and enable the switches to be remotely positioned.
- The electrification monitoring system will provide information to the OMC on each electrification circuit (and sub-circuit) regarding status (energized or not), power supply voltage and regulation, and power consumption. The electrification control system will be tied to the OMC, so that circuits can be remotely de-energized (at any time) and energized (when the local switches are in an enabled position).

The SET's specific monitoring and control requirements will be determined as its design progresses along with the designs of the systems with which it interfaces. Those requirements will establish what instruments, signals, operational sequences, and alarm functions are required.

6.3 GENERAL TRACK SYSTEM DESIGN

To the extent possible, the track will be designed and constructed using standard, commercially available materials.

Turnouts to the emplacement drifts are one of the major components of the track system. A track turnout will consist of a switch and a frog with guardrails, as defined in Code/Standard 4.3.4 (Section 101-82, page 1). The switches will be actuated both locally and remotely, and their position status will be monitored remotely. Interface control and interlock logic will be developed in coordination with the OMC during the design phase. All switches, frogs, and guardrails will be designed in accordance with the rail design standard selected in Section 6.4 and the AREA (Code/Standard 4.3.4) specifications and track work plans.

The track system components shall be designed as set forth in Sections 6.4 through 6.9.

6.4 RAIL DESIGN

The rail design encompasses the rail and any associated rail joint bars and assemblies.

The waste package transport equipment that operates on the SET track has been classified in accordance with CMAA 70 (Code/Standard 4.3.3). This equipment is classified as equivalent crane service Class "F" equipment because it performs critical tasks under severe conditions (Reference 8.8 Attachments I and II; Reference 8.9, Attachments I and II; and Reference 8.14, Attachment I).

The rail shall be designed to handle the vertical (downward) and horizontal loads that occur under normal operations and conditions.

The design will use rail that conforms to ASCE (Code/Standard 4.3.6), AAR (Code/Standard 4.3.5), or AREA (Code/Standard 4.3.4) specifications if the selected rail can adequately handle the loads. Crane rail (Code/Standard 4.3.1, Part 1) may be used if the design determines that no ASCE, AAR, or AREA standard rail sections can handle the design loads. Crane rail has greater lateral strength than the ASCE, AAR, or AREA rail sections because of increased web thickness. Crane rail shall be designed in accordance with either AISC M016-89 (Code/Standard 4.3.1) or CMAA 70 specifications (Code/Standard 4.3.3).

Rails shall be joined by standard joint bars or by welding. If the rail joints are welded, the rail must be anchored or other provisions made to control the effects of expansion and contraction due to temperature changes.

6.5 RAIL ANCHORAGE DESIGN

The rail anchorage system shall perform two main functions. First, it shall secure the rails in place to prevent unacceptable longitudinal, lateral, or vertical movement. Second, it shall distribute the rail loads onto the support structure in a manner that prevents overstress or damage to the support structure. Additionally, the rail anchorage system may include electrical insulation pads or other devices to isolate the rail from the support structure as required for the proper and safe operation of the electrification and track control systems.

The rail anchorage system shall be compatible with the rail design selected. It shall also be compatible with the design method used to control thermal expansion and contraction. For example, if jointed rail is used, a correctly designed anchorage system will permit limited longitudinal rail movement to allow length changes to be accommodated at the gaps between individual pieces of rail. If fully anchored welded rail is used, a properly designed anchorage system will prevent longitudinal rail movement and transfer the resulting forces onto the support structure.

The components of a rail anchorage system depend on the type of support structure used. The components will generally include a rail (or tie) plate to distribute rail loads and protect the support structure, rail fasteners to limit rail movement, and rail support anchors to attach the rail and rail anchorage components to the support structure.

6.6 RAIL SUPPORT DESIGN

The type of rail support structure depends on the location of the track. Three types will be used. The main type is the conventional tie system, which includes the tie, ballast, and subgrade. This system will probably be used on the surface between the waste handling building and the North Portal, and underground in the ramps, main access drifts, and emplacement drift turnouts. The second support system consists of runway girders mounted directly to the ground support system. This type of support system will likely be used for the rails in the emplacement drifts. The third type is a structural slab with the rail anchorage assembly fastened directly to it. This type of system will probably be used at the loading dock in the waste handling building.

The rail support design shall take into account the mechanical and environmental loads and conditions, load distributions, thermal expansions, and rail gauges for the various waste package transport equipment configurations. The rail support shall be designed to minimize uneven track settlement, to be very stiff in the lateral direction, and to be highly resistant to track buckling and panel shift. The system shall be designed using noncombustible and fire-resistant construction materials (Reference 8.13, page 5). Rail support design shall comply with the rail design standard selected according to Section 6.4. The rail support design shall interface with the GCS and XCS designs.

6.7 SEISMIC DESIGN

The SET is classified as non-quality affecting and, therefore, is not required to comply with any of the special seismic criteria that apply to quality-affecting systems. As stated in Section 6.4, the waste package transport equipment that operates on the track system has been classified in accordance with CMAA 70 (Code/Standard 4.3.3) as equivalent crane service Class "F." The track system components will also be designed to the loading criteria established in CMAA 70 (Code/Standard 4.3.3), which will be considered normal operating conditions for the track components. In addition, seismic loads will be incorporated into the transportation system according to UBC Seismic Zone 3 (Code/Standard 4.3.8, Figure 16-2), with a seismic importance factor of 1.5, based on occupancy Code 2 (Code/Standard 4.3.8, Table 16-K).

The UBC seismic event represents a lower bounding limit for defining the design seismic event. The SET design shall include a value engineering study to compare the incremental capital costs to upgrade the track to withstand a more severe seismic event with the cost of lost operations and repairs resulting from track damage if such an event occurs. If the benefits of designing for a more severe seismic event clearly exceed the costs, the design seismic event shall be adjusted accordingly.

If AREA, ASCE, or AAR design criteria are used for rail design rather than CMAA 70, as described in Section 6.4, the same loading criteria for seismic loads will be used and incorporated into the design. AREA design criteria do not provide a seismic loading component. Standard AREA, ASCE, or AAR track design assumes that moderate damage will occur to rail structures, signals, and communications systems at an AREA seismic Level 1 event (50- to 100-year return period). At AREA seismic Levels 2 and 3 (200- to 500-year return period and 500- to 1,000-year return period, respectively), track and structures are assumed to experience heavy to severe damage, putting the rail system out of service for an extended period.

The OMC will monitor the site for seismic events (Code/Standard 4.3.9.1). If an event of sufficient magnitude to damage the SET is detected, the OMC will suspend normal operations involving rail-mounted equipment (Code/Standard 4.3.9.2). After such an event has occurred, the SET components will be inspected for damage or misalignment. Components of the SET will be repaired and adjusted, as required, before resuming normal operations.

6.8 THERMAL EXPANSION

In retrieval operations, the emplacement drift will be cooled from an ambient temperature of 220°C (maximum) to below 50°C (Parameter 4.1.5). The lower bound for the cool-down temperature is 10°C (Parameter 4.1.5). When retrieval is completed, the emplacement drifts will be closed, allowing the ambient temperature return to 220°C if waste packages are present. The emplacement drift track and the electrification system design shall accommodate the thermal expansion and contraction created by these temperature extremes.

The following calculation indicates the effect of the expected temperature changes on the emplacement drift rails. The length of a representative section of rail is based on the preliminary repository layout in *Repository Subsurface Layout Confirmation Analysis* (Reference 8.18). Figure 7-22 therein shows a ventilation raise intercepting the invert of an emplacement drift at approximately the midpoint of the drift. The presence of the ventilation raise suggests that each emplacement drift will have two sections of track, one on either side of the raise. Table I-3 of Reference 8.18 indicates that there are 120 emplacement drifts, each divided into an east and west section, with a total length of 133,115 meters. Dividing 133,115 m by 240 sections gives an average length per section of 555 m. The coefficient of expansion of steel is obtained from Code/Standard 4.3.1, pages 6-3 to 6-6. As calculated below, the unrestrained change in length of a 555-m steel rail that experiences a temperature range of 210°C is 1.36 m. The electrical third rail will change length in a similar manner, depending on the material of construction.

$$\text{Change of length} = \text{COE} \times T \times L \text{ (Code/Standard 4.3.1, p. 6-6)}$$

Where: COE = coefficient of expansion for steel = 0.0000065 (1/°F)

T = change in temperature = 220 – 10 = 210°C = 378°F

L = length of rail = 555 m

$$\text{Change of length} = 0.0000065 \times 378 \times 55 = 1.36 \text{ m}$$

This calculation is based on preliminary information and is presented solely to illustrate the order of magnitude of the temperature effects that must be addressed during final design. The calculation does not take into account the change in the length of the emplacement drift itself because of the same temperature change. However, because the drift is restrained at both ends, any such length change would be negligible.

6.9 RADIATION SAFETY

During waste package emplacement and retrieval, personnel access to areas with radiation fields will be restricted. Under normal operations, these areas would include the emplacement drift turnouts when waste package are being transferred to or from the emplacement drifts and the emplacement drifts any time a waste package is present. Radiation fields may also be present

anywhere along the SET due to an off-normal event resulting in an unshielded waste package or a release of radioactive material. Any time radiation fields are present, remotely controlled operations will be used to limit occupational radiation doses to a level as low as reasonably achievable (Reference 8.11, CPA 020). Since waste packages will normally be present in the emplacement drift, the portion of the SET that will be inside those drifts shall be designed so that either no routine maintenance is required or that routine maintenance can be performed by remote control. If non-routine maintenance that cannot be remotely controlled is required, the waste packages will first have to be removed from the drift. The portion of the SET that will be within the emplacement drift turnouts shall be designed such that no routine maintenance will be required while waste packages are being transferred. Since the SET will be required to support recovery operations after off-normal events, it is likely that repairs to the SET may be required whenever unshielded waste packages or other radiation sources are present. The portion of the SET outside the emplacement drifts shall be designed considering this requirement, and the design shall provide a means for repair by remote control where practical.

The SET shall be designed taking into account that SET components will or may be exposed to relatively high levels of radiation. Portions of the SET in the emplacement drift will be exposed to radiation levels from the waste packages of as much as 370 rem/hr (Parameter 4.1.7) over a long period. As waste packages are transferred, portions of the SET in the emplacement drift turnouts will be periodically exposed to the same radiation levels over short periods. The entire SET may experience high-level short-term exposure resulting from off-normal events.

6.10 CLEARANCES

To avoid interference between systems, the design and layout of the SET will be coordinated with the designs of the rail-mounted equipment and the designs of the surface-mounted utilities. One result of this coordination shall be that the rail-mounted equipment, including any waste packages and pallets being carried, fits within the ground control clearance envelopes as set forth in *Basis for Ground Control Clearance Envelopes and Design Loads* (Reference 8.10). The other result shall be that the GCS, SET, and the surface-mounted utilities shall not interfere with each other and shall not extend within the ground control clearance envelopes of the mobile equipment, except as necessary to support the equipment.

6.11 INTERFACES

6.11.1 General

The SET will be used by or in conjunction with other systems for the operation of the MGR. The major system interfaces are described below.

6.11.2 Waste Handling Building

The SET shall operate within the physical constraints of the waste package loading area of the waste handling building. Additionally, the SET must accommodate the requirements of and not interfere with the waste package handling system that loads the waste packages on and removes them from the rail-mounted waste package transportation equipment. The design of the waste handling building's structure and foundations must accommodate the loads imposed by the SET and loaded rail-mounted equipment.

6.11.3 MGR Surface Site Layout

The portion of the SET that runs from the waste handling building to the North Portal is on the surface. Therefore, the SET shall operate within the physical constraints of the MGR surface site layout.

6.11.4 Waste Emplacement System

One of the principal functions of the SET is to provide the track and power systems for the mobile emplacement equipment that makes up the WES. The SET must be capable of supporting the WES so that the WES can handle and emplace waste packages at the rates set forth in Criterion 4.2.3. The physical and electrical loads of this equipment are required to design the SET components. The OMC uses the SET to route and manage the WES equipment. The SET provides information to the OMC regarding the location and activity of the WES equipment.

6.11.5 Waste Retrieval System

Another principal function of the SET is to provide the track and power systems for the mobile retrieval equipment that makes up the WRS. The physical and electrical loads of the equipment are required to design the SET components. The OMC uses the SET to route and manage the WRS equipment. The SET provides information to the OMC regarding the location and activity of the WRS equipment.

6.11.6 Ground Control System

As discussed in Section 6.10, the design of the SET must be coordinated with the design of mobile equipment and underground utilities to ensure that the components of these systems stay within the ground control clearance envelopes set forth in *Basis for Ground Control Clearance Envelopes and Design Loads* (Reference 8.10). This will ensure that there is no interference with the GCS. The SET will also use GCS structures to support various components, so SET loads must be considered when designing the GCS structures.

6.11.7 Ex-Container System

The SET shall be laid out and designed to avoid interfering with the XCS. Additionally, if part of the XCS is transported with the waste package, then the SET track must be designed to accommodate the additional load.

6.11.8 Subsurface Electrical Distribution System

The power requirements and supply locations of the SET electrification system are needed to design the SED. Likewise, knowledge of the characteristics of the power supplied by the SED is required to design the transformers, rectifiers, and related equipment for the SET. The SED will also supply power to the SET instruments, actuators, and signals. The locations and power requirements for these devices need to be coordinated between the SED and SET designs.

6.11.9 MGR Operations Monitoring and Control System

The SET provides status information regarding its components to the OMC. It also provides the OMC with data that the OMC can use to determine the location, speed, and direction of rail-mounted equipment. The OMC can remotely operate the SET's turnouts and can turn portions of the electrification system on or off.

6.11.10 Subsurface Facility System

The SET shall operate within the physical envelope of the ramps, main access drifts, turnouts, and emplacement drifts.

6.11.11 Subsurface Fire Protection System

The SET design will use materials and equipment that meet SFR fire safety requirements.

Through the OMC, the SFR will be able to shut off power to parts of the electrification system whenever fire is detected so that water can be safely used to fight the fire.

SFR mobile equipment will use the SET to gain access to fires.

6.11.12 Performance Confirmation Drift Monitoring System

The PCM will dispatch rail-mounted mobile equipment to an emplacement drift containing waste packages. To inspect drift and waste package conditions, the equipment will travel on the emplacement drift tracks of the SET and be powered by the third-rail electrification system. The SET shall accommodate the requirements of this equipment.

6.11.13 Backfill Emplacement System

The mobile equipment of the BES will use the SET to transport and place fill in the MGR underground openings as part of pre-closure activities (Reference 8.17, p. 4). The design of the BES must take into account the limitations imposed by the SET.

6.11.14 Coordination of Interface Requirements

The designs of the waste handling building, MGR surface facilities, SFS, and GCS will define the general layout of and the spatial restrictions on the SET. The progress of the SET design will be restricted until this information becomes available. Once the design loads imposed on the SET rail support structures are determined, the waste handling building and GCS structural designs must be checked to verify that these structures can handle those loads.

The WES, WRS, XCS, and PCM will be designed in parallel with the SET design. This integrated design effort will allow economic evaluations to be performed to provide the best choices for the following components of those systems:

- Equipment – number of axles
- Equipment – wheel size

- Equipment – wheel hardness
- Rail – rail type and size
- Rail Support – rail support type, size, and spacing

These component variables affect both equipment and track design. For example, the rail size is affected by the wheel load distribution of the WES mobile equipment, size of equipment wheels, hardness of the wheel and rail, type of rail supports, and type of invert used in the drifts. A technical evaluation of the interfacing systems is recommended to establish an optimum design. After this technical evaluation is complete, an economic evaluation is recommended. The results of the two evaluations then need to be factored together. The second recommendation is driven by the great amount of material and labor costs involved in the installation of the track and rail electrification subsystems.

For the interfaces with the SED, OMC, SFR, and BES, the SET design will start first, so that SET configurations or requirements will be available to provide basis criteria for defining the other systems.

7. CONCLUSIONS

The SET consists of the track system used by mobile equipment for MGR underground operations, the electrification system used to power that equipment, and the instrumentation and controls required to monitor and control the track and electrification systems. The SET is a non-quality affecting system. Its main purpose is to provide support, guidance, and power to the WES and WRS mobile equipment. The SET must also interface with at least eight other systems.

This analysis recommends that the following requirements be used as the basis of the SET SDD:

1. The SET shall comply with all applicable laws, statutes, and codes as listed in Section 4.3.
2. The SET shall be designed and fabricated in accordance the applicable parts of the industry codes and standards listed in Section 4.3.
3. The operational life of the SET for waste handling operations shall be 100 years after initial waste emplacement, with the exception that it shall be capable of being restored or repaired as necessary to support retrieval operations for up to 300 years after initial waste emplacement. The operational life of the SET to support performance confirmation monitoring operations shall be 300 years after initial waste emplacement.
4. The layout of the SET must accommodate the spatial constraints imposed by the loading dock facility of the waste handling building, the MGR surface facility arrangement, and the SFS configuration. The grade limits set forth in Parameters 4.1.2, 4.1.8, and 4.1.9 are based on those constraints. Curve restrictions are as set forth in Parameter 4.1.6.

5. The SET design shall be coordinated with the rail-mounted mobile equipment and utilities designs to ensure that the ground control clearance envelope requirements set forth in Reference 8.10 are achieved.
6. The SET shall accommodate the operating loads imposed by the WES and WRS rail-mounted equipment carrying XCS pallets loaded with waste packages with the range of characteristics set forth in Parameter 4.1.3.
7. The SET shall be designed to accommodate environmentally induced loads resulting from a range of expected environmental conditions. The range of surface conditions is listed in Parameter 4.1.4. The range of subsurface conditions is listed in Parameter 4.1.5.
8. The track shall be designed to accommodate the loading criteria established in CMAA 70 (Code/Standard 4.3.3), which are based on the waste package transportation equipment using the track being classified as equivalent crane service Class "F" per CMAA 70.
9. Minimum seismic loads shall be determined based on an UBC Seismic Zone 3 and a seismic importance factor of 1.5.
10. The SET components in the emplacement drift shall be capable of withstanding long-term exposure to radiation levels as high as 370 rem/hr (Section 6.9). The SET components in an emplacement drift turnout at the interface with an emplacement drift shall be capable of withstanding periodic short-term exposure to radiation levels as high as 370 rem/hr (Section 6.9).
11. The SET components in areas with elevated radiation fields shall be designed with operations and maintenance requirements that limit occupational radiation doses to levels as low as reasonably achievable (Section 6.9).
12. The SET shall receive the power from the SED.
13. The SET shall furnish electrical power for operating the WES, WRS, PCM, and BES rail-mounted equipment.
14. The SET instrumentation and control components shall have the following basic functions:
 - a. Provide data to other systems to indicate the locations of rail-mounted equipment.
 - b. Provide data to other systems to indicate the positions of all switches.
 - c. Interface with other systems such that the switches can be controlled remotely.
 - d. Provide data to other systems regarding the status of major components of the electrification system.

- e. Interface with other systems such that portions of the electrification system can be controlled remotely.

15. The SET shall interface with other systems as indicated in Section 6.11.

An explicit list of track gauge in the SDD is not recommended. The requirement to match the track gauge to the equipment is implied by the interface requirements of Sections 6.11.4 and 6.11.5. As noted in Section 6.1.3, the gauge of the emplacement track is unverified and is subject to change as the designs of the emplacement method and the equipment required to implement the method evolve.

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9. ATTACHMENTS

Not used.