

**OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET**

Complete Only Applicable Items

1. QA: QA

Page: 1 of 53

2. <input checked="" type="checkbox"/> Analysis Check all that apply		3. <input type="checkbox"/> Model Check all that apply	
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**OFFICE OF CIVILIAN RADIOACTIVE WASTE
MANAGEMENT**

ANALYSIS/MODEL REVISION RECORD

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1. Page: 2 of 53

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ACRONYMS AND ABBREVIATIONS

Acronyms

AC	Air Conditioning
CAD	Computer Aided Design
DC	Direct Current
MGR	Monitored Geologic Repository
TBD	To Be Determined
TBV	To Be Verified
WP	Waste Package

Abbreviations

ft	Feet
hp	Horsepower
hr	Hour
Hz	Hertz
in	Inches
kg	Kilogram
lbs	Pounds
m	Meters
mm	Millimeters
mph	Miles per Hour
MT	Metric Ton
rem	Roentgen Equivalent Man (measure of absorbed dose)
rpm	Rotations per Minute
s	Second

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1. PURPOSE

The purpose of this analysis is to present and document the conceptual design of a system that will transport and install drip shields over previously emplaced waste packages (WPs) within the emplacement drifts. This analysis will demonstrate the feasibility of such a system and document major features of the mechanical equipment at the conceptual level. Installation of the drip shields within the emplacement drifts is envisioned to occur immediately prior to closure of the subsurface repository. The current schedule for closure of the potential repository ranges from 50 to 100 years after waste emplacement (Wilkins and Heath 1999, Enclosure 2, Section 13.0), with the option to defer closure for 300 years (CRWMS M&O 1999f, Section 2.1.1.3).

The Enhanced Design Alternative II concept requires the use and installation of drip shields over the WPs prior to closure. The drip shields will provide defense-in-depth for postclosure performance (CRWMS M&O 1999a, p. v).

As stated in the development plan (CRWMS M&O 1999g), the principal objective of this analysis is to show that future emplacement of drip shields over previously emplaced WPs, within the confines of the emplacement drift, is feasible and can be achieved using current technologies. Because the drip shield design is currently ongoing, it is not possible nor necessary to show detailed dimensional information. Instead, it is the overall concept for drip shield emplacement that is intended to be shown within this analysis. This analysis will include the conceptual development of equipment required to transport the drip shields from a surface facility to the emplacement drifts and the equipment required to transport and place the drip shield within the emplacement drifts.

Although preliminary, this analysis will discuss the major considerations for such an emplacement concept. The method and requirements for the transportation and emplacement of drip shields from the surface to the emplacement drifts will be discussed. Due to the radioactive and high-temperature environment within the emplacement drift, a brief description will be made of the electrical and control system envisioned to remotely control the gantry. Also investigated are the interfaces between the drip shield and the Drip Shield Emplacement Gantry, the drip shield and the emplacement drift invert, the drip shield and the Drip Shield Transporter, and the Drip Shield Emplacement Gantry and the Drip Shield Gantry Carrier.

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2. QUALITY ASSURANCE

The quality assurance classification of repository structures, systems, and components has been performed in accordance with QAP-2-3, *Classification of Permanent Items*. The Drip Shield has been classified as quality affecting (QL-1) by *Classification of the MGR Ex-Container System* (CRWMS M&O 1999b). However, until a classification analysis is prepared for Drip Shield Emplacement, per QAP-2-3, the system is assumed to have a quality level of QL-2 (CRWMS M&O 2000).

This design activity has been developed in accordance with AP-3.10Q *Analysis and Models*, and has been evaluated in accordance with QAP-2-0, *Conduct of Activities*. The activity evaluation for Ex-Container and Backfill Systems (CRWMS M&O 1999c), also known as the Emplacement Drift System, has determined that the activity is subject to the requirements of *Quality Assurance Requirements and Description* (DOE 2000).

Unqualified data and input requiring confirmation will be identified as to -be-verified/to-be-determined (TBV/TBD), and will be tracked in accordance with AP-3.15Q, *Managing Technical Product Input*. 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.

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3. COMPUTER SOFTWARE AND MODEL USAGE

No engineering or scientific design computer software programs subject to QA controls were used in the preparation of this analysis. However, the Project-standard suite of office software for word processing has been used in the preparation of this analysis. Also, the figures have been drawn using Computer Aided Design Drafting programs. These are commercially available software programs that are appropriate for the application and approved for the Project. Therefore, no qualifications are needed.

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4. INPUTS

The criteria that define the requirements of and limitations on the drip shield emplacement concept are not explicitly stated in current System Description Documents. A formal input request was initiated that called for applicable functions and criteria for the Drip Shield Emplacement System. The input transmittal *System Description Document for Drip Shield Emplacement* (CRWMS M&O 2000) provided guidance for parameters and criteria for the system. The defining criteria are identified within this section.

4.1 DATA AND PARAMETERS

4.1.1 Not Applicable

4.2 CRITERIA

- 4.2.1 The system shall be designed to install drip shields in a manner that results in a single, contiguous barrier for the entire length of the emplacement drift occupied by WPs.
(CRWMS M&O 2000, Section 1.2.1.4)
- 4.2.2 The system shall be capable of transporting and placing the drip shield sections over a maximum grade of ± 2.7 percent between the surface and the emplacement drifts, and transporting and placing the drip shield sections over a maximum grade of ± 1.0 percent within the emplacement drifts.
(CRWMS M&O 2000, Section 1.2.1.5)
- 4.2.3 The system shall be capable of installing drip shields from either end of an emplacement drift.
(CRWMS M&O 2000, Section 1.2.1.7)
- 4.2.4 The system shall support the use of remotely operated equipment in subsurface emplacement areas that are restricted from access by personnel (i.e., emplacement drifts where waste is emplaced).
(CRWMS M&O 2000, Section 1.2.2.1.1)
- 4.2.5 The system, as a minimum, shall be designed to operate (while within an emplacement drift) during and after exposure to a maximum air temperature (ventilated) of 50 degrees Celsius dry bulb.
(CRWMS M&O 2000, Section 1.2.3.1)
- 4.2.6 The system, as a minimum, shall be capable of operating while within an emplacement drift at a relative humidity range of between 10 and 100 percent.
(CRWMS M&O 2000, Section 1.2.3.2)
- 4.2.7 The system shall be designed such that components susceptible to radiation damage can withstand and operate in the radiation environment (TBD-405) in which the component is located.
(CRWMS M&O 2000, Section 1.2.3.3)
- 4.2.8 The system shall interface with the Emplacement Drift System to establish the physical relationship between drip shields and the other components located in the emplacement drift.
(CRWMS M&O 2000, Section 1.2.4.1)

4.2.9 The system shall receive inputs and send outputs identified in Table 1 to the Monitored Geologic Repository (MGR) Operations Monitoring and Control System for communication with other systems. (CRWMS M&O 2000, Section 1.2.4.3)

Table 1. System Input/Output Data

Inputs To Be Received	Outputs To Be Provided With Monitoring Of The Status Of The Signal
MGR Operation Monitoring and Control System data and status monitoring	Equipment status and status of operations
Subsurface Electrical Distribution System data and status monitoring	Alarm equipment status
Subsurface Fire Suppression System data and status monitoring	Control equipment status
Identification and tracking data	Video equipment status
Operation message advisory	Communications equipment status
Activity plans and procedures	N/A

4.2.10 The system will interface with the Subsurface Electrical Distribution System for operating power underground. (CRWMS M&O 2000, Section 1.2.4.4)

4.2.11 The system shall operate, where practical, on the track provided by the Subsurface Emplacement Transportation System as identified in Table 2.

(CRWMS M&O 2000, Section 1.2.4.6)

Table 2. Rail Interface

Area	Track Gauge	Rail Size
Surface Facilities, Ramps, Main Drifts, and Turnouts	1.44 m (56.7 in)	57.05 kg/m (115 lbs/yd)
Emplacement Drifts	2.58 m (101.6 in)	44.64 kg/m (90 lbs/yd)

4.2.12 The system shall operate within the Subsurface Emplacement Transportation System curvatures identified in Table 3. (CRWMS M&O 2000, Section 1.2.4.7)

Table 3. Subsurface Waste Emplacement Transportation System Curvatures

Location	Minimum Radius
Ramps and Mains	305 m (1,000 ft)
Emplacement Drift Turnouts	20 m (65.6 ft)

4.2.13 The system will interface with the Site Communications System to provide voice communications between surface and subsurface portions of the system.

(CRWMS M&O 2000, Section 1.2.4.11)

4.2.14 The system will interface with the Subsurface Fire Protection System and Site Fire Protection System to provide fire response support.

(CRWMS M&O 2000, Section 1.2.4.12 and Section 1.2.4.13)

4.3 CODES AND STANDARDS

4.3.1 American Society of Mechanical Engineers

NOG-1-1995 *Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge Multiple Girder) 1995.*

4.3.2 American Society for Testing and Materials

ASTM A 36/A 36M-97a *Standard Specification for Carbon Structural Steel* 1998.

4.3.3 Association of American Railroads

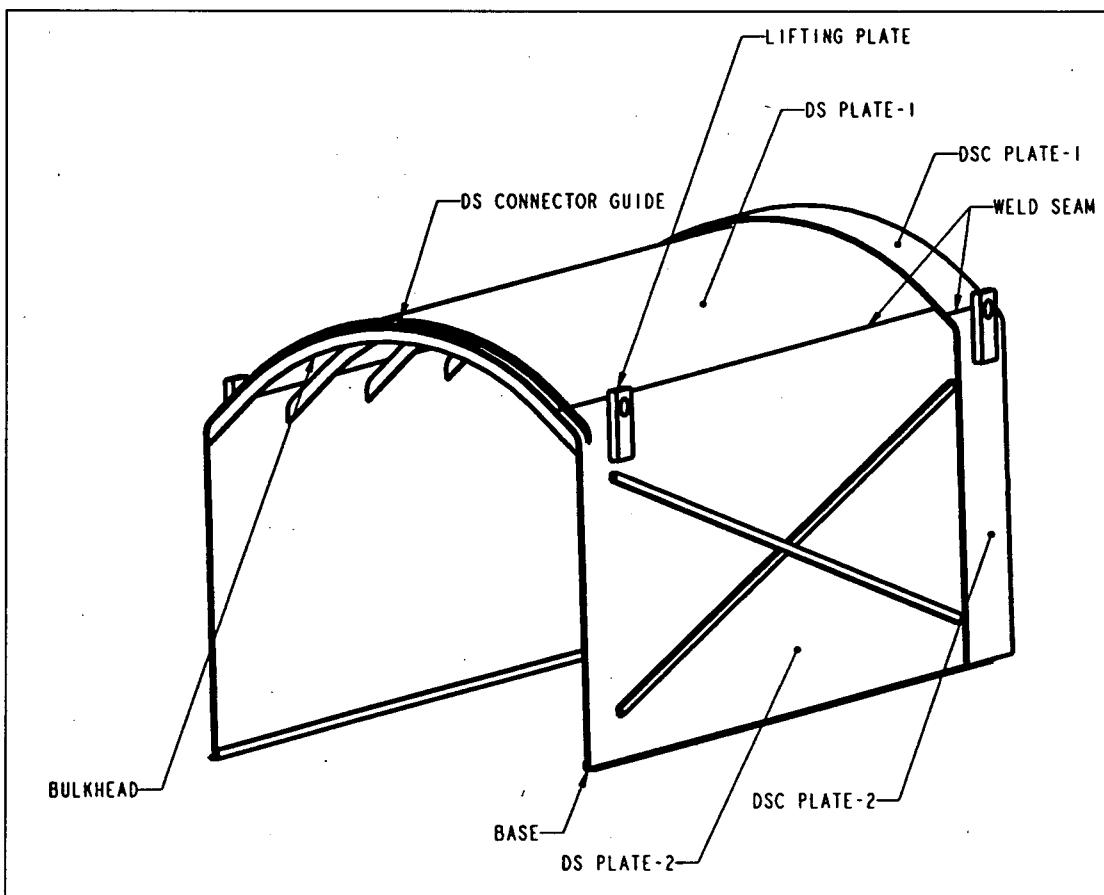
M-1001 *Manual of Standards and Recommended Practices Section C – Part II, Specifications for Design, Fabrication and Construction of Freight Cars M-1001 Volume I and II Standards* 1993.

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5. ASSUMPTIONS

5.1 *Assumption:* The detail design of the drip shield has not been finalized. Therefore, the design is assumed to be flexible and able to tolerate changes to the conceptual design in order to simplify and facilitate the transportation and emplacement of the drip shield.

Basis: The input transmittal *Drip Shield Design* (CRWMS M&O 1999d) provided initial information on the drip shield design, as shown in Figure 1. It is known that the drip shield, at the initiation of this analysis, was in the process of design iterations to enhance the overall design of the drip shield.



Source: CRWMS M&O 1999d

NOTE: This is a partial view of Sketch number SK-0148 REV 01 from the input transmittal *Drip Shield Design* (CRWMS M&O 1999d)

Figure 1. Drip Shield

An input request was issued requesting an updated version of the drip shield design than that presented in *Drip Shield Design* (CRWMS M&O 1999d). However, the design of the drip shield continued to evolve and an input transmittal, in response to the input request, was not issued due to the continued development of the drip shield. It was agreed to retract the input request so that this analysis could proceed with the

assumption that the drip shield design will change. This agreement provided the flexibility to assume modifications to the conceptual drip shield design and allowed for major assumptions on the detail design of the drip shield. However, when the drip shield design is baselined, this analysis must be revisited to show the feasibility of the drip shield emplacement concept.

Used In: This assumption is used throughout the analysis.

5.2 *Assumption:* The length of the drip shield is assumed constant.

Basis: In association with Assumption 5.1, the input transmittal *Drip Shield Design* (CRWMS M&O 1999d) provided information on only one size of drip shield. There is no mention of matching the drip shield length to the length of a particular WP.

Used In: This assumption is used to develop a conceptual Drip Shield Emplacement Gantry as described in Section 6.2 and a conceptual Drip Shield Transporter as described in Section 6.3.

5.3 *Assumption:* Each drip shield lifting plate is assumed to have a cut-out, as shown in Figure 2, and all lifting plates are to be spaced at a constant distance.

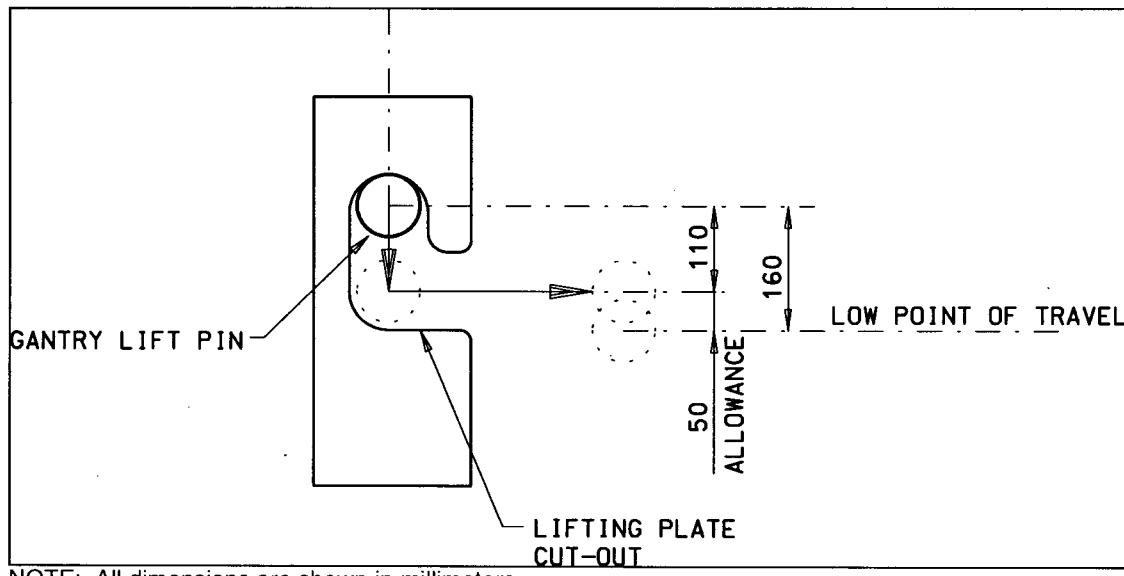


Figure 2. Lift Plate Cut-Out

Basis: In association with Assumption 5.1, the input transmittal *Drip Shield Design* (CRWMS M&O 1999d), the Drip Shield Emplacement Gantry lifting pins will not have to adjust for varying lifting plate spacing, thus, simplifying the gantry design. The cut-out provides a means for the Drip Shield Emplacement Gantry to engage and lift the drip shield by the lifting plates.

Used In: This is used to describe the gantry/drip shield interface in Section 6.2.2.

5.4 *Assumption:* The drip shield overall mass will be assumed as 4.00 MT.

Basis: In association with Assumption 5.1, the drip shield design is expected to change and, therefore, the mass of the drip shield is expected to vary. The input transmittal *Drip Shield Design* (CRWMS M&O 1999d) states that the drip shield mass is 3.087 MT. A 4.00 MT assumed weight is approximately 30 percent greater than 3.087 MT. This provides an upper bounding limit on drip shield weight and allows for variations in weight with limited impact on this analysis.

Used In: This information is used to size the gantry ball-screw mechanism, as described in Section 6.2.3.

5.5 *Assumption:* The lifting heights and dimensions shown in Figure 3 and summarized in Table 4 are assumed values.

Basis: In association with Assumption 5.1, the design of the drip shield will have a direct impact on the Drip Shield Emplacement Gantry and the Drip Shield Transporter designs. Therefore, clearances, dimensions, tolerances, and other pertinent information are estimated or assumed. As the design evolves, geometric analyses of the clearances, dimensions, tolerances, and other pertinent information must be performed to ensure an adequate operating envelope for the Drip Shield Emplacement System.

Table 4. Conceptual Design Dimensions

Description	Value (mm)	Basis/Source
Top of Turnout Rail to Top of Gantry Rail	1,420	CAD Drawing – Values based on estimated equipment drawings.
Top of Drip Shield Transporter Deck from Top of Turnout Rail	1,165	CAD Drawing – Values based on estimated equipment drawings.
Top of Gantry Rail to Top of Structural Invert	394	CAD Drawing – Values based on estimated equipment drawings.
Base of drip shield to Pin Engagement	2,045	<i>Drip Shield Design</i> (CRWMS M&O 1999d)
Clearance Height of drip shield above Structural Invert During Travel	500	CAD Drawing – Values based on estimated equipment drawings.
Engagement of drip shield lifting plates	160	Assumption 5.3, Figure 2.

Used In: This information is used to determine the maximum lifting height required for the gantry ball-screw mechanism, as described in Section 6.2.3.

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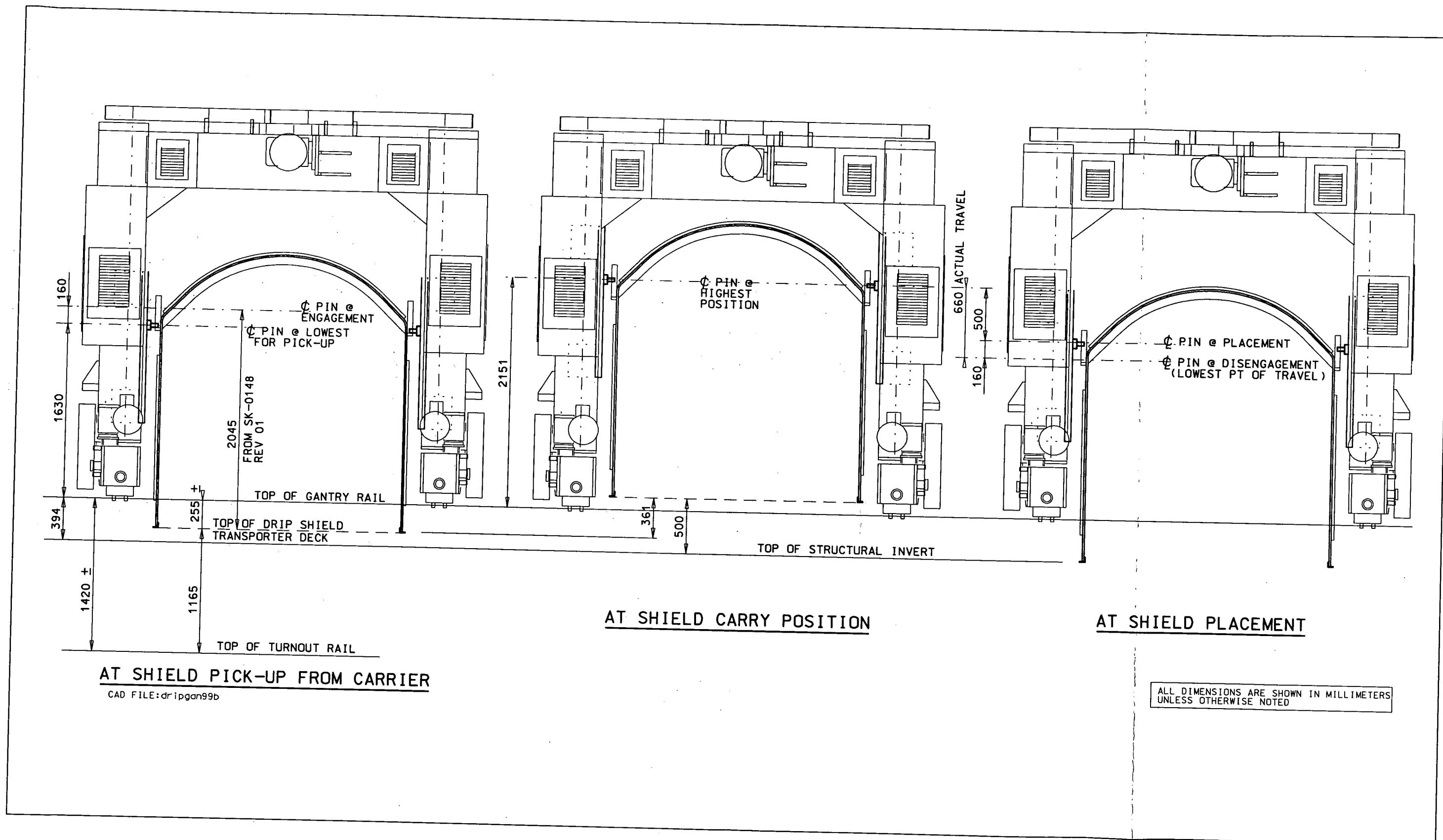


Figure 3. Drip Shield Lifting Heights

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6. ANALYSIS/MODEL

Although preliminary, this analysis discusses the major considerations for a drip shield emplacement concept. A transportation method for the drip shields from the surface to the emplacement drift transfer dock is presented. An emplacement equipment concept, currently a gantry crane, is presented for the transportation and emplacement of the drip shields within the emplacement drift. Due to unusual conditions presented by the radioactive and high-temperature environment within the emplacement drift, a description is made of the electrical and control system envisioned for the emplacement gantry. Also investigated are the interfaces between the emplacement gantry and the drip shield, the drip shield and the emplacement drift invert, the interfaces between the gantry and the gantry transportation equipment, and the interfaces between the emplacement gantry and the drip shield transportation equipment.

The input transmittal *Drip Shield Design* (CRWMS M&O 1999d) provided information on one particular drip shield design. This design is at the conceptual level and, therefore, design details have not been developed. Because the drip shield design is currently ongoing, it is not possible nor necessary to show detailed dimensional information. Instead, it is the overall concept for drip shield emplacement that is intended to be shown within this analysis. Although not affecting the overall concept of the drip shield, some basic design assumptions (Sections 5.1 through 5.5) have been made so that the drip shield can be easily handled.

6.1 DRIP SHIELD EMPLACEMENT SYSTEM SELECTION

The drip shield emplacement concept is patterned after the Waste Emplacement/Retrieval System (CRWMS M&O 1999e and CRWMS M&O 1998, Section 7.2 and 7.3) and consists of a Drip Shield Emplacement Gantry (gantry) (see Section 6.2), a Drip Shield Transporter (transporter) (see Section 6.3), a Drip Shield Gantry Carrier (carrier) (see Section 6.4), and a locomotive (see Section 6.5). The Waste Emplacement/Retrieval System was selected as the basis for the Drip Shield Emplacement System concept because of the similarity between the two systems. The Drip Shield Emplacement System will have similar equipment, with comparable operating procedures, maintenance requirements, and reliability as the Waste Emplacement/Retrieval System.

The Drip Shield Transporter is a rail car moved by a locomotive and is used for transporting the drip shields from the surface facilities to the emplacement drift transfer dock. The Drip Shield Emplacement Gantry is used for retrieving the drip shield (shield) from the Drip Shield Transporter, carrying the shield through the emplacement drift, and placing the shield in its final position over the WPs. The Drip Shield Gantry Carrier transports the gantry to and from the surface facilities and the emplacement drifts, and from emplacement drift to emplacement drift. Depending on the length of time between the conclusion of waste emplacement and the commencement of drip shield emplacement, the locomotive may be the same locomotive used for the Waste Emplacement/Retrieval System (CRWMS M&O 1998, Section 7.3).

The Drip Shield Emplacement System will utilize and interface with many of the same systems that the Waste Emplacement/Retrieval System utilizes. Systems that interface with the

Drip Shield Emplacement System may include, but are not limited to (CRWMS M&O 2000):

- Waste Emplacement/Retrieval System
- Emplacement Drift System
- Ground Control System
- MGR Operations Monitoring and Control System
- Subsurface Electrical Distribution System
- Site Electrical Power System
- Maintenance and Supply System
- Subsurface Emplacement Transportation System
- Site Operations System
- Site Communications System
- Subsurface Fire Protection System
- Subsurface Facility System

It is understood that other interfaces exist and will need further investigation and/or analysis. For example, interfaces will exist with the surface facilities for the logistical support for the drip shield emplacement operations and for the handling and loading of the drip shields onto the Drip Shield Transporter.

Like the Waste Emplacement/Retrieval System, the Drip Shield Emplacement System must interface with the above systems and perform similar tasks. Therefore, depending on the length of time between the conclusion of waste emplacement and the commencement of drip shield emplacement, common pieces of equipment may be used for both Waste Emplacement/Retrieval and drip shield emplacement. Key common components may include:

- Main drift and emplacement drift rail system
- Locomotives and their related electrical and control systems
- Gantry carrier and related electrical and control system (used for transportation of the gantry)
- Electrical and control systems for the emplacement drift and emplacement drift turnout

The sequence of operations for drip shield emplacement starts with the transportation of the Drip Shield Emplacement Gantry to the emplacement drift. This is performed with the locomotive and the Drip Shield Gantry Carrier. Then, a single drip shield is transported on the Drip Shield Transporter to the emplacement drift transfer dock. Here, the gantry lifts the drip shield vertically off the Drip Shield Transporter and transfers the shield through the isolation doors and down the emplacement drift. Prior to lowering the drip shield, the gantry operator visually ensures, via remote on-board cameras (see Section 6.2.5.4), that the correct amount of overlap exists between the drip shield being emplaced and the previously installed drip shield. The gantry then lowers the shield directly onto the drift transverse beams. The steel transverse beams are part of the drift floor support structure, or invert, which also supports the emplacement drift rail system and third-rail power system. After the drip shield is lowered onto the invert and the required overlap between drip shields is visually verified, the gantry returns to the emplacement drift transfer dock, and the cycle is repeated.

This system allows for the emplacement of drip shields from either end of the emplacement drift (Criteria 4.2.3) and in a manner that results in a single contiguous barrier for the useful length of the emplacement drift (Criteria 4.2.1).

6.2 DRIP SHIELD EMPLACEMENT GANTRY

6.2.1 Gantry General Arrangement

The Drip Shield Emplacement Gantry, as shown in Figure 4, will receive and transport drip shields from the Drip Shield Transporter located at the emplacement drift transfer dock to the permanent position of the drip shield over the WPs. The gantry is self-propelled, utilizing the third-rail power system, and remotely operated (Criteria 4.2.4). In performing the drip shield placement function, the gantry must:

- Position itself accurately over the drip shield, which is located on the Drip Shield Transporter at the emplacement drift transfer dock, and engage the drip shield lifting plates with the gantry lifting mechanisms.
- Lift the drip shield to a height that will clear all obstacles or equipment located in the emplacement drift.
- Transport the drip shield to its designated emplacement position.
- Position the flared portion of the drip shield, known as the Drip Shield Connector (DSC) plate (see Figure 1), over the previously placed drip shield.
- Lower the drip shield into position and release.
- Return to the emplacement drift transfer dock.

To complete the above functions, the Drip Shield Emplacement Gantry, shown in Figure 5, is composed of several components and systems, including the gantry frame, traversing system, hoist system with drip shield engagement attachments, electrical third-rail power system, and remote control systems. The gantry will be designed to utilize the Subsurface Electrical Distribution System (e.g., third-rail) and MGR Operations Monitoring and Control System that controls the Waste Emplacement/Retrieval System. Similarly, the Drip Shield Emplacement Gantry will use the rails of the Emplacement Drift envisioned for use by the waste emplacement gantry.

The gantry frame will be a steel structure designed to support its own weight plus the weight of a drip shield and any seismic loads or external forces anticipated. The frame will support and contain the ball-screw jacks used to raise the drip shields. A truck, also known as a bogie, is the common name for the suspension assembly consisting of rail wheels, axles, brakes, bolsters, springs, shock absorbers, frame members, and any other suspension-related equipment. The trucks used to propel the gantry are mounted to the base of the frame. Attached to the sides of the trucks are trunnions, which may be used to lift or drag the emplacement gantry. This could be used in off-normal scenarios where the emplacement gantry may become disabled within the emplacement drift.

The Drip Shield Emplacement Gantry is self-propelled, using four two-wheeled trucks with one truck placed at each corner of the gantry frame. One wheel in each truck is driven by a direct-current (DC) variable-speed electric motor through a gear reducer and chain drive.

Braking is performed through the integral brake within the DC electric motor. Integral brake motors can be purchased in a fail-safe configuration, where if the electric motor should lose power, the brakes are applied via a spring mechanism. All motors, including the ball-screw jack motors, and any other operating components of the gantry, will be electrically operated and controlled.

Although the gantry design is at the conceptual stage, it is anticipated that the frame will be composed of standard structural shapes composed of ASTM A36 (ASTM A 36/A 36M-97a, 1998) steel and fabricated according to American Welding Society standards. The ASTM A36 and possibly other high-strength steels will be evaluated for appropriate use during final design of the gantry. As stated previously, the Drip Shield Emplacement Gantry is based on the Waste Emplacement Gantry. A comprehensive structural analysis was performed on the Waste Emplacement Gantry in *Preliminary Waste Package Transport and Emplacement Equipment Design* (CRWMS M&O 1997a, Attachment II). From this analysis, the gantry is shown to be structurally stable and able to withstand seismic events.

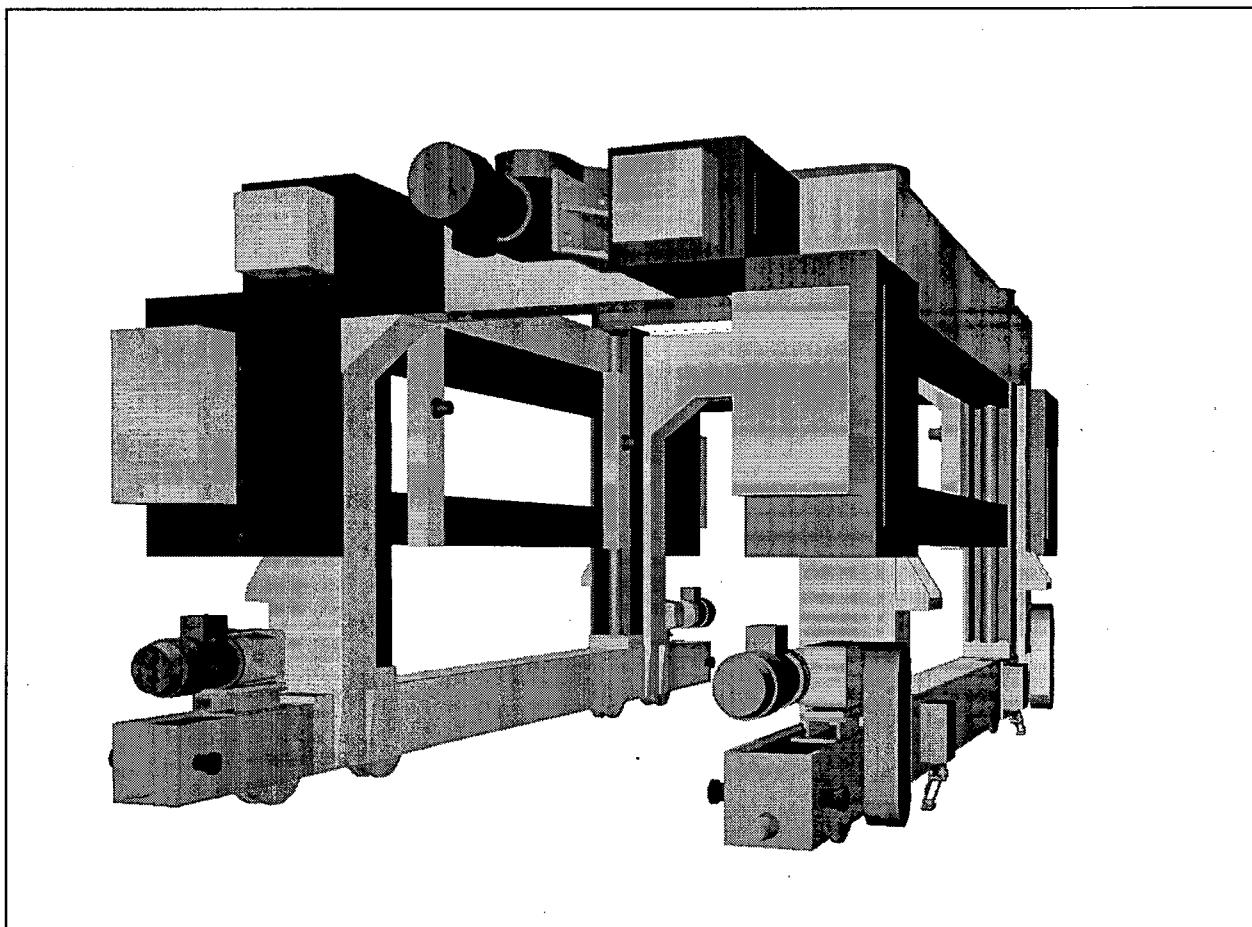


Figure 4. Rendering of Drip Shield Gantry

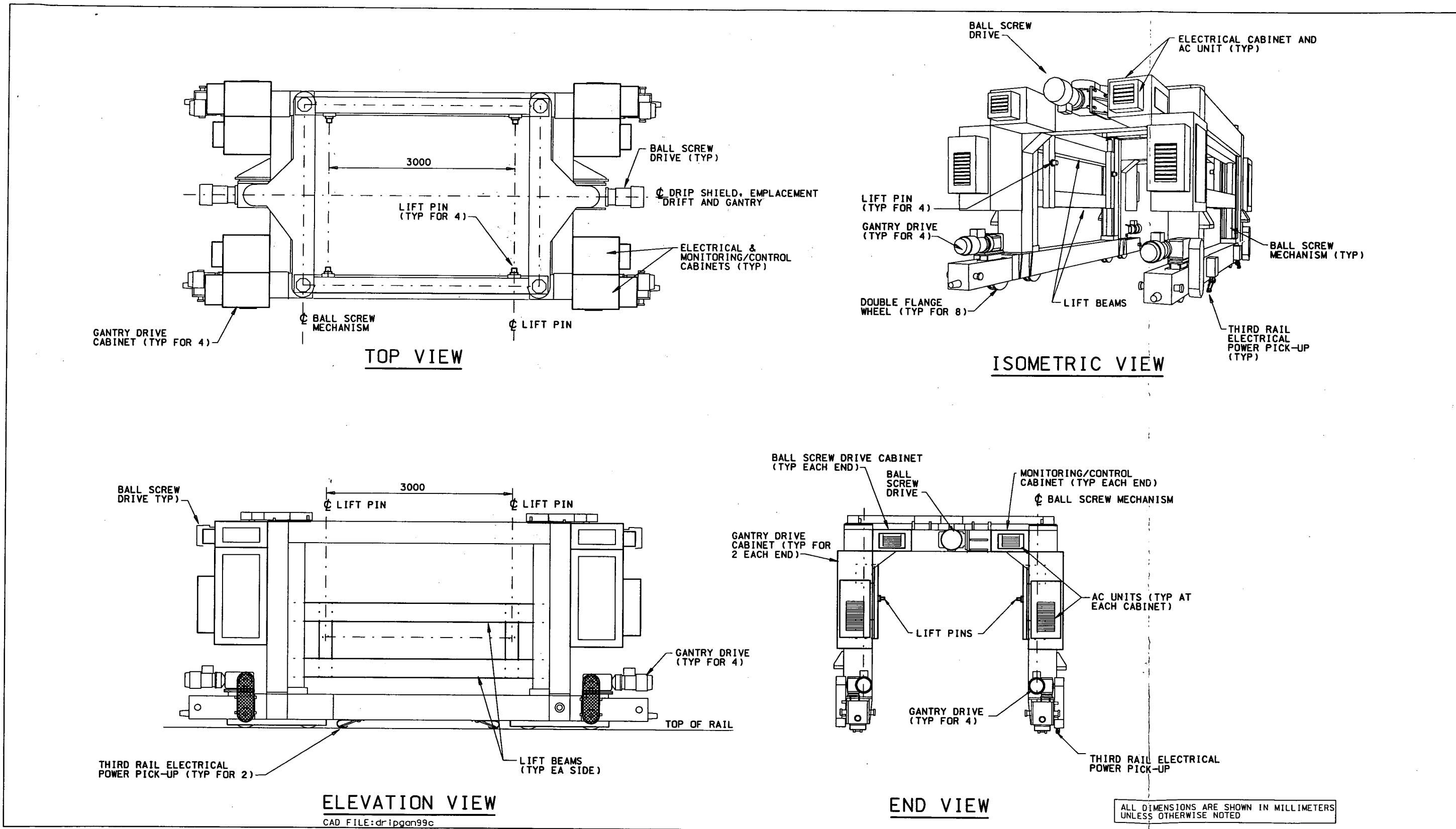


Figure 5. Drip Shield Emplacement Gantry

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6.2.2 Interface with Drip Shield

The drip shield preliminary design (CRWMS M&O 1999d) utilizes lifting plates, as shown in Figure 1, for the engagement and lifting of the shield by the Drip Shield Emplacement Gantry. The gantry will have lifting pins that will engage the drip shield lifting plates and raise the shield to the required height for transportation, as shown in Figure 2 and Figure 3.

Being remotely controlled, the Drip Shield Emplacement Gantry will engage the drip shield lifting plate through a series of simple operations. These simple operations will lift and move the drip shield from the Drip Shield Transporter, located at the emplacement drift transfer dock, into the emplacement drift, and lower the drip shield to its final resting position.

The sequence of operations starts with the drip shield on the Drip Shield Transporter within the emplacement drift transfer dock. The gantry is remotely driven to the emplacement drift transfer dock with the lifting pins in the fully raised position, allowing clearance between the gantry lifting pins and the top of the drip shield lifting plates (see Section 6.3.3). The lifting pins are lowered to the height of the lifting plate cut-out (Assumption 5.3). The gantry is then moved forward until the gantry pins engage the lifting plates. The drip shield is raised by the lifting pins, which are powered by four ball-screw mechanisms. Once the drip shield is raised to a height that will clear all obstructions within the drift, the Drip Shield Emplacement Gantry travels down the emplacement drift to the final resting position of the drip shield. The drip shield is lowered to the floor of the emplacement drift with the drip shield connector plate (shown as DSC Plate-1 in Figure 1) overlapping the connector guide of the previously placed drip shield.

6.2.3 Lifting Mechanism

The Drip Shield Emplacement Gantry lifting mechanism is envisioned to be a ball-screw mechanism, which is a common form of screw jack used for lifting heavy loads. A ball-screw mechanism has the advantages of longer duty cycles and higher efficiencies compared to a typical machine-screw mechanism. As shown in Figure 5, a ball screw will be located within each of the four vertical steel members of the gantry and will be driven by two DC motors, where one motor will drive two of the four ball screws. Ball screws are sized according to the required lifting capacity, duty cycles, and total distance needed to lift. Currently available industry-standard ball-screw mechanisms can lift loads over 228 MT (250 tons) (Pow-R-Jac, Section BSJ) and, correctly sized, are a good selection for this application.

Although a mature design of the drip shield was not available at the start of this analysis (Assumption 5.1), a preliminary sizing of each ball-screw mechanism is performed below and is based solely on the weight of the drip shield.

- Total ball screw load (4 ball screws) is 4.00 MT (Assumption 5.4)
- Each individual lift screw has to carry:

$4.00 \text{ MT} \div 4 = 1.00 \text{ MT}$ (2,205 lbs): if 90 percent efficiency is estimated for the ball screw, use 1.1 MT (2,425 lbs). This estimate accounts for the 10 percent increase in load caused by friction loss within the ball-screw mechanisms.

- A maximum lift screw vertical travel of 660 mm (26.0 in) provides sufficient clearance of the drip shield over the rail transporter (394 mm) and emplacement drift structural invert (500 mm), and includes the travel required for pin disengagement (160 mm), where $660 \text{ mm} = 500 \text{ mm} + 160 \text{ mm}$ (Assumption 5.5).
- Approximate number of drip shields needed for the potential repository

$$10,000 \times 25 \text{ percent contingency} = 12,500 \text{ total drip shields}$$

- Preliminary ball screw size is 1-in (25.4 mm) diameter with 0.5-in (12.7 mm) lead. This is based on total travel of $1,320 \text{ mm} \times 12,500 \text{ drip shields} = 16.5 \times 10^6 \text{ mm}$ ($0.65 \times 10^6 \text{ in}$) and load of 1.1 MT (2,425 lbs) (Thomson Saginaw Ball Screw Company 1995, p. 19)

660-mm raise per drip shield + 660-mm lower per drip shield = 1,320 mm Total Travel per drip shield

- The normal slow lifting speed for loads of 0 to 3.6 MT (0 to 4 tons) is 0.152 m/s (30 ft/min) and for loads of 4.5 to 8.2 MT (5 to 9 tons) is 0.127 m/s (25 ft/min) (ASME NOG-1-1995, Table NOG-5331.1-1).
- Since the required lift is only 660 mm (26.0 in), a lifting time of 30 seconds is reasonable.
- Therefore, the lifting speed is $660 \text{ mm} / 30 \text{ s} = 0.022 \text{ m/s}$ (4.33 ft/min). This is well within the slow lifting speed limit for 4.5 to 8.2 MT as indicated in NOG-1-1995 (ASME NOG-1-1995, Table NOG-5331.1-1).

6.2.4 Drive System and Wheel/Rail Interface

The Drip Shield Emplacement Gantry is self-propelled using four two-wheel trucks with one truck mounted at each corner of the gantry frame. All wheels are dual-flanged rail wheels sized for the emplacement drift rail. It is envisioned that one wheel per truck will be driven by a 5-hp DC variable-speed integral-brake electric motor through a right-angle gear reducer and roller chain assembly. The gear reducer, preliminarily sized with a nominal reduction ratio of 50:1 and a chain drive of 1:1, will provide a maximum wheel output speed of 35-rpm (assuming a standard maximum motor speed of 1,750 rpm). Although wheel size has yet to be determined, maximum gantry speed can be estimated using a 400-mm wheel size. Using 35 rpm and 400 mm diameter, maximum gantry speed is 0.733 m/s (1.64 mph).

$$V = \pi d \times \omega = 400 \text{ mm} \times 3.1415 \times 35 \text{ rpm} = 43,981 \text{ mm/min} = 0.733 \text{ m/s} (1.64 \text{ mph}) \quad (\text{Eq. 1})$$

where:

V = Velocity

d = Diameter

ω = Rotational Speed (rpm)

The integral motor brake will provide deceleration and will be capable of holding the gantry the maximum ± 1.0 percent grade of the emplacement drift (Criteria 4.2.2). Integral brake motors can be purchased in a fail-safe configuration, where if the electric motor should lose power, the brakes are automatically applied via a spring mechanism. The *Preliminary Waste Package Transport and Emplacement Equipment Design* (CRWMS M&O 1997a, Attachment v, Section 3.2) shows that a 5-hp DC motor is adequately sized for waste emplacement operations and can traverse a maximum emplacement drift grade of ± 1 percent (Criteria 4.2.2). The Drip Shield Emplacement Gantry will handle weights far less than the Waste Emplacement Gantry and, therefore, the sizing of the DC motors and drive train is adequate for this application.

6.2.5 Electrical and Control Systems

The Drip Shield Emplacement Gantry is one of the most critical components of the Drip Shield Emplacement System. The gantry will utilize one of several alternative mobile communication technologies to interface with the MGR Operations Monitoring and Control System and Site Communications System in order to transmit and receive voice, video, and data communications for its monitoring and control functions (Criteria 4.2.9 and 4.2.13). A number of different technologies currently available have been examined and evaluated for the waste emplacement operations in *Subsurface Waste Package Handling - Remote Control and Data Communications Analysis* (CRWMS M&O 1997b, Section 7.4.2).

It is designed to operate within the moderately high temperature of 50 degrees Celsius (Criteria 4.2.5), moderate humidity of 10 to 100 percent (Criteria 4.2.6), and the radiation environment (Criteria 4.2.7) inside the emplacement drifts. Because of this harsh environment, operators at a remote-control console located at the surface will remotely control the Drip Shield Emplacement Gantry (Criteria 4.2.4).

The design of the Drip Shield Emplacement Gantry and its control system must impose limitations on system complexity if it is to perform its intended functions in a highly reliable manner. Incorporating high-quality software and hardware components will further enhance control system reliability. These components include redundant programmable control computers, instrumentation, and communications equipment. Design strategies such as employing diverse technologies, physically separating redundant components, and providing backup electrical power and data communication systems will be implemented to ensure fault-tolerant operation.

6.2.5.1 Electrical Power

The preliminary Drip Shield Emplacement Gantry design utilizes an electrified third-rail (conductor bar) system as the primary source of electrical power for the vehicle. The third-rail

power is part of the Subsurface Electrical Distribution System (Criteria 4.2.10). As shown in Figure 5, the vehicle will be outfitted with redundant power pick-up mechanisms to ensure a reliable and continuous source of power. In addition to this primary power system, the gantry will carry an emergency backup power system that will provide a limited supply of electrical power. This backup system should be able to provide enough power to lower and release a drip shield, and drive the gantry to the emplacement drift entrance. A set of on-board rechargeable storage batteries may prove adequate for this purpose, but further investigation into the capabilities of this technology for this application will be necessary. Other backup power technologies should also be studied and evaluated.

6.2.5.2 Locomotion and Braking Controls

As shown in Figure 5, the locomotion system for the gantry is designed with four independent DC drive motors, each located at one of the four wheel assemblies. The motors will be connected directly to electrical power and motor control devices housed in on-board electrical cabinets located on the gantry. The motor controllers will receive forward/reverse and acceleration commands, positioning coordinates, and speed setpoints from the gantry's control computers. In turn, the motor controllers will perform all direction, positioning, speed, and acceleration control functions, as well as providing actual direction, position, speed, and acceleration feedback to the control computers in real-time. There will be fail-safe braking systems aboard the gantry. The braking system will be such that, in the event of power or communication loss, or a vehicle control system malfunction, the braking system would engage and bring the gantry to a stop.

The on-board cabinets house various electrical power and control devices, and will require active cooling systems for dissipating heat buildup. These cooling systems may simply be in the form of air conditioning (AC) units mounted to each of the enclosures, as shown in Figure 5. It may also be necessary to provide cooling to the drive motors themselves. Further investigation into motor cooling requirements will be necessary when considering the detail design of the vehicle.

6.2.5.3 Lifting Mechanism Controls

As shown in Figure 5 and described in Section 6.2.3, the ball-screw lifting mechanism for the gantry is designed with two independent DC drive motors located at each end of the vehicle. The power and control system for these motors will be similar to that for the gantry drives as discussed in Section 6.2.5.2.

6.2.5.4 Vision System

The gantry's vision system will provide operators at the remote control console with real-time feedback about the operating environment and vehicle performance. This system will consist of several on-board high-resolution, articulated, closed-circuit television cameras and a series of high-intensity lights.

6.2.5.5 Thermal and Radiological Monitoring Systems

The gantry will be equipped with thermal and radiological sensing instrumentation. These instruments will provide remote operators with the real-time status of thermal and radiological conditions within the emplacement drifts.

The on-board thermal monitoring system will monitor the internal temperatures of drive motors and other mechanisms aboard the gantry. The system will alert remote operators if temperatures approach predefined operational limits and necessitating removal of the gantry from the emplacement drift.

The on-board radiological monitoring system will continuously monitor the atmosphere inside the emplacement drift for trace radionuclide gases that would indicate a potential concern. This system will also record the cumulative dose radiation exposure of on-board electronics sensitive to radiation (Criteria 4.2.7). The system will alert remote operators of a malfunction or impending malfunction of various electronic devices that would necessitate the removal of the gantry from the emplacement drift for troubleshooting and repair.

6.2.5.6 Fire Protection Syste

The gantry will be equipped with redundant fire protection systems that will interface with the Subsurface Fire Protection System and/or the Site Fire Protection System (Criteria 4.2.14). The fire suppression portion of the system will respond automatically should an on-board fire be detected. The fire detection portion of the system will immediately notify remote operators, through the gantry control computers, of the location and nature of the fire.

6.2.5.7 Data Communication Syste

As stated in Section 6.2.5, the gantry will utilize two of several alternative mobile communication technologies to interface with the MGR Operations Monitoring and Control System and Site Communications System in order to transmit and receive voice and data communications for its monitoring and control functions (Criteria 4.2.9 and 4.2.13). A number of different technologies currently available were examined and evaluated for the waste emplacement operations in *Subsurface Waste Package Handling – Remote Control and Data Communications Analysis* (CRWMS M&O 1997b, Section 7.4.2). In the referenced analysis, the data communication technologies that are considered for mobile equipment within the emplacement drifts include direct radio, leaky feeder, and slotted microwave guide systems.

Due to the critical need for a reliable mobile data communication system for the gantry, the current design approach will be to implement redundant systems on the gantry. Diverse communication technologies, as noted in *Subsurface Waste Package Handling – Remote Control and Data Communications Analysis* (CRWMS M&O 1997b, Section 7.4.2), will be implemented to further ensure reliability. Thus, the gantry will be capable of interfacing with remote operators over two communication networks that employ different technologies and are physically separated. The application of diverse technologies will reduce the likelihood of common-cause failures and prevent the failure of one system causing the failure of the other system.

6.3 DRIP SHIELD TRANSPORTER

6.3.1 General Arrangement

The conceptual design of the Drip Shield Transporter is based on a standard railroad-industry flatcar, where an underframe and two truck assemblies support a flat deck. Guide rails will be mounted to the deck of the transporter to restrain and accurately locate the shield during transportation and gantry engagement (see Figure 6). The transporter will be pulled and maneuvered through the access main and the emplacement drift turnouts by a locomotive, and will utilize the existing rails of the Subsurface Emplacement Transportation System (Criteria 4.2.11 and 4.2.12). The locomotive will be remotely controlled when the locomotive and the Drip Shield Transporter are maneuvered within the emplacement drift turnouts while the isolation doors are open.

The components of the Drip Shield Transporter include:

- A flat deck with drip shield guides
- An underframe with supporting beams, stringers, and bolster plates
- The trucks including bearings, axles, wheels, springs, brakes, etc.

6.3.2 Drip Shield Guides

The Drip Shield Transporter will utilize guides to prevent any shifting of the drip shield during transportation. The guides, as shown in Detail A and B of Figure 6, also provide accurate alignment between the drip shield and the emplacement drift transfer dock, thereby facilitating the engagement of the shield by the Drip Shield Emplacement Gantry

The guides consist of parallel metal channels running along the length of the transporter deck. The channels are flared near the top to assist in loading the shields onto the transporter. Adjustable end blocks (chocks) are provided to position the shield at the center of the rail car deck and to prevent longitudinal shifting. It is envisioned that the drip shield will be placed on the transporter with the channels and end blocks used to assist in positioning the drip shield.

6.3.3 Emplacement Drift Interface

The emplacement drift transfer dock is designed for the Waste Emplacement/Retrieval System so that the gantry rails straddle the Waste Package Transporter. The locomotive pushes the Waste Package Transporter into a slot within the emplacement drift transfer dock (CRWMS M&O 1999e, Section 6.1). This configuration permits the Waste Package Transporter deck height to change while the relatively heavy WP is unloaded off the transporter. As the transporter is unloaded, the springs within the truck suspension decompress and raise the overall deck height above top-of-rail. In a similar manner, the Drip Shield Transporter interfaces with the emplacement drift transfer dock, as shown in Figure 7. The Drip Shield Emplacement Gantry will straddle the Drip Shield Transporter, engage the drip shield, and lift the shield off the transporter.

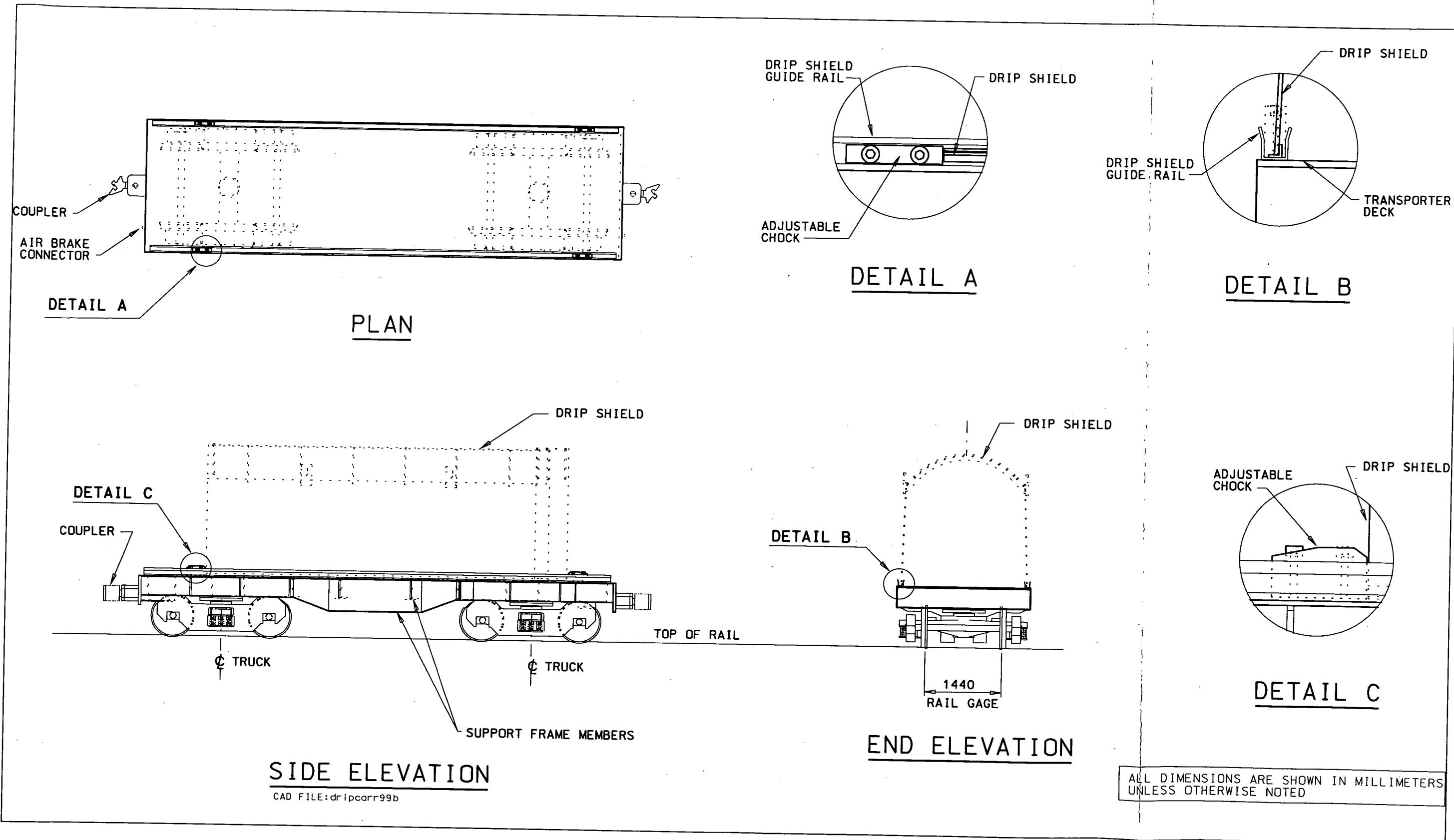


Figure 6. Drip Shield Transporter

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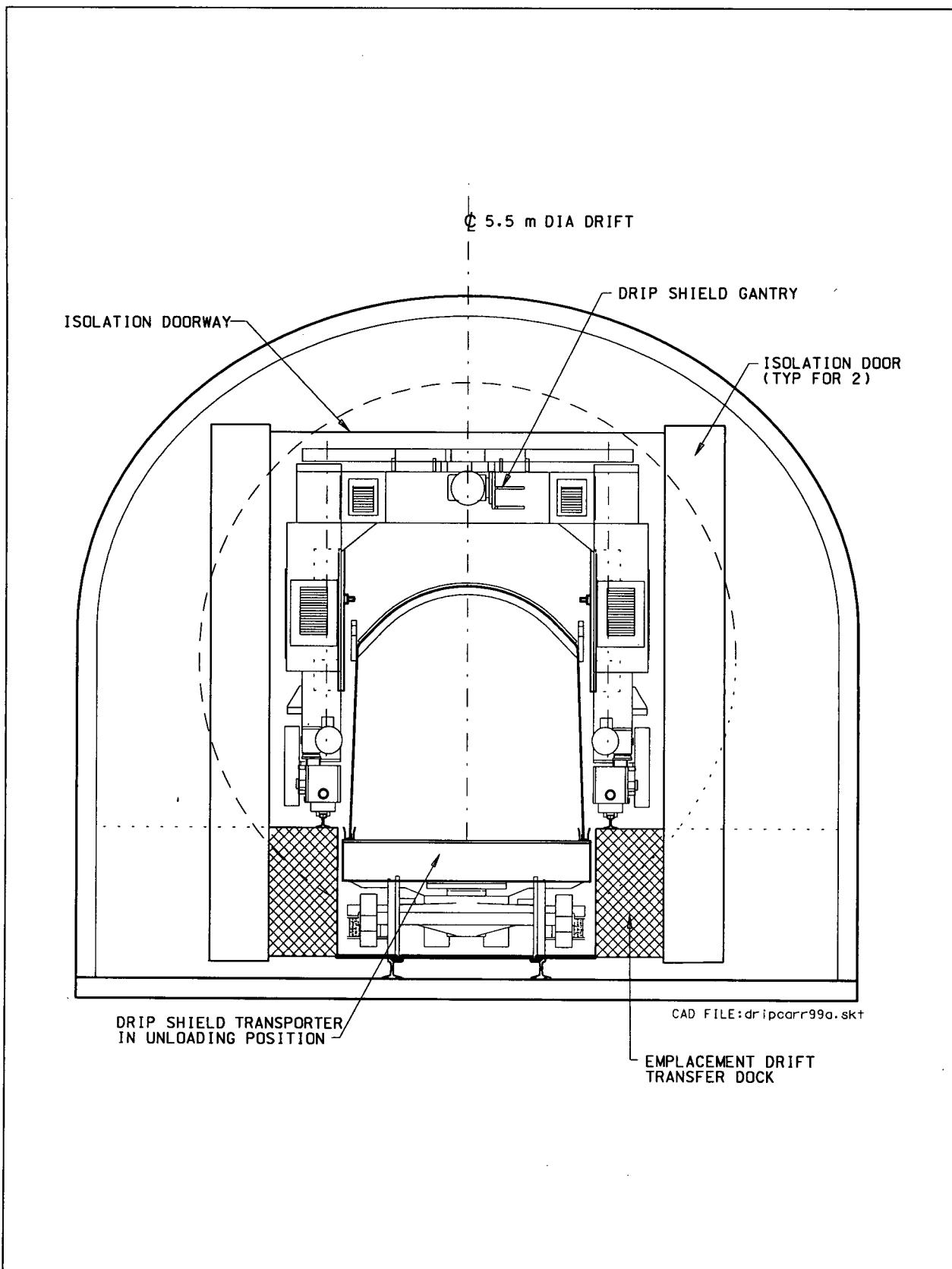


Figure 7. Emplacement Drift Interface

6.3.4 Underframe

Although the Drip Shield Transporter concept is subject to change, the current conceptual design of the underframe structure will be based on a standard railroad flatcar design. The underframe is considered as the entire structural framework of the rail car below the deck, including the center, side, and end sills, bolster plate, cross members, stringers, and other attached components (Kratville 1997, p. 1118). The underframe will be fabricated of structural sections and plate with welded and/or bolted connections.

A standard railroad flatcar design utilizes stringers running the full length of the car. Stringers are longitudinal structural members of the rail car underframe usually designed to be a load-bearing floor support (Kratville 1997, p. 1112). The stringers are supported at each end of the rail car by the bolster plates. The stringers also provide an anchor point for the couplers located at either end of the car. Stringers located at the outside edge of the rail car will be attached to the main stringers with crossbeams, spaced at close intervals and running at 90 degrees to the main stringers. These outer stringers and crossbeams will support the weight of the drip shield. The bolster plates are the structural members designed to support and transfer the load of the stringers to each truck bolster. The bolster plate accepts the centering kingpin of the truck bolster and reduces the pivot-motion friction between the truck bolster and the bolster plate.

It is anticipated that the Drip Shield Transporter will be manufactured with standard structural shapes composed of ASTM A36 steel (ASTM A 36/A 36M-97a. 1998) with design, fabrication, and construction according to Association of American Railroads standard M-1001 (AAR 1993, M-1001). The ASTM A36 and possibly other high-strength steels will be evaluated for appropriate use during final design of the transporter.

6.3.5 Trucks

Also known as bogies, trucks are the common name for the assembly of wheels, axles, bearings, side frames, springs, bolster, brake rigging, and any other related equipment used to provide mobility, suspension, and guidance to the rail car (Kratville 1997, p. 1117). The trucks envisioned for use on the Drip Shield Transporter are based on a standard truck configuration, as shown in Figure 8. The truck bolster, which is the main transverse member of the truck assembly, transmits the load from the bolster plate of the transporter underframe to the side frames through the suspension system (i.e., springs). The truck bolster accepts a kingpin that centers the truck with the underframe bolster plate and allows the trucks to pivot and negotiate curves.

The Drip Shield Transporter capacity is based on the capacity of a standard rail car of similar size and axle configuration. From *The Car and Locomotive Cyclopedia of American Practices* (Kratville 1997, p. 5), the 6-in \times 12-in (152-mm \times 305-mm) journal bearing is the most popular axle/bearing size for the construction of new rail cars. Four-axle rail cars equipped with this journal bearing size are rated up to 119.3 MT (263,000 lbs) gross weight. Depending on the weight of the empty rail car (tare), the capacity of the rail car is approximately 90 MT (200,000 lbs) and is commonly known as a 100-ton car. The assumed drip shield weight of 4 MT is a

fraction of the capacity for a standard rail car. Therefore, a standard rail car is satisfactory for this application.

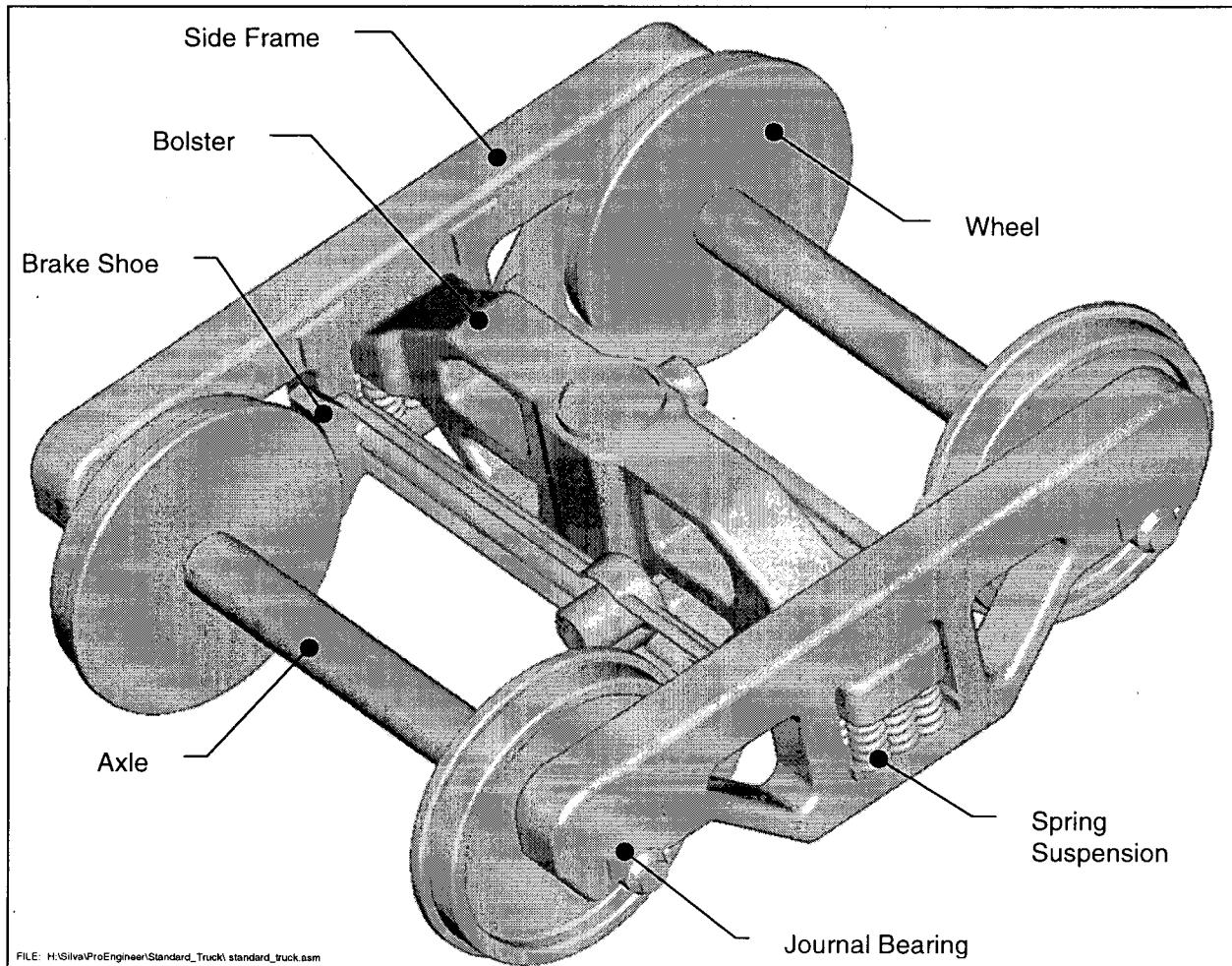


Figure 8. Typical Standard Truck Assembl

6.3.6 Couplers and Connectors

The Drip Shield Transporter is equipped with a standard coupler at each end of the rail car. One locomotive is sufficient for the transportation of the drip shield and Drip Shield Transporter to and from the emplacement drift. However, a second coupler, located on the opposite end of the transporter, will increase equipment flexibility and will not interfere with the operation. A second coupler is part of a standard rail car configuration and, therefore, the rail car shall include a second coupler.

6.3.7 Brake System

The Drip Shield Transporter is equipped with a fail-safe air brake system that is interconnected and operates in conjunction with the locomotive, similar to standard rail-industry practice. The system utilizes spring-set air-release brakes, and includes the brake shoes, air cylinders, and

operating linkage installed on the trucks with the piping and miscellaneous equipment located on the underframe. The air brakes are connected to the locomotive with standard rail-industry manual connections.

6.4 DRIP SHIELD GANTRY CARRIER

6.4.1 General Arrangement

The purpose of the Drip Shield Gantry Carrier (carrier), as shown in Figure 9, is to transfer the Drip Shield Emplacement Gantry to and from the surface facilities and the subsurface emplacement drifts. The carrier will also transfer the gantry from drift to drift during normal drip shield emplacement operations. Like the Drip Shield Transporter (see Section 6.3), the Drip Shield Gantry Carrier design is based on a standard railroad flatcar. The Drip Shield Gantry Carrier can be the same piece of equipment as the Waste Package Emplacement Gantry Carrier as described in *Mobile Waste Handling Support Equipment* (CRWMS M&O 1998, Section 7.2).

To accommodate the gantry, the Drip Shield Gantry Carrier will have rail of the same size as the emplacement drift mounted to the deck. In addition, a third-rail is mounted on the carrier bed to supply power to the gantry during loading and unloading operations. The locomotive DC power system provides electrical power to the third-rail.

Due to the high radiation levels within the entrance of the emplacement drift while the drift isolation doors are open, the movement of the Drip Shield Gantry Carrier into the emplacement drift turnout will be performed remotely. A single locomotive will be remotely controlled and will move the carrier into the emplacement drift turnout and mate the carrier to the emplacement drift transfer dock, as shown in Figure 10.

The trucks, couplers, and brakes envisioned for use on the Drip Shield Gantry Carrier are the same as for the Drip Shield Transporter, as described in Section 6.3. The estimated weight of the Drip Shield Emplacement Gantry, based on *Bottom/Side Lift Gantry Conceptual Design* (CRWMS M&O 1999e, Section 6.3.4), is 45 MT (49.6 tons) and is within the 90 MT (200,000 lbs) capacity of the railcar.

6.4.2 Emplacement Drift Interface

The Drip Shield Gantry Carrier will interface with the transfer docks of both the surface facilities and the emplacement drifts. Accurate rail-to-rail alignment, both vertically (top-of-rail) and laterally, is particularly important during the remote operations of transferring the gantry to and from the emplacement drift transfer dock and the carrier. The carrier is backed into the emplacement drift by a remotely controlled locomotive. Remote operation is necessary because the emplacement drift isolation doors are open during the gantry transfer. Therefore, accurate alignment of the emplacement drift rails and the rails mounted to the carrier deck must also be performed remotely.

Although the gage of the emplacement drift turnout rail is fixed at 1.44 m (Criteria 4.2.11 and 4.2.12), exact centering of the rail car with respect to the emplacement drift is not possible due to wheel/rail slack. To provide horizontal alignment, the front of the emplacement drift transfer

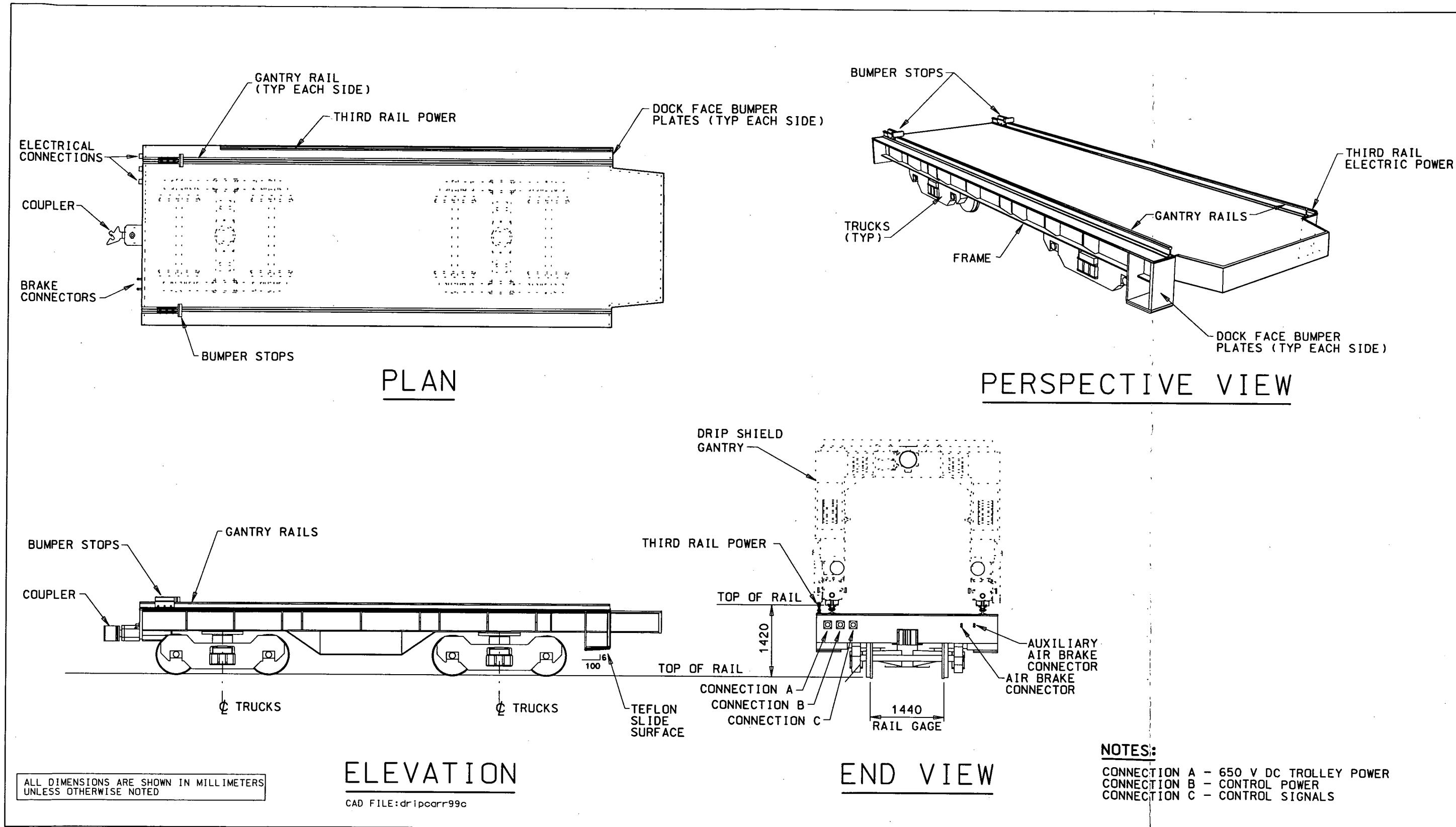


Figure 9. Drip Shield Gantry Carrier

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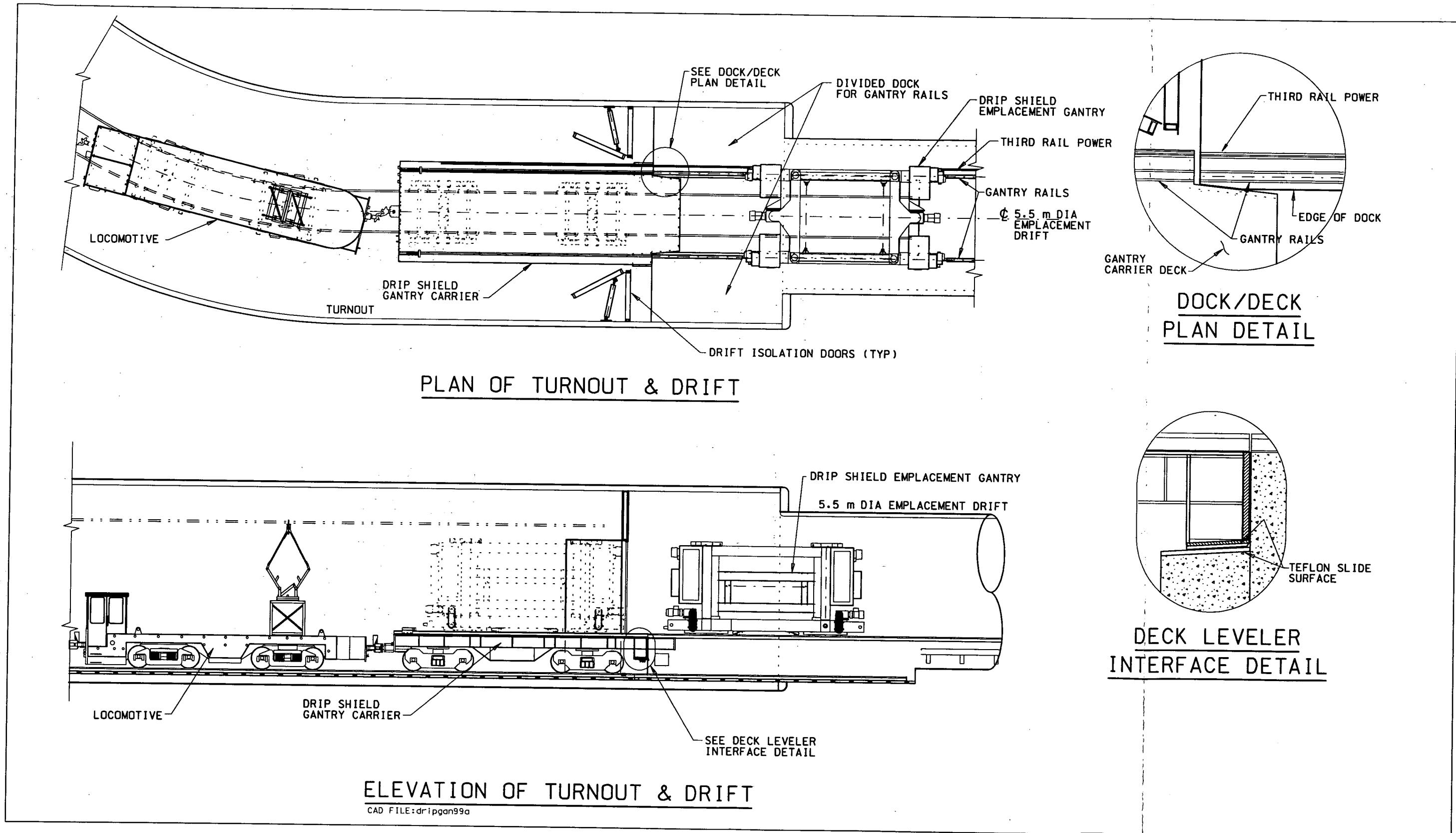


Figure 10. Emplacement Drift Interface

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dock and the front of the Drip Shield Gantry Carrier will have mating bevels, as shown in the Dock/Deck Plan Detail of Figure 10. As the carrier approaches the drift, any lateral misalignment will be reduced as the two surfaces interact and self-center the carrier with the emplacement drift loading dock, resulting in laterally aligned rails.

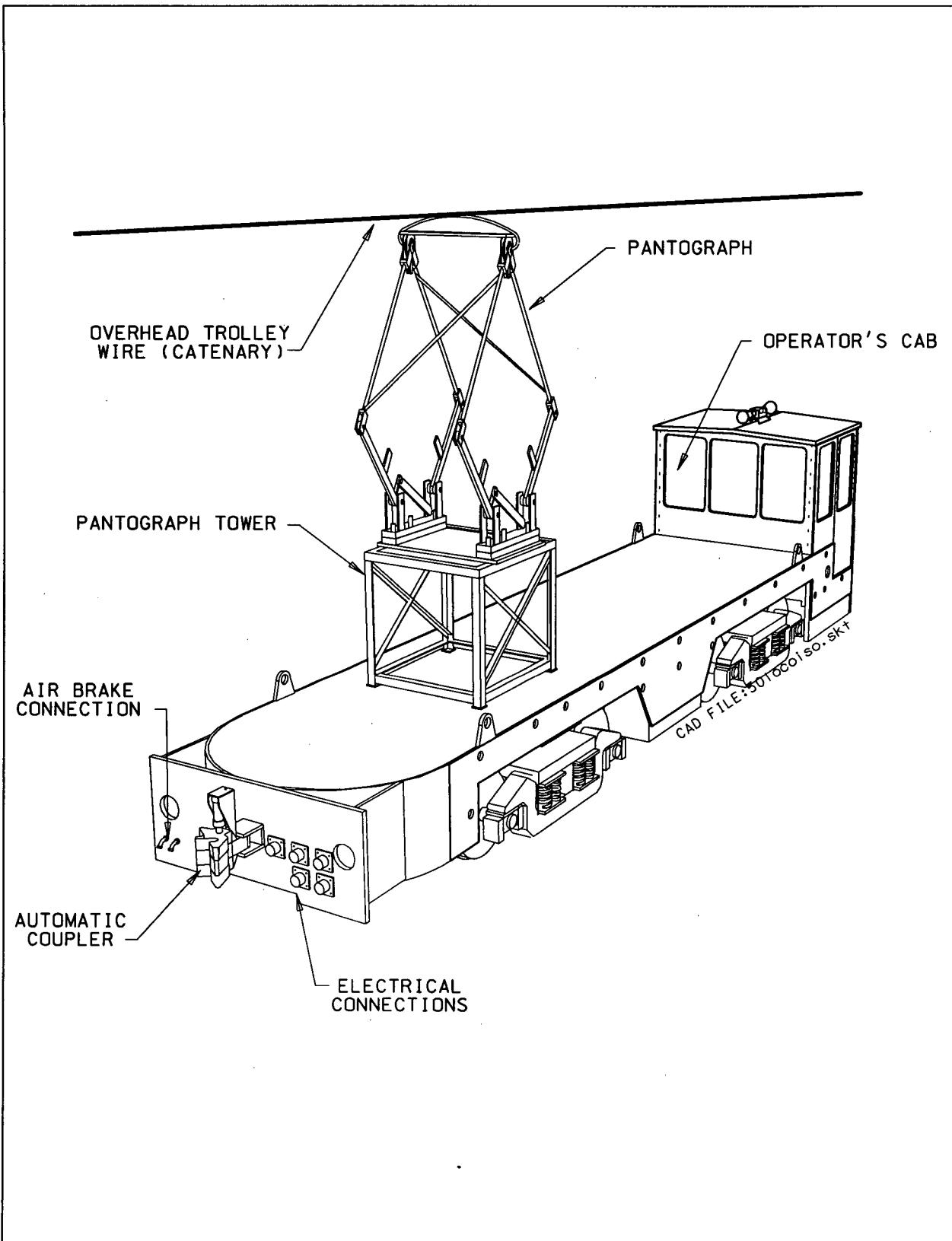
To provide alignment between top-of-rail of the Drip Shield Carrier and top-of-rail of the loading dock, a sloped ledge designed into the face of the emplacement drift loading dock will engage a corresponding sloped front ledge of the carrier, as shown in the Deck Leveler Interface Detail of Figure 10. As the carrier is pushed against the emplacement drift transfer dock, the Teflon[®]-coated (or other low-resistance surface) sloped edge will lift the carrier deck to a constant vertical height, resulting in top-of-rail alignment.

6.5 LOCOMOTIVE

The primary function of the locomotive is to provide the prime moving force for the Waste Emplacement/Retrieval operations. However, the locomotive will also be used to transport the drip shields via the Drip Shield Transporter and the Drip Shield Gantry via the Drip Shield Gantry Carrier. The 50-ton (45.4 MT) locomotive is powered by an overhead electrical trolley wire/pantograph configuration, as shown in Figure 11. This power system is part of the Subsurface Electrical Distribution System (Criteria 4.2.10).

Quick-disconnect couplings will be installed at each end of the locomotive for brakes, power, and controls. These provide the Drip Shield Transporter and the Drip Shield Gantry Carrier with air pressure for brakes, power for on-board third-rail systems (see Figure 9), and electrical connections for digital control, instrumentation, and communications.

The selection of a 50-ton (45.4 MT) locomotive was made in *Mobile Waste Handling Support Equipment* (CRWMS M&O 1998, Attachment III), and has been shown to be capable of handling the fully loaded Waste Package Transporter in both the main drifts and the emplacement drift turnouts. The maximum gross weight needed for transport for the Drip Shield Emplacement System is expected to be the weight of the loaded Drip Shield Gantry Carrier. The gross weight of the loaded carrier is expected to be far less than the gross weight of the loaded Waste Package Transporter. Therefore, the locomotive is capable of hauling the Drip Shield Transporter and the Drip Shield Gantry Carrier over a maximum grade of ± 2.7 percent (Criteria 4.2.2) between the surface and the emplacement drifts.



Source: CRWMS M&O 1998, Section 7.3

Figure 11. Locomotive

7. CONCLUSIONS

This design analysis has shown that, on a conceptual level, the emplacement of drip shields is feasible with current technology and equipment. A plan for drip shield emplacement was presented using a Drip Shield Transporter, a Drip Shield Emplacement Gantry, a locomotive, and a Drip Shield Gantry Carrier. The use of a Drip Shield Emplacement Gantry as an emplacement concept results in a system that is simple, reliable, and interfaces with the numerous other existing repository systems. Using the Waste Emplacement/Retrieval System design as a basis for the drip shield emplacement concept proved to simplify the system by utilizing existing equipment, such as the gantry carrier, locomotive, Electrical and Control systems, and many other systems, structures, and components.

Restricted working envelopes for the Drip Shield Emplacement System require further consideration and must be addressed to show that the emplacement operations can be performed as the repository design evolves. Section 6.1 describes how the Drip Shield Emplacement System may utilize existing equipment. Depending on the length of time between the conclusion of waste emplacement and the commencement of drip shield emplacement, this equipment could include the locomotives, the gantry carrier, and the electrical, control, and rail systems. If the existing equipment is selected for use in the Drip Shield Emplacement System, then the length of time after the final stages of waste emplacement and start of drip shield emplacement may pose a concern for the life cycle of the system (e.g., reliability, maintainability, availability, etc.). Further investigation should be performed to consider the use of existing equipment for drip shield emplacement operations.

As discussed in Section 6.1, it is understood that some interfaces exist and were not explicitly discussed. These interfaces will need further investigation and/or analysis, as applicable. For example, interfaces will exist with the surface facilities for the logistical support of the drip shield emplacement operations and for the handling and loading of the drip shields onto the Drip Shield Transporter.

When the emplacement drift isolation doors are in the open position, heat from within the emplacement drift may increase the temperature within the emplacement drift turnout. This, in turn, may increase the temperature of key equipment components. Although the Drip Shield Transporter and the Drip Shield Gantry Carrier will be docked outside the emplacement drift and, on a cursory level, the temperature affects will be negligible, further investigation is needed to explore the heat transfer from the emplacement drift to the turnout and the related thermal effects from localized warming of the brakes and braking system. The elevated temperatures within the emplacement drift will also require future investigation into the thermal effects on the Drip Shield Emplacement Gantry systems, i.e., computer systems, drive motors, and braking systems.

As expected, this conceptual design requires further design development. As the preliminary design of the drip shield evolves (Assumption 5.1), the drip shield emplacement equipment design must be evaluated and updated accordingly. Many design details were assumed in Section 5, and need further investigation and refinement.

Although the findings of this analysis are accurate for the assumptions made, further refinements of this analysis are needed as the project parameters change. The designs of the drip shield, the Emplacement Drift, and the other drip shield emplacement equipment all have a direct effect on the overall design feasibility.

This analysis describes an engineering design of a Drip Shield Emplacement Gantry and related support equipment, and is based on known and accepted engineering practice and principles. Individual components of the overall system were selected based on previous use in industry where it has been shown that the component has functioned properly. This design combines different components in a configuration that satisfies the requirements for design. By relying on individual parts, components or systems that have been shown to function in industry, the resulting design of the overall system configures the subparts relative to each other into a system that will perform the intended overall function that is desired.

Where practical, degrees of freedom of motion have been minimized to make overall functioning simpler and less complex than a highly sophisticated system. Capacities, strength of materials, speed and other engineering parameters are bounded to achieve a design that is within certain limits. Since the design uses components and systems that are not experimental, but have been applied under different working conditions, it remains to properly combine them relative to each other in order to achieve overall system results. Standard acceptable industry practice is used where applicable. The methodology, reasonableness, and selection of this design is documented throughout the analysis when the description and application of concepts are discussed.

Also, this analysis may be affected by technical product input information that requires confirmation. Any changes to the document that may occur as a result of completing the confirmation activities will be reflected in subsequent revisions. The status of the input information quality may be confirmed by review of the Document Input Reference System database.

The following TBVs and TBDs have a direct impact on this analysis:

TBV-182	Maximum air temperature (ventilated) within the emplacement drifts of 50 degrees Celsius dry bulb
TBV-183	Emplacement drift relative humidity range of between 10 and 100 percent.
TBV-253	Subsurface Waste Emplacement Transportation System curvatures
TBV-274	Track Gauge for Surface Facilities, ramps, Main Drifts, and turnouts.
TBV-305	Rail Size for emplacement drifts.
TBV-306	Rail Size for Surface Facilities, ramps, Main Drifts, and turnouts.
TBD-405	Components susceptible to radiation can withstand and operate in the radiation environment (TBD) in which the component is located
TBV-4306	QA Levels for Drip Shield Emplacement
TBV-4307	Drip Shield Emplacement System Criteria
TBV-4308	Drip Shield System Interfaces
TBV-4309	Drip Shield Design

8. INPUTS AND REFERENCES

8.1 DOCUMENTS CITED

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ATTACHMENTS

Not Applicable