**Design Calculation or Analysis Cover Sheet**

**BSC**

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**Title**

Drip Shield Gantry Mechanical Equipment Envelope Calculation

**Group**

Engineering/Mechanical/Subsurface Mechanical Handling

**Document Status Designation**

- [ ] Preliminary
- [x] Committed
- [ ] Confirmed
- [ ] Cancelled/Superseded

**Notes/Comments**

**Attachments**

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DISCLAIMER

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TABLES

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ACRONYMS AND ABBREVIATIONS

BSC Bechtel SAIC Company, LLC
DOE U.S. Department of Energy
DSG drip shield gantry
SAIC Science Application International Corporation
TAD transportation, aging, and disposal (canister)
1.0 PURPOSE

The purpose of the *Drip Shield Gantry Mechanical Equipment Envelope Calculation* is to determine the following:

- Drip shield gantry chassis dimensions
- Lift mechanism capacity
- Total weight estimate of drip shield gantry both loaded and unloaded
- Horizontal drive capacity
- Overall envelope for drip shield gantry

2.0 REFERENCES

2.1 Procedures / Directives


2.2 Design Inputs


2.2.6 BSC 2003. *Underground Layout Configuration*. 800-P0C-MGR0-00100-000-00E. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20031002.0007; ENG.20050817.0005.


2.2.8 BSC 2007. *Basis of Design for the TAD Canister-Based Repository Design Concept*. 000-3DR-MGR0-00300-000-001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071002.0042; ENG.20071026.0033; ENG.20071108.0002; ENG.20071109.0001; ENG.20071120.0023; ENG.20071126.0049; ENG.20071214.0009; ENG.20071213.0005; ENG.20071227.0018.

January 2008


2.3 Design Constraints

None

2.4 Design Outputs

3.0 ASSUMPTIONS

3.1 Assumptions Requiring Verification

3.1.1 Drip Shield Weight

Assumption: The drip shield is assumed to weigh 11,600 [lbf].

Rationale: The *Repository Design Drip Shield Envelope Dimensions* (Reference 2.2.4) preliminary drawing states the drip shield is 11,600 [lb.]. This is a preliminary design and will be verified upon issuance of the final drip shield design.

3.1.2 Final Drip Shield Gantry Mechanical Equipment Envelope

Assumption: The final drip shield gantry design will not exceed the operating envelope of the emplacement drift or exceed the weight limit of the emplacement drift rail.

Rationale: An equipment supplier will perform the final design of the drip shield gantry. Final vendor design documents will be reviewed to ensure that the drip shield gantry fits within the calculated envelope.

3.2 Assumptions Not Requiring Verification

3.2.1 Moving Component Clearance

Assumption: A clearance of two [in.] is used for the interfaces between the lifting beam lifting features and the drip shield lifting features during loading and unloading (Figure 1). An additional clearance of 4.25 [in.] is used for the interface between the drip shield ends (front and rear) and the drip shield gantry crossbeam (Figure 2).

Rationale: A clearance of two [in.] allows loading and unloading of the drip shield gantry without contacting the drip shield. The additional clearance of 4.25 [in.] allows for loaded drip shield misalignment and potential drip shield design changes without effecting drip shield gantry operations.

![Figure 1: Drip Shield Gantry End View (Drip Shield in Lowered Position)](image-url)
3.2.2 Drip Shield Gantry Lifting Features

Assumption: The lift feature on the drip shield gantry will be no more than 18 [in.] long from the center of the lifting beam.

Rationale: The location of the lifting beam is located above the rails, within the drip shield gantry side-frames. Since the drip shield is emplaced between the crane rails and over the waste package, the lifting features extend 18 [in.] from the centerline of the lifting beam to engage the drip shield lifting features (Figure 2).

3.2.3 Beam Dimensions

Assume: the following dimensions:

There will be 2 lifting beams with the length of 225 [in.].
There will be 2 gantry structure crossbeams with the length of 142 [in.] (Figure 3).
There will be 4 gantry structure vertical side-frame beams with the length of 108 [in.] (Figure 3).
There will be 4 gantry structure horizontal side-frame beams with the length of 280.75 [in.] (Figure 2).

Additionally, the cross-section of these beams are 18 [in.] x 6 [in.] structural steel tubing with a wall thickness of 3/8 [in.]. These beams will be constructed from structural steel according to ASTM A 36/A 36M-05 (Reference 2.2.3).

Rationale: These beams allow adequate spacing around the drip shield for drip shield transportation and emplacement operations. Furthermore, the beams provide the structure of the drip shield gantry including mountings for the wheel trucks, lifting mechanisms, and electrical enclosures.
3.2.4 Structural Steel Beams

**Assume:** The cross-section of these beams are 18 [in.] x 6 [in.] structural steel tubing with a wall thickness of 3/8 [in.]. These beams will be constructed from structural steel manufactured according to ASTM A 36/A 36M-05 (Reference 2.2.3) resulting in a yield strength of 36 [ksi].

**Rationale:** Various beam cross-sections and steel specifications may provide the structural strength needed for transportation and emplacemt of the drip shield. The cross-section of 18 [in.] x 6 [in.] is a standard beam dimension and verification of cross-section suitability will be evaluated later in this calculation. ASTM A 36/A 36M-05 (Reference 2.2.3) is a standard structural steel that is listed as material for structural beams and is acceptable in use of nuclear grade cranes according to ASME NOG-1-2004 (Reference 2.2.2, Table 4211-1).

3.2.5 Lifting Beam Load

**Assumption:** The shear and bending stress will be calculated based on a force applied at the center of the lifting beam.

**Rationale:** The drip shield has two lifting features per side. Likewise, the lifting beam will have two corresponding lift features. For the purpose of this calculation, the lifting beam will be analyzed using a single point at the center of the beam, with fixed ends. The forces and internal stresses are elevated; therefore, creating a worst-case bounding scenario for the lifting beam.

3.2.6 Factor of Safety for Weight

**Assumption:** A 10 % factor of safety will be added to the lifting weight and drip shield gantry weight.
Rationale: The 10% factor of safety is used to account for additional components (for example electrical components, electrical cabinets, cableways, cameras, etc.), fabrications, and other design changes to create a bounding condition.

3.2.7 Lift Mechanisms

Assumption: The lift mechanisms will be machine screw actuators with 5 [ton] capacity. The following properties are also assumed:

- Weight with base = 30 [lbf]
- Weight for each inch of rise = 0.7 [lbf per inch raise]
- Required input torque = 138 [lbf-in.]

Rationale: Consulting the Pow-R-Jac catalog (or equivalent), the weight of the jack is 30 [lbf] with "0" travel and 0.7 [lbf] per inch of travel on a 1.5-inch diameter screw. The required input torque is 11.5 [lbf-ft], or 138 [lbf-in.] with the optional ratio (Reference 2.2.10, Page MSJ-2). Confirmation of the lifting mechanism selection is determined later in the calculation.

3.2.8 Motor Weight – Lifting

Assumption: A gear motor with sufficient capacity to drive the lift mechanisms, needs to provide an input torque of 138 lbf-in (11.5 ft-lbf) for a 5-ton jack (Assumptions 3.2.7). The closest gear motor to this in the review of vendor catalogs that delivers the required input torque is a parallel helical gear unit with a 0.33 [hp] motor. The weight of the lift 0.33 [hp] gearbox and motor is approximately 31 [lbf].

Rationale: Consulting the SEW-Eurodrive (or equivalent) catalog, the models DT71D6 AC-motor and R17 gearbox are selected. The selected motor and gearbox is a 0.33 [hp] with an output speed of 96 [RPM] and a torque of 215 [lbf-in.]. Additionally, the motor and gearbox with brake weighs 24 [lbf] + 6.5 [lbf] = 30.5 [lbf], rounded up to 31 [lbf] (Reference 2.2.11, Pages 20 and 130). Confirmation of the motor and gearbox selection is determined later in the calculation.

3.2.9 Drip Shield Gantry Wheel Size

Assumption: The drip shield gantry will be driven by 4 sheaved wheels that are assumed to be 36 [in.] diameter, with an 8 [in.] width. The weight of the wheel is 2,000 [lbf].

Rationale: Ultimately the size and number of wheels will be determined during detail design. These dimensions shown here provide a reasonable conservative value, for this preliminary design.

3.2.10 Wheel Block Size

Assumption: The dimensions of the wheel blocks are 48 [in.] in length, 28 [in.] in height (without the wheel), 40 [in.] in height (with the wheel), and 16 [in.] in width. A clearance of 2 inches is used around the wheel block (Figure 2 and Figure 4).

Rationale: The width allows for an 8 [in.] wheel width (Assumption 3.2.9), 1 [in.] clearance either side of the wheel, and a 2 [in.] thick plate mounted either side of the wheel. The length allows for a 36 [in.] diameter wheel (Assumption 3.2.9), a pivot pin, and clearances.
3.2.11 Drive System Motor and Gearbox

**Assumption:** The drive motor for the drip shield gantry is assumed to have the following properties:

- Weight is approximately 500 [lbf].
- Gearbox Efficiency of 0.94.

**Rationale:** Consulting the SEW-Eurodrive (or equivalent) catalog, the models DV132M4 AC-motor and KAF97 gearbox are selected. The selected motor and gearbox is a 10 [hp] with a maximum output speed of 17 [RPM] and a maximum torque of 38,100 [lbf-in]. Additionally, the motor and gearbox with brake weighs 411 [lbf] + 53 [lbf] = 464 [lbf], rounded up to 500 [lbf]. Furthermore, the selected motor and gearbox has an efficiency of 94% (bearing efficiency is considered negligible) (Reference 2.2.11, Pages 10, 289, 344, 376-377). Confirmation of the motor and gearbox selection is determined later in the calculation.

3.2.12 Shielded Electrical Enclosures

**Assumption:** The external dimensions of the enclosures are 72 [in.] x 21 [in.] x 72 [in.] and the internal dimensions are 63 [in.] x 12 [in.] x 63 [in.].

**Rationale:** The internal dimensions allow proper space for the drip shield gantry controls. Based on the conclusions of the *Emplacement and Inspection Gantry Shielding Calculations* (Reference 2.2.7, Section 6.5), the shielding thickness could be as high as 4.5 [in.] of steel. The outer electrical enclosure walls (facing the emplacement drift wall) may be thinner, but the weight difference would be absorbed by the electrical components. Therefore, the external dimensions are 72 [in.] x 21 [in.] x 72 [in.].

3.2.13 Constants Used for Tractive Effort Calculation

**Assumption:** The following constants are assumed to be appropriate, conservative values for use in the drip shield gantry tractive effort calculation.

- $R_w =$ Frictional resistance of locomotive $= 20$ [lbf/ton]
- $a =$ rate of acceleration $= 0.2$ [mph/sec$^2$]
A = Acceleration force = 100 [lbf/ton/mph/sec²]
C = Resistance due to track curvature = 0.8 [lbf/ton/degree]

Rationale: The preceding values were extracted from tables in SME Mining Engineering Handbook (Reference 2.2.9, Section 14).

3.2.14 Wheel Block and Drip Shield Gantry Chassis Frame Overlap
Assumption: The wheel block and drip shield gantry chassis frame overlap is 6.5 [in.].

Rationale: The overall length of the wheel block is 48 [in.] (Section 3.2.10 and Figure 4). An overlap of 6.5 [in.] allows for pivot pin connection between the wheel block and the drip shield gantry chassis frame. The remaining distance is 41.5 [in.] as shown in Figure 2.

3.2.15 Crossbeam Projection
Assumption: The crossbeam projects above the horizontal side-frame beams 9.75 [in.] (Figure 4).

Rationale: This arrangement allows for drip shield loading and unloading clearances, while still maintaining a solid fabrication with the side frames.

4.0 METHODOLOGY

4.1 QUALITY ASSURANCE
This calculation has been prepared in accordance with the Calculations and Analyses procedure (Reference 2.1.1). The Basis of Design for the TAD Canister-Based Repository Design Concept does not identify any Systems, Structures, or Components on the Drip Shield Gantry as Important to Safety or Important to Waste Isolation, therefore the approved version is designated QA: N/A (Reference 2.2.8, Section 14.1.2).

4.2 USE OF SOFTWARE
The following commercially available software has been used to generate the results of this calculation. All inputs, outputs, and equations are shown in their appropriate sections in the body of this document, and the results have been verified by hand calculation.

MathCAD
  • Version: 13
  • Operating Environment: Windows 2000
  • Computer Type: Dell personal computer

4.3 DESIGN METHODOLOGY
  • Show that the lift beam is capable of lifting the drip shield.
  • Determine the lift weight.
  • Estimate the capacity of the lift mechanism and associated drive motor size.
  • Estimate the size of the main drip shield gantry chassis beams.
  • Estimate the total weight of the drip shield gantry loaded and unloaded.
  • Estimate linear motion drive motor and gearbox capacity.
  • Estimate the total length, width, and height of the drip shield gantry.
5.0 LIST OF ATTACHMENTS

Attachment 1: One CD including MathCAD file: DSG MEE Calculation.xmcd

6.0 BODY OF CALCULATION

6.1 Structural Capacity of Lifting Beams

6.1.1 Verification of Shear Stress in the Lifting Beam

To verify the size and material of the lifting beam, a shear stress calculation is needed. The shear stress ($\tau$) is calculated by the equation from *Roark's Formulas for Stress and Strain* (Reference 2.2.12, Page 352):

$$\tau_{\text{average}} = \frac{T}{2 \cdot t \cdot (a - t) \cdot (b - t)}$$

The lifting beam engages the drip shield in four locations. Per Assumption 3.2.5, The lifting beam will have a single point load at the center of the beam. From Assumption 3.1.1 the weight of the drip shield is 11,600 [lbf]. The torque ($T$) is calculated by multiplying the drip shield weight (divided by 2) and the length of the lifting feature. The wall thickness ($t$), beam width ($a$), and beam height ($b$) are defined within Assumption 3.2.4.

Where:

$T = 5,800$ [lbf] x 18 [in.], derived using Assumptions 3.1.1 and 3.2.2.
$t = \frac{3}{8}$ [in.], from Assumption 3.2.4.
$a = 6$ [in.], from Assumption 3.2.4.
$b = 18$ [in.], from Assumption 3.2.4.

$$t_{\text{average}} = \frac{5800 \text{ lbf} \cdot 18 \text{ in}}{2 \cdot \frac{3}{8} \text{ in} \cdot \left(6 \text{ in} - \frac{3}{8} \text{ in}\right) \cdot \left(18 \text{ in} - \frac{3}{8} \text{ in}\right)}$$

The calculated shear stress is 1.40 [ksi]. As discussed in *Manual of Steel Construction, Allowable Stress Design*, the allowable shear stress ($F_v$) is 0.40 multiplied by ($F_y$) (Reference 2.2.1, Page 5-49):

$$F_v = 0.40 \cdot F_y$$

Where:

$F_y = 36$ [ksi], from Assumption 3.2.4

The calculated allowable shear stress is:

$$F_v = 14.4 \text{ ksi}$$

The shear stress of 1.40 [ksi] is below the allowable 14.4 [ksi].
6.1.2 Verification of Bending Stress in the Lifting Beam

To verify the size and material of the lifting beam, a bending stress calculation is needed. The bending moment (M) in the lifting beam is calculated using an equation from the *Manual of Steel Construction, Allowable Stress Design* (Reference 2.2.1, Page 2-298):

\[
M = \frac{P}{4} \cdot l
\]

The force (P) is the drip shield weight divided by 2, since both lifting beams lift the drip shield. The length of the lifting beam (l) is defined within Assumption 3.2.3.

Where:
- \( P = 5,800 \text{ [lbf]} \), from Assumption 3.1.1 (drip shield weight divided by 2).
- \( l = 225 \text{ [in.]} \), from Assumption 3.2.3.

The bending stress in the lifting beam is calculated using an equation from the *Manual of Steel Construction, Allowable Stress Design* (Reference 2.2.1, Page 2-294):

\[
\sigma = \frac{M \cdot y}{I}
\]

The bending stress (\( \sigma \)) is calculated using the moment (M) (presented above), half the beam height (y), and the moment of inertia (I).

Where:
- \( y = 9 \text{ [in.]} \), from Assumption 3.2.4.
- \( I = 641 \text{ [in.}^4\text{]} \), from Reference 2.2.1, Page 1-97.

Combining the previous equations and substituting values gives:

\[
\sigma = \frac{5800 \text{ [lbf]} \cdot 225 \text{ [in.]}}{4 \cdot 9 \text{ [in.]}} = \frac{12750000 \text{ [lbf-in]}}{36 \text{ [in.]}} = \frac{127500000}{36} = 354722.22 \text{ [ksi]}
\]

The bending stress is calculated as 4.58 [ksi]. As discussed in *Manual of Steel Construction, Allowable Stress Design*, the allowable bending stress (\( F_b \)) is 0.66 multiplied by \( F_y \) (Reference 2.2.1, Page 5-48): The allowable bending stress for 36 [ksi] steel discussed in Assumption 3.2.4 is:

\[
F_b = 0.66 F_y
\]

Where:
- \( F_y = 36 \text{ [ksi]} \), from Assumption 3.2.4.

The calculated allowable bending stress is:
The bending stress of 4.58 [ksi] is below the allowable 23.76 [ksi]. Therefore, the selected beam cross-section and material are capable of carrying the drip shield.

### 6.2 Lifting Weight

The lifting weight is the lifting beam weights and the drip shield weight.

#### 6.2.1 Lifting Beams Weight

The lifting beam weight is calculated by multiplying the length of the beam by the weight per length. The length of the lifting beam is assumed to be 225 [in.] long (or 18.75 [ft]). Additionally, the lifting beam is an 18 [in.] x 6 [in.] cross-section and 3/8 [in.] thick walls (Assumption 3.2.3). Based on this information, the weight per length is 58.1 [lbf per ft] (Reference 2.2.1, Page 1-97).

\[
18.75 \text{ [ft]} \times 58.1 \text{ [lbf per ft]} = 1,089.38 \text{ [lbf]}
\]

Since the drip shield gantry has 2 lifting beams (1 per side), the total lifting beams weight is 2,178.76 [lbf].

#### 6.2.2 Total Lifting Weight

The lifting weight for the lifting mechanisms is the weight of the two lifting beams (Section 6.2.1) and the weight of the drip shield (Assumption 3.1.1):

\[
2,178.76 \text{ [lbf]} + 11,600 \text{ [lbf]} = 13,778.76 \text{ [lbf]}
\]

The total lifting weight for the lifting mechanisms is the lifting weight multiplied by the factor of safety of 1.10 (Assumption 3.2.6).

\[
13,778.76 \text{ [lbf]} \times 1.10 = 15,156.64 \text{ [lbf]}
\]

The total lifting weight is 15,156.64 [lbf].

### 6.3 Lift Mechanism

#### 6.3.1 Section Inputs

- Lift mechanism weight = 30 [lbf], from Assumption 3.2.7.
- Lift mechanism weight for each inch of rise = 0.7 [lbf], from Assumption 3.2.7.
- Lift gearbox and motor weight = 31 [lbf], from Assumption 3.2.8.

#### 6.3.2 Section Methodology

Verify selected lifting system.

#### 6.3.3 Calculation

##### 6.3.3.1 Lifting Mechanism Screw Length

The lifting mechanism screw length is calculated using the drip shield clearance, the drip shield lift height and the lifting beam height, where:
Drip Shield Clearance = 2 [in], from Assumption 3.2.1.
Lift Height = 40 [in], from Reference 2.2.5.
Lifting Beam Height = 18 [in], from Assumption 3.2.3.

Screw Length = 2 [in.] + 40 [in.] + 18 [in.] = 60 [in.]

6.3.3.2 Capacity
A total of 4 lifting mechanisms will be used to lift the drip shield, 2 per side. To determine the lifting mechanism capacity, the total lifting weight (Section 6.2.2) is divided by 4. 

\[ \frac{15,156.64 \text{ [lbf]}}{4} = 3,789.16 \text{ [lbf]}, \text{ rounded to } 3,789 \text{ [lbf] (or } 1.9 \text{ [ton])} \]

For conservatism, a 5 [ton] lifting mechanism discussed in Assumption 3.2.7 will be used for the 1.9 [ton] lift. To drive the lifting mechanism, a 0.33 [hp] motor (with gearbox) in Assumption 3.2.8 will be used.

6.3.3.3 Lift System Weight
The screw weight is the screw length multiplied by the screw weight per length. The screw length is 60 [in] (Section 6.3.3.1); and the screw weight per length is 0.7 [lb per in] (Assumption 3.2.7). Therefore, the screw weight is:

\[ 60 \text{ [in]} \times 0.7 \text{ [lb per in]} = 42 \text{ [lb]} \]

The total weight for the screw is 42 [lb]. The base of the screw jack weighs 30 [lb] (Assumption 3.2.7). The drive motor with internal brake weighs 31 [lb] (Assumption 3.2.8). Therefore, each lift system weighs:

\[ 42 \text{ [lbf]} + 30 \text{ [lbf]} + 31 \text{ [lbf]} = 103 \text{ [lbf]} \]

6.4 Drip Shield Gantry Component Weights
6.4.1 Drip Shield Gantry Chassis Frame
The drip shield gantry chassis frame is composed of 2 crossbeams, 4 vertical side-frame beams, and 4 horizontal side-frame beams (Figure 5) (Assumption 3.2.3).
The crossbeams have an 18 [in.] x 6 [in.] cross-section (with 3/8 [in.] wall thickness) and a length of 142 [in.] (Assumptions 3.2.3 and 3.2.4). The weight is calculated by multiplying the beam length by the weight per length, 58.1 [lbf per foot] (Reference 2.2.1, Page 1-97).

\[
142 \text{ [in.]} / 12 \text{ [in. per foot]} \times 58.1 \text{ [lbf per foot]} = 687.52 \text{ [lbf]}
\]

The vertical side-frame beams have an 18 [in.] x 6 [in.] cross-section (with 3/8 [in.] wall thickness) and a length of 108 [in.] (Assumptions 3.2.3 and 3.2.4). The weight is calculated by multiplying the beam length by the weight per length, 58.1 [lbf per foot] (Reference 2.2.1, Page 1-97).

\[
108 \text{ [in.]} / 12 \text{ [in. per foot]} \times 58.1 \text{ [lbf per foot]} = 522.9 \text{ [lbf]}
\]

The horizontal side-frame beams have an 18 [in.] x 6 [in.] cross-section (with 3/8 [in.] wall thickness) and a length of 280.75 [in.] (Assumptions 3.2.3 and 3.2.4). The weight is calculated by multiplying the beam length by the weight per length, 58.1 [lbf per foot] (Reference 2.2.1, Page 1-97).

\[
280.75 \text{ [in.]} / 12 \text{ [in. per foot]} \times 58.1 \text{ [lbf per foot]} = 1,359.3 \text{ [lbf]}
\]

Therefore, the combined structure weight of the drip shield gantry is the crossbeam, vertical side-frame beam and horizontal side-frame beam weights multiplied by the corresponding quantity of beams.
(2 x 687.52 [lbf]) + (4 x 522.90 [lbf]) + (4 x 1,359.30 [lbf]) = 8,903.84 [lbf]

### 6.4.2 Total Wheel Block Weight

The wheel block side weight is determined by multiplying the wheel block length, the wheel block height, the wheel block thickness, and the density of steel.

Where:
- Wheel Block Length = 48 [in.], from Assumption 3.2.10.
- Wheel Block Height = 28 [in.], from Assumption 3.2.10.
- Wheel Block Plate Thickness = 2 [in.], from Assumption 3.2.10.
- Density Steel = 490 [lbf per cubic foot] or 0.284 [lbf per cubic in.], from Reference 2.2.1, Page 6-8.

\[
48 \text{ [in.]} \times 28 \text{ [in.]} \times 2 \text{ [in.]} \times 0.284 \text{ [lbf per cubic in.]} = 763.39 \text{ [lbf]}
\]

The wheel block end weight is determined by multiplying the wheel block width (minus 2 times the wheel block thickness), the wheel block height, the wheel block thickness, and the density of steel.

Where:
- Wheel Block Width = 16 [in.], from Assumption 3.2.10.
- Wheel Block Height = 28 [in.], from Assumption 3.2.10.
- Wheel Block Thickness = 2 [in.], from Assumption 3.2.10.
- Density Steel = 490 [lbf per cubic foot] or 0.284 [lbf per cubic in.], from Reference 2.2.1, Page 6-8.

\[
(16 \text{ [in.]} - 2 \times 2 \text{ [in.]} ) \times 28 \text{ [in.]} \times 2 \text{ [in.]} \times 0.284 \text{ [lbf per cubic in.]} = 190.85 \text{ [lbf]}
\]

The weight for a wheel block structure is determined adding 2 times the wheel block side weight and the wheel block end weight.

Where:
- Wheel Block Side Weight = 763.39 [lbf], from within this section.
- Wheel Block End Weight = 190.85 [lbf], from within this section.

\[
(2 \times 763.39 \text{ [lbf]}) + 190.85 \text{ [lbf]} = 1,717.63 \text{ [lbf]}
\]

The total wheel block weight is calculated by adding the wheel block structure, wheel weight, and the drive system.

Where:
- Wheel Block Structure Weight = 1,717.63 [lbf], from within this section.
- Wheel Weight = 2,000 [lbf], from Assumption 3.2.9.
- Drive System = 500 [lbf], from Assumption 3.2.11.

\[
1,717.63 \text{ [lbf]} + 2,000 \text{ [lbf]} + 500 \text{ [lbf]} = 4,217.63 \text{ [lbf]}
\]

### 6.4.3 Shielded Electronics Enclosure Weight

The total weight for each shielded electronics enclosure is calculated by multiplying the volume of steel and the density of steel.
Where:
Density Steel = 490 [lbf per cubic foot] or 0.284 [lbf per cubic in.], from Reference 2.2.1, Page 6-8.

\[(72 \text{ [in.]} \times 21 \text{ [in.]} \times 72 \text{ [in.]}) - (63 \text{ [in.]} \times 12 \text{ [in.]} \times 63 \text{ [in.]}) \times (0.284 \text{ [lbf per cubic in.]}) = 17,391.02 \text{ [lbf]}\]

6.5 Drip Shield Gantry Weight

6.5.1 Empty Drip Shield Gantry Weight

The empty drip shield gantry weight is calculated by adding the lifting beam weight (times 2), lift system weight (times 4), drip shield gantry chassis frame weight, total wheel block weight (times 4), and the shielded electrical enclosure weight (times 4).

Where:
Lifting Beam Weight = 1,089.38 [lbf], from Section 6.2.1.
Lift System Weight = 103 [lbf], from Section 6.3.3.3.
Drip Shield Gantry Chassis Frame Weight = 8,903.84 [lbf], from Section 6.4.1.
Total Wheel Block Weight = 4,217.63 [lbf], from Section 6.4.2.
Shielded Electrical Enclosure Weight = 17,391.02 [lbf], from Section 6.4.3.

\[(1,089.38 \text{ [lbf]} \times 2) + (103 \text{ [lbf]} \times 4) + (8,903.84) + (4,217.63 \text{ [lbf]} \times 4) + (17,391.02 \text{ [lbf]} \times 4) = 97,929.2 \text{ [lbf]}\]

6.5.2 Loaded Drip Shield Gantry Weight

The loaded drip shield gantry weight is calculated by adding the empty drip shield gantry weight and the drip shield weight.

Where:
Empty Drip Shield Gantry Weight = 97,929.2 [lbf], from previous section.
Drip Shield Weight = 11,600 [lbf], from Assumption 3.1.1.

\[97,929.2 \text{ [lbf]} + 11,600 \text{ [lbf]} = 109,529.2 \text{ [lbf]}\]

6.5.3 Bounded Drip Shield Gantry Weight

The bounded loaded drip shield gantry weight is calculated by multiplying the loaded drip shield gantry weight and the factor of safety.

Where:
Loaded Drip Shield Gantry Weight = 109,529.2 [lbf], from previous section.
Factor of Safety = 1.10, from Assumption 3.2.6.

\[109,529.2 \text{ [lbf]} \times 1.10 = 120,482.12 \text{ [lbf]} \text{ or } 60.24 \text{ [ton]}\]
6.6 Drip Shield Gantry Horizontal Drive System

6.6.1 Section Inputs

No new inputs.

6.6.2 Tractive Effort

From the SME Mining Engineering Handbook, the tractive effort required to haul a train is the sum of the various tractive resistances of both the locomotive and the load (Reference 2.2.9, Page 14-11, Equation (1)). Since the drip shield gantry is only one vehicle, some of the terms in the equation drop out. The Tractive Effort is calculated using Equation 1.

\[
\text{TE} = W R_w + L R + T g G + T a A + T c C
\]

Equation 1

Where:
- \( W \) = The tractive effort of the locomotive [lbf]
- \( R_w \) = Frictional resistance of locomotive [lbf/ton]
- \( L \) = Trailing load, zero for this calculation [ton]
- \( g \) = percent grade [%grade]
- \( G \) = Grade resistance [lbf/ton/%grade]
- \( a \) = rate of acceleration [mph/sec^2]
- \( A \) = Acceleration force [lbf/ton/mph/sec^2]
- \( c \) = degrees of track curvature [degree]
- \( C \) = Resistance due to track curvature [lbf/ton]

The drip shield gantry does not retrieve drip shields from the emplacement drifts. For conservatism, the drip shield gantry is sized to transport drip shields up the design grade of the north ramp and north ramp curve. Therefore, three scenarios are evaluated, tractive effort on a grade, tractive effort in a curve (200-ft radius) and tractive effort on a grade in a curve (1000-ft radius) (Reference 2.2.6, Figure 3). Whichever scenario produces the highest tractive effort, is used to develop the horsepower.

**Tractive effort on a grade**

To calculate the tractive effort up a grade, the curvature and trailing load terms in Equation 1 are reduced to 0.

Where:
- \( W, T = 60.24 \) [ton], from Section 6.5.3.
- \( R_w = 20 \) [lbf/ton], from Assumption 3.2.13.
- \( g = 2.5 \) [%grade], from Reference 2.2.8, Section 9.9.2.2.4.
- \( G = 20 \) [lbf/ton/%grade], from Reference 2.2.9, Section 14.
- \( a = 0.2 \) [mph/sec^2], from Assumption 3.2.13.
- \( A = 100 \) [lbf/ton/mph/sec^2], from Assumption 3.2.13.
Tractive effort in curve

The drip shield gantry must negotiate a 200-ft radius curve (Reference 2.2.8, Section 9.9.2.2.4). The degrees of track curvature, \( c \) [degree], is defined as \( \frac{5730 \text{ [ft]}}{\text{radius [ft]}} \) (SME Mining Engineering Handbook, Page 18-4, Reference 2.2.9). Therefore, the degree of track curvature, \( c \), is calculated as 28.65 [degree], rounded up to 30 [degree]. This equation does not prove that the drip shield gantry will not derail while traveling a curve, but does show how much effort is needed to overcome the resistances while traveling around the curve. In this scenario the grade terms of the equation drop out, as well as the trailing resistance terms.

Where:

- \( W, T = 60.24 \text{ [ton]} \), from Section 6.5.3.
- \( R_w = 20 \text{ [lbf/ton]} \), from Assumption 3.2.13.
- \( a = 0.2 \text{ [mph/sec}^2] \), from Assumption 3.2.13.
- \( A = 100 \text{ [lbf/ton/mph/sec}^2] \), from Assumption 3.2.13.
- \( c = 30 \text{ [degree]} \), from within this section
- \( C = 0.8 \text{ [lbf/ton/degree]} \), from Assumption 3.2.13.

Tractive effort on a grade with a curve

To calculate the tractive effort up a grade with curve, the drip shield gantry must negotiate a 1000-ft (305-m) radius curve (Reference 2.2.6, Figure 3). The degrees of track curvature, \( c \) [degrees], is defined as \( \frac{5730 \text{ [ft]}}{\text{radius [ft]}} \) (SME Mining Engineering Handbook, Page 18-4, Reference 2.2.9). Therefore, the degree of track curvature, \( c \), is calculated as 5.73 [degrees], rounded up to 6 [degrees]. This equation does not prove that the drip shield gantry will not derail while traveling a curve, but does show how much effort is needed to overcome the resistances while traveling around the curve.
Where:

\( W, T = 64 \text{ [ton]}, \text{ from Section 6.5.3.} \)
\( R_w = 20 \text{ [lbf/ton]}, \text{ from Assumption 3.2.13.} \)
\( g = 2.5 \text{ [%grade]}, \text{ from Reference 2.2.2, Section 9.9.2.2.4.} \)
\( G = 20 \text{ [lbf/ton/%grade]}, \text{ from Reference 2.2.9, Section 14.} \)
\( a = 0.2 \text{ [mph/sec^2]}, \text{ from Assumption 3.2.13.} \)
\( A = 100 \text{ [lbf/(ton/mph/sec^2)]}, \text{ from Assumption 3.2.13.} \)
\( c = 6 \text{ [degree]}, \text{ from this section} \)
\( C = 0.8 \text{ [lbf/ton/degree]}, \text{ from Assumption 3.2.13.} \)

\[
\text{TE}_{\text{Curve Grade}} = W R_w + T g G + T a A + T c C
\]
\[
= 60.24 \text{ ton} \cdot 20 \text{ lb/ton} + 60.24 \text{ ton} \cdot 2.5 \text{ %grade} \cdot 20 \text{ lb/ton %grade} + 60.24 \text{ ton} \cdot 0.2 \text{ mph/sec}^2 + 60.24 \text{ ton} \cdot 6 \text{ degree} \cdot 8 \text{ lb/ton degree}
\]
\[
= 5710.8 \text{ lbf}
\]

The tractive effort on the grade with a curve has the largest value and is used to determine the horsepower.

### 6.6.3 Horsepower

Horsepower is found by the following formula from the *SME Mining Engineering Handbook*, Page 14-11 (Reference 2.2.9, Equation (9)). The maximum recommended “Fast” speed for the drip shield gantry is 175 [fpm] (Reference 2.2.2, Table 5333.1-1) which converts to 1.989 [mph]. Therefore, the motors have been sized to provide a maximum climbing speed of 1.989 [mph].

\[
HP = \frac{(\text{TE})(\text{MPH})}{375 \cdot \text{eff}}
\]

Equation 2

Where:

\( \text{TE} = 5,710.8 \text{ [lbf]}, \text{ from previous section} \)
\( \text{MPH} = \text{speed, 1.989 [mph]} \)
\( \text{Conversion Factor} = 375 \text{ [lbf-mph/hp]} \)
\( \text{eff} = \text{an efficiency factor to account for the losses in the drivetrain, 0.94, see Assumption 3.2.11.} \)

\[
HP = \frac{5710.8 \text{ lbf} \cdot 1.989 \text{ mph}}{375 \cdot \text{lbf-mph/hp} \cdot 0.94}
\]
\[
= 32.22 \text{ hp}
\]
Since 4 wheels will drive the drip shield gantry, the total horsepower is divided by 4.

\[
\text{HP}_{\text{per Wheel}} = \frac{\text{HP}}{\text{number of wheels}} = 2.06 \text{ hp}
\]

The next commercially available motor size is a 10 [hp] motor. The weight, efficiency, and gearbox width are discussed in Assumption 3.2.11. The motor and gearbox combination discussed in Assumption 3.2.11 provides a maximum output speed of 17 RPM at a maximum torque of 38,100 [lbf-in], which is sufficient.

6.6.4 Drip Shield Gantry Dimensions
6.6.4.1 Drip Shield Gantry Length

The drip shield gantry length is calculated by adding the horizontal side-frame beams and 2 wheel block lengths (subtracting the wheel block and drip shield gantry overlap).

Where:
- Wheel Block Length = 48 [in.], from Assumption 3.2.10.
- Horizontal Side-Frame Beam Length = 280.75 [in.], from Assumption 3.2.3.
- Wheel Block and Drip Shield Gantry Chassis Frame Overlap = 6.5 [in.], from Assumption 3.2.14.

\[
48 \text{ [in.]} - 6.5 \text{ [in.]} + 280.75 \text{ [in.]} + 48 \text{ [in.]} - 6.5 \text{ [in.]} = 363.75 \text{ [in.]} 
\]

6.6.4.2 Drip Shield Gantry Width

The drip shield gantry width is calculated by adding the crossbeam length and the external shielded electronics enclosure depth (one per side).

Where:
- External Shielded Electronics Enclosure Depth = 21 [in.], from Assumption 3.2.12.
- Crossbeam Length = 142 [in.], from Assumption 3.2.3.

\[
21 \text{ [in.]} + 142 \text{ [in.]} + 21 \text{ [in.]} = 184 \text{ [in.]} 
\]

6.6.4.3 Drip Shield Gantry Height

The ground clearance is calculated by subtracting half the horizontal side-frame height from the wheel radius. The horizontal side frame beam is 18 [in.] x 6 [in.] (Assumption 3.2.4), therefore the horizontal side-frame height is 18 [in.]. The wheel is 36 [in.] in diameter, so the radius is 18 [in.].

\[
18 \text{ [in.]} - (\frac{1}{2} \times 18 \text{ [in.]}) = 9 \text{ [in.]} 
\]

Adding the ground clearance, crossbeam height (allowing for fabrication), and the vertical side-frame beam calculate the drip shield gantry height.

Where:
- Ground Clearance = 9 [in.], from within this section.
- Vertical Side-Frame Height = 108 [in.], from Assumption 3.2.3.
- Crossbeam Projection = 9.75 [in.], from Assumption 3.2.15.

\[
9 \text{ [in.]} + 108 \text{ [in.]} + 9.75 \text{ [in.]} = 126.75 \text{ [in.]} 
\]
7.0 CONCLUSIONS

The results of this calculation including number of units, capacities, motor horsepower, overall size and weight are summarized below. The results are reasonable for mechanical handling equipment based upon available inputs and representative manufacturer’s data. The results are suitable for use as input to the Drip Shield Emplacement Gantry Mechanical Equipment Envelope.

Table 1: Summary of Equipment Sizing

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.3.2</td>
<td>Lift Capacity</td>
<td>15,156.64 [lbf]</td>
</tr>
<tr>
<td>6.3.2</td>
<td>Lift System Comprised of four 5 [ton] screw jacks, each coupled to 0.33 [hp] motors</td>
<td></td>
</tr>
<tr>
<td>6.4.3</td>
<td>Shielded Electrical Enclosure Weight</td>
<td>17,391.02 [lbf] each</td>
</tr>
<tr>
<td>6.4.1</td>
<td>Drip Shield Gantry Chassis Frame Weight</td>
<td>8,903.84 [lbf]</td>
</tr>
<tr>
<td>6.5.1</td>
<td>Empty Drip Shield Gantry Weight</td>
<td>97,929.22 [lbf]</td>
</tr>
<tr>
<td>6.5.3</td>
<td>Bounded Loaded Drip Shield Gantry Weight</td>
<td>120,482.12 [lbf] or 60.24 [ton] For interface purposes, 60.24 [ton] minimum.</td>
</tr>
<tr>
<td>6.6.3</td>
<td>Selected Drive Motors Horsepower</td>
<td>Four 10 [hp] gearmotors.</td>
</tr>
<tr>
<td>6.6.1</td>
<td>Drip Shield Gantry Length</td>
<td>363.75 [in.]</td>
</tr>
<tr>
<td>6.6.2</td>
<td>Drip Shield Gantry Width</td>
<td>184 [in.]</td>
</tr>
<tr>
<td>6.6.3</td>
<td>Drip Shield Gantry Height</td>
<td>126.75 [in.]</td>
</tr>
</tbody>
</table>

The MEE Drawing shall indicate sufficient clearance around the drip shield gantry actual dimensions to determine the bounding operation or clearance envelope.