Appendix I
Test and Ballast Load Calculation and Drawings

APPENDIX I-1 CALCULATION CALC-3021251-000

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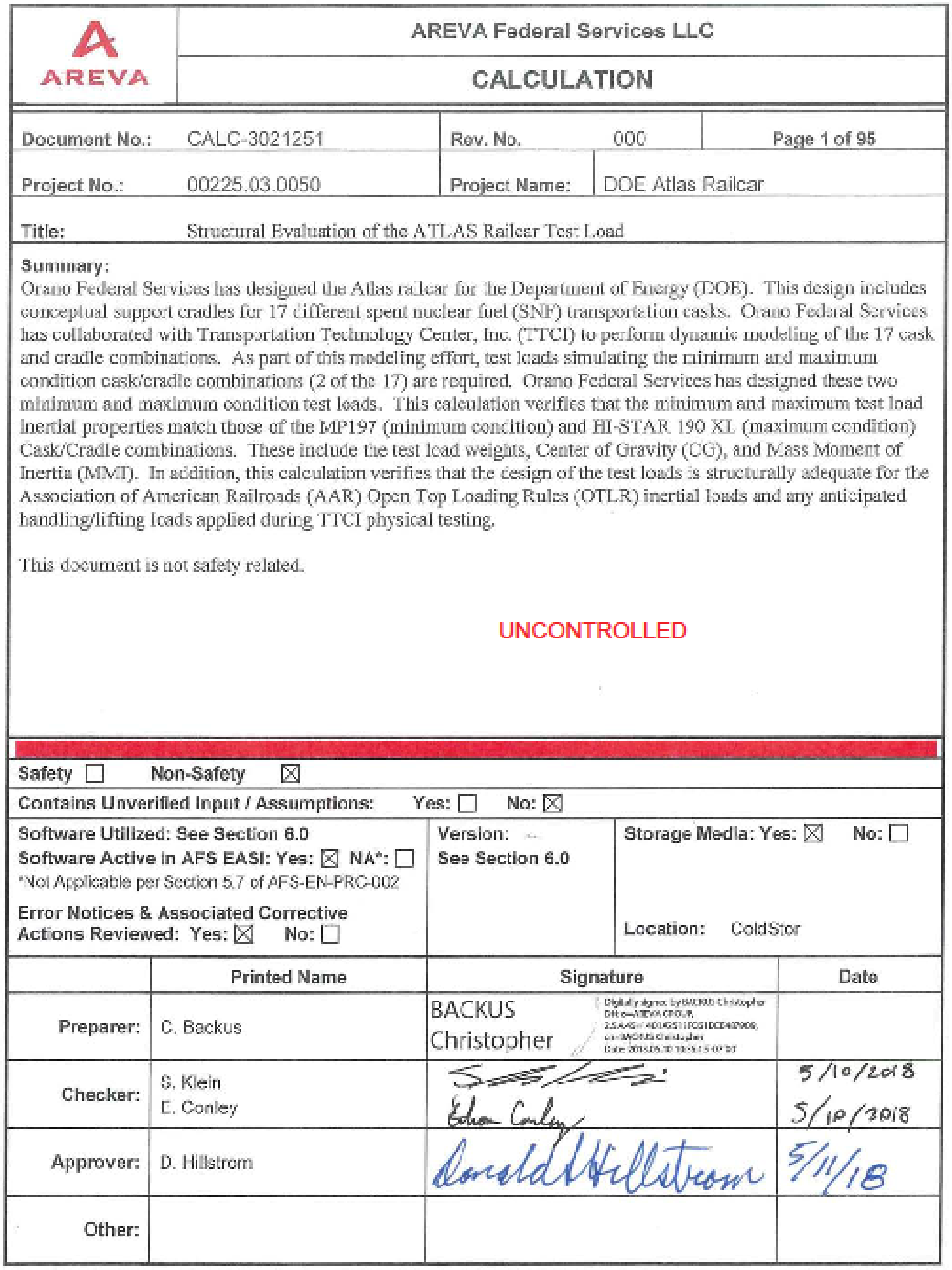
FOR INFORMATION ONLY



AREVA Federal Services LLC

CALCULATION

Document No.:	CALC-3021251	**Rev. No.**	000	Page 1 of 95
Project No.:	00225.03.0050	**Project Name:**	DOE Atlas Railcar	
Title:	Structural Evaluation of the ATLAS Railcar Test Load			

Summary:

Orano Federal Services has designed the Atlas railcar for the Department of Energy (DOE). This design includes conceptual support cradles for 17 different spent nuclear fuel (SNF) transportation casks. Orano Federal Services has collaborated with Transportation Technology Center, Inc. (TTCI) to perform dynamic modeling of the 17 cask and cradle combinations. As part of this modeling effort, test loads simulating the minimum and maximum condition cask/cradle combinations (2 of the 17) are required. Orano Federal Services has designed these two minimum and maximum condition test loads. This calculation verifies that the minimum and maximum test load inertial properties match those of the MP197 (minimum condition) and HI-STAR 190 XL (maximum condition) Cask/Cradle combinations. These include the test load weights, Center of Gravity (CG), and Mass Moment of Inertia (MMI). In addition, this calculation verifies that the design of the test loads is structurally adequate for the Association of American Railroads (AAR) Open Top Loading Rules (OTLR) inertial loads and any anticipated handling/lifting loads applied during TTCI physical testing.

This document is not safety related.

UNCONTROLLED

Safety ☐ **Non-Safety** ☒

Contains Unverified Input / Assumptions: **Yes:** ☐ **No:** ☒

Software Utilized: See Section 6.0 **Software Active in AFS EASI: Yes:** ☒ **NA*:** ☐ *Not Applicable per Section 5.7 of AFS-EN-PRC-002 **Error Notices & Associated Corrective Actions Reviewed: Yes:** ☒ **No:** ☐	**Version:** -- **See Section 6.0**	**Storage Media: Yes:** ☒ **No:** ☐ **Location:** ColdStor

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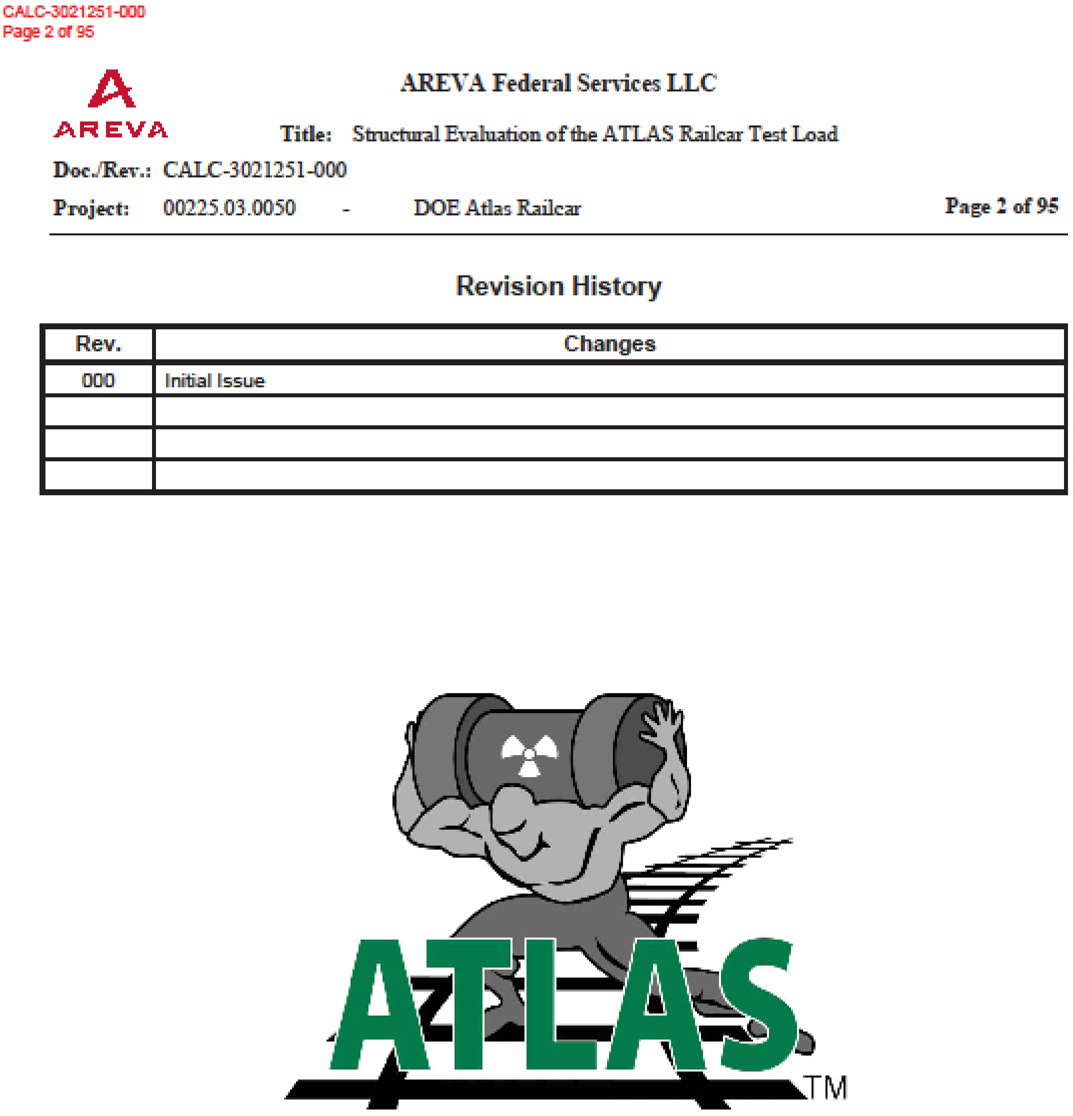

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AREVA Federal Services LLC

Title: Structural Evaluation of the ATLAS Railcar Test Load

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Revision History

Rev.	Changes
000	Initial Issue

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1.0 PURPOSE

Orano Federal Services has designed the cradles and attachments for the Department of Energy (DOE) Atlas railcar. The design phase included support cradle conceptual designs for 17 different spent nuclear fuel (SNF) transportation casks. Orano Federal Services has collaborated with Transportation Technology Center, Inc. (TTCI) to perform dynamic modeling of the 17 cask and cradle combinations. As part of this modeling effort, test loads simulating the minimum and maximum condition cask/cradle combinations (2 of the 17) are required. Orano Federal Services has designed these two minimum and maximum condition test loads. Developed under Orano Federal Services calculation procedure AFS-ENG-PRC-002 [45], this calculation verifies that the minimum and maximum test load inertial properties match those of the MP197 (minimum condition) and HI-STAR 190 XL (maximum condition) cask/cradle combinations (See Figure 2-2 through Figure 2-5) from the preceding design phase activities. These inertial properties include the test load weights, Center of Gravity (CG), and Mass Moment of Inertia (MMI). In addition, this calculation verifies that the design of the test loads is structurally adequate for the Association of American Railroads (AAR) Open Top Loading Rules (OTLR) inertial loads (Section 5.1 of [1]) and any anticipated handling/lifting loads applied during TTCI physical testing.

2.0 METHODOLOGY

Section 4.3.2 describes the railcar test loads needed for use during the Atlas Phase 4 Single Railcar Testing and Phase 5 Multi-Railcar Testing. The inertial properties (weight, CG and MMI) of both the minimum and maximum condition test loads and their accompanying minimum and maximum condition test load cradle variations is calculated based on the design drawings for each:

- Maximum Condition Test Load – Drawing 3020460 [2]
- Minimum Condition Test Load – Drawing 3020458 [3]
- Maximum Condition Test Load Cradle – Drawing 3020461 [4]
- Minimum Condition Test Load Cradle – Drawing 3020459 [5]

The Solidworks® Premium 2016 (SW) models used with these drawings will be memorialized herein with data extracted for the weights, CGs, and MMIs. However, there may be minor discrepancies from the final drawing model, which result in a negligible impact on results. A comparison of these test load values will be checked with the design phase cradle and cask data as documented in CALC-3015934 [20]. Some of the data from the comparison calculation may be extracted from the original design calculations and drawings to ensure the most accurate comparison. The acceptance criteria for these inertial property checks are covered in detail in Section 4.3.2.

For the structural calculations, the test load strongback (See Figure 2-1) is used with both the minimum and maximum condition test loads. Key features of the strongback structure will be structurally verified with the applied design loads taken separately, 3g longitudinally, 2g laterally, and 2g vertically in the most conservative load case(s) [6]. Classic strength of materials equations will be applied and compared with the material yield stress.

The tie-rods used for securing the “Drop-In” weights (See Figure 2-6 and Figure 2-7) on the test loads are checked against the Allowable Loads from the American Institute of Steel Construction (AISC) Steel Construction Manual (SCM) [17]. Similarly, the “Drop-In” weights securement to the Test Load Strongback with structural bolts will be verified to comply with the AISC Allowable Strength Design (ASD) criteria. Of note, it is recognized that neither the tie-rods, nor the bolts as used in this application are “steel buildings and other structures” as defined in the scope of the AISC code. However, the code is conservatively used for these fastener components strength and slip-critical connection verification checks.

Although the test loads are not a Below the Hook Lifting Device, the lifting evaluations for the lift points are analyzed utilizing the general methodology contained in ASME BTH-1[18], as applicable.

Other portions of both the test load structure, including welds for the strongback structure and lifting attachment structural capacity will also be verified for adequacy when compared to allowable yield stress. Classic strength of materials equations will be applied and compared with the material base metal or weld metal yield stress for the material.

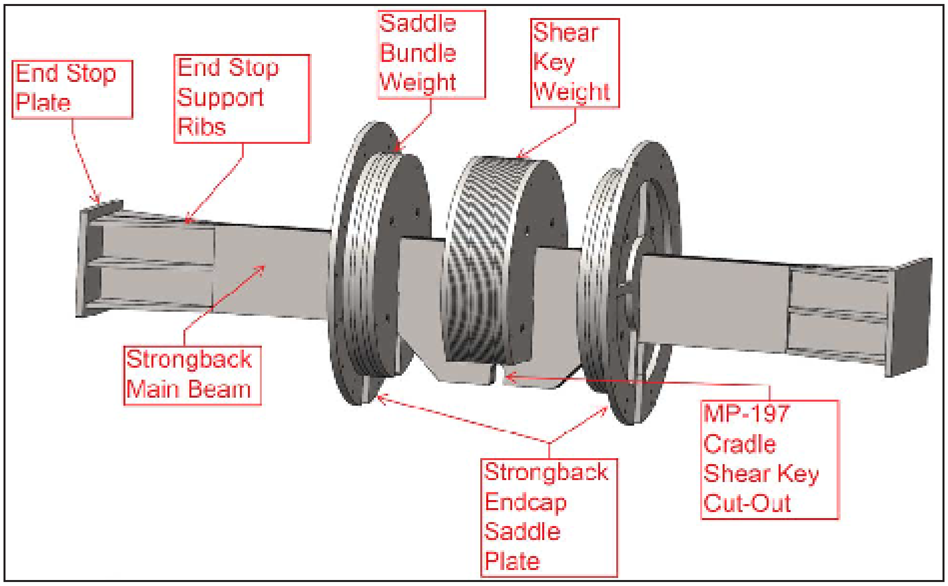


Figure 2-1: Test Load Strongback Structure

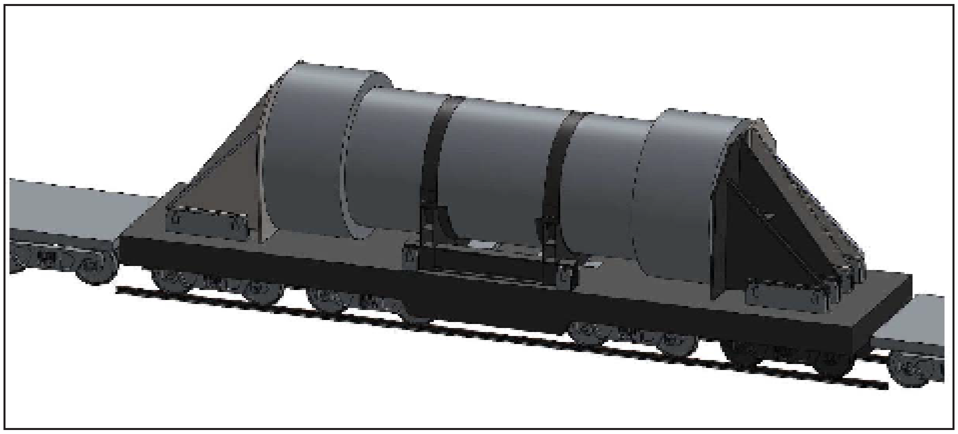


Figure 2-2: HI-Star 190 XL Depiction on Atlas Railcar

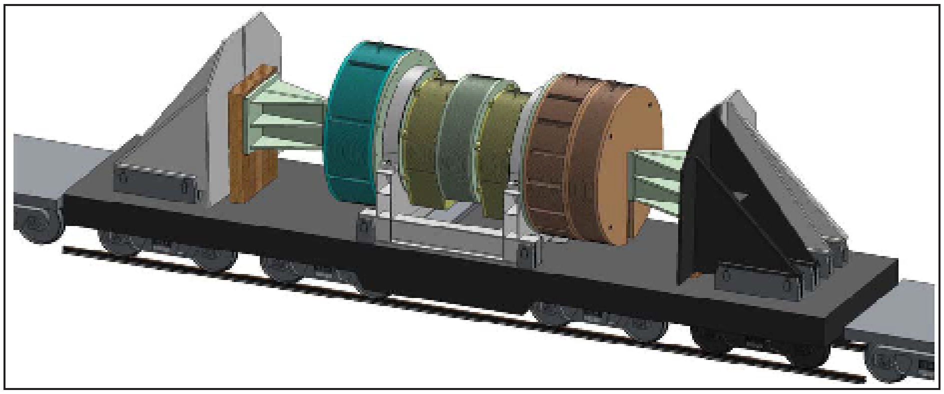


Figure 2-3: HI-Star 190 XL Maximum Condition Test Load Depiction on Atlas Railcar

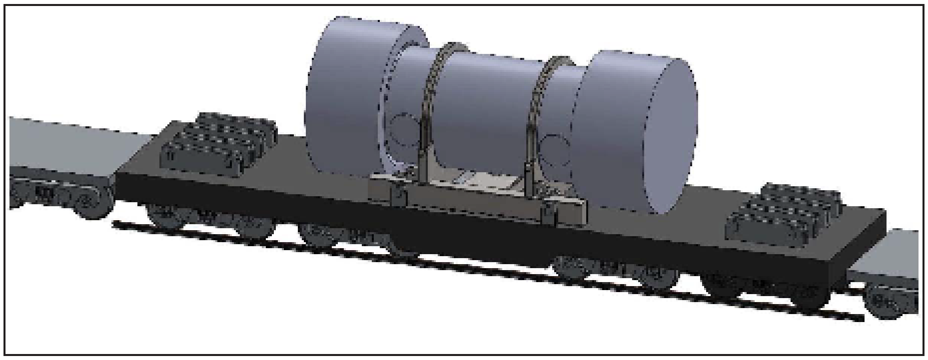


Figure 2-4: MP-197 Depiction on Atlas Railcar

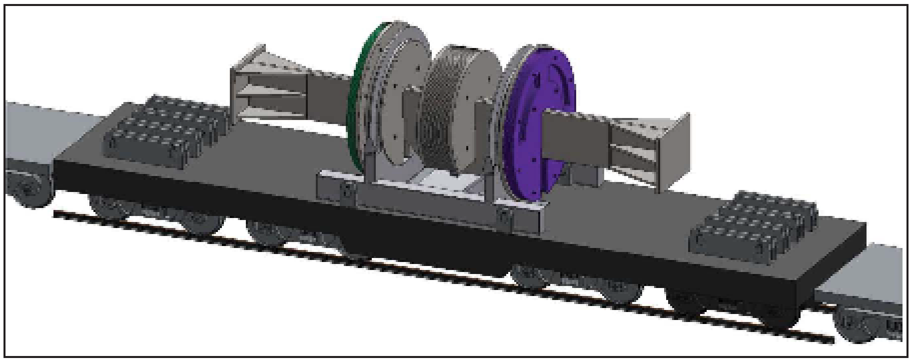


Figure 2-5: MP-197 Minimum Condition Test Load Depiction on Atlas Railcar

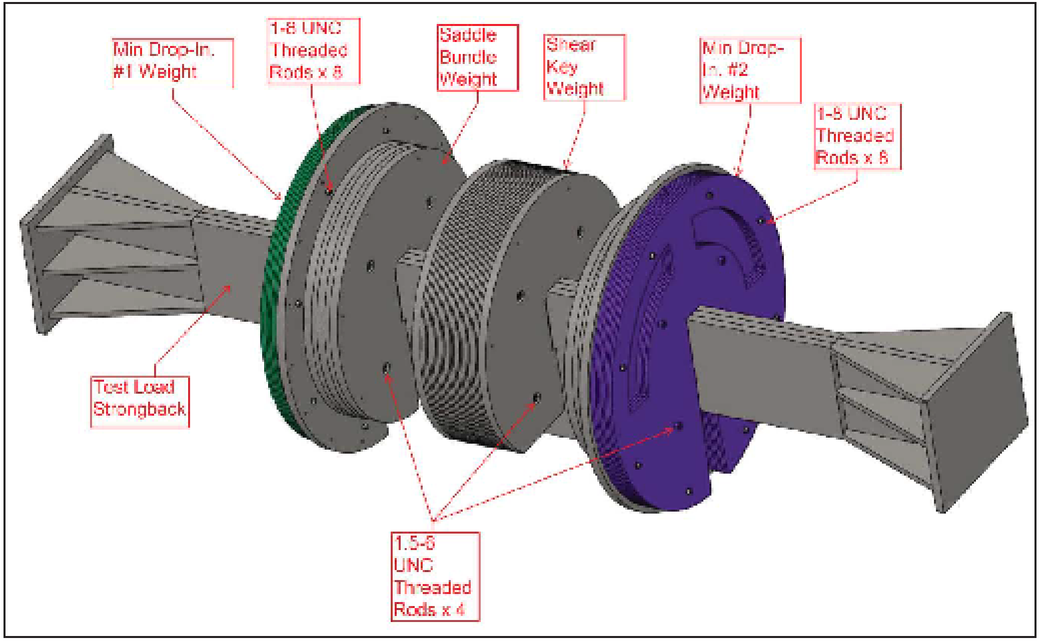


Figure 2-6: Minimum Condition Test Load Drop-in Load Connections

Notes:

- "Test Long Strongback" is "Central Beam Weldment A2" on Drawing 3020935 [33]
- "Shear Key Weight" is "Bundle Assembly A3" on Drawing 3020935 [33]
- "Saddle Bundle Weight" is "Saddle Bundle Assembly A4" on Drawing 3020935 [33]
- "Minimum Drop-In #1 Weight" is "Minimum Weight 7 Plate Assembly A2" on Drawing 3020458 [3]
- "Minimum Drop-In #2 Weight" is "Minimum Weight 8 Plate Assembly A3" on Drawing 3020458 [3]

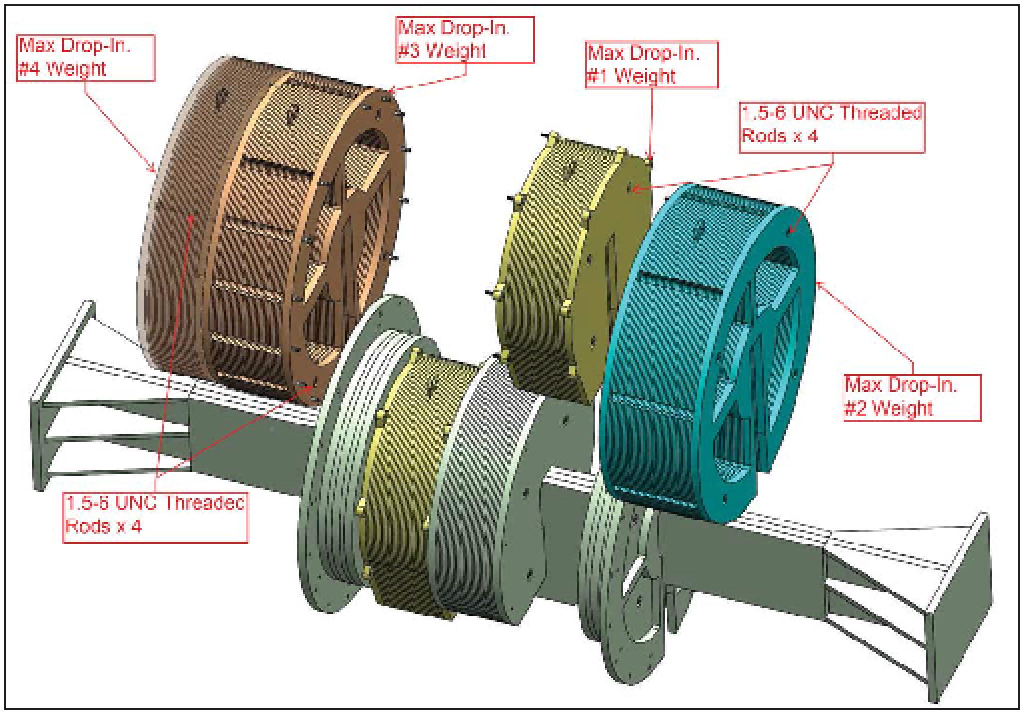


Figure 2-7: Maximum Condition Test Load Drop-in Load Connections

Notes:

- "Maximum Drop-In #1 Weight" is "Max Weight 25 Plate Assembly A3" on Drawing 3020460 [2]
- "Maximum Drop-In #2 Weight" is "Max Weight 34 Plate Assembly A2" on Drawing 3020460 [2]
- "Maximum Drop-In #3 Weight" is "Max Weight 29 Plate Assembly A4" on Drawing 3020460 [2]
- "Maximum Drop-In #4 Weight" is "Max Weight 21 Plate Assembly A5" on Drawing 3020460 [2]

3.0 ASSUMPTIONS

3.1 Unverified Inputs/Assumptions

There are no Unverified Assumptions.

3.2 Justified Assumptions

3.2.1 The inertial properties from Calculation CALC-3015934 [20] are assumed to represent the test load conditions for both the minimum and maximum design-phase cask models. This reflects the fact that CALC-3015934 provides simplifications in the MMI calculations (e.g., casks are modelled as solid right, circular cylinders with no separate geometric representation of the impact limiter's mass).

Justification: DOE has reviewed and approved the dynamic modelling assumptions and methodology (See Table 1-3 of [7]).

3.2.2 When computing inertial properties, personnel barriers are neglected from the SW models for both the test load cradles and the design-phase comparator cradle.

Justification: In accordance with § 2.2.4.7.d of the Design Basis Requirements Document (DBRD) [6], the test load cradles will not have personnel barriers. In addition, since the barrier's overall mass is small, the barrier's overall impact on these inertial properties is inconsequential. The design-phase cradle models in drawings 3015139 [23] and 3015137 [25] for the MP197 and HI-Star 190 XL, respectively, also excluded personnel barriers.

3.2.3 The reference conceptual design phase MP197 cradle in drawing 3015139 [23] shows that the shear key for locating the cask longitudinally on the cradle is offset 1.77-in. to one side. Both the input comparator calculation CALC-3015934 [20] and the minimum condition test load cradle DWG-3020459 [5] have the cask centered on the cradle, not offset to one side. Therefore, the model used in this calculation, which represents the reference conceptual design phase MP197 cradle from drawing 3015139, will consider the shear key cutout centered (See Table A-2).

Justification: In accordance with TTCI correspondence [8], a longitudinal CG location further offset from the geometric centerline is more conservative for dynamic modelling considerations. Therefore, centering the comparison cask location on its cradle thereby not compensating for the cask's offset CG would also be considered more conservative. This would also be a more realistic configuration of the cask's actual CG location on the cradle once any final cradle design is complete. Doing so also has the benefit that the reference calculation CALC-3015934 used as input and as the comparator does not need revision to match the Revision 0 conceptual cradle drawings.

3.2.4 The longitudinal CG of 17.70 inches for the HI-STAR 190 XL reference maximum condition cask stems from calculation CALC-3015133 [26]. However, no source for a longitudinal offset CG location was located in CALC-3015133. Nonetheless, this longitudinal CG value will be assumed conservative for the comparison evaluation.

Justification: A longitudinal CG location further offset from the geometric centerline is more conservative for dynamic modelling considerations [8]. Cask vendor confirmed a longitudinal CG offset that is nominally on center ±7-in., which is less than the conservatively as-modelled 17.70-in. condition [9].

3.2.5 The longitudinal CG offset of 1.15 inches for the MP197 reference minimum condition cask stems from calculations for a loaded cask, not an empty cask (See Table 5-1 of [20]). The actual empty cask longitudinal CG was calculated at 1.58 inches {104 inches – 102.42 inches (from [22]}. However, the 1.15-in. longitudinal CG value will be assumed for the comparison evaluation.

Justification: DOE has reviewed and approved the modelling assumptions for the MP197 Cask (See Table 1-3 of [7]).

3.2.6 For structural evaluations of the test loads, it is assumed that material property reductions are unnecessary (e.g., null-ductility studies are not required for low temperature conditions) for any temperature-related considerations, including for lifting operations. Therefore, consistent with Section 1-4.7 of ASME BTH-1 [18], the design provisions of this calculation are considered applicable when the service temperature is within the range of 25°F to 150°F. Therefore, no material property reductions are required beyond the minimums required in the material specifications.

Justification: The inertial load evaluations are based on the OTLR manual acceleration forces, which is essentially for accident-based conditions, not normal conditions. Therefore, by engineering judgment, the imposition of different material properties for low or high temperature service is deemed unnecessary. In addition, for operational and handling activities (including lifting), all lifts are expected to occur indoors and thus minimum and maximum service temperatures are controlled, therefore no material property reductions are applied.

3.2.7 Nominal weights of all components are assumed with no adjustment for material size or thickness variations from nominal. In addition, no inclusion of weld wire weight is added to the inertial property analyses.

Justification: The tolerance ranges for the inertial property acceptability in Table 4-6 and Table 4-7 are wide enough to justify excluding variance of material sizes and weld allowances.

4.0 DESIGN INPUTS

4.1 Test Load Material Properties

The material strength properties listed in Table 4-1 are used in the design of the test loads. The proof, yield, and ultimate stresses are the minimum values found in the ASTM standards. The test load structure is primarily ASTM A36, plain carbon structural steel, while the hardware and tie-rod material is high strength, low-alloy steel. A couple of the cradle components (i.e., shear key and pin sleeve inserts) used with the minimum condition cradle are stainless steel.

SW model materials are defined using densities taken from ASME B&PV Code Section II, Part D, Table PRD [10] for Carbon Steels and Low alloy steels with a density of .280 lb/in^3 and .290 lb/in^3 density for High Alloy Steels (300 series). For calculation of comparison weights, density for the rubber used with the design phase HI-Star 190 XL cradle (for cask cushioning on saddles) is .04 lb/in^3 [11].

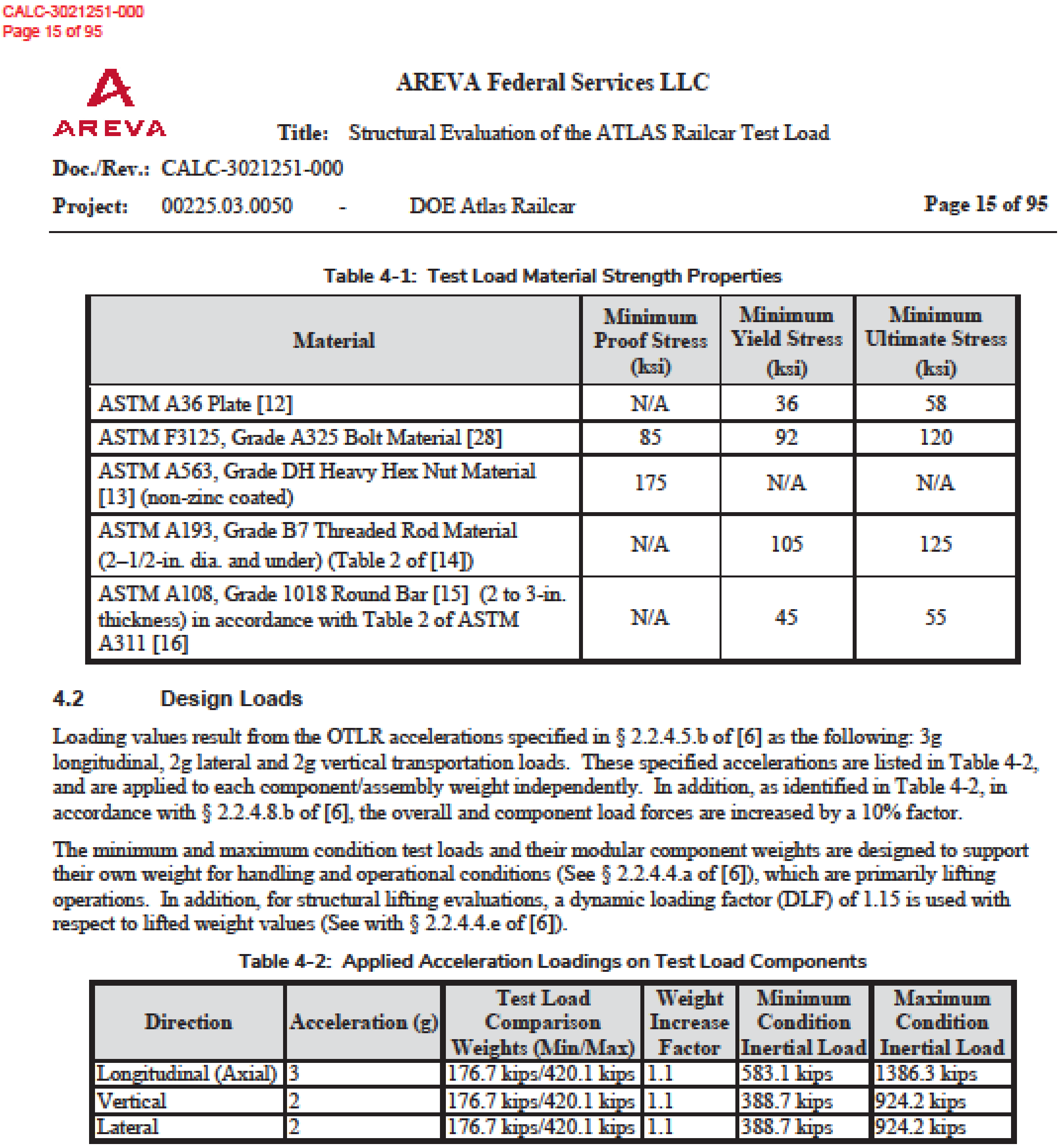


Table 4-1: Test Load Material Strength Properties

Material	Minimum Proof Stress (ksi)	Minimum Yield Stress (ksi)	Minimum Ultimate Stress (ksi)
ASTM A36 Plate [12]	N/A	36	58
ASTM F3125, Grade A325 Bolt Material [28]	85	92	120
ASTM A563, Grade DH Heavy Hex Nut Material [13] (non-zinc coated)	175	N/A	N/A
ASTM A193, Grade B7 Threaded Rod Material (2–1/2-in. dia. and under) (Table 2 of [14])	N/A	105	125
ASTM A108, Grade 1018 Round Bar [15] (2 to 3-in. thickness) in accordance with Table 2 of ASTM A311 [16]	N/A	45	55

4.2 Design Loads

Loading values result from the OTLR accelerations specified in § 2.2.4.5.b of [6] as the following: 3g longitudinal, 2g lateral and 2g vertical transportation loads. These specified accelerations are listed in Table 4-2, and are applied to each component/assembly weight independently. In addition, as identified in Table 4-2, in accordance with § 2.2.4.8.b of [6], the overall and component load forces are increased by a 10% factor.

The minimum and maximum condition test loads and their modular component weights are designed to support their own weight for handling and operational conditions (See § 2.2.4.4.a of [6]), which are primarily lifting operations. In addition, for structural lifting evaluations, a dynamic loading factor (DLF) of 1.15 is used with respect to lifted weight values (See with § 2.2.4.4.e of [6]).

Table 4-2: Applied Acceleration Loadings on Test Load Components

Direction	Acceleration (g)	Test Load Comparison Weights (Min/Max)	Weight Increase Factor	Minimum Condition Inertial Load	Maximum Condition Inertial Load
Longitudinal (Axial)	3	176.7 kips/420.1 kips	1.1	583.1 kips	1386.3 kips
Vertical	2	176.7 kips/420.1 kips	1.1	388.7 kips	924.2 kips
Lateral	2	176.7 kips/420.1 kips	1.1	388.7 kips	924.2 kips

4.3 Acceptance Criteria

4.3.1 Allowable Limits

The yield, proof, and ultimate tensile stress are the structural material strength limits and are listed in Table 4-1. As needed, shear or compressive allowable stress limits will be determined within the calculation body. For the bolting and tie-rod calculations, allowable limits from the AISC SCM [17] using ASD methodology are conservatively used. Otherwise, loading stresses for the imposed load cases of 3g longitudinal, 2g lateral and 2g vertical load cases are compared directly against yield stresses. As stated in Section 4.2, this calculation is performed using applied forces that are +10% of the nominal calculated weight values.

Margins on all allowables are calculated using the following formula, reporting as a percentage variance to the allowable limit:

$$Margin = \frac{Allowable - Required}{Allowable}$$

Values 0% and above are acceptable while values below are not.

For lifting attachment evaluations, ASME BTH-1 (Chapter 3) [18] design allowable criteria are imposed (See § 2.2.4.4.c of [6]). Based on anticipated usage at TTCI, structural lift points are categorized as Design Category A, Service Class 0 in accordance with Chapter 2 of [18]. This is considered valid since the lifting features of the test load will have limited use (< 20,000 cycles) during the testing of the Atlas railcar, and will be lifted in a controlled manner according to standard rigging practices. As such, for lifting structural assessments, a nominal design factor of 2.0 to limit states of yielding or buckling, and 2.4 to limit states of fracture are utilized herein. Since the lifting speed of the crane is expected to be slow, due to the large scale of components being lifted, the dynamic loads will be small. Thus, a conservative DLF of 1.15 is assumed to account for the dynamic forces, which is consistent with Section 4.2.

4.3.2 Test Load Conditions Inertial Data Acceptance Criteria

The test load is defined as the weight of the dummy cask payload (i.e., test load) used to simulate an actual given bounding condition railcar cask. Two conditions (minimum and maximum) are evaluated to simulate both a minimum load condition and a maximum load condition. The "load" condition refers to the Atlas railcar, in addition to the cask and its support cradle, any load securement components (i.e., axial end stop plates) and the railcar securement attachments (See Figure 2-3 and Figure 2-5). The test setup configurations will represent these actual minimum and maximum conditions via the following: a test load cask, a test load cradle, actual end stops (if applicable), the tested Atlas railcar, and any cradle/end stop attachment components. A comparison between the analyzed conditions for the actual minimum and maximum conditions will be checked with respect to the design phase configuration. The parameters of interest for comparison include the following: weight, CG locations (vertical, lateral and longitudinal), the Mass Moments of Inertia (X, Y and Z-axes), and the lowest natural (modal) frequency. Of note, for the comparator evaluation CALC-3015934 [20] used herein, Justified Assumption 3.2.1 states that the cask component mass is normalized over a solid cylindrical body for the MMI determinations. In addition, as stated in Justified Assumption 3.2.2 for the comparison cradles, personnel barriers are not included in the inertial properties.

A summarized comparison of the overall test load weights (minimum and maximum condition) are listed in Table 4-3 and Table 4-8, respectively, with each of the minimum and maximum design phase and expected test load configurations shown in Figure 2-2 through Figure 2-5. Table 4-4 and Table 4-5 provide the extracted target criteria used for establishing the test loads and their cradle's inertial properties, respectively. A detailed, individualized comparison of the minimum and maximum conditions is provided in Sections 4.3.2.1 and 4.3.2.2.

Table 4-3: Analyzed Atlas Railcar Weight Comparison with Expected Atlas Railcar Test Configuration (Minimum Condition)

Actual Atlas Railcar Component Parameter	Evaluated Design Phase Configuration	Atlas Railcar Testing Configuration
Atlas Railcar Weight	195,000 lb – Analyzed Railcar (Section 5.4 of [19])	195,000 lb – Assume Proposed Test Railcar is lightest railcar
Payload Weight	176,710 lb – MP197 Empty Cask (See Table 5-1 of [20])	172,298 lb – Minimum Test Load Cask Representation (See Table 5-2)
Cask Cradle Weight	24,366 lb (See Table A-1)	22,888 lb – Minimum Test Load Cradle Representation (See Table 5-4)
Railcar Attachment Components	28,332 lb – (Table 9-1 of [19])	28,614 lb (See Table 5-6)

Table 4-4: Cask Target Criteria for Reference Inertial Property

Inertial Property	Minimum Condition Test Load Cask (Empty MP-197 Cask)	Maximum Condition Test Load Cask (Loaded HI-STAR 190 XL Cask)
Minimum (Empty) Cask Weight (lb)	176,710 (Table 5-1 of [20])	Not Applicable
Maximum (Loaded) Cask Weight (lb)	Not Applicable	420,769 (Table 5-1 of [20])
Vertical CG from railcar deck (inches)	62.50 (Table 5-1 of [20])	65.00 (Table 5-1 of [20])
Lateral CG from railcar center (inches)	0 (Table 5-1 of [20])	0 (Table 5-1 of [20])
Longitudinal CG from railcar center (inches)	1.15 (Table 5-1 of [20])	17.70 (Table 5-1 of [20])
Rotational MMI Vertical Axis (lb × in^2)	729,798,421 (Table 5-3 of [20])	2,399,616,416 (Table 5-2 of [20])
Rotational MMI Lateral Axis (lb × in^2)	729,798,421 (Table 5-3 of [20])	2,399,616,416 (Table 5-2 of [20])
Rotational MMI Longitudinal Axis (lb × in^2)	184,932,537 (Table 5-3 of 20])	596,558,399 (Table 5-2 of [20])
Minimum Modal Frequency (Hz)	14.1 (§2.2.4.3 of [6])	14.1 (§2.2.4.3 of [6])

Table 4-5: Cradle Target Criteria for Reference Inertial Property

Inertial Property	Minimum Condition Test Load Cradle (MP-197 Cradle)	Maximum Condition Test Load Cradle (HI-STAR 190 XL Cradle)
Cradle Weight (lb)	24,366 (Table A-1)	12,368 (Table A-3)
Vertical CG from railcar deck (inches)	16.80 (Table A-2)	22.12 (Table A-4)
Lateral CG from railcar center (inches)	-0.02 (Table A-2)	0 (Table A-4)
Longitudinal CG from railcar center (inches)	-0.01 (Table A-2)	-0.18 (Table A-4)
Rotational MMI Vertical Axis (lb × in^2)	78,164,217 (Table A-2)	47,747,964 (Table A-4)
Rotational MMI Lateral Axis (lb × in^2)	50,623,981 (Table A-2)	37,932,623 (Table A-4)
Rotational MMI Longitudinal Axis (lb × in^2)	50,158,279 (Table A-2)	29,548,022 (Table A-4)

4.3.2.1 Minimum Test Load Condition Weight, CG and MMI Acceptance Data

The minimum condition is represented by the lightest combination of unloaded cask (i.e., no SNF canister), its conceptual design phase cradle, and the railcar attachment components. In accordance with Appendix A of EIR-3018318 [21], the MP 197 Cask and its design phase cradle represent the minimum load condition (See Figure 2-4). This is considered the minimum condition configuration since it has no end stops and is a lighter configuration than a HI STAR 60 cask with its cradle and end stops. A summary weight comparison of the minimum condition test load between the MP 197 and its test load on its cradle is provided in Table 4-3, and a depiction of the representative test load on its cradle is shown in Figure 2-5.

Based on the target data for the Minimum Condition Cask and Cradle from Table 4-4 and Table 4-5 inputted into the SW model, the combined cask/cradle inertial properties are determined for the minimum condition test load. Based on the SW models used herein, Table 4-6 below provides the combined cask/cradle inertial property requirements used for the comparator checks in Section 7.0, Results/Conclusions. This data is pulled from the SW model data shown in Figure 4-1 which uses the sub-assemblies "MP197-100-A2.sldasm" and "MP197.sldasm" in the top-level assembly "Test Load Railcar Top-Level.sldasm" and with the "MP197 Actual" configuration activated. With both selected in SW, the two sub-assemblies are isolated using the "View/Display/Isolate" Command. Then the "Tools/Evaluate/Mass Properties" command is picked within SW, resulting in the generation of Figure 4-1.

4.3.2.1.1 MP197 Cask Inertial Properties

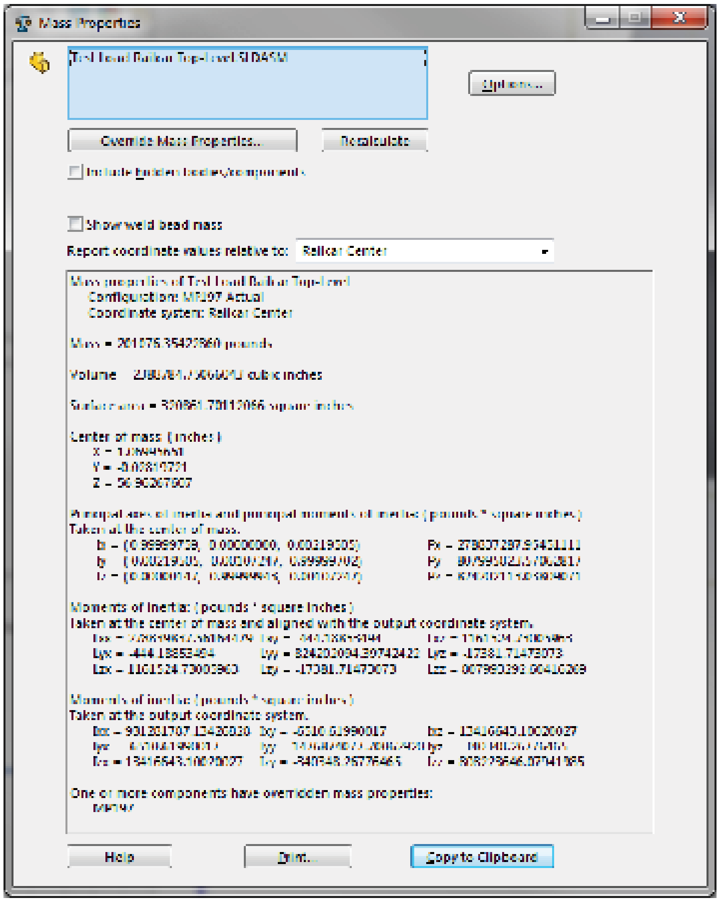
The MP-197 Cask used for comparison is provided in CALC-3015934 [20]. The minimum (empty) MP197 cask weight is listed at 176,710 pounds in Table 5-3 of [20]. The CG values from Table 5-1 of [20], lists the vertical CG location as 62.5 inches, the longitudinal CG location as 1.15 inches and the lateral CG location as 0 inches. For reference in this calculation, it is noted in Footnote 3 to Table 5-1 of [20] that the 62.5-in. vertical CG location is raised ½-in. to compensate for the placement of the cradle on the railcar attachments ½-in thick shim plate. It is also recognized that the longitudinal CG of 1.15 inches stems from calculations for a loaded cask, not an empty cask. The actual empty cask longitudinal CG was calculated at 1.58 inches {104 inches – 102.42 inches (from [22])}. However, the 1.15-in. longitudinal CG value will be assumed for the comparison evaluation (See Justified Assumption 3.2.5). The cask weight and CG data were normalized over the cask body diameter (a right circular cylinder of 125-in. ∅ by 208-in. length) in CALC-3015934 in order to establish the MMI values in Table 5-3 of [20] (See Justified Assumption 3.2.1).

4.3.2.1.2 MP-197 Cradle Inertial Properties

The MP-197 Cradle used for comparison is shown as part of the Family 3 conceptual cradles on drawing 3015139 [23]. The "Dynamic Modeling Inputs" calculation CALC-3015934 [20] used this MP-197 cradle design in its evaluation of inertial properties. A SW override weight of 26,000 pounds was used in CALC-3015934, since that weight was based on hand calculations in CALC-3015135 [24] driven from geometry on drawing 3015139 [23]. However, for a more accurate comparison, the weight, and CG calculated from the SW models are used. These SW models are also used by CALC-3015934 and used to generate drawing 3015139. The Appendix A.3.1 of [20] representative SW model provides a total weight of 24,366 pounds for the cradle. This SW model is used herein and a summary of the weight is listed in Table A-1. However, the SW model is tweaked with Justified Assumption 3.2.3, ensuring the longitudinal placement of the cask upon the cradle is not offset from the geometric center. The CG and MMI for the MP-197 Cradle are shown in Table A-2.

Table 4-6: MP197 Cask/Cradle Combination Comparison Acceptance Criteria for Reference Inertial Property

Inertial Property	Comparator Minimum Condition Cask/Cradle (Empty MP-197 Cask on Cradle)
Minimum (Empty) Cask/Cradle Weight (lb)	≥ -5% of 201,076
Vertical CG from railcar deck (inches)	±.25-in. of 56.96
Lateral CG from railcar center (inches)	±.50-in. of -0.028
Longitudinal CG from railcar center (inches)	±.50-in. of 1.07
Rotational MMI Vertical Axis (lb × in^2)	±10% of 807,993,293
Rotational MMI Lateral Axis (lb × in^2)	±10% of 824,202,094
Rotational MMI Longitudinal Axis (lb × in^2)	±10% of 278,839,838



Test Load Railcar Top-Level [illegible]

☐ Include hidden bodies/components

☐ Show weld bead mass

Report coordinate values relative to: Railcar Center

```
Mass properties of Test Load Railcar Top-Level
     Configuration: MP197 Actual
     Coordinate system: Railcar Center

Mass = 201076.35422860 pounds

Volume = [illegible] cubic inches

Surface area = 320861.70112066 square inches

Center of mass: ( inches )
       X = [illegible]
       Y = -0.00819721
       Z = 56.90267907

Principal axes of inertia and principal moments of inertia: ( pounds * square inches )
Taken at the center of mass.
        Ix = (0.99999728, 0.00000000, 0.00219305)           Px = 278037297.99431111
        Iy = ([illegible])                                   Py = [illegible]
        Iz = ([illegible])                                   Pz = [illegible]

Moments of inertia: ( pounds * square inches )
Taken at the center of mass and aligned with the output coordinate system.
       Lxx = [illegible]            Lxy = [illegible]            Lxz = [illegible]
       Lyx = -444.18853494          Lyy = 824202094.39742422     Lyz = -17381.71473073
       Lzx = 1161524.73003960       Lzy = -17381.71473073        Lzz = 807980392.00416269

Moments of inertia: ( pounds * square inches )
Taken at the output coordinate system.
       Ixx = 931201707.13430030     Ixy = -6310.61990017         Ixz = 13416643.10020027
       Iyx = [illegible]            Iyy = [illegible]            Iyz = [illegible]
       Izx = 13416643.10020027      Izy = -340548.25776465       Izz = 808279646.07741065

One or more components have overridden mass properties:
       MP197
```

Figure 4-1: MP197 Cask and Cradle Minimum Condition Inertial Property Comparison

4.3.2.2 Maximum Test Load Condition Weight, CG and MMI Acceptance Data

The maximum condition test load is represented by the heaviest combination of loaded cask (i.e., with SNF canister), its conceptual design phase cradle and any longitudinal end stops. In accordance with Appendix A of EIR-3018318 [21], the HI-STAR 190 XL cask and its design phase cradle with longitudinal end stops represent the maximum load condition (See Figure 2-2). A summary weight comparison of the maximum condition test load between the HI-STAR 190 XL and its test load on its cradle is provided in Table 4-8, and a depiction of the representative test load on its cradle is shown in Figure 2-3.

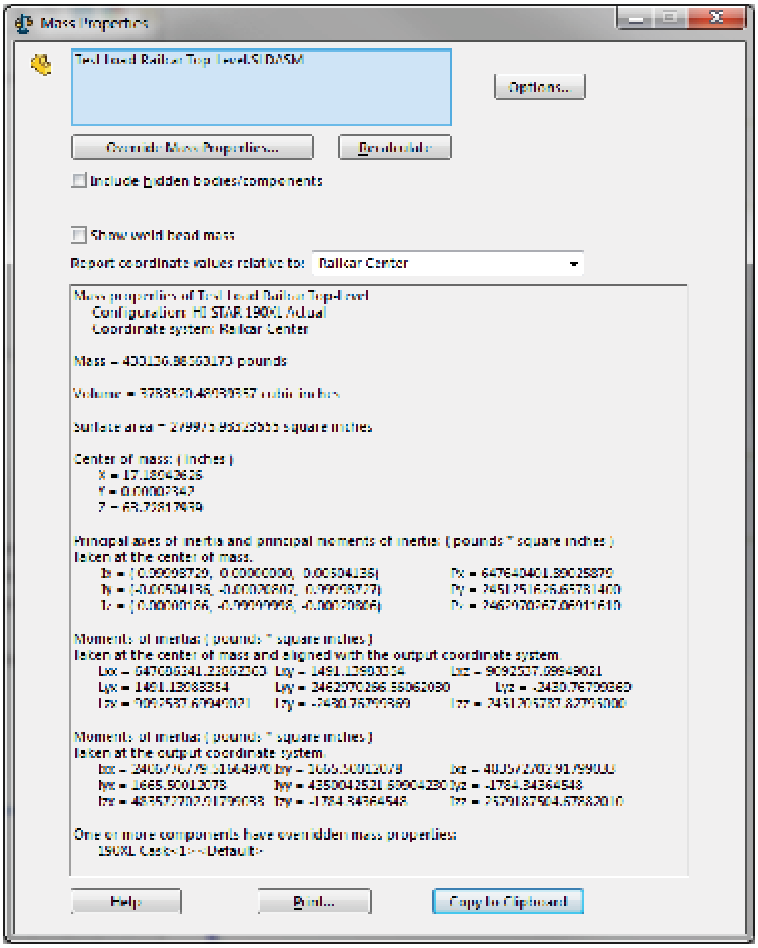
Based on the target data for the Maximum Condition Cask and Cradle from Table 4-4 and Table 4-5 inputted into the SW model, the combined cask/cradle inertial properties are determined for the maximum condition test load. Based on the SW models used herein, Table 4-7 below provides the combined cask/cradle inertial property requirements used for the comparator checks in Section 7.0, Results/Conclusions. This data is pulled from the SW model data shown in Figure 4-2 which uses the sub-assemblies "190XL Cask.sldasm" and "190 XL Skid Assembly.sldasm" in the top-level assembly "Test Load Railcar Top-Level.sldasm" and with the "HI-STAR 190XL Actual" configuration activated. With both selected in SW, the two sub-assemblies are isolated using the "View/Display/Isolate" Command. Then the "Tools/Evaluate/Mass Properties" command is picked within SW, resulting in the generation of Figure 4-2.

The TTCI dynamic modeling plan also requires a maximum vertical height CG condition. The maximum weight condition with the loaded HI-STAR 190 XL cask also represents the highest vertical CG condition. In part, this maximum vertical CG verification check is necessary in order to ensure the combined maximum railcar vertical CG height is below 98 inches (See Section 5.4 of [19]). Therefore, the total vertical CG height of the loaded maximum condition railcar will be verified. The lightest railcar weight of 195,000 pounds (See Table 4-8) will be used to verify the 98-in. value is observed, since a lighter railcar will have less influence in lowering the overall vertical CG height. Table 4-8 below provides a chart of the parameters needed as a comparison for a determination of the maximum test load total vertical CG height. For the railcar vertical CG comparison evaluation, the railcar deck height is conservatively set at the unloaded deck height of 59.25-in. from the top of the rail to deck surface (Section 5.4 of [19]). In addition, the railcar vertical CG is located 35.3 inches from the top of the rail to deck surface (Section 5.4 of [19]).

This maximum vertical railcar CG is based on the following components: Maximum Test Load, Maximum Test Load Cradle, 195-kip Railcar, Railcar Attachment Components, and End Stop Assemblies (See Table 4-8 for a list of the design phase parameters and the Test Analysis Configuration). The Railcar Attachment Components weight and CG are determined in Appendix A of CALC-3015276 [19]. The End Stop weight was determined in reference inputs to the comparator calculation (Table 4-3 of [20]) as 40,000 pounds. The actual models of the end stops from those reference inputs, specifically the design phase drawing 3015137 [25] is used for making the comparison. The End Stop reference vertical CG location is listed in Table 4-3 of [20] as 62.2 inches.

Table 4-7: HI-STAR 190 XL Cask/Cradle Combination Comparison Acceptance Criteria for Reference Inertial Property

Inertial Property	Comparator Maximum Condition Cask/Cradle (Loaded HI-STAR 190 XL Cask on Cradle)
Maximum (Loaded) Cask/Cradle Weight (lb)	≤ +5% of 433,137
Vertical CG from railcar deck (inches)	±.25-in. of 63.73
Lateral CG from railcar center (inches)	±.50-in. of 0
Longitudinal CG from railcar center (inches)	±.50-in. of 17.19
Rotational MMI Vertical Axis ($\text{lb} \times \text{in}^2$)	±10% of 2,451,205,788
Rotational MMI Lateral Axis ($\text{lb} \times \text{in}^2$)	±10% of 2,462,970,267
Rotational MMI Longitudinal Axis ($\text{lb} \times \text{in}^2$)	±10% of 647,686,241



Test Load Railcar Top Level.SLDASM

☐ Include hidden bodies/components

☐ Show weld bead mass

Report coordinate values relative to: Railcar Center

```
Mass properties of Test Load Railcar Top-Level
     Configuration: HI STAR 190XL Actual
     Coordinate system: Railcar Center

Mass = 400136.88363173 pounds

Volume = 3783520.48939357 cubic inches

Surface area = 279975.95325555 square inches

Center of mass: ( inches )
        X = 17.18043626
        Y = 0.00007347
        Z = 63.72817939

Principal axes of inertia and principal moments of inertia: ( pounds * square inches )
Taken at the center of mass.
        Ix = ( 0.99998729,  0.00000000,  0.00504136)          Px = 647640401.89025879
        Iy = (-0.00504136, -0.00020807,  0.99998727)          Py = 2451251676.65781400
        Iz = ( 0.00000105, -0.99999998, -0.00020806)          Pz = 2462070267.06911610

Moments of inertia: ( pounds * square inches )
Taken at the center of mass and aligned with the output coordinate system.
        Lxx = 647606341.23062360  Lxy = 1491.13083354          Lxz = 9092537.08949021
        Lyx = 1491.13083354       Lyy = 2462070266.56062080        Lyz = -2430.76799360
        Lzx = 9092537.08949021    Lzy = -2430.76799360         Lzz = 2451205787.62795000

Moments of inertia: ( pounds * square inches )
Taken at the output coordinate system.
        Ixx = 2406776779.51164970 Ixy = 1665.50012078          Ixz = 483577702.91799033
        Iyx = 1665.50012078       Iyy = 4350042521.69904230 Iyz = -1784.34364548
        Izx = 483577702.91799033  Izy = -1784.34364548         Izz = 2579187504.67882010

One or more components have overridden mass properties:
        190XL Cask<1>-<Default>
```

Figure 4-2: HI-STAR 190 XL and Cradle Maximum Condition Inertial Property Comparison

Table 4-8: Analyzed Atlas Railcar Weight Comparison with Expected Atlas Railcar Test Configuration (Maximum Condition)

Actual Atlas Railcar Component Parameter	Evaluated Design Phase Configuration	Atlas Railcar Test Load Configuration
Atlas Railcar Weight	195,000 lb – Analyzed Railcar (Section 5.4 of [19], Section 4.3.2.2)	195,000 lb – Assume same as design phase
Atlas Railcar Vertical CG from railcar deck	-23.95 inches (-59.25 + 35.3 inches) (See Section 4.3.2.2)	-23.95 inches (-59.25 + 35.3 inches) (See Section 4.3.2.2) – Assume same as design phase
Cask Weight	420,769 lb – HI-Star 190 XL Loaded Cask (Table 5-1 of [20])	417,990 lb – Maximum Test Load Cask Representation – (See Table 5-3)
Cask Vertical CG from railcar deck	65.0 inches – (Table 5-1 of [20])	65.06 inches – (See Table 5-9)
Cask Cradle Weight	12,368 lb – HI-Star 190 XL Cradle (See Table A-3)	12,866 lb – Maximum Test Load Cradle Representation – (See Table 5-5)
Cask Cradle Vertical CG from railcar deck	22.12 inches – (See Table A-4)	22.20 inches – (See Table 5-10)
Longitudinal End Stop Weight	40,000 lb – (Table 4-3 of [20])	42,161 lb – (See Table 5-7)
End Stop Vertical CG from railcar deck	62.2 inches – (Table 4-3 of [20])	47.8 inches – (See Table 5-14)
Railcar Attachment Components	28,332 lb – (Table 9-1 of [19])	28,614 lb – (See Table 5-6)
Railcar Attachments Vertical CG from railcar deck	7.99 inches – (Table 9-1 of [19])	7.49 inches – (See Table 5-13)

4.3.2.2.1 HI-Star 190XL Cask Inertial Properties

The HI-Star 190XL Cask used for comparison is provided in CALC-3015934 [20]. The maximum (loaded) HI-Star 190XL cask weight is listed at 420,769 pounds in Table 5-2 of [20]. The CG values from Table 5-1 of [20], lists the vertical CG location as 65.0 inches, the longitudinal CG location as 17.70 inches and the lateral CG location as 0 inches. For reference in this calculation, it is noted in Footnote 3 to Table 5-1 of [20] that the 65.0-in. vertical CG location is raised ½-in. to compensate for the placement of the cradle on the railcar attachments ½-in thick shim plate. It is also recognized that the longitudinal CG of 17.70 inches stems from calculation CALC-3015133 [26]. However, no source for this data was located in CALC-3015133. Nonetheless, this longitudinal CG value will be assumed conservative for the comparison evaluation (See Justified Assumption 3.2.4). The cask weight and CG data were normalized over the cask body diameter (a right circular cylinder of 130-in. ∅ by 237-in. length) in CALC-3015934 in order to establish the MMI values in Table 5-2 of [20] (See Justified Assumption 3.2.1).

4.3.2.2.2 HI-Star 190XL Cradle Inertial Properties

The HI-Star 190XL Cradle used for comparison is shown as part of the Family 1 conceptual cradles on drawing 3015137 [25]. The “Dynamic Modeling Inputs” calculation CALC-3015934 [20] used this HI-Star 190XL cradle design in its evaluation of inertial properties. A SW override weight of 13,636 pounds was used in CALC-3015934, since that weight was based on hand calculations in CALC-3015133 [26] driven from geometry on drawing 3015137 [10]. The 13,636-pound weight value was calculated based on a 10,776-pound cradle without personnel barrier weight plus a 2,758-pound personnel barrier weight. However, for a more accurate comparison, the weight, and CG calculated from the SW models are used. These SW models are also used by CALC-3015934 and used to generate drawing 3015137. The Appendix A.1 of [20] representative SW model provides a total weight of 12,367.9 pounds for the cradle. This SW model is used herein and a summary of the weight is listed in Table A-3. The CG and MMI for the HI-Star 190XL Cradle are shown in Table A-4.

5.0 CALCULATIONS

As stated in Justified Assumption 3.2.7, all structural evaluations are assumed with nominal material sizes and with the exclusion of weld wire material. In addition, as stated in Justified Assumption 3.2.6, all structural evaluations are assumed with nominal material temperatures.

5.1 Test Load Inertial Values

The inertial properties (weight, CG and MMI) for the Minimum and Maximum Condition Test Loads and Test Load Cradles are determined using Solidworks® Premium 2016 Computer Aided Design (CAD) software. Likewise, inertial properties for the End Stop assemblies and Railcar Attachments for the Maximum Test Load Condition overall railcar CG determination are evaluated using SW. The inertial properties output from SW use the designs documented by the following drawings and the same basic parent SW models:

- Maximum Condition Test Load – Drawing 3020460 [2]
- Minimum Condition Test Load – Drawing 3020458 [3]
- Maximum Condition Test Load Cradle – Drawing 3020461 [4]
- Minimum Condition Test Load Cradle – Drawing 3020459 [5]
- Maximum Condition End Stops – Drawing 3015137 [25]
- Railcar Attachments – Drawing 3015278 [27]

The density for the models used with the components of these drawings is provided in Section 4.1. However, where required, the densities in the parent SW models from the above drawings have been corrected to match the densities used from Section 4.1.

5.1.1 Weight Determinations

Based on the drawings and parent SW models, each of the piece component and subassembly weights, densities, and total weight tallies are listed in Table 5-2, Table 5-3, Table 5-4, and Table 5-5 for the Minimum Condition Test Load, Maximum Condition Test Load, Minimum Condition Test Load Cradle, and Maximum Condition Test Load Cradle, respectively. As stated in Justified Assumption 3.2.7, all weight computations are assumed with nominal material sizes and with the exclusion of weld wire material. The weight tables are generated for each assembly using the SW command, “Tools/Evaluate/Assembly Visualization” and then right clicking on the “Assembly Visualization” header bar and choosing “Save As”, “Indented” and clicking the “Save” button.

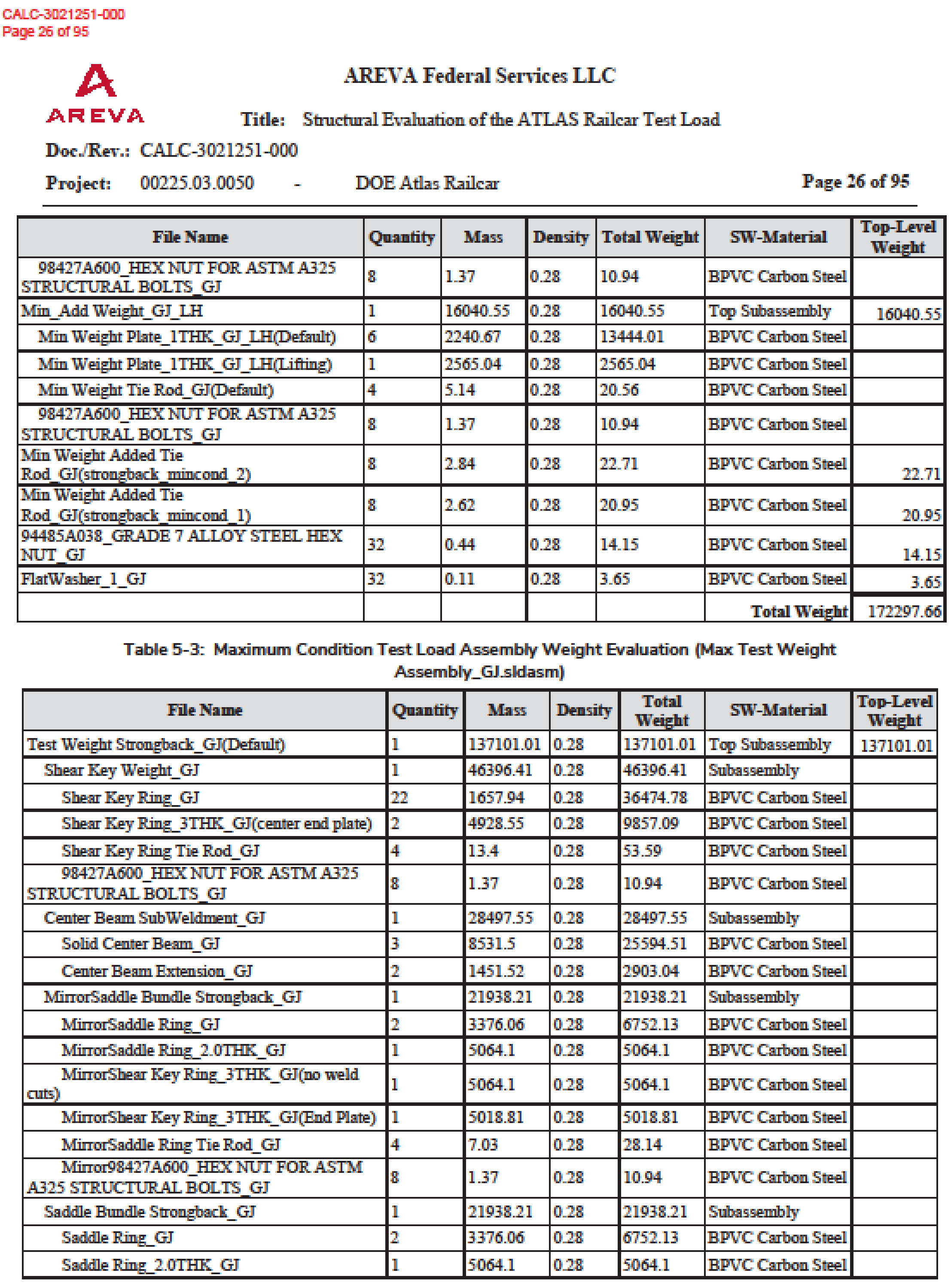
Likewise, the Maximum Condition Test Load End Stops and Railcar Attachment Components weights are extracted from the parent SW models of the drawings from Section 5.1. Railcar Attachment Components and Maximum Condition Test Load End Stop Assembly weights are listed in Table 5-6 and Table 5-7, respectively. As stated in Section 4.3.2.2, the End Stop weight was determined in reference inputs to the comparator calculation (Table 4-3 of [20]) as 40,000 pounds. However, the actual SW models of the end stops from those reference inputs, specifically the design phase drawing 3015137 [25] is used for the weight and overall railcar CG evaluations. The detailed End Stop weight is listed in Table 5-7. The Railcar Attachment Components weight and CG are determined in Appendix A of CALC-3015276 [19]. The SW models from the drawings used therein for railcar attachments (3015278) [27] are reported as the weight and geometry in this calculation (See Table 5-6). Based on data from Table 5-2, Table 5-3, Table 5-4, and Table 5-5, the combined test load and cradle weight for both minimum and maximum conditions are tabulated in Table 5-1.

Table 5-1: Test Load with Cradle Overall Weights

Test Load Version	Test Load Weight (lb.)	Cradle Weight (lb.)	Combined Weight (lb.)
Minimum Condition	172,298	22,888	195,186
Maximum Condition	417,992	12,866	430,858

Table 5-2: Minimum Condition Test Load Assembly Weight Evaluation (Min Test Weight Assembly_GJ.sldasm)

File Name	Quantity	Mass	Density	Total Weight	SW-Material	Top-Level Weight
Test Weight Strongback_GJ(Default)	1	137101.01	0.28	137101.01	Top Subassembly	137101.01
Shear Key Weight_GJ	1	46396.41	0.28	46396.41	Subassembly	
Shear Key Ring_GJ	22	1657.94	0.28	36474.78	BPVC Carbon Steel	
Shear Key Ring_3THK_GJ(center end plate)	2	4928.55	0.28	9857.09	BPVC Carbon Steel	
Shear Key Ring Tie Rod_GJ	4	13.4	0.28	53.59	BPVC Carbon Steel	
98427A600_HEX NUT FOR ASTM A325 STRUCTURAL BOLTS_GJ	8	1.37	0.28	10.94	BPVC Carbon Steel	
Center Beam SubWeldment_GJ	1	28497.55	0.28	28497.55	Subassembly	
Solid Center Beam_GJ	3	8531.5	0.28	25594.51	BPVC Carbon Steel	
Center Beam Extension_GJ	2	1451.52	0.28	2903.04	BPVC Carbon Steel	
MirrorSaddle Bundle Strongback_GJ	1	21938.21	0.28	21938.21	Subassembly	
MirrorSaddle Ring_GJ	2	3376.06	0.28	6752.13	BPVC Carbon Steel	
MirrorSaddle Ring_2.0THK_GJ	1	5064.1	0.28	5064.1	BPVC Carbon Steel	
MirrorShear Key Ring_3THK_GJ(no weld cuts)	1	5064.1	0.28	5064.1	BPVC Carbon Steel	
MirrorShear Key Ring_3THK_GJ(End Plate)	1	5018.81	0.28	5018.81	BPVC Carbon Steel	
MirrorSaddle Ring Tie Rod_GJ	4	7.03	0.28	28.14	BPVC Carbon Steel	
Mirror98427A600_HEX NUT FOR ASTM A325 STRUCTURAL BOLTS_GJ	8	1.37	0.28	10.94	BPVC Carbon Steel	
Saddle Bundle Strongback_GJ	1	21938.21	0.28	21938.21	Subassembly	
Saddle Ring_GJ	2	3376.06	0.28	6752.13	BPVC Carbon Steel	
Saddle Ring_2.0THK_GJ	1	5064.1	0.28	5064.1	BPVC Carbon Steel	
Shear Key Ring_3THK_GJ(no weld cuts)	1	5064.1	0.28	5064.1	BPVC Carbon Steel	
Shear Key Ring_3THK_GJ(End Plate)	1	5018.81	0.28	5018.81	BPVC Carbon Steel	
Saddle Ring Tie Rod_GJ	4	7.04	0.28	28.14	BPVC Carbon Steel	
98427A600_HEX NUT FOR ASTM A325 STRUCTURAL BOLTS_GJ	8	1.37	0.28	10.94	BPVC Carbon Steel	
MirrorSaddle End Cap Plate_GJ	1	4974.14	0.28	4974.14	BPVC Carbon Steel	
Saddle End Cap Plate_GJ(Default)	1	4974.14	0.28	4974.14	BPVC Carbon Steel	
Gusset_GJ	12	353.64	0.28	4243.68	BPVC Carbon Steel	
End Plate_GJ	2	2069.34	0.28	4138.68	BPVC Carbon Steel	
Min_Add Weight_2_GJ	1	19094.64	0.28	19094.64	Top Subassembly	19094.64
Min Weight Plate_1THK_GJ(Default)	4	2202.25	0.28	8808.98	BPVC Carbon Steel	
Min Weight Plate_1THK_GJ(no cuts)	3	2562.71	0.28	7688.12	BPVC Carbon Steel	
Min Weight Plate_1THK_GJ(Lifting)	1	2565.04	0.28	2565.04	BPVC Carbon Steel	
Min Weight Tie Rod_GJ(min_dropin2_length)	4	5.39	0.28	21.55	BPVC Carbon Steel	



File Name	Quantity	Mass	Density	Total Weight	SW-Material	Top-Level Weight
98427A600_HEX NUT FOR ASTM A325 STRUCTURAL BOLTS_GJ	8	1.37	0.28	10.94	BPVC Carbon Steel	
Min_Add Weight_GJ_LH	1	16040.55	0.28	16040.55	Top Subassembly	16040.55
Min Weight Plate_1THK_GJ_LH(Default)	6	2240.67	0.28	13444.01	BPVC Carbon Steel	
Min Weight Plate_1THK_GJ_LH(Lifting)	1	2565.04	0.28	2565.04	BPVC Carbon Steel	
Min Weight Tie Rod_GJ(Default)	4	5.14	0.28	20.56	BPVC Carbon Steel	
98427A600_HEX NUT FOR ASTM A325 STRUCTURAL BOLTS_GJ	8	1.37	0.28	10.94	BPVC Carbon Steel	
Min Weight Added Tie Rod_GJ(strongback_mincond_2)	8	2.84	0.28	22.71	BPVC Carbon Steel	22.71
Min Weight Added Tie Rod_GJ(strongback_mincond_1)	8	2.62	0.28	20.95	BPVC Carbon Steel	20.95
94485A038_GRADE 7 ALLOY STEEL HEX NUT_GJ	32	0.44	0.28	14.15	BPVC Carbon Steel	14.15
FlatWasher_1_GJ	32	0.11	0.28	3.65	BPVC Carbon Steel	3.65
					Total Weight	172297.66

Table 5-3: Maximum Condition Test Load Assembly Weight Evaluation (Max Test Weight Assembly_GJ.sldasm)

File Name	Quantity	Mass	Density	Total Weight	SW-Material	Top-Level Weight
Test Weight Strongback_GJ(Default)	1	137101.01	0.28	137101.01	Top Subassembly	137101.01
Shear Key Weight_GJ	1	46396.41	0.28	46396.41	Subassembly	
Shear Key Ring_GJ	22	1657.94	0.28	36474.78	BPVC Carbon Steel	
Shear Key Ring_3THK_GJ(center end plate)	2	4928.55	0.28	9857.09	BPVC Carbon Steel	
Shear Key Ring Tie Rod_GJ	4	13.4	0.28	53.59	BPVC Carbon Steel	
98427A600_HEX NUT FOR ASTM A325 STRUCTURAL BOLTS_GJ	8	1.37	0.28	10.94	BPVC Carbon Steel	
Center Beam SubWeldment_GJ	1	28497.55	0.28	28497.55	Subassembly	
Solid Center Beam_GJ	3	8531.5	0.28	25594.51	BPVC Carbon Steel	
Center Beam Extension_GJ	2	1451.52	0.28	2903.04	BPVC Carbon Steel	
MirrorSaddle Bundle Strongback_GJ	1	21938.21	0.28	21938.21	Subassembly	
MirrorSaddle Ring_GJ	2	3376.06	0.28	6752.13	BPVC Carbon Steel	
MirrorSaddle Ring_2.0THK_GJ	1	5064.1	0.28	5064.1	BPVC Carbon Steel	
MirrorShear Key Ring_3THK_GJ(no weld cuts)	1	5064.1	0.28	5064.1	BPVC Carbon Steel	
MirrorShear Key Ring_3THK_GJ(End Plate)	1	5018.81	0.28	5018.81	BPVC Carbon Steel	
MirrorSaddle Ring Tie Rod_GJ	4	7.03	0.28	28.14	BPVC Carbon Steel	
Mirror98427A600_HEX NUT FOR ASTM A325 STRUCTURAL BOLTS_GJ	8	1.37	0.28	10.94	BPVC Carbon Steel	
Saddle Bundle Strongback_GJ	1	21938.21	0.28	21938.21	Subassembly	
Saddle Ring_GJ	2	3376.06	0.28	6752.13	BPVC Carbon Steel	
Saddle Ring_2.0THK_GJ	1	5064.1	0.28	5064.1	BPVC Carbon Steel	

File Name	Quantity	Mass	Density	Total Weight	SW-Material	Top-Level Weight
Shear Key Ring_3THK_GJ(no weld cuts)	1	5064.1	0.28	5064.1	BPVC Carbon Steel	
Shear Key Ring_3THK_GJ(End Plate)	1	5018.81	0.28	5018.81	BPVC Carbon Steel	
Saddle Ring Tie Rod_GJ	4	7.04	0.28	28.14	BPVC Carbon Steel	
98427A600_HEX NUT FOR ASTM A325 STRUCTURAL BOLTS_GJ	8	1.37	0.28	10.94	BPVC Carbon Steel	
MirrorSaddle End Cap Plate_GJ	1	4974.14	0.28	4974.14	BPVC Carbon Steel	
Saddle End Cap Plate_GJ(Default)	1	4974.14	0.28	4974.14	BPVC Carbon Steel	
Gusset_GJ	12	353.64	0.28	4243.68	BPVC Carbon Steel	
End Plate_GJ	2	2069.34	0.28	4138.68	BPVC Carbon Steel	
Max_Add Weight_1_GJ	2	40472.92	0.28	80945.84	Top Subassembly	80945.84
Dropin Weight Heavy_GJ(Default)	44	1412.51	0.28	62150.28	BPVC Carbon Steel	
Dropin Weight Heavy_2.75THK_GJ(end plate)	4	3951.56	0.28	15806.25	BPVC Carbon Steel	
Dropin Weight Heavy_GJ(lifting)	2	1420.83	0.28	2841.66	BPVC Carbon Steel	
Max Weight Tie Rod_GJ(max_weight1_length)	8	13.8	0.28	110.39	BPVC Carbon Steel	
98427A600_HEX NUT FOR ASTM A325 STRUCTURAL BOLTS_GJ	16	1.37	0.28	21.89	BPVC Carbon Steel	
Lift Lug Reinforce_GJ	2	7.69	0.28	15.38	BPVC Carbon Steel	
Max_Add Weight_3_GJ	1	68125.01	0.28	68125.01	Top Subassembly	68125.01
Dropin Weight Heavy End1_1THK_GJ(no center cuts)	10	2689.09	0.28	26890.89	BPVC Carbon Steel	
Dropin Weight Heavy End1_1THK_GJ(Default)	16	1643.39	0.28	26294.17	BPVC Carbon Steel	
Dropin Weight Heavy End2_3THK_rear_GJ(With Holes)	1	8104.41	0.28	8104.41	BPVC Carbon Steel	
Dropin Weight Heavy End1_3THK_GJ(Default)	1	5102.16	0.28	5102.16	BPVC Carbon Steel	
Dropin Weight Heavy End1_1THK_GJ(Lifting)	1	1651.14	0.28	1651.14	BPVC Carbon Steel	
Max Weight Tie Rod_3_GJ(Default)	4	15.9	0.28	63.6	BPVC Carbon Steel	
98427A600_HEX NUT FOR ASTM A325 STRUCTURAL BOLTS_GJ	8	1.37	0.28	10.94	BPVC Carbon Steel	
Lift Lug Reinforce_GJ	1	7.69	0.28	7.69	BPVC Carbon Steel	
Max_Add Weight_4_GJ	1	67806.85	0.28	67806.85	Top Subassembly	67806.85
Dropin Weight Heavy End2_1THK_rear_GJ(Default)	18	2711.14	0.28	48800.49	BPVC Carbon Steel	
Dropin Weight Heavy End2_3THK_rear_GJ(Default)	1	8113.5	0.28	8113.5	BPVC Carbon Steel	
Dropin Weight Heavy End2_3THK_rear_GJ(with threads)	1	8107	0.28	8107	BPVC Carbon Steel	
Dropin Weight Heavy End2_1THK_rear_GJ(Lifting)	1	2719.45	0.28	2719.45	BPVC Carbon Steel	
Max Weight Tie Rod_4_GJ	4	11.94	0.28	47.77	BPVC Carbon Steel	
98427A600_HEX NUT FOR ASTM A325 STRUCTURAL BOLTS_GJ	8	1.37	0.28	10.94	BPVC Carbon Steel	
Lift Lug Reinforce_GJ	1	7.69	0.28	7.69	BPVC Carbon Steel	
Max_Add Weight_2_GJ	1	63896.03	0.28	63896.03	Top Subassembly	63896.03

File Name	Quantity	Mass	Density	Total Weight	SW-Material	Top-Level Weight
Dropin Weight Heavy End1_1THK_GJ(drop-in_no2)	31	1674.02	0.28	51894.75	BPVC Carbon Steel	
Dropin Weight Heavy End1_3THK_GJ(Unbolted)	1	5124.71	0.28	5124.71	BPVC Carbon Steel	
Dropin Weight Heavy End1_3THK_GJ(Default)	1	5102.16	0.28	5102.16	BPVC Carbon Steel	
Dropin Weight Heavy End1_1THK_GJ(lifting_drop-in_no2)	1	1681.78	0.28	1681.78	BPVC Carbon Steel	
Max Weight Tie Rod_3_GJ(drop_in_wt2_length)	4	18.5	0.28	74	BPVC Carbon Steel	
98427A600_HEX NUT FOR ASTM A325 STRUCTURAL BOLTS_GJ	8	1.37	0.28	10.94	BPVC Carbon Steel	
Lift Lug Reinforce_GJ	1	7.69	0.28	7.69	BPVC Carbon Steel	
91583A359_GALVANIZED STL HEAVY HEX HEAD STRUCTURAL BOLT_GJ(91583A359)	30	2.72	0.28	81.59	BPVC Carbon Steel	81.59
91571A340_STEEL HEAVY HEX HEAD STRUCTURAL BOLT_GJ(92620A966)	24	1.51	0.28	36.13	BPVC Carbon Steel	36.13
					Total Weight	417992.46

Table 5-4: Minimum Condition Test Load Cradle Weight Evaluation

File Name	Quantity	Mass	Density	Total Weight	SW-Material	Top-Level Weight
A2-Base Weldment Assembly	1	19978.14	0.28	19978.14	Top Subassembly	19978.14
A2-Key Sub assy	1	7155.4	0.28	7155.4	Subassembly	
A2-12 Plate 3.0 X 93.5 X 37.75(Bot Plt)	1	2711.81	0.28	2711.81	Low Alloy Steel	
A2-12 Plate 3.0 X 93.5 X 37.75(Top Plt)	1	2696.44	0.28	2696.44	Low Alloy Steel	
A2-13 Plate 3.0 X 93.5 X 9.5	2	745.89	0.28	1491.78	Low Alloy Steel	
A2-10 Plate 2.0 X 24.0 X 15.5	2	127.68	0.28	255.36	Low Alloy Steel	
A2-Beam Weldment	2	3512.69	0.28	7025.38	Subassembly	
A2-01 W 18 X 119	2	1726.58	0.28	3453.17	Low Alloy Steel	
A2-03 Plate 1.0 X 178.1 X 16.9	4	821.22	0.28	3284.89	Low Alloy Steel	
A2-16 Round 6.5 DIA X 11.25	4	64.66	0.29	258.64	BPVC 300 Series	
A2-02 Plate .13 X 19 X 11.3	4	7.17	0.28	28.68	Low Alloy Steel	
A2-Saddle Sub Weldment	2	1956.2	0.28	3912.4	Subassembly	
A2-05 Plate 1.0 X 112.0X 50.0	4	755.39	0.28	3021.55	Low Alloy Steel	
A2-06 Plate 1.0 X 122.5 X 8.25	2	261.94	0.28	523.88	Low Alloy Steel	
A2-11 Plate 2.0 X 14.7 X 6.25	4	56.46	0.28	225.84	Low Alloy Steel	
A2-04 Plate 1.0 X 24.0 X 15.5(Default)	4	35.28	0.28	141.12	Low Alloy Steel	
A2-15 Plate 3.0 X 6.0 X 93.5	4	471.24	0.28	1884.96	Low Alloy Steel	
A3-4-Bolt Tiedown Weldment	2	1013.65	0.28	2027.3	Top Subassembly	2027.3
A3-08 Plate 4-Bolt	2	575.17	0.28	1150.34	Low Alloy Steel	
A3-07 Plate 4-Bolt	2	321.94	0.28	643.88	Low Alloy Steel	
A3-09 4-Bolt	4	37.48	0.28	149.93	Low Alloy Steel	
A3-0X Cap 4-Bolt	4	20.79	0.28	83.15	Low Alloy Steel	
A1-14 Key	1	836.84	0.29	836.84	BPVC 300 Series	836.84
HX-SHCS 1.375-6x4.25x3.5-N	16	2.85	0.28	45.52	BPVC Carbon Steel	45.52
					Total Weight	22887.8

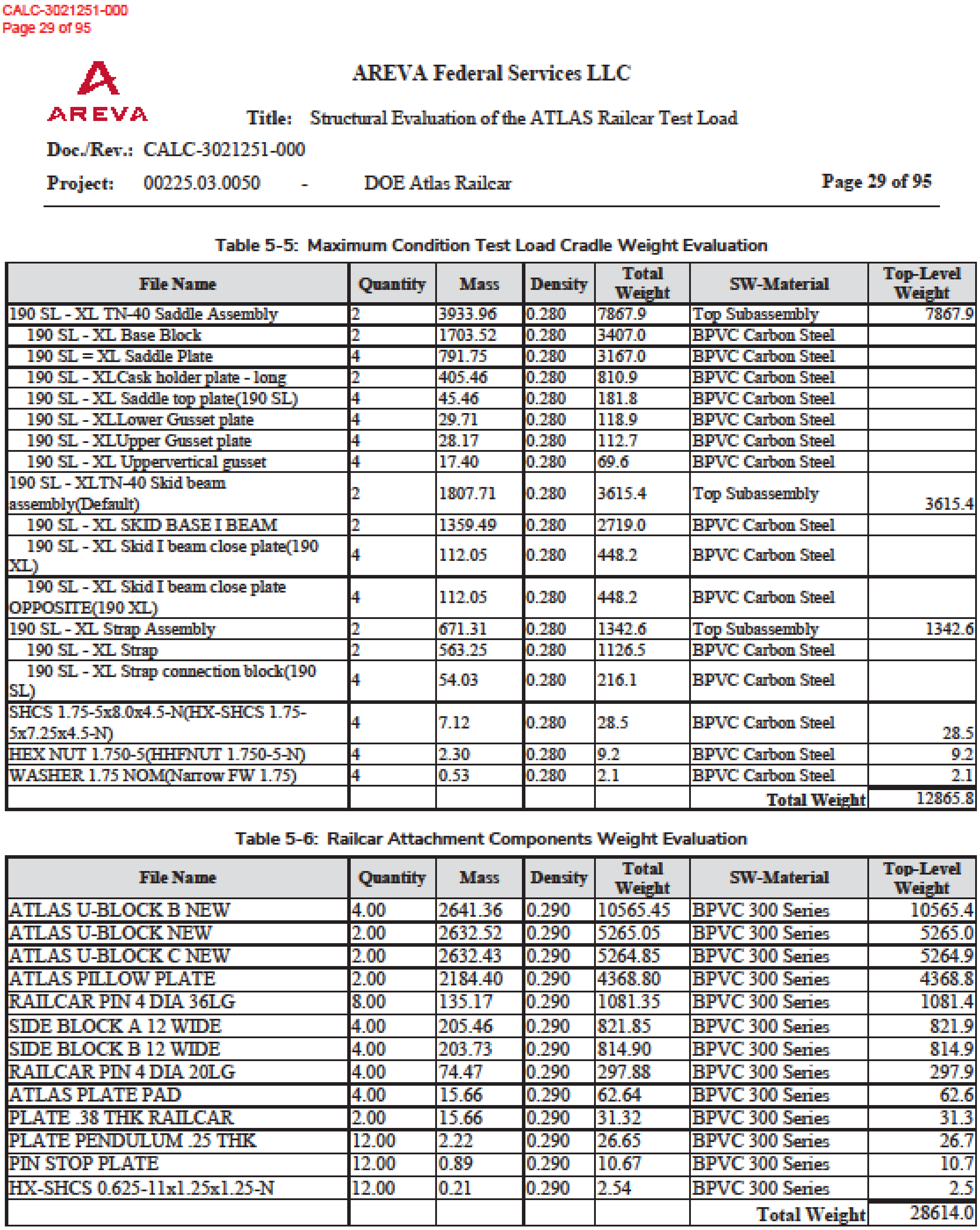


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Table 5-5: Maximum Condition Test Load Cradle Weight Evaluation

File Name	Quantity	Mass	Density	Total Weight	SW-Material	Top-Level Weight
190 SL - XL TN-40 Saddle Assembly	2	3933.96	0.280	7867.9	Top Subassembly	7867.9
190 SL - XL Base Block	2	1703.52	0.280	3407.0	BPVC Carbon Steel	
190 SL = XL Saddle Plate	4	791.75	0.280	3167.0	BPVC Carbon Steel	
190 SL - XLCask holder plate - long	2	405.46	0.280	810.9	BPVC Carbon Steel	
190 SL - XL Saddle top plate(190 SL)	4	45.46	0.280	181.8	BPVC Carbon Steel	
190 SL - XLLower Gusset plate	4	29.71	0.280	118.9	BPVC Carbon Steel	
190 SL - XLUpper Gusset plate	4	28.17	0.280	112.7	BPVC Carbon Steel	
190 SL - XL Uppervertical gusset	4	17.40	0.280	69.6	BPVC Carbon Steel	
190 SL - XLTN-40 Skid beam assembly(Default)	2	1807.71	0.280	3615.4	Top Subassembly	3615.4
190 SL - XL SKID BASE I BEAM	2	1359.49	0.280	2719.0	BPVC Carbon Steel	
190 SL - XL Skid I beam close plate(190 XL)	4	112.05	0.280	448.2	BPVC Carbon Steel	
190 SL - XL Skid I beam close plate OPPOSITE(190 XL)	4	112.05	0.280	448.2	BPVC Carbon Steel	
190 SL - XL Strap Assembly	2	671.31	0.280	1342.6	Top Subassembly	1342.6
190 SL - XL Strap	2	563.25	0.280	1126.5	BPVC Carbon Steel	
190 SL - XL Strap connection block(190 SL)	4	54.03	0.280	216.1	BPVC Carbon Steel	
SHCS 1.75-5x8.0x4.5-N(HX-SHCS 1.75-5x7.25x4.5-N)	4	7.12	0.280	28.5	BPVC Carbon Steel	28.5
HEX NUT 1.750-5(HHFNUT 1.750-5-N)	4	2.30	0.280	9.2	BPVC Carbon Steel	9.2
WASHER 1.75 NOM(Narrow FW 1.75)	4	0.53	0.280	2.1	BPVC Carbon Steel	2.1
					Total Weight	12865.8

Table 5-6: Railcar Attachment Components Weight Evaluation

File Name	Quantity	Mass	Density	Total Weight	SW-Material	Top-Level Weight
ATLAS U-BLOCK B NEW	4.00	2641.36	0.290	10565.45	BPVC 300 Series	10565.4
ATLAS U-BLOCK NEW	2.00	2632.52	0.290	5265.05	BPVC 300 Series	5265.0
ATLAS U-BLOCK C NEW	2.00	2632.43	0.290	5264.85	BPVC 300 Series	5264.9
ATLAS PILLOW PLATE	2.00	2184.40	0.290	4368.80	BPVC 300 Series	4368.8
RAILCAR PIN 4 DIA 36LG	8.00	135.17	0.290	1081.35	BPVC 300 Series	1081.4
SIDE BLOCK A 12 WIDE	4.00	205.46	0.290	821.85	BPVC 300 Series	821.9
SIDE BLOCK B 12 WIDE	4.00	203.73	0.290	814.90	BPVC 300 Series	814.9
RAILCAR PIN 4 DIA 20LG	4.00	74.47	0.290	297.88	BPVC 300 Series	297.9
ATLAS PLATE PAD	4.00	15.66	0.290	62.64	BPVC 300 Series	62.6
PLATE .38 THK RAILCAR	2.00	15.66	0.290	31.32	BPVC 300 Series	31.3
PLATE PENDULUM .25 THK	12.00	2.22	0.290	26.65	BPVC 300 Series	26.7
PIN STOP PLATE	12.00	0.89	0.290	10.67	BPVC 300 Series	10.7
HX-SHCS 0.625-11x1.25x1.25-N	12.00	0.21	0.290	2.54	BPVC 300 Series	2.5
					Total Weight	28614.0

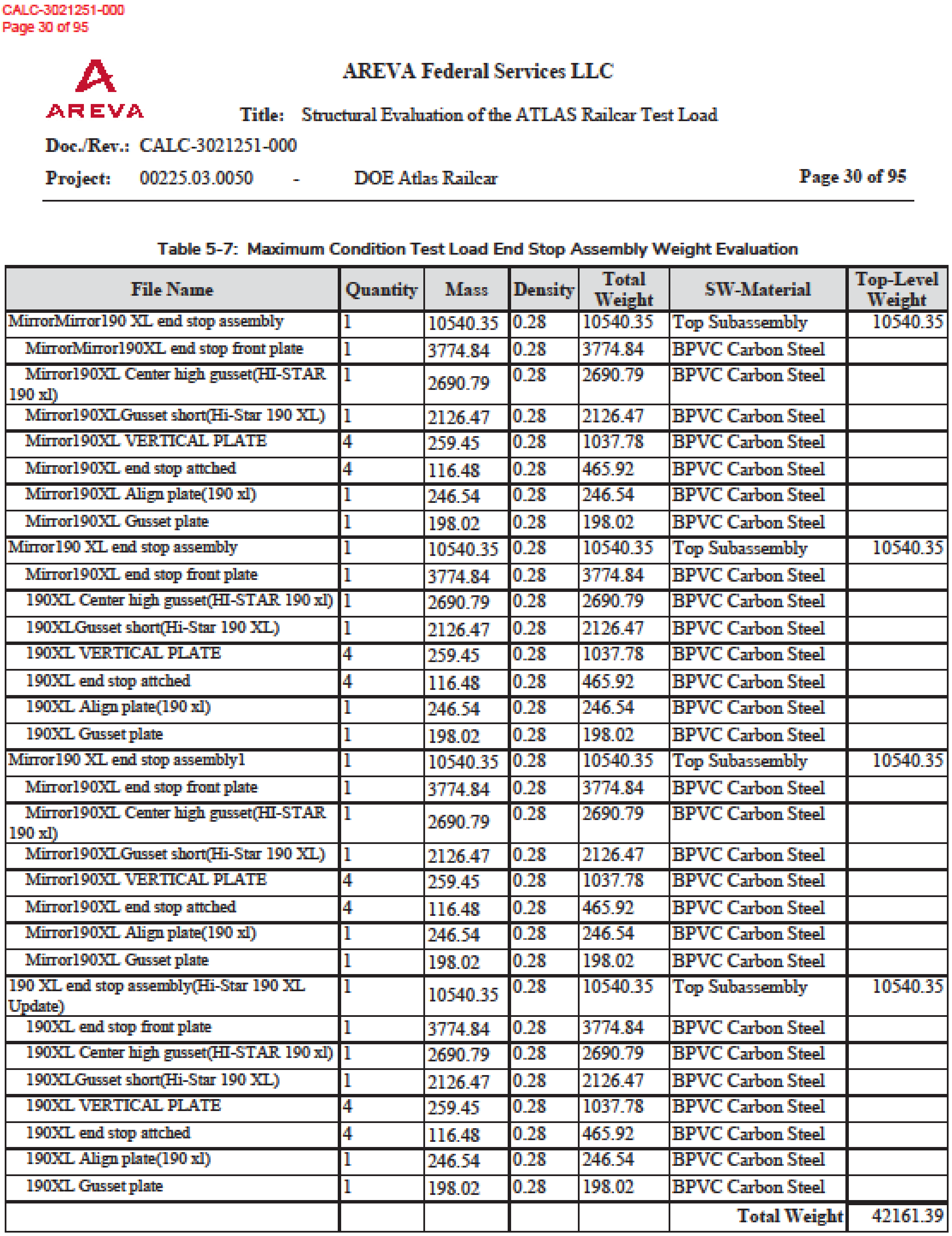

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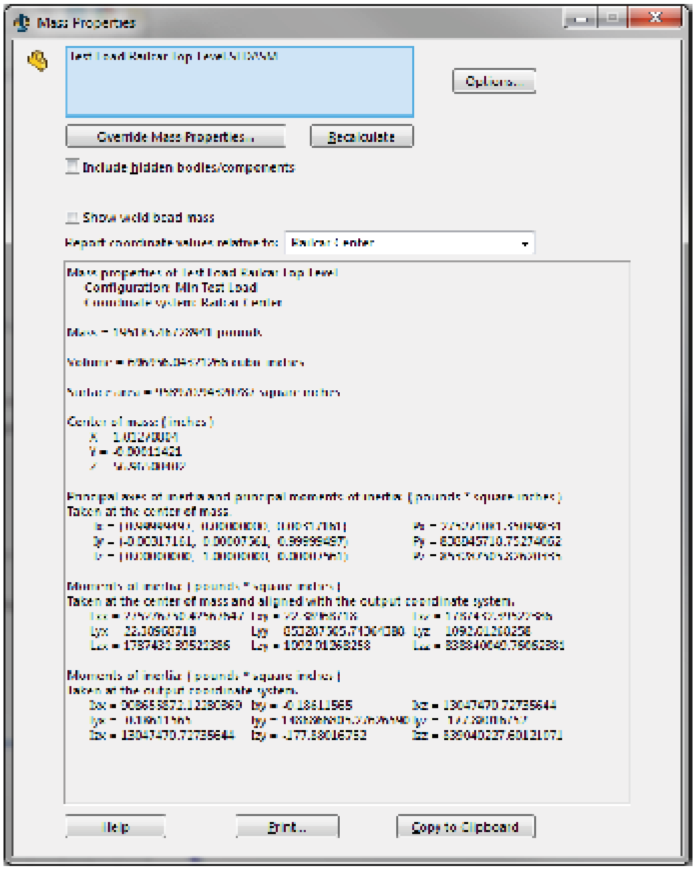
Table 5-7: Maximum Condition Test Load End Stop Assembly Weight Evaluation

File Name	Quantity	Mass	Density	Total Weight	SW-Material	Top-Level Weight
MirrorMirror190 XL end stop assembly	1	10540.35	0.28	10540.35	Top Subassembly	10540.35
MirrorMirror190XL end stop front plate	1	3774.84	0.28	3774.84	BPVC Carbon Steel	
Mirror190XL Center high gusset(HI-STAR 190 xl)	1	2690.79	0.28	2690.79	BPVC Carbon Steel	
Mirror190XLGusset short(Hi-Star 190 XL)	1	2126.47	0.28	2126.47	BPVC Carbon Steel	
Mirror190XL VERTICAL PLATE	4	259.45	0.28	1037.78	BPVC Carbon Steel	
Mirror190XL end stop attched	4	116.48	0.28	465.92	BPVC Carbon Steel	
Mirror190XL Align plate(190 xl)	1	246.54	0.28	246.54	BPVC Carbon Steel	
Mirror190XL Gusset plate	1	198.02	0.28	198.02	BPVC Carbon Steel	
Mirror190 XL end stop assembly	1	10540.35	0.28	10540.35	Top Subassembly	10540.35
Mirror190XL end stop front plate	1	3774.84	0.28	3774.84	BPVC Carbon Steel	
190XL Center high gusset(HI-STAR 190 xl)	1	2690.79	0.28	2690.79	BPVC Carbon Steel	
190XLGusset short(Hi-Star 190 XL)	1	2126.47	0.28	2126.47	BPVC Carbon Steel	
190XL VERTICAL PLATE	4	259.45	0.28	1037.78	BPVC Carbon Steel	
190XL end stop attched	4	116.48	0.28	465.92	BPVC Carbon Steel	
190XL Align plate(190 xl)	1	246.54	0.28	246.54	BPVC Carbon Steel	
190XL Gusset plate	1	198.02	0.28	198.02	BPVC Carbon Steel	
Mirror190 XL end stop assembly1	1	10540.35	0.28	10540.35	Top Subassembly	10540.35
Mirror190XL end stop front plate	1	3774.84	0.28	3774.84	BPVC Carbon Steel	
Mirror190XL Center high gusset(HI-STAR 190 xl)	1	2690.79	0.28	2690.79	BPVC Carbon Steel	
Mirror190XLGusset short(Hi-Star 190 XL)	1	2126.47	0.28	2126.47	BPVC Carbon Steel	
Mirror190XL VERTICAL PLATE	4	259.45	0.28	1037.78	BPVC Carbon Steel	
Mirror190XL end stop attched	4	116.48	0.28	465.92	BPVC Carbon Steel	
Mirror190XL Align plate(190 xl)	1	246.54	0.28	246.54	BPVC Carbon Steel	
Mirror190XL Gusset plate	1	198.02	0.28	198.02	BPVC Carbon Steel	
190 XL end stop assembly(Hi-Star 190 XL Update)	1	10540.35	0.28	10540.35	Top Subassembly	10540.35
190XL end stop front plate	1	3774.84	0.28	3774.84	BPVC Carbon Steel	
190XL Center high gusset(HI-STAR 190 xl)	1	2690.79	0.28	2690.79	BPVC Carbon Steel	
190XLGusset short(Hi-Star 190 XL)	1	2126.47	0.28	2126.47	BPVC Carbon Steel	
190XL VERTICAL PLATE	4	259.45	0.28	1037.78	BPVC Carbon Steel	
190XL end stop attched	4	116.48	0.28	465.92	BPVC Carbon Steel	
190XL Align plate(190 xl)	1	246.54	0.28	246.54	BPVC Carbon Steel	
190XL Gusset plate	1	198.02	0.28	198.02	BPVC Carbon Steel	
					Total Weight	42161.39

5.1.2 Center of Gravity and Mass Moment of Inertia Determinations

The Minimum Condition Test Load, Maximum Condition Test Load, Minimum Condition Test Load Cradle, and Maximum Condition Test Load Cradle CG and MMI values are provided in Table 5-9, Table 5-10, Table 5-11, and Table 5-12, respectively. These values are all based on the railcar reference coordinate system, which is centered between the two cradle pin centerlines and centered laterally on the railcar deck surface. The CG data for the Maximum Condition Test Load End Stops and Railcar Attachment Components is identified in Table 5-13 and Table 5-14. All MMIs and CGs output from SW use the same basic SW models that are documented by drawings identified in Section 5.1. The principal difference being as stated in Section 5.1 the weights in the SW models used herein were corrected for density errors in the drawing models.

Based on the design for the Minimum Condition Cask and Cradle inputted into the SW model, the combined cask/cradle inertial properties are determined for both the minimum and maximum condition test load/cradle combinations. These values are shown in Figure 5-1 and Figure 5-2 below for the minimum and maximum conditions, respectively.

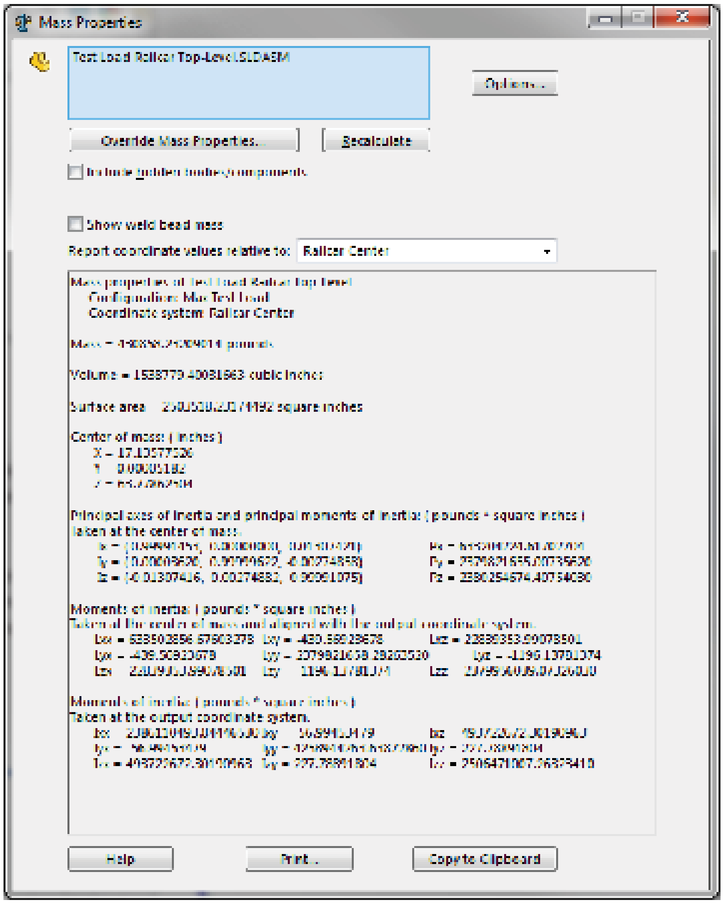


```
    Configuration: Min Test Load

Taken at the center of mass.

Taken at the center of mass and aligned with the output coordinate system.
```

Figure 5-1: Combined Minimum Condition Test Load/Cradle Mass Properties



Report coordinate values relative to: Railcar Center

```
Mass properties of Test Load Railcar Top-Level
    Configuration: Max Test Load
    Coordinate system: Railcar Center

Mass = [illegible] pounds

Volume = 1538779.40081663 cubic inches

Surface area = [illegible] square inches

Center of mass: ( inches )
    X = 17.10577526
    Y = 0.00005182
    Z = [illegible]

Principal axes of inertia and principal moments of inertia: ( pounds * square inches )
Taken at the center of mass.
    Ix = [illegible]                                    Px = [illegible]
    Iy = (0.00008626, 0.99999622, -0.00274858)          Py = 2579821655.00735620
    Iz = (-0.01307416, 0.00274882, 0.99991075)          Pz = 2380254674.40754030

Moments of inertia: ( pounds * square inches )
Taken at the center of mass and aligned with the output coordinate system.
    Lxx = 633502856.67903278  Lxy = -430.58628678        Lxz = 22880353.90078501
    Lyx = -430.50920679       Lyy = 2379821638.29202520     Lyz = -1196.13701374
    Lzx = [illegible]         Lzy = [illegible]          Lzz = [illegible]

Moments of inertia: ( pounds * square inches )
Taken at the output coordinate system.
    Ixx = [illegible]         Ixy = [illegible]          Ixz = [illegible]
    Iyx = [illegible]         Iyy = [illegible]          Iyz = [illegible]
    Izx = [illegible]         Izy = [illegible]          Izz = [illegible]
```

Figure 5-2: Combined Maximum Condition Test Load/Cradle Mass Properties

5.1.2.1 Overall Railcar Vertical CG Determination

Section 4.3.2.2 and Table 4-8 provides the parameters used in making a determination and comparison between the design phase overall railcar configuration for the maximum condition and the test load configuration.

The combined railcar overall vertical CG is a function of the mass and vertical center of gravity of each component and is calculated using the following equation:

$$cg\_z = \frac{m_{railcar} * cg_{z,railcar} + m_{Cask} * cg_{z,Cask} + m_{Cradle} * cg_{z,Cradle} + m_{endstops} * cg_{z,endstops} + m_{attach} * cg_{z,attach}}{m_{railcar} + m_{Cask} + m_{Cradle} + m_{endstops} + m_{attach}}$$

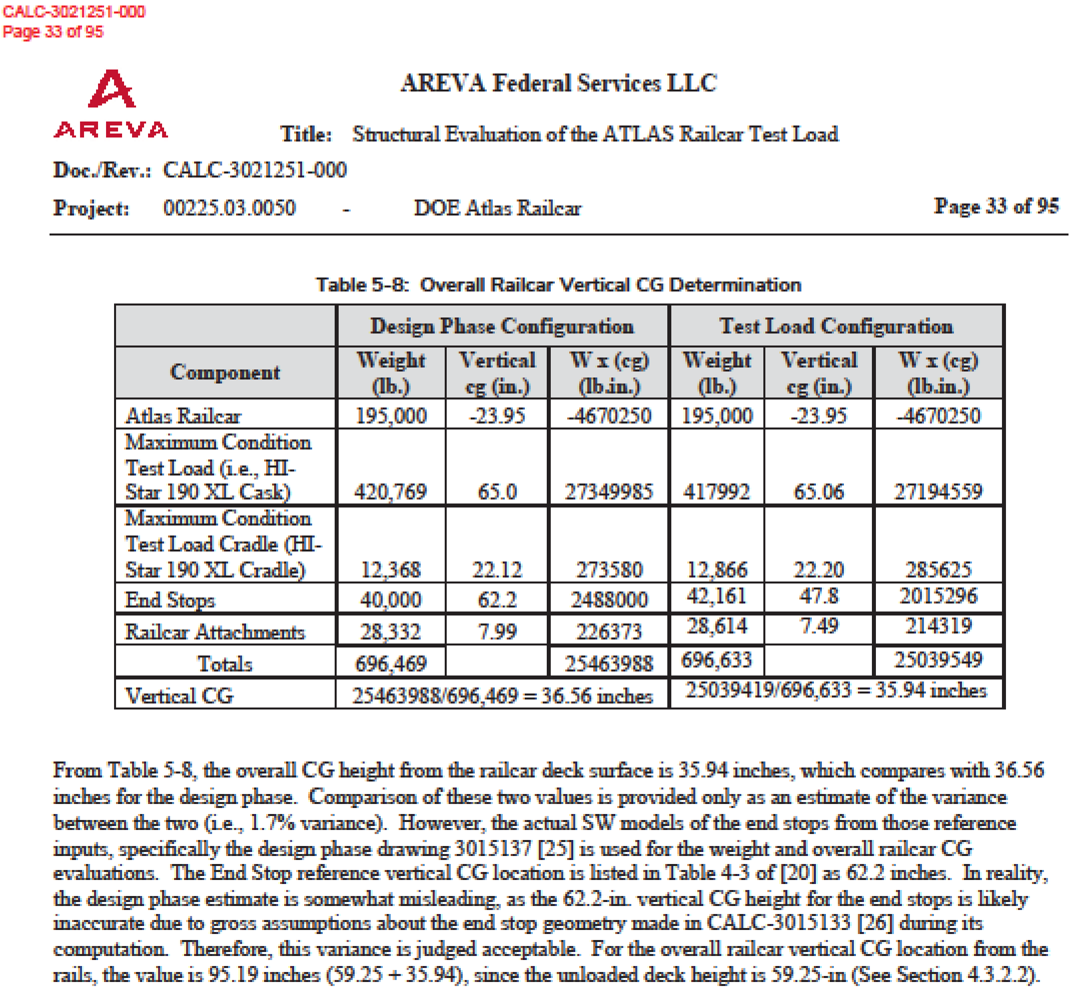


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Table 5-8: Overall Railcar Vertical CG Determination

	Design Phase Configuration			Test Load Configuration		
Component	**Weight (lb.)**	**Vertical cg (in.)**	**W x (cg) (lb.in.)**	**Weight (lb.)**	**Vertical cg (in.)**	**W x (cg) (lb.in.)**
Atlas Railcar	195,000	-23.95	-4670250	195,000	-23.95	-4670250
Maximum Condition Test Load (i.e., HI-Star 190 XL Cask)	420,769	65.0	27349985	417992	65.06	27194559
Maximum Condition Test Load Cradle (HI-Star 190 XL Cradle)	12,368	22.12	273580	12,866	22.20	285625
End Stops	40,000	62.2	2488000	42,161	47.8	2015296
Railcar Attachments	28,332	7.99	226373	28,614	7.49	214319
Totals	696,469		25463988	696,633		25039549
Vertical CG	25463988/696,469 = 36.56 inches			25039419/696,633 = 35.94 inches		

From Table 5-8, the overall CG height from the railcar deck surface is 35.94 inches, which compares with 36.56 inches for the design phase. Comparison of these two values is provided only as an estimate of the variance between the two (i.e., 1.7% variance). However, the actual SW models of the end stops from those reference inputs, specifically the design phase drawing 3015137 [25] is used for the weight and overall railcar CG evaluations. The End Stop reference vertical CG location is listed in Table 4-3 of [20] as 62.2 inches. In reality, the design phase estimate is somewhat misleading, as the 62.2-in. vertical CG height for the end stops is likely inaccurate due to gross assumptions about the end stop geometry made in CALC-3015133 [26] during its computation. Therefore, this variance is judged acceptable. For the overall railcar vertical CG location from the rails, the value is 95.19 inches (59.25 + 35.94), since the unloaded deck height is 59.25-in (See Section 4.3.2.2).

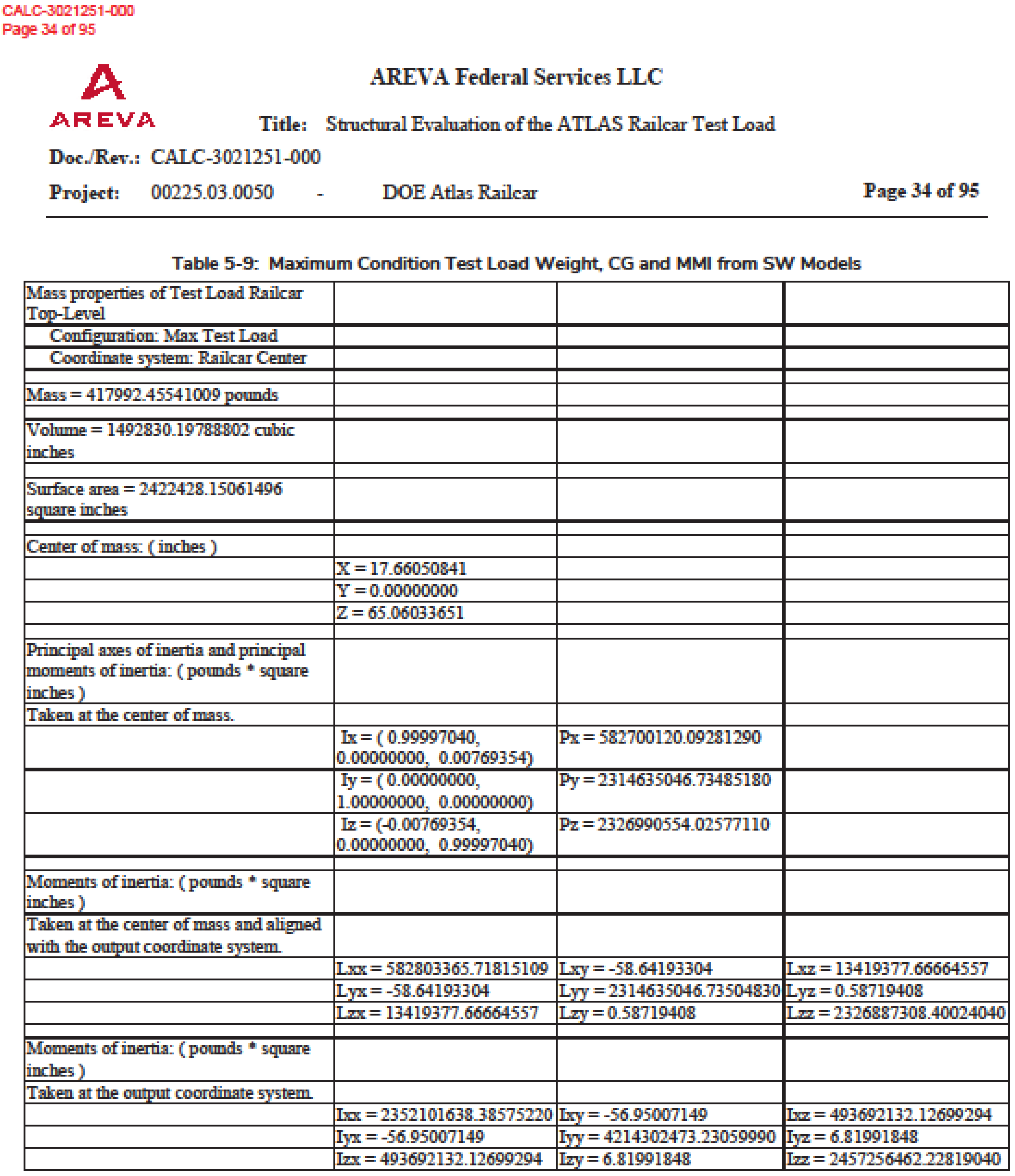

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Table 5-9: Maximum Condition Test Load Weight, CG and MMI from SW Models

Mass properties of Test Load Railcar Top-Level			
Configuration: Max Test Load			
Coordinate system: Railcar Center			
Mass = 417992.45541009 pounds			
Volume = 1492830.19788802 cubic inches			
Surface area = 2422428.15061496 square inches			
Center of mass: (inches)			
	X = 17.66050841		
	Y = 0.00000000		
	Z = 65.06033651		
Principal axes of inertia and principal moments of inertia: (pounds * square inches)			
Taken at the center of mass.			
	Ix = (0.99997040, 0.00000000, 0.00769354)	Px = 582700120.09281290	
	Iy = (0.00000000, 1.00000000, 0.00000000)	Py = 2314635046.73485180	
	Iz = (-0.00769354, 0.00000000, 0.99997040)	Pz = 2326990554.02577110	
Moments of inertia: (pounds * square inches)			
Taken at the center of mass and aligned with the output coordinate system.			
	Lxx = 582803365.71815109	Lxy = -58.64193304	Lxz = 13419377.66664557
	Lyx = -58.64193304	Lyy = 2314635046.73504830	Lyz = 0.58719408
	Lzx = 13419377.66664557	Lzy = 0.58719408	Lzz = 2326887308.40024040
Moments of inertia: (pounds * square inches)			
Taken at the output coordinate system.			
	Ixx = 2352101638.38575220	Ixy = -56.95007149	Ixz = 493692132.12699294
	Iyx = -56.95007149	Iyy = 4214302473.23059990	Iyz = 6.81991848
	Izx = 493692132.12699294	Izy = 6.81991848	Izz = 2457256462.22819040

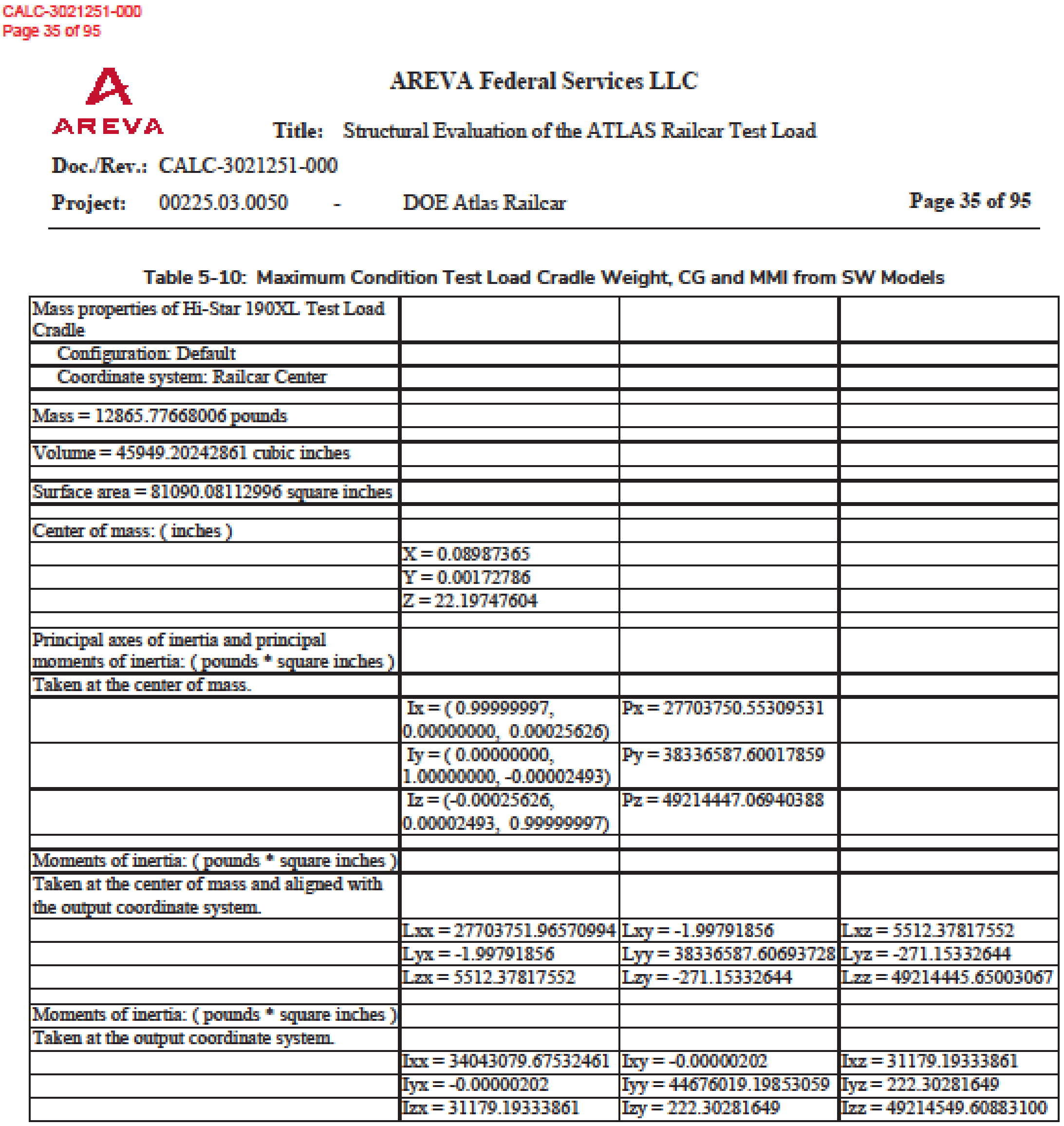

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Table 5-10: Maximum Condition Test Load Cradle Weight, CG and MMI from SW Models

Mass properties of Hi-Star 190XL Test Load Cradle			
Configuration: Default			
Coordinate system: Railcar Center			
Mass = 12865.77668006 pounds			
Volume = 45949.20242861 cubic inches			
Surface area = 81090.08112996 square inches			
Center of mass: (inches)			
	X = 0.08987365		
	Y = 0.00172786		
	Z = 22.19747604		
Principal axes of inertia and principal moments of inertia: (pounds * square inches)			
Taken at the center of mass.			
	Ix = (0.99999997, 0.00000000, 0.00025626)	Px = 27703750.55309531	
	Iy = (0.00000000, 1.00000000, -0.00002493)	Py = 38336587.60017859	
	Iz = (-0.00025626, 0.00002493, 0.99999997)	Pz = 49214447.06940388	
Moments of inertia: (pounds * square inches)			
Taken at the center of mass and aligned with the output coordinate system.			
	Lxx = 27703751.96570994	Lxy = -1.99791856	Lxz = 5512.37817552
	Lyx = -1.99791856	Lyy = 38336587.60693728	Lyz = -271.15332644
	Lzx = 5512.37817552	Lzy = -271.15332644	Lzz = 49214445.65003067
Moments of inertia: (pounds * square inches)			
Taken at the output coordinate system.			
	Ixx = 34043079.67532461	Ixy = -0.00000202	Ixz = 31179.19333861
	Iyx = -0.00000202	Iyy = 44676019.19853059	Iyz = 222.30281649
	Izx = 31179.19333861	Izy = 222.30281649	Izz = 49214549.60883100

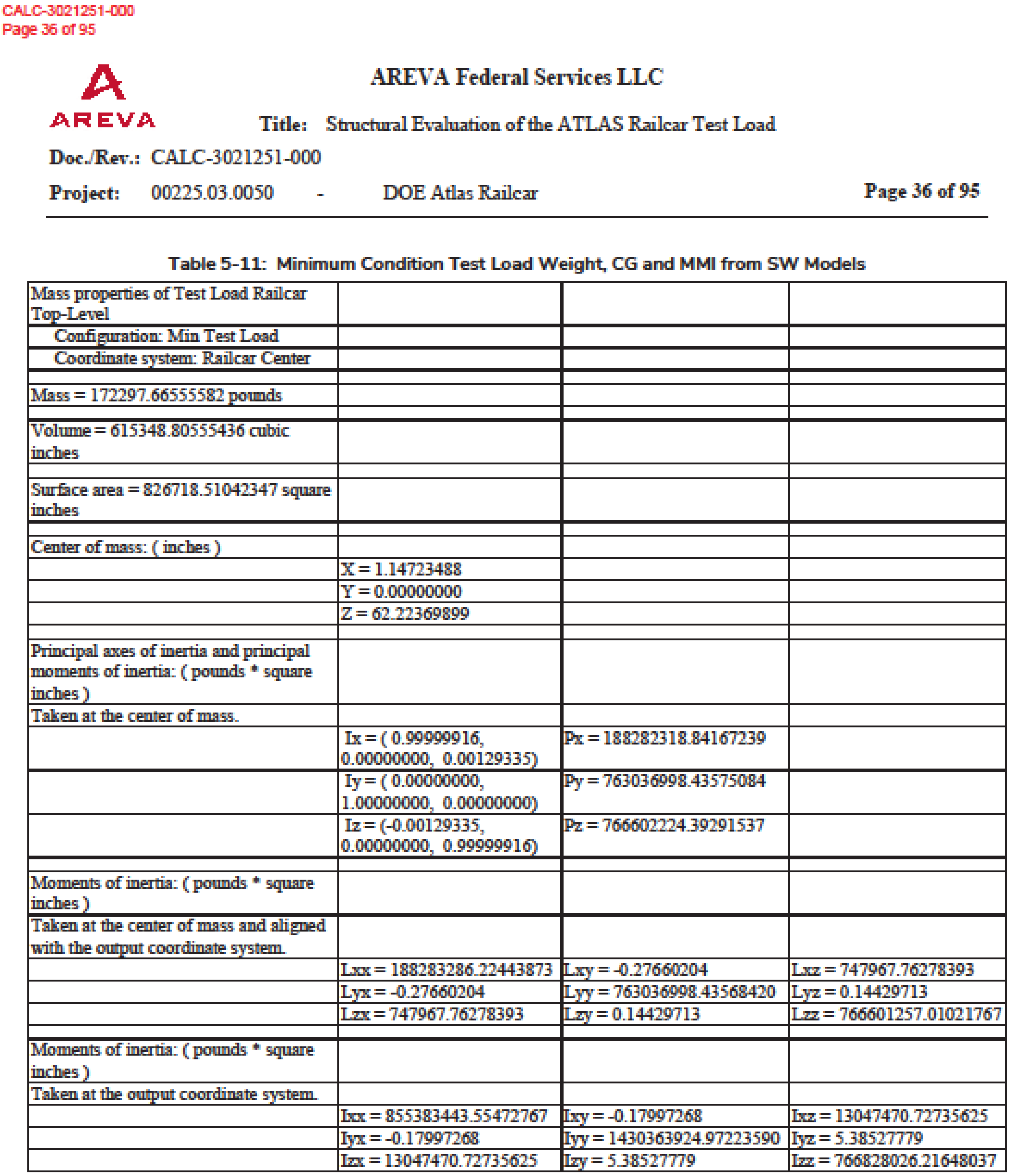

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Table 5-11: Minimum Condition Test Load Weight, CG and MMI from SW Models

Mass properties of Test Load Railcar Top-Level			
Configuration: Min Test Load			
Coordinate system: Railcar Center			
Mass = 172297.66555582 pounds			
Volume = 615348.80555436 cubic inches			
Surface area = 826718.51042347 square inches			
Center of mass: (inches)			
	X = 1.14723488		
	Y = 0.00000000		
	Z = 62.22369899		
Principal axes of inertia and principal moments of inertia: (pounds * square inches)			
Taken at the center of mass.			
	Ix = (0.99999916, 0.00000000, 0.00129335)	Px = 188282318.84167239	
	Iy = (0.00000000, 1.00000000, 0.00000000)	Py = 763036998.43575084	
	Iz = (-0.00129335, 0.00000000, 0.99999916)	Pz = 766602224.39291537	
Moments of inertia: (pounds * square inches)			
Taken at the center of mass and aligned with the output coordinate system.			
	Lxx = 188283286.22443873	Lxy = -0.27660204	Lxz = 747967.76278393
	Lyx = -0.27660204	Lyy = 763036998.43568420	Lyz = 0.14429713
	Lzx = 747967.76278393	Lzy = 0.14429713	Lzz = 766601257.01021767
Moments of inertia: (pounds * square inches)			
Taken at the output coordinate system.			
	Ixx = 855383443.55472767	Ixy = -0.17997268	Ixz = 13047470.72735625
	Iyx = -0.17997268	Iyy = 1430363924.97223590	Iyz = 5.38527779
	Izx = 13047470.72735625	Izy = 5.38527779	Izz = 766828026.21648037

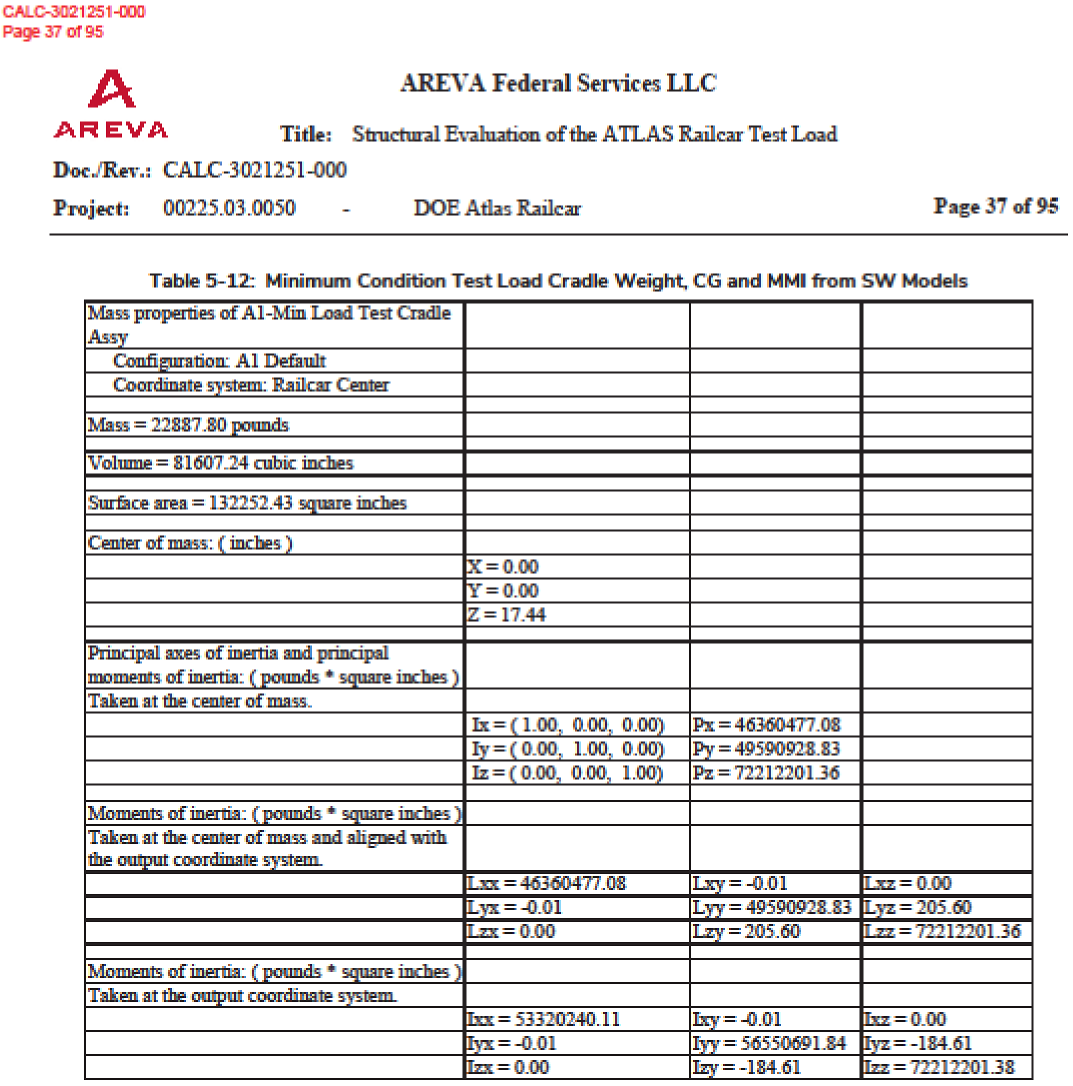

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Table 5-12: Minimum Condition Test Load Cradle Weight, CG and MMI from SW Models

Mass properties of A1-Min Load Test Cradle Assy			
Configuration: A1 Default			
Coordinate system: Railcar Center			
Mass = 22887.80 pounds			
Volume = 81607.24 cubic inches			
Surface area = 132252.43 square inches			
Center of mass: (inches)			
	X = 0.00		
	Y = 0.00		
	Z = 17.44		
Principal axes of inertia and principal moments of inertia: (pounds * square inches)			
Taken at the center of mass.			
	Ix = (1.00, 0.00, 0.00)	Px = 46360477.08	
	Iy = (0.00, 1.00, 0.00)	Py = 49590928.83	
	Iz = (0.00, 0.00, 1.00)	Pz = 72212201.36	
Moments of inertia: (pounds * square inches)			
Taken at the center of mass and aligned with the output coordinate system.			
	Lxx = 46360477.08	Lxy = -0.01	Lxz = 0.00
	Lyx = -0.01	Lyy = 49590928.83	Lyz = 205.60
	Lzx = 0.00	Lzy = 205.60	Lzz = 72212201.36
Moments of inertia: (pounds * square inches)			
Taken at the output coordinate system.			
	Ixx = 53320240.11	Ixy = -0.01	Ixz = 0.00
	Iyx = -0.01	Iyy = 56550691.84	Iyz = -184.61
	Izx = 0.00	Izy = -184.61	Izz = 72212201.38

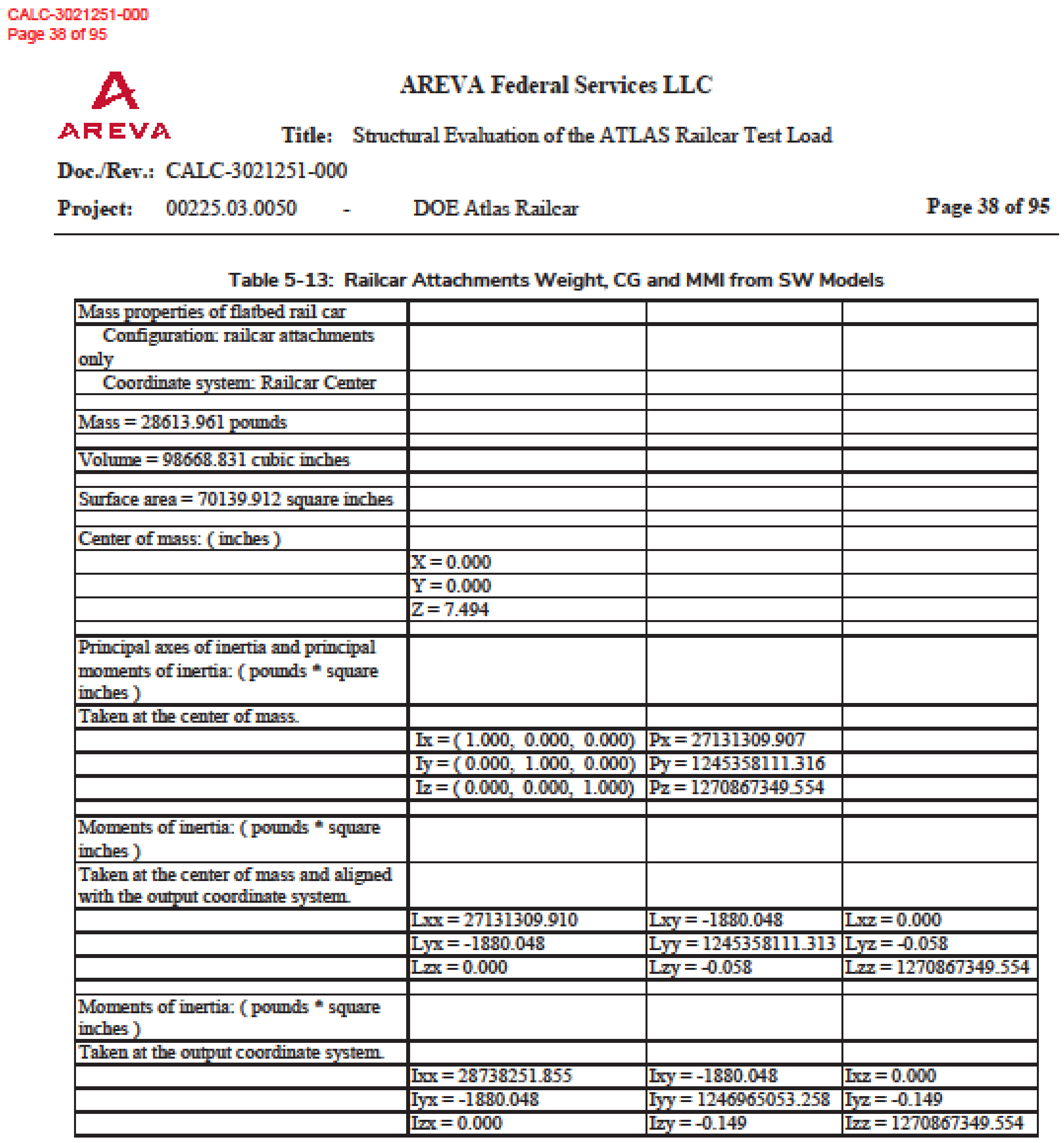

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Table 5-13: Railcar Attachments Weight, CG and MMI from SW Models

Mass properties of flatbed rail car			
Configuration: railcar attachments only			
Coordinate system: Railcar Center			
Mass = 28613.961 pounds			
Volume = 98668.831 cubic inches			
Surface area = 70139.912 square inches			
Center of mass: (inches)			
	X = 0.000		
	Y = 0.000		
	Z = 7.494		
Principal axes of inertia and principal moments of inertia: (pounds * square inches)			
Taken at the center of mass.			
	Ix = (1.000, 0.000, 0.000)	Px = 27131309.907	
	Iy = (0.000, 1.000, 0.000)	Py = 1245358111.316	
	Iz = (0.000, 0.000, 1.000)	Pz = 1270867349.554	
Moments of inertia: (pounds * square inches)			
Taken at the center of mass and aligned with the output coordinate system.			
	Lxx = 27131309.910	Lxy = -1880.048	Lxz = 0.000
	Lyx = -1880.048	Lyy = 1245358111.313	Lyz = -0.058
	Lzx = 0.000	Lzy = -0.058	Lzz = 1270867349.554
Moments of inertia: (pounds * square inches)			
Taken at the output coordinate system.			
	Ixx = 28738251.855	Ixy = -1880.048	Ixz = 0.000
	Iyx = -1880.048	Iyy = 1246965053.258	Iyz = -0.149
	Izx = 0.000	Izy = -0.149	Izz = 1270867349.554

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Table 5-14: End Stops Weight, CG and MMI from SW Models

Mass properties of Test Load Railcar Top-Level			
Configuration: End Stops only			
Coordinate system: Railcar Center			
Mass = 42161.39142871 pounds			
Volume = 150576.39795916 cubic inches			
Surface area = 180179.56112098 square inches			
Center of mass: (inches)			
	X = 0.00000000		
	Y = 0.00000000		
	Z = 47.76032135		
Principal axes of inertia and principal moments of inertia: (pounds * square inches)			
Taken at the center of mass.			
	Ix = (1.00000000, 0.00000000, 0.00000000)	Px = 78401369.88170610	
	Iy = (0.00000000, 1.00000000, 0.00000000)	Py = 1854108536.35488010	
	Iz = (0.00000000, 0.00000000, 1.00000000)	Pz = 1856261426.89542410	
Moments of inertia: (pounds * square inches)			
Taken at the center of mass and aligned with the output coordinate system.			
	Lxx = 78401369.88170607	Lxy = 0.00000000	Lxz = -0.00000578
	Lyx = 0.00000000	Lyy = 1854108536.35485670	Lyz = 0.00000000
	Lzx = -0.00000578	Lzy = 0.00000000	Lzz = 1856261426.89545230
Moments of inertia: (pounds * square inches)			
Taken at the output coordinate system.			
	Ixx = 174573539.93471280	Ixy = 0.00000000	Ixz = -0.00000359
	Iyx = 0.00000000	Iyy = 1950280706.40786310	Iyz = 0.00000000
	Izx = -0.00000359	Izy = 0.00000000	Izz = 1856261426.89545230

5.2 Structural Calculations

5.2.1 Drop-In Weight Tie-Rod Evaluations

This section provides minimum structural properties for the Tie-Rods used as load support for each individual drop-in weight. The drop-in weights are used for both the minimum and maximum condition test loads (See Drawings 3020458 [3] and 3020460 [2]). As shown in Figure 2-6 and Figure 2-7, each drop-in weight is made-up of individual plates, which are stacked together and held secure by heavy hex nuts on the outside plates. The center of mass of each plate bundle is reacted by the clamping friction forces in the threaded connections. The principle function of the tie-rods is to keep the plates together during handling operations, indicating the rods primary function is to take the 1g self-weight and any dynamic factor from lifting. However, for conservatism, the analysis below also conducts a simplified review of the tie-rod threaded connections provided the inertial loads act on each of the drop-in weights, independently. See spreadsheet CALC-30201251-000.xlsx identified in Section 6.1 for detailed load evaluations and computations.

Since the CG location for each bundle is assumed symmetric with the tie-rods used to secure the bundle, each threaded connection will take a fraction of the total inertial load, dependent upon the number of rods in the bundle. For this evaluation, it is assumed that the worst-case 2g (either lateral or vertical) or 3g (longitudinal) load acts at the CG location and is reacted by each of the threaded connections. For minimum condition Drop-In Weights #1 and #2, both have threaded rods for self-retention and threaded rods for securement to the strongback endcap saddle plate. For self-retention in all drop-in weight cases, four 1.5-6 UNC threaded rod connections are used. For the two drop-in weights on the strongback (Min Drop-In #1 and #2), eight 1-8 UNC threaded rods are used instead. A shear strength analysis and slip critical joint analysis from the AISC SCM are conducted to ensure the allowable strength is greater than the required strength.

For all tie rods, the material is ASTM A193, Grade B7 [14] threaded rod stock. Since the ASTM A563 Heavy Hex Nuts are Grade DH [13] with a proof load stress of 175ksi (See Section 4.1), then the threaded rod tensile strength is bounding for the load evaluations. The 10 different drop-in weight combinations from Table 5-16 are shown in Figure 2-6 and Figure 2-7.

First, calculate the allowable shear strength (R_n/Ω) for the connections using the AISC Steel Construction Manual [17]. Equation J3-1 from [17] is provided for the allowable shear strength as:

$$R_n = F_{nv} \times A_b$$

Where, F_{nv} = Shear Stress – this is provided by ($0.4 \times F_u$) when threads are not excluded from the shear plane

A_b = Nominal unthreaded Body Diameter

Ω = Allow. Shear Safety Factor = 2

Next, calculate the allowable slip resistance (R_n/Ω) for the connections from Equation J3-4 [17]:

$$R_n = \mu \times D_u \times h_f \times T_b \times N_s$$

Where,

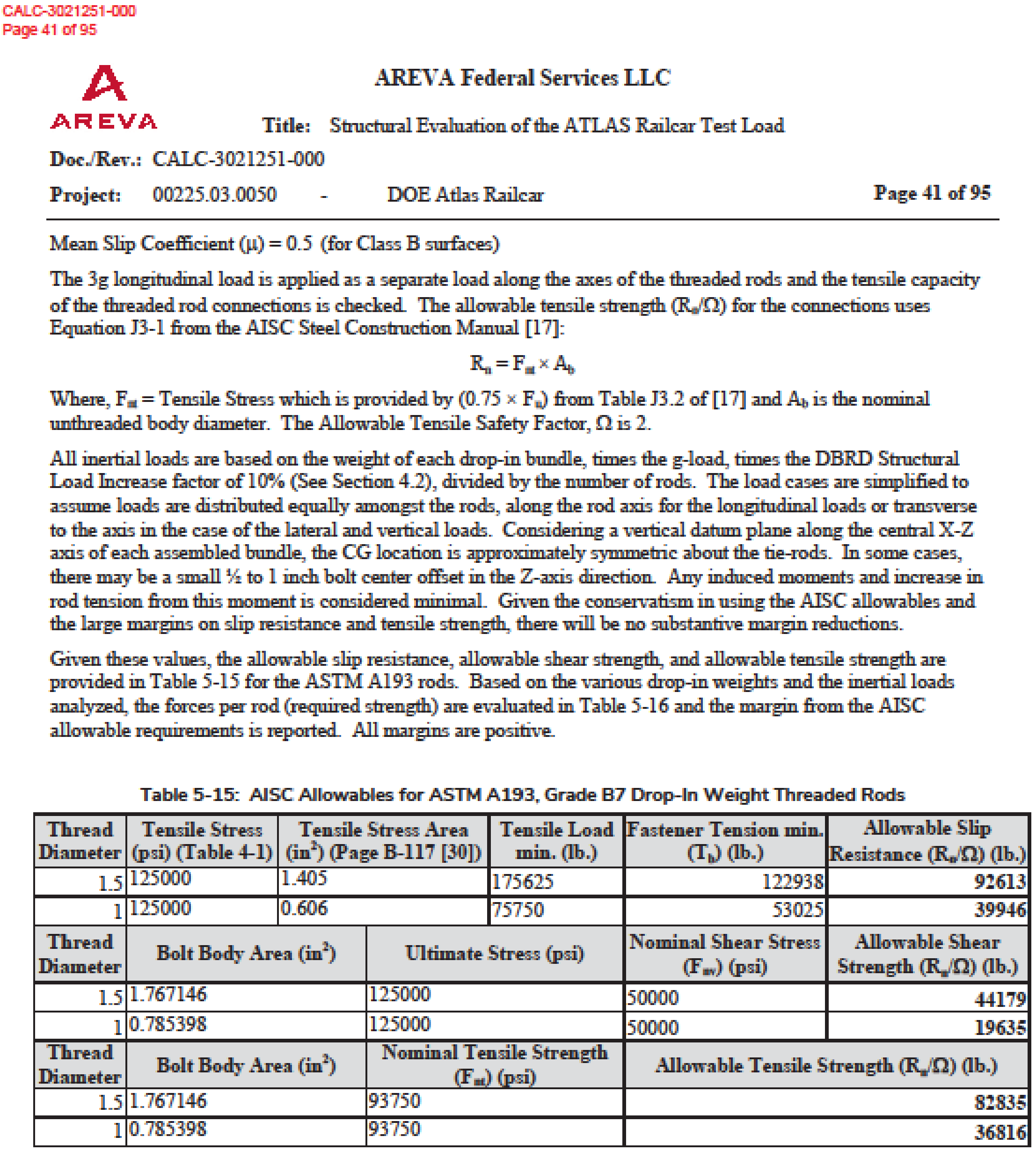
Ω = Allow. Slip Safety Factor = 1.5 (for standard size holes)

Minimum Fastener Tension (T_b) (lb.) – this is provided by (0.7 × tensile strength as provided in Table 4 of ASTM A193 [14]). Of note, Table J3.1 of [17] is basis for 0.7 factor.

Number of Slip Planes (N_s) = 2 (conservatively chosen considering only two outer bundle plates)

Filler Factor (h_f) = 1 (although multiple plates in bundle, assume this value is 1)

Multiplier Factor (D_u) = 1.13



Mean Slip Coefficient (μ) = 0.5 (for Class B surfaces)

The 3g longitudinal load is applied as a separate load along the axes of the threaded rods and the tensile capacity of the threaded rod connections is checked. The allowable tensile strength (R_n/Ω) for the connections uses Equation J3-1 from the AISC Steel Construction Manual [17]:

$$R_n = F_{nt} \times A_b$$

Where, F_{nt} = Tensile Stress which is provided by ($0.75 \times F_u$) from Table J3.2 of [17] and A_b is the nominal unthreaded body diameter. The Allowable Tensile Safety Factor, Ω is 2.

All inertial loads are based on the weight of each drop-in bundle, times the g-load, times the DBRD Structural Load Increase factor of 10% (See Section 4.2), divided by the number of rods. The load cases are simplified to assume loads are distributed equally amongst the rods, along the rod axis for the longitudinal loads or transverse to the axis in the case of the lateral and vertical loads. Considering a vertical datum plane along the central X-Z axis of each assembled bundle, the CG location is approximately symmetric about the tie-rods. In some cases, there may be a small ½ to 1 inch bolt center offset in the Z-axis direction. Any induced moments and increase in rod tension from this moment is considered minimal. Given the conservatism in using the AISC allowables and the large margins on slip resistance and tensile strength, there will be no substantive margin reductions.

Given these values, the allowable slip resistance, allowable shear strength, and allowable tensile strength are provided in Table 5-15 for the ASTM A193 rods. Based on the various drop-in weights and the inertial loads analyzed, the forces per rod (required strength) are evaluated in Table 5-16 and the margin from the AISC allowable requirements is reported. All margins are positive.

Table 5-15: AISC Allowables for ASTM A193, Grade B7 Drop-In Weight Threaded Rods

<table>
<tr><th>Thread Diameter</th><th>Tensile Stress (psi) (Table 4-1)</th><th>Tensile Stress Area (in^2) (Page B-117 [30])</th><th>Tensile Load min. (lb.)</th><th>Fastener Tension min. (T_b) (lb.)</th><th>Allowable Slip Resistance (R_n/Ω) (lb.)</th></tr>
<tr><td>1.5</td><td>125000</td><td>1.405</td><td>175625</td><td>122938</td><td>92613</td></tr>
<tr><td>1</td><td>125000</td><td>0.606</td><td>75750</td><td>53025</td><td>39946</td></tr>
<tr><th>Thread Diameter</th><th colspan="2">Bolt Body Area (in^2)</th><th>Ultimate Stress (psi)</th><th>Nominal Shear Stress (F_{nv}) (psi)</th><th>Allowable Shear Strength (R_n/Ω) (lb.)</th></tr>
<tr><td>1.5</td><td colspan="2">1.767146</td><td>125000</td><td>50000</td><td>44179</td></tr>
<tr><td>1</td><td colspan="2">0.785398</td><td>125000</td><td>50000</td><td>19635</td></tr>
<tr><th>Thread Diameter</th><th colspan="2">Bolt Body Area (in^2)</th><th>Nominal Tensile Strength (F_{nt}) (psi)</th><th colspan="2">Allowable Tensile Strength (R_n/Ω) (lb.)</th></tr>
<tr><td>1.5</td><td colspan="2">1.767146</td><td>93750</td><td colspan="2">82835</td></tr>
<tr><td>1</td><td colspan="2">0.785398</td><td>93750</td><td colspan="2">36816</td></tr>
</table>

5.2.1.1 Slip-Critical Joint Installation to Obtain Joint Preload

When assembled, all joint surfaces including those between the drop-in plate connection faying surfaces shall be free of scale. Per the AISC code, for the slip-critical connection analysis, it is conservatively evaluated as one joint per rod, instead of one joint per connecting nut. The preload places strain on the threaded rod and causes compression on the clamped drop-in weights. When a tensile load is applied to the joint, some portion of the applied load acts to relieve the compression in the clamped parts and the other portion further strains the rod. The portion of the applied load that is carried by the threaded connection is dependent on the relative stiffness of the rod and the clamped parts. This ability of the joint to prevent separation is verified via the slip-critical resistance verification check.

For the AISC code requirements, it is invalid to use published values based on a torque tension relationship. In accordance with the SCM (Page 16.1-118 [17]), there are four allowed methods for maintaining sufficient clamping load in a slip-critical joint: turn-of-nut method, a direct-tension-indicator, twist-off-type tension-control bolt, calibrated wrench, or alternative bolt design. For this application, the recommendation either is to use the turn-of-nut method or calibrated wrench method for only the minimum condition drop-in weight tie-rods self-retention and securement to the strongback endcap saddle plate. However, for the remainder of the tie-rod axial clamping assemblies, direct tensioning of the tie-rods is required (e.g. Hydraulic Tensioners), since the overall length of the tie-rods does not meet the requirement to be less than 12 times the rod diameter (See Section J3.1 of [17]).

Table 5-16: Tie-Rod Required Shear Strength, Slip Resistance and Tensile Strength and Margins to Allowables

Evaluated Weight Configuration	Inertial Accelerations			Self Weight (lb.)	Tie-Rods		Required Strength			Margin Evaluations (R_n/Ω)		
	Lateral	Vertical	Longitudinal		Diameter (in.)	Qty.	Forces/Per Rod (lb.)			Allowable Slip Resistance	Allowable Shear Strength	Allowable Tensile Strength
							Lateral	Vertical	Longitudinal	Lateral or Vertical	Lateral or Vertical	Longitudinal
Min. Drop-In #1 (self)	2	2	3	16041	1.5	4	8823	8823	13234	90%	80%	84%
Min. Drop-In #1 (on strongback)	2	2	3	16041	1	8	4411	4411	6617	89%	78%	82%
Min. Drop-In #2 (self)	2	2	3	19095	1.5	4	10502	10502	15753	89%	76%	81%
Min. Drop-In #2 (on strongback)	2	2	3	19095	1	8	5251	5251	7877	87%	73%	79%
Max. Drop-In #1	2	2	3	40472	1.5	4	22260	22260	33389	76%	50%	60%
Max. Drop-In #2	2	2	3	63896	1.5	4	35143	35143	52714	62%	20%	36%
Max. Drop-In #3	2	2	3	68125	1.5	4	37469	37469	56203	60%	15%	32%
Max. Drop-In #4	2	2	3	67806	1.5	4	37293	37293	55940	60%	16%	32%
Saddle Bundle Weight	2	2	3	26912	1.5	4	14802	14802	22202	84%	66%	73%
Shear Key Weight	2	2	3	46396	1.5	4	25518	25518	38277	72%	42%	54%

5.2.2 Drop-In Weight Bolt Evaluations

This section provides minimum structural properties for the bolts used to connect each individual drop-in weight to the strongback (See Figure 5-5 and Figure 5-6). The bolts are used for the drop-in weights on the maximum condition test load (See Drawing 3020460 [2]). The bolts secure the weights and react the inertial loads from the weight of the individual drop-in weight assemblies. As shown in Figure 5-5, each Max Drop-in Weight #1 is connected on its outer plate with twelve 1-8 UNC bolts (6 on each side). Max Drop-in Weight #3 is secured to the saddle endcap plate on the inside and to the Max Drop-In Weight #4 on the outside with 22, 1.25-7 UNC bolts (14 on the inside and 8 on the outside).

In addition, this section evaluates the bolt loading occurring due to the combined weight of Max Drop-in #3 and Max Drop-in Weight #4 as a single weight reacted by its connection to the strongback structure. This combined Max Drop-in #3 and #4 Weight is secured on the inside face via the 14 1.25-7 UNC bolts which secure it to the saddle endcap plate. Finally, as shown in Figure 5-6, Max Drop-in Weight #2 is connected on its outer plate with eight 1.25-7 UNC bolts to the saddle endcap plate.

The center of mass of each plate bundle is reacted by the clamping friction forces in the bolted connections. The CG location for each bundle's bolt pattern is calculated in the spreadsheet CALC-30201251-000.xlsx identified in Section 6.1, with each bolt taking a portion of the total inertial load. For this evaluation, the inertial loads on the bolted connections are applied, with each of the 2g (either lateral or vertical) and 3g (longitudinal) loads acting independently at the CG location. A combined shear and tension strength analysis and slip critical joint analysis from the SCM [17] are conducted to ensure the allowable strength is greater than the required strength. In addition, the longitudinal 3g load is considered acting on each of the plate bundle assemblies. The five distinct drop-in load combinations are shown in Table 5-18, with the margin evaluations shown in Table 5-19.

In similar fashion to the tie-rod connection analysis in Section 5.2.1.1, the bolted connections reviewed are to maintain preload as a slip-critical connection in accordance with the AISC code. For the AISC code requirements, it is invalid to use published values based on a torque tension relationship when using a slip-critical connection. Therefore, the four allowed methods for maintaining sufficient clamping load in a slip-critical joint: turn-of-nut method, a direct-tension-indicator, twist-off-type tension-control bolt, calibrated wrench, or alternative bolt design. For this application, the recommendation either is to use the turn-of-nut method or calibrated wrench method for all of the bolted connections.

Per Section 4.1, the material for the bolted connections is 120 ksi – Grade A325 ASTM F3125 steel [28]. The AISC calculated allowables for this material are shown in Table 5-17. These values were determined in identical fashion to the tie-rod bolt allowable determinations from Section 5.2.1, except using the different material and fastener diameters. The only adjustment to the lateral and longitudinal allowable slip resistance comes because of the induced moments on the bolts, which reduces the net clamping force. This factor (k_{sc}) is provided in Section J3.9 of the SCM [17] as follows:

$$k_{sc} = 1 - \frac{1.5T_a}{D_u T_b n_b}$$

Where,

T_a = required Tensile force using ASD load combinations

n_b = number of bolts carrying the applied tension

Minimum Fastener Tension (T_b) (lb.) – this is provided by (0.7 × tensile strength as provided in Table 4 of ASTM F3125 [28]). Of note, Table J3.1 of [17] is basis for 0.7 factor.

Multiplier Factor (D_u) = 1.13

The shear and tensile required bolt loads for each of the three loading cases on the bolt patterns is calculated in the spreadsheet CALC-30201251-000.xlsx identified in Section 6.1, with each individual bolt load reported. The maximum shear and tensile force is drawn from the analysis and used to assess the margins on shear strength, tensile strength and slip resistance. The bolt pattern dimensions, distances to the CG for moment calculations, and drop-in weight values are all taken from the attached SW model "Max Test Weight Assembly_GJ.SLDASM" (See Appendix B). First, the moments of inertia of the bolt are determined using the bolt locations relative to the centroid of the pattern and the bolt areas. It is conservatively assumed that moments will tend to cause the pattern to rotate about its centroid, so moments of inertia about the pattern centroid are of interest. The moments at the centroid are calculated as the sum of all applied moments, plus the sum of the cross product of each applied force with the vector from the centroid to the location of that applied force as:

$$\bar{M}_c = \sum_i \bar{M}_i + \sum_i (\bar{R}_{c,i} + \bar{F}_i)$$

Where, $\bar{F}$ is a force vector composed of the force components in each direction: F_x, F_y, and F_z. Likewise, $\bar{M}$ is a moment vector composed of moments about each axis. $\bar{R}$ is the location vector specifying the location of the applied inertial force with respect to the pattern centroid.

The axial forces are a result of the direct force in the axial direction, $F_{c.z}$, the centroidal moment about the X-axis, $M_{c.x}$, and the centroidal moment about the Y-axis, $M_{c.y}$, as shown in Figure 5-3. Note: For sake of the bolt load calculations, the axes shown in Figure 5-3 are not congruent with the railcar centerline axis orientations. For reference, the axes in Figure 5-3 correspond with the railcar centerline axes as follows: Z-axis equals X-Axis, Y-Axis equals Z-axis, X-Axis equals Y-Axis.

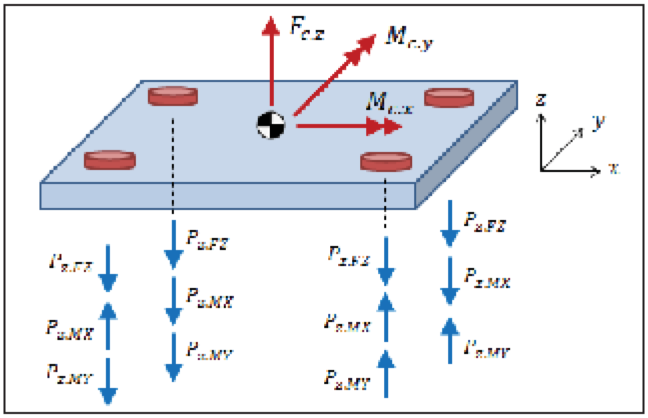


Figure 5-3: Axial Forces Acting on Typical Bolt Pattern

The direct force along the bolt axis, $F_{c.z}$, is divided between the individual bolted joints according to the bolt stiffnesses. Because the bolts are all assumed to have the same material and length, the stiffness is dependent only on area. The axial force on a bolted joint due to the direct force in Z is calculated as:

$$P_{z.FZ} = \frac{F_{c.z} A}{\sum_i A_i}$$

Where A is the area of the bolt in question and A_i is the total area of all the bolts in the pattern. The axial forces on a bolt due to moments about X- and Y- axes from the axial force due to M_x and M_y moments, respectively, are calculated as follows:

$$P_{z.MX} = \frac{M_{c.x} r_{c.y}}{I_{c.x}} \times A \qquad P_{z.MY} = \frac{M_{c.y} r_{c.x}}{I_{c.y}} \times A$$

Where $M_{c.x}$ and $M_{c.y}$ are the centroidal moments about the X- and Y- axes, $r_{c.x}$ and $r_{c.y}$ are the bolt distances from the centroid in the X- and Y-directions, and $I_{c.x}$ and $I_{c.y}$ are the pattern moments of inertia about the X- and Y- axes given by:

$$I_{c.x} = \sum_i r^2{}_{c.y,i} \times A_i$$

$$I_{c.y} = \sum_i r^2{}_{c.x,i} \times A_i$$

Where A_i is the bolt area and $r_{c.x,i}$ and $r_{c.y,i}$ are the x- and y- distances of the bolt from the pattern centroid, respectively. The total axial force on a bolt is the sum of the axial force components:

$$P_{axial} = P_{z.FZ} + P_{z.MX} + P_{z.MY}$$

The shear forces are a result of the direct force in the X-direction, $F_{c.x}$, the direct force in the Y-direction, $F_{c.y}$, and the centroidal moment about the bolt axis, $M_{c.z}$, as shown in Figure 5-4.

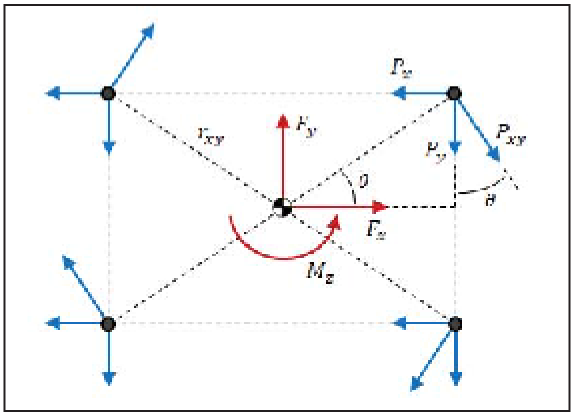


Figure 5-4: Shear Forces Acting on Typical Bolt Pattern

The direct forces in the X- and Y- directions, $F_{c.x}$ and $F_{c.y}$, respectively, are divided between the bolts according to the bolt stiffnesses. Because the bolts are all assumed to have the same material and length, the stiffness is dependent only on area. The shear forces on a bolt due to the direct forces in X- and Y- are calculated as:

$$P_{x.FX} = \frac{F_{c.x} A}{\sum_i A_i} \qquad P_{y.FY} = \frac{F_{c.y} A}{\sum_i A_i}$$

The shear force on a bolt due to moment about the Z-axis is calculated as:

$$P_{xy.MZ} = \frac{M_{c.z} r_{c.xy}}{I_{c.p}} \times A$$

Where $M_{c.z}$ is the centroidal moment about the Z-axis and $I_{c.p}$ is the pattern's polar moment of inertia given by:

$$I_{c.p} = I_{c.x} + I_{c.y}$$

The value $r_{c.xy}$ is the shortest distance between the bolt and the centroid and is calculated as: $r_{c.xy} = \sqrt{r_{c.x}^2 + r_{c.y}^2}$.

The shear force $P_{xy.MZ}$ is then resolved into X- and Y- components based on the angle θ (see Figure 5-4 above):

$P_{x.MZ} = P_{xy.MZ} \times \sin\theta$ X-force on bolt due to M_Z about centroid

$P_{y.MZ} = P_{xy.MZ} \times \cos\theta$ Y-force on bolt due to M_Z about centroid

The value θ is the angle between the bolt location and the positive X-axis and is calculated as:

$$\theta = \tan^{-1}\frac{r_{c.y}}{r_{c.x}}$$

The total shear force on a bolt is calculated as the vector sum of the X- components plus the Y- components:

$$P_{shear} = \sqrt{(P_{x.FX} + P_{x.MZ})^2 + \left(P_{y.FY} + P_{y.MZ}\right)^2}$$

Table 5-17: AISC Allowables for ASTM F3125, Grade A325 Drop-In Weight Bolts

<table>
<tr><th>Thread Diameter</th><th>Tensile Load min. (lb.) (Table 4 [28])</th><th>Fastener Tension min. (T_b) (lb.)</th><th colspan="2">Allowable Slip Resistance (R_n/Ω) (lb.)</th></tr>
<tr><td>1.25</td><td>116300</td><td>81410</td><td colspan="2">61329</td></tr>
<tr><td>1</td><td>72700</td><td>50890</td><td colspan="2">38337</td></tr>
<tr><th>Thread Diameter</th><th>Bolt Body Area (in²)</th><th>Ultimate Stress (psi) (Table 4-1)</th><th>Nominal Shear Stress (F_{nv}) (psi)</th><th>Allowable Shear Strength (R_n/Ω) (lb.)</th></tr>
<tr><td>1.25</td><td>1.2271846</td><td>120000</td><td>48000</td><td>29452</td></tr>
<tr><td>1</td><td>0.7853982</td><td>120000</td><td>48000</td><td>18850</td></tr>
<tr><th>Thread Diameter</th><th>Bolt Body Area (in²)</th><th>Nominal Tensile Strength (F_{nt}) (psi)</th><th colspan="2">Allowable Tensile Strength (R_n/Ω) (lb.)</th></tr>
<tr><td>1.25</td><td>1.2271846</td><td>90000</td><td colspan="2">55223</td></tr>
<tr><td>1</td><td>0.7853982</td><td>90000</td><td colspan="2">35343</td></tr>
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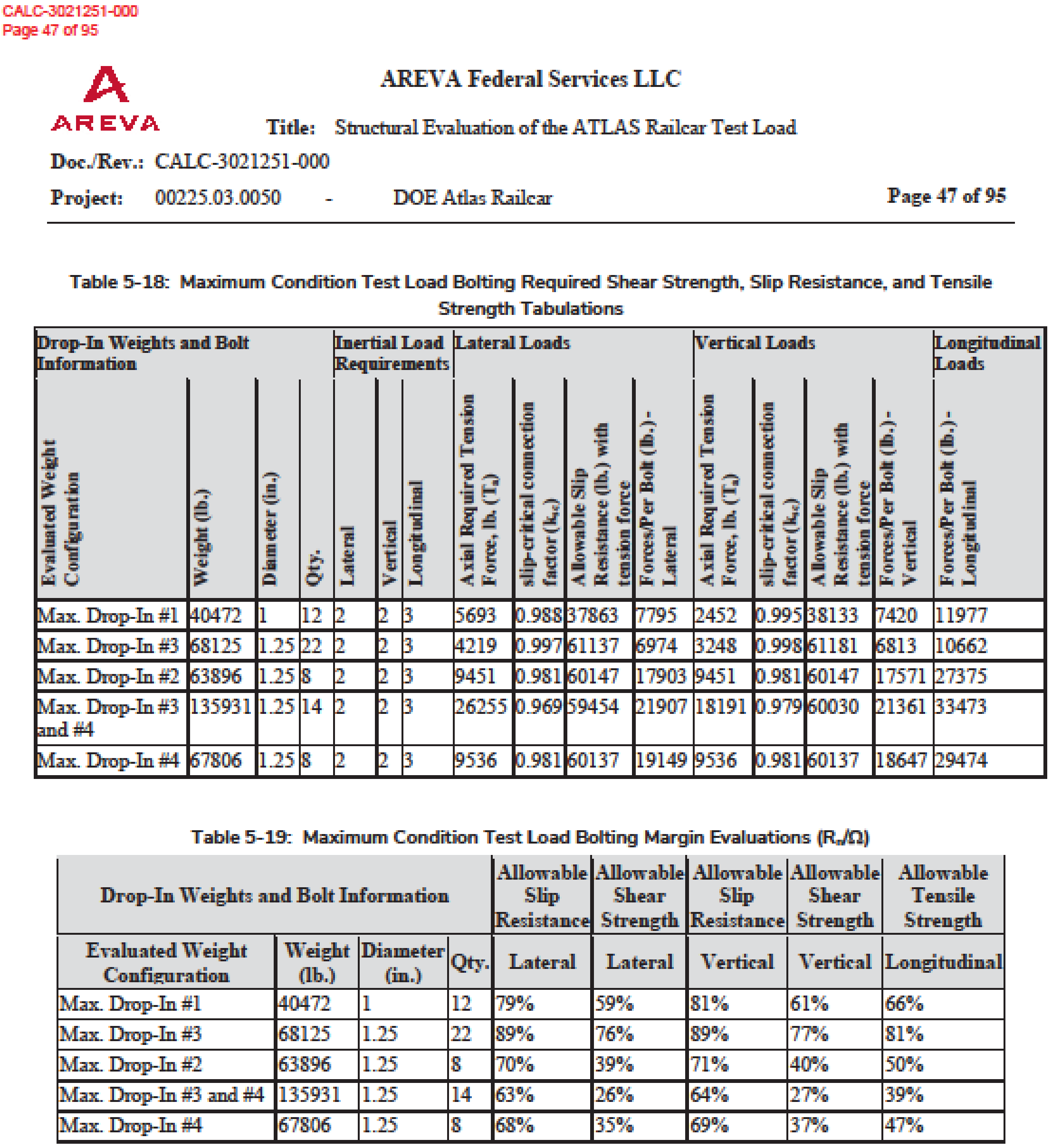

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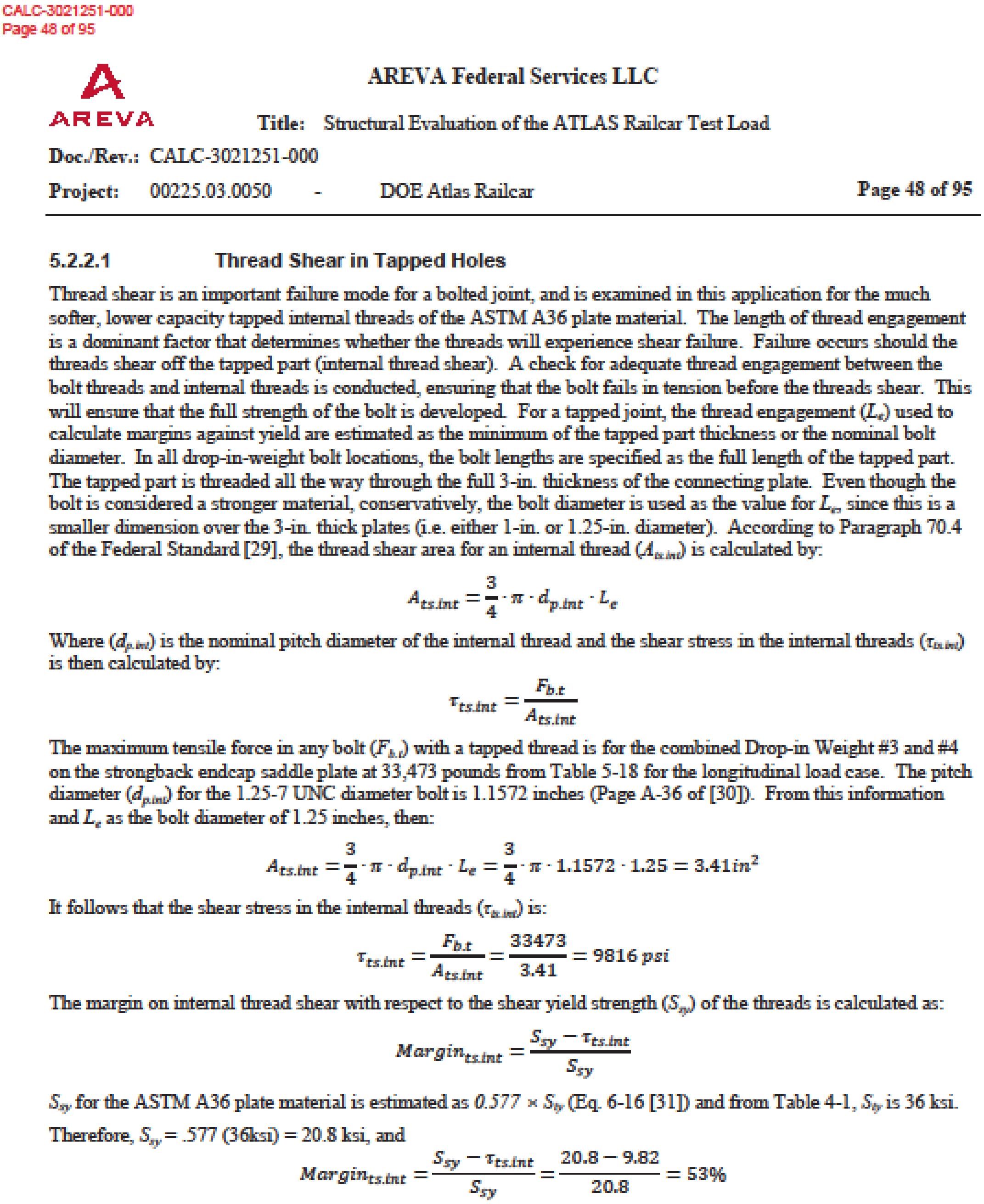
Table 5-18: Maximum Condition Test Load Bolting Required Shear Strength, Slip Resistance, and Tensile Strength Tabulations

Drop-In Weights and Bolt Information				Inertial Load Requirements			Lateral Loads				Vertical Loads				Longitudinal Loads
Evaluated Weight Configuration	Weight (lb.)	Diameter (in.)	Qty.	Lateral	Vertical	Longitudinal	Axial Required Tension Force, lb. (T_a)	slip-critical connection factor (k_{sc})	Allowable Slip Resistance (lb.) with tension force	Forces/Per Bolt (lb.) - Lateral	Axial Required Tension Force, lb. (T_a)	slip-critical connection factor (k_{sc})	Allowable Slip Resistance (lb.) with tension force	Forces/Per Bolt (lb.) - Vertical	Forces/Per Bolt (lb.) - Longitudinal
Max. Drop-In #1	40472	1	12	2	2	3	5693	0.988	37863	7795	2452	0.995	38133	7420	11977
Max. Drop-In #3	68125	1.25	22	2	2	3	4219	0.997	61137	6974	3248	0.998	61181	6813	10662
Max. Drop-In #2	63896	1.25	8	2	2	3	9451	0.981	60147	17903	9451	0.981	60147	17571	27375
Max. Drop-In #3 and #4	135931	1.25	14	2	2	3	26255	0.969	59454	21907	18191	0.979	60030	21361	33473
Max. Drop-In #4	67806	1.25	8	2	2	3	9536	0.981	60137	19149	9536	0.981	60137	18647	29474

Table 5-19: Maximum Condition Test Load Bolting Margin Evaluations (R_n/Ω)

Drop-In Weights and Bolt Information				Allowable Slip Resistance	Allowable Shear Strength	Allowable Slip Resistance	Allowable Shear Strength	Allowable Tensile Strength
Evaluated Weight Configuration	Weight (lb.)	Diameter (in.)	Qty.	Lateral	Lateral	Vertical	Vertical	Longitudinal
Max. Drop-In #1	40472	1	12	79%	59%	81%	61%	66%
Max. Drop-In #3	68125	1.25	22	89%	76%	89%	77%	81%
Max. Drop-In #2	63896	1.25	8	70%	39%	71%	40%	50%
Max. Drop-In #3 and #4	135931	1.25	14	63%	26%	64%	27%	39%
Max. Drop-In #4	67806	1.25	8	68%	35%	69%	37%	47%



5.2.2.1 Thread Shear in Tapped Holes

Thread shear is an important failure mode for a bolted joint, and is examined in this application for the much softer, lower capacity tapped internal threads of the ASTM A36 plate material. The length of thread engagement is a dominant factor that determines whether the threads will experience shear failure. Failure occurs should the threads shear off the tapped part (internal thread shear). A check for adequate thread engagement between the bolt threads and internal threads is conducted, ensuring that the bolt fails in tension before the threads shear. This will ensure that the full strength of the bolt is developed. For a tapped joint, the thread engagement (L_e) used to calculate margins against yield are estimated as the minimum of the tapped part thickness or the nominal bolt diameter. In all drop-in-weight bolt locations, the bolt lengths are specified as the full length of the tapped part. The tapped part is threaded all the way through the full 3-in. thickness of the connecting plate. Even though the bolt is considered a stronger material, conservatively, the bolt diameter is used as the value for L_e, since this is a smaller dimension over the 3-in. thick plates (i.e. either 1-in. or 1.25-in. diameter). According to Paragraph 70.4 of the Federal Standard [29], the thread shear area for an internal thread ($A_{ts.int}$) is calculated by:

$$A_{ts.int} = \frac{3}{4} \cdot \pi \cdot d_{p.int} \cdot L_e$$

Where ($d_{p.int}$) is the nominal pitch diameter of the internal thread and the shear stress in the internal threads ($\tau_{ts.int}$) is then calculated by:

$$\tau_{ts.int} = \frac{F_{b.t}}{A_{ts.int}}$$

The maximum tensile force in any bolt ($F_{b.t}$) with a tapped thread is for the combined Drop-in Weight #3 and #4 on the strongback endcap saddle plate at 33,473 pounds from Table 5-18 for the longitudinal load case. The pitch diameter ($d_{p.int}$) for the 1.25-7 UNC diameter bolt is 1.1572 inches (Page A-36 of [30]). From this information and L_e as the bolt diameter of 1.25 inches, then:

$$A_{ts.int} = \frac{3}{4} \cdot \pi \cdot d_{p.int} \cdot L_e = \frac{3}{4} \cdot \pi \cdot 1.1572 \cdot 1.25 = 3.41 in^2$$

It follows that the shear stress in the internal threads ($\tau_{ts.int}$) is:

$$\tau_{ts.int} = \frac{F_{b.t}}{A_{ts.int}} = \frac{33473}{3.41} = 9816\, psi$$

The margin on internal thread shear with respect to the shear yield strength (S_{sy}) of the threads is calculated as:

$$Margin_{ts.int} = \frac{S_{sy} - \tau_{ts.int}}{S_{sy}}$$

S_{sy} for the ASTM A36 plate material is estimated as $0.577 \times S_{ty}$ (Eq. 6-16 [31]) and from Table 4-1, S_{ty} is 36 ksi.

Therefore, S_{sy} = .577 (36ksi) = 20.8 ksi, and

$$Margin_{ts.int} = \frac{S_{sy} - \tau_{ts.int}}{S_{sy}} = \frac{20.8 - 9.82}{20.8} = 53\%$$

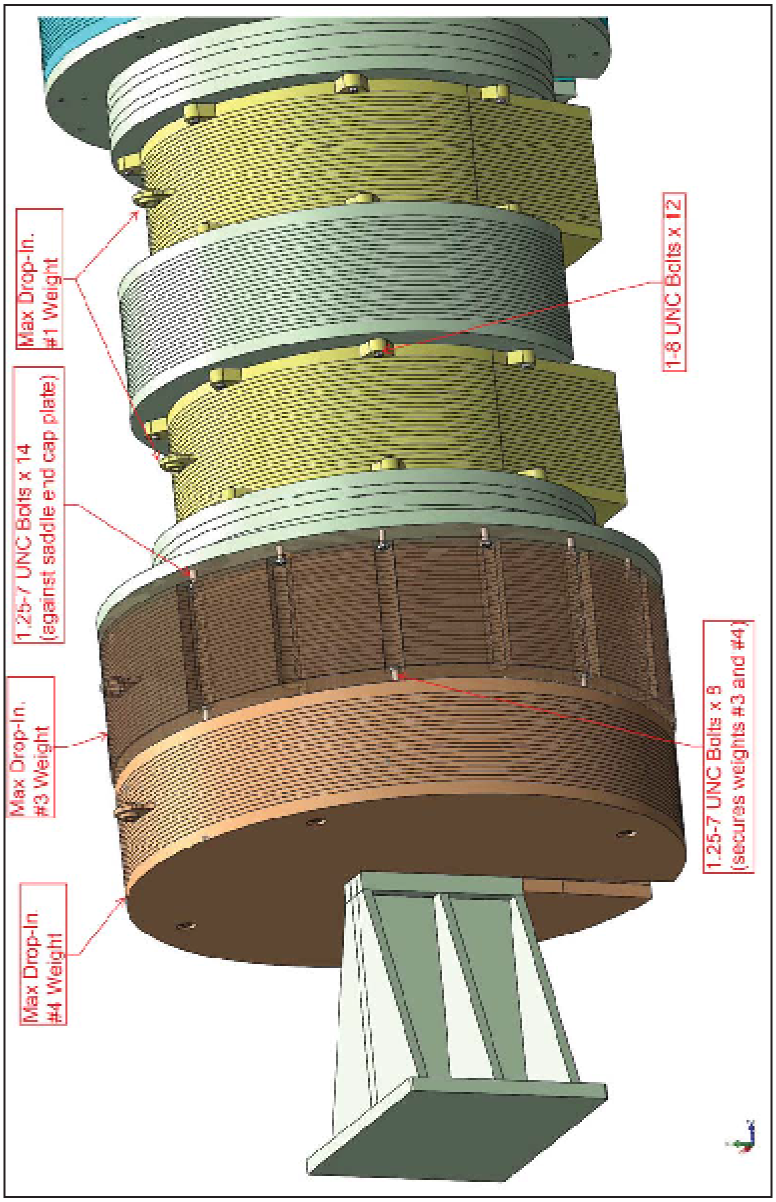


Figure 5-5: Bolted Connections on Max. Condition Test Load (Bottom End)

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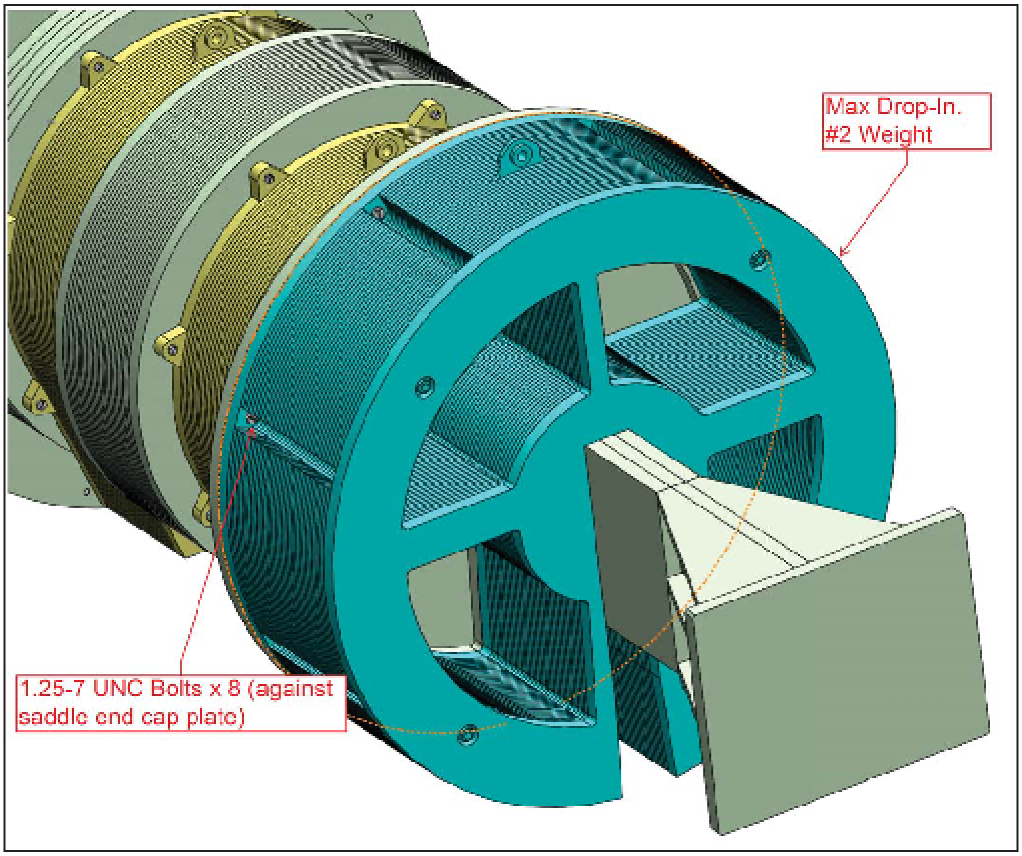


Figure 5-6: Bolted Connections on Maximum Condition Test Load (Top End)

5.2.3 Bearing Stress on Shear Key Support

The bearing force on the strongback shear key reaction zone occurs from the longitudinal load applied to the zone from the minimum condition test load. This stress is represented as follows: $\sigma_b=P/A$, where A is the height times depth of the bearing area. The height through the zone is 4.88 inches and the depth is 9 inches since it is three 3-in. thick plates stacked up. Then the bearing area (A) = 43.92 inches (See Drawing 3020935 [33]). The 4.88-in. height of the shear zone excludes the chamfer shown in Zone D3 (Sheet 3 of [33]) and is determined from: 5.75-in minus (.5-in. × tan 60°). From Table 4-2, the minimum condition design load (P) in the longitudinal direction is 583.1 kips. Therefore, the bearing stress on the section is as follows:

$$\sigma_b = \frac{P}{A} = \frac{583.1kips}{9in \times 4.88in} = \frac{583.1kips}{43.92in^2} = 13.3ksi$$

The yield stress for ASTM A36 (σ_y= 36 ksi) may be used directly as an allowable comparison since compression on this shear key zone is not based on flexural local buckling (i.e., small Length to Radius of Gyration ratio). It follows that the margin on local compressive yielding due to bearing stress is:

Margin:
$$\frac{\sigma_y - \sigma_b}{\sigma_y} = \frac{36 - 13.3}{36} = 63\%$$

5.2.4 Combined Loading on Strongback End Stop Plate

The strongback's end stop (shown in Figure 2-1) will take the worst-case longitudinal inertial load. Treating as a beam, a uniformly distributed load is applied over the face of the end stop plate. Bending stresses in the plate arise from the applied longitudinal load. From Table 4-2, the maximum condition design load (P) in the longitudinal direction of 1386.3 kips applies to the end stop plate's face. Conservatively, analyze the bending stresses in the plate along the z-axis with the plate width of 56-in. The plate is 3-in. thick and 44-in. tall (See Drawing 3020935 [33]). Assume the beam is simply supported by the three end support rib plates, with a center-to-center spacing between each of the rib plates of 17 inches. Then, the moment of inertia about the weak axis (z-axis) is:

$$I_z = \frac{1}{12}bh^3 = \frac{1}{12}56 \times 3^3 = 126\ in.^4$$

The maximum moment in the plate occurs at the central rib support and is given by the equation (Figure 29 of [32]):

$$M_{max} = \frac{wl^2}{8} = \frac{\left(\frac{1386.3kips}{44in}\right)(17in)^2}{8} = 1138.2kip - in.$$

Therefore, the bending stress on the plate is as follows:

$$\sigma_c = \frac{Mc}{I_z} = \frac{1138.2kip\text{-}in.\,(1.5in)}{126\ in.^4} = 13.55ksi$$

The maximum shear force occurs at the central rib and is determined as follows (Figure 29 of [32]):

$$F = \frac{5wl}{8} = \frac{5\left(\frac{1386.3kips}{44in}\right)17in}{8} = 334.8\ kips$$

It follows, that the maximum shear stress in the plate is:

$$\tau_s = \frac{F}{A} = \frac{334.8}{(56in \times 3in)} = 2\ ksi$$

Then the combined shear and bending stress on a section through the center of the plate is given as:

$$\sigma_c = \sqrt{\sigma_c{}^2 + \tau_s{}^2} = \sqrt{13.55^2 + 2^2} = 13.7ksi$$

The yield stress for ASTM A36 ($\sigma_y = 36$ ksi) may be used directly as an allowable comparison since loading on this plate is not based on flexural local buckling (i.e., small Length to Radius of Gyration ratio). It follows that the margin on flexural yielding due to the combined stress state is:

Margin:
$$\frac{\sigma_y - \sigma_c}{\sigma_y} = \frac{36 - 13.7}{36} = 62\%$$

5.2.5 Compressive Stress on End Support Rib Plate

The strongback's end support rib plate (shown as the triangular-shaped member in Figure 2-1) will take a portion of the longitudinal inertial load due to compression. Compressive stress occurs from the longitudinal load applied to the zone from the maximum condition test load. From Table 4-2, the maximum condition design load (P) in the longitudinal direction is 1386.3 kips. Conservatively analyze the compressive stresses on the ribs, assuming the smallest y-axis width of the member (3-in. zone where it ties into the strongback beam). Each plate is 2-in. thick and there are six plates. The load is taken by the rib plate and the center plate of the main beam which is 3-in. wide by 36-in. tall. Then the compressive area is provided as:

$$A_{rib} = (2in \times 3in)6 = 36\ in.^2$$

Assume the axial load is equally distributed amongst the entire area, then the fraction of the load taken by the ribs is as follows:

$$P_{rib} = P\left(\frac{A_{rib}}{A_{rib} + A_{beam}}\right) = 1386.3\left(\frac{36in^2}{36in^2 + (3in \times 36in)}\right) = 346.6kips$$

Therefore, the compressive stress on the minimum rib cross-section is as follows:

$$\sigma_c = \frac{P}{A_{rib}} = \frac{346.6kips}{36in^2} = 9.63ksi$$

The yield stress for ASTM A36 ($\sigma_y = 36$ ksi) may be used directly as an allowable comparison since compression on this rib plate is not based on flexural local buckling (i.e., small Length to Radius of Gyration ratio). It follows that the margin on local compressive yielding is:

Margin:
$$\frac{\sigma_y - \sigma_b}{\sigma_y} = \frac{36 - 9.63}{36} = 73\%$$

5.2.6 Central Beam Shear Continuity

The central beam sub-weldment of the strongback (see Assembly A2 on [33]) is welded together using eight 3-in. diameter shear keys holding the three 3-in. plates together. 3/8-in. welds on either side of the strongback for each of the strongback shear keys retain the shear keys in the plates. Check the shear strength capacity of the keys from the vertical or longitudinal load cases. The lateral case is bounded by these evaluations. The strongback shear key welds do not transfer horizontal shear at their outer plate connection, therefore they do not require evaluation.

The Central Beam Weldment (Assembly A2 of [33]) gravitational weight is applied as a uniform load distributed over its entire 344-in. length. Using a static evaluation for the point loads along the beam, the reaction forces (R_1 and R_2) at the central plane of the two cradle saddles is determined (See Figure 5-7).

A shear diagram plot is generated for the beam, and planar shear forces along the beam are computed. All distances are from the left-hand end stop outer plate surface. These beam shear values are shown in Figure 5-8 and are developed using the following approximations in the CALC-30201251-000.xlsx spreadsheet identified in Section 6.1:

- 2g vertical loading with 1.1 structural factor is applied to each of the drop-in weights and beam weight
- The drop-in weights, including the permanent drop-in weights on the strongback weldment (i.e., Saddle Lefthand and Righthand Bundles and Shear Key Bundles) are each applied as gravitational point loads at their individual CGs or X-axis midpoint of their lift lug. Based on the SW model, the saddle bundle CG location is 50.99 inches from the geometric centerline of the beam. Therefore, their location from the beam end is 344/2-50.99 = 121.01-in. and 344/2+50.99 = 222.99-in. for each of the left and right hand saddle bundle, respectively.
- The reaction loads at the front and rear saddles are calculated to be 296 kips and 623 kips, respectively and are each located at the geometric centerline of their respective saddle cradle supports.

From spreadsheet CALC-30201251-000.xlsx, the maximum planar shear force of 387.1 kips along the beam occurs at Reaction Load R_2. Conservatively, assume the maximum shear load is 400 kips. First, calculate the allowable shear strength ($F_n = V_n/\Omega$) for the connections using the AISC Steel Construction Manual [17]. Use Equation G2-1 from [17] for the nominal shear strength (V_n) as:

$$V_n = 0.6F_y \times A_w \times C_v$$

Where, F_y = Minimum Yield Stress

A_w = Total Cross-Sectional Area of Shear keys

C_v = Web Shear Coefficient (Assume = 1.0)

Ω = Allowable Shear Safety Factor = 1.5

By dividing V_n by A_w and substituting for C_v, the nominal shear stress $F_n = 0.6F_y$. Dividing by Ω, the allowable shear stress then becomes $F_v = 0.4F_y$. Since the ASTM A36 yield stress (F_y) is 36 ksi (See Table 4-1), the allowable shear stress $F_v = 14.4$ksi.

Then, the minimum required shear area for the maximum 400-kip shear force is (400kip/14.4ksi = 27.8 in^2). Each shear key is in double shear due to the stack up of the three 3-in. plates. Then, for the 3-in. diameter shear key, the calculated shear area for eight keys is, $A_w = 8 \times \pi \times (3/2)^2 \times 2$ shear planes = 113.1 in^2. Therefore, the margin on the shear stress given by the shear area is 307%.

Next, check the minimum required shear area for a 1386.3-kip longitudinal shear force (See Table 4-2) assuming exclusively pure shear transfer. Then, the minimum required shear area is (1386.3 kip/14.4ksi = 96.3 in^2). Therefore, given the calculated shear area of 113.1 in^2, the margin on the shear stress is 15%.

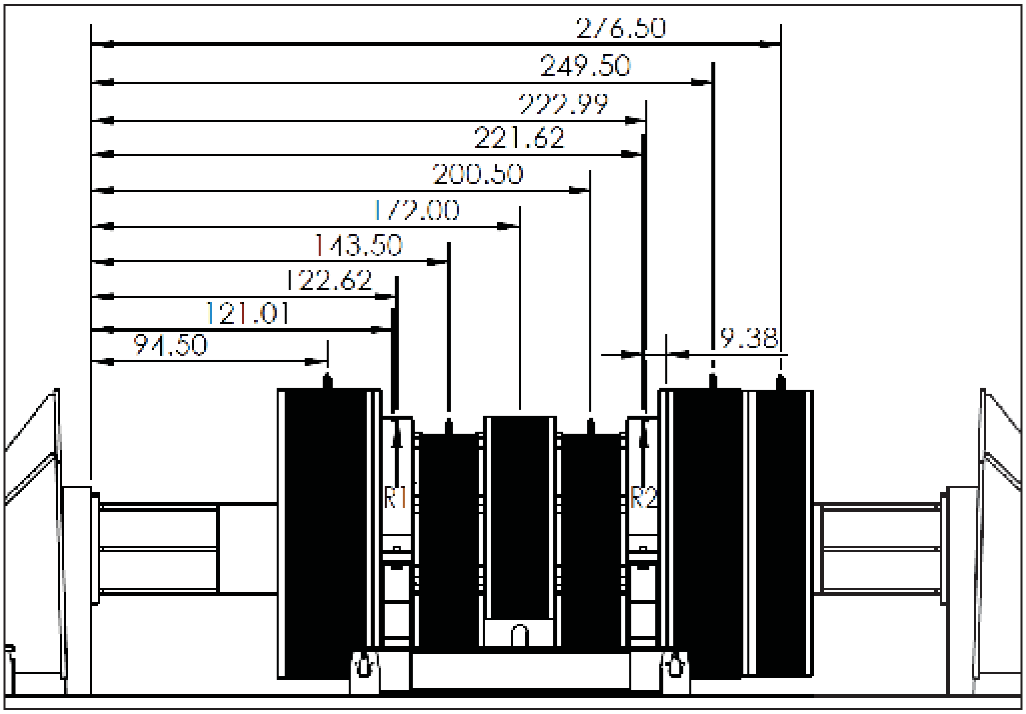


Figure 5-7: Beam Load Distances and Reaction Force Locations at Cradle Saddles

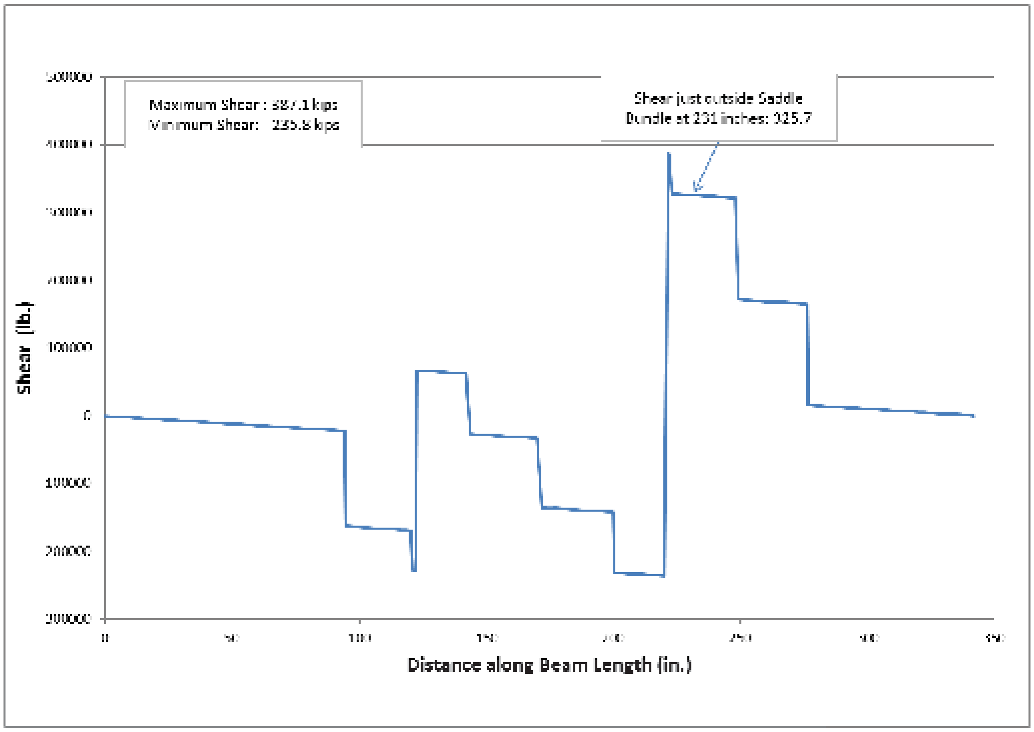


Figure 5-8: Beam Shear in Central Beam Weldment under 2g

5.3 Lifting Evaluations

In accordance with Section 4.3.1, for lifting attachment evaluations, ASME BTH-1 (Chapter 3) [18] design allowable criteria are imposed. Based on anticipated usage at TTCI, structural lift points are categorized as Design Category A, Service Class 0 in accordance with Chapter 2 of [18]. All lifts are expected to occur indoors and the maximum service temperature is assumed less than 150°F. Therefore, no reduction is required beyond the strength minimums required in the material specifications, and no null-ductility studies are required for low temperature lifts (See Justified Assumption 3.2.6). The drop-in weight values used for the minimum and maximum condition test loads are identified in Table 5-16. However, a higher maximum lift Working Load Limit (WLL) is provided in Drawing 3020460 [2] and Drawing 3020458 [3] for each of the drop-in weights. In addition, per Section 4.3.1, a dynamic load factor (DLF) of 1.15 is applied to lifted loads. Per ASME BTH-1 Section 3-1.3 [18] (Design Category A, Service Class 0 lifters), for allowable stresses, a nominal design factor of 2.0 to limit states of yielding or buckling, and 2.4 to limit states of fracture are applied for margin evaluations.

5.3.1 Test Load Drop-In Assembly Lift Points

The four drop-in weight assemblies used for the maximum test loads use the same lift lug design and the two drop-in plate assemblies for the minimum test loads use the same lift lug design. The design geometries are provided on drawing 3020460 [2] for the maximum condition and 3020458 [3] for the minimum condition.

For the maximum condition lift lug in Figure 5-9, a central 1-in. thick plate in the drop-in bundle extends up above the top of the assembly forming a lift point for use with a 2−1/4-in. diameter pin shackle (e.g., Skookum® part number 626316 with 52 Ton WLL). The lug illustrated in Figure 5-9 and Figure 5-10 consists primarily of a 4.25-in. diameter round bar with a 2.31-in. diameter hole. The lug is welded to the central plate with an all-around ¾-in. fillet weld. Of note, as called out in Section 4.1, the round bar doubler plate is specified as an ASTM A108, Grade 1018 [15] with minimum yield strength of 45 ksi and a minimum ultimate strength of 55 ksi. However, ASTM A36 [12] is used as the limiting material condition in all evaluations.

For the minimum condition lift lug in Figure 5-11, a central plate in the plate bundle extends up above the top of the assembly forming a lift point for use with a 1.38-in. diameter pin shackle with a WLL of 12 tons (e.g., Crosby® part number 1018570). The lug illustrated in Figure 5-11 consists primarily of a 3-in. diameter round bar with a 1.44-in. diameter hole. Unlike the maximum condition, the minimum condition lift lug, there is no doubler plate. Again, the minimum condition plate material is ASTM A36 [12].

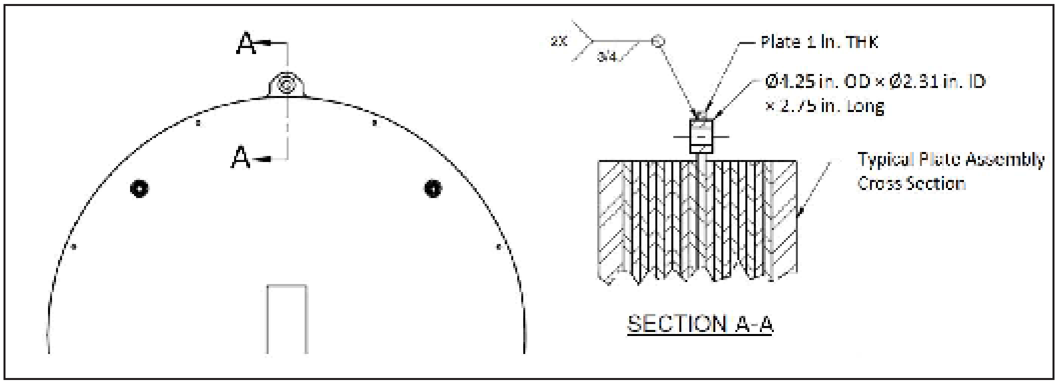


Figure 5-9: Typical Test Load Plate Assembly Lift Lug Design (Maximum Condition)

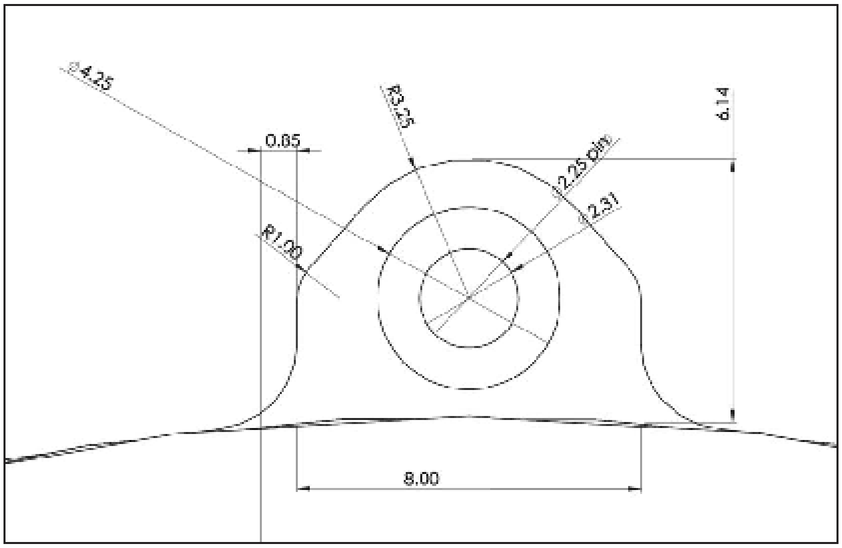


Figure 5-10: Maximum Condition Lift Lug Geometry

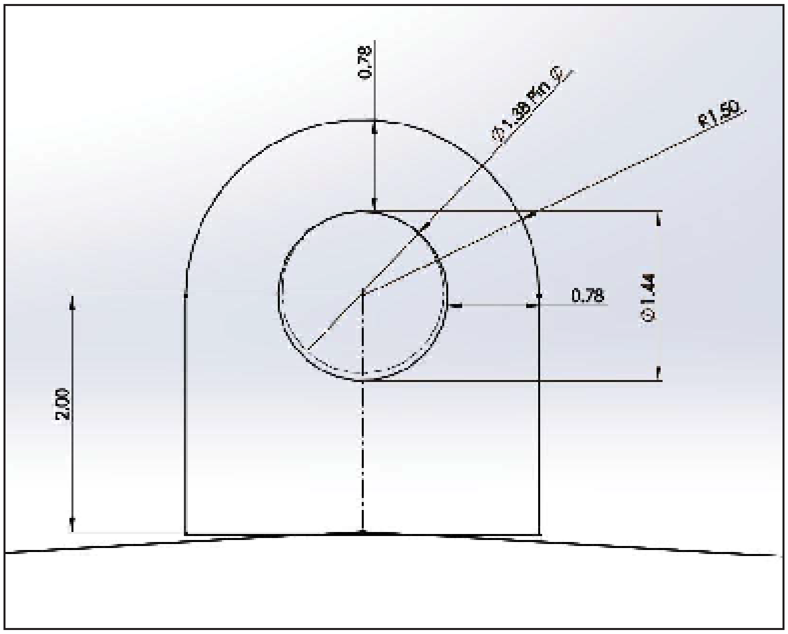


Figure 5-11: Minimum Condition Lift Lug Geometry

5.3.1.1 Static Strength of Lift Lug Pin Plates

The maximum condition drop-in weight from Table 5-16 is 68,125 pounds for Drop-in Weight Assembly #3. However, the maximum permitted weight for this configuration is 71,000 lb. (See Note on [2]). The minimum condition drop-in weight from Table 5-16 is 19,095 pounds for Drop-in Weight Assembly #2. However, the maximum permitted weight for this configuration is 21,000 lb. (See Note on [3]). Since the assemblies are lifted straight up using a single point lift with a shackle, there is no additional load reduction from any sling angles or center of gravity effects. From Section 4.2 there is an applied dynamic load factor of 1.15 for lifting applications. However, the actual drop-in weights are used in evaluations identified in the Section 6.1 spreadsheet CALC-30201251-000.xlsx, with the 1.15 dynamic factor bounding the 71kip and 21kip drawing WLL values for the lift lugs.

The methods of paragraph 3-3.3.1 of ASME BTH-1 [18] are used to check the static strength of this pinned connection for both the minimum condition drop-in weights without doubler plate and for the maximum condition drop-in weights with doubler plate analyzed independently. The strength of a pin-connected plate in the region of the pinhole shall be taken as the least value of:

- the tensile strength of the effective area on a plane through the center of the pinhole perpendicular to the line of action of the applied load (P_t)
- the fracture strength beyond the pinhole on a single plane parallel to the line of action of the applied load (P_b)
- the double plane shear strength beyond the pinhole parallel to the line of action of the applied load (P_v).
- In addition, per paragraph 3-3.3.4 of ASME BTH-1, the bearing stress between the pin and the plate is checked. This bearing stress is based on the projected area of the pin and limited by the ASTM A36 yield point (Equation 3-53 of [18]).

Of note, since the maximum condition drop-in weight's doubler plate is welded to the base plate, and the weld is analyzed separately in Section 5.3.1.2, then the doubler plate is analyzed using its geometry independent of the base plate. This is acceptable since the load is transferred through the weld to the base plate. In addition, it is conservative, as the additional material profile beyond the perimeter of the doubler plate would increase its overall load capacity. Specifically, Section 5.3.1.2 demonstrates ½ of the doubler plate (i.e., 50% margin) weld to the lug can take the entire vertical lifting load. As such, a failure of the lifting lug around the doubler plate cannot occur, since the bottom half of the weld is capable of transferring all lifting loads.

Also, reviewing the tensile stress in the base plate through the bottom tangency of the doubler (i.e. $\sigma = P/A$) provides a tensile stress in the section of 9.8 ksi. This value is computed using the maximum condition lift load of 78.3 kips from Table 5-21 divided by the gross cross-sectional area (8-in. x 1-in. thick). Note: Conservatively assume the minimum plate width of 8-in., ignoring the bonus from the fillet radius. Provided the ASTM A36 base plate material strength values in Table 4-1, this yields a calculated margin of 45.6% on the allowable stress from Equation 3-1 [18] $\left(F_t = \frac{F_y}{N_d}\right)$ of 18 ksi.

Next, check the bearing stress. The bearing stress (F_p) shall not exceed the value given by (Equation 3-53 of [18]):

$$F_p = \frac{1.25\,F_y}{N_d} = \frac{1.25\,(36)}{2} = 22.5\ ksi$$

Therefore, the allowable bearing strength (P_{bear}) is given by:

$$P_{bear} = F_p \times A_{bear}$$

Where,

A_{bear} = bearing area (pin diameter (D_p) x thickness of plate (t))

Next, the allowable tensile strength through the pinhole (P_t) is checked.
It is calculated as follows, (Equation 3-45 [18]):

$$P_t = C_r \frac{F_u}{1.20N_d}(2t \cdot b_{eff})$$

Where,

F_u = Minimum Tensile Strength (ASTM A36 plate)

C_r = Strength Reduction Factor for pin-connected plates computed as follows (Eq. 3-46 [18]):

$$C_r = 1 - 0.275\sqrt{1 - \frac{{D_p}^2}{{D_h}^2}}$$

Where,

D_h = Hole Diameter

The effective width (b_{eff}) to each side of the pinhole shall be taken as the smaller of the values calculated as follows (Eq. 3-47 and Eq. 3-48 [18]):

$$b_{eff} = 4t \leq b_e$$

$$b_{eff} = b_e \cdot 0.6\frac{F_u}{F_y}\sqrt{\frac{D_h}{b_e}} \leq b_e$$

Where,

b_e = actual width of pin-connected plate between the edge of the hole and the edge of the plate on a line perpendicular to the line of action of the applied load

Next, the allowable single plane fracture strength beyond the pinhole (P_b) is calculated (Equation 3-49 [18]):

$$P_b = C_r \frac{F_u}{1.2N_d}\left[1.13\left(R - \frac{D_h}{2}\right) + \left(\frac{0.92b_e}{1 + {}^{b_e}/_{D_h}}\right)\right]t$$

Where,

R = Distance from center of hole to plate edge

In accordance with Equation 3-50 [18], the allowable double plane shear strength beyond the pinhole (P_v) is:

$$P_v = \frac{0.70F_u}{1.20N_d}(A_v)$$

Where in accordance with Equation 3-51 and 3-52 [18],

A_v = total area of the two shear planes beyond the pinhole calculated from the following equation:

$$A_v = 2\left[a + \frac{D_p}{2}(1 - \cos \emptyset)\right]t \qquad \text{and,}$$

$$\emptyset = 55\frac{D_p}{D_h}$$

Where,

a = distance from the edge of the pinhole to the edge of the plate in the direction of the applied load

$\varnothing$ = shear plane locating angle for pin-connected plates, (degrees)

The shear plane area defined by Equation 3-51 of [18] is based on the geometry of a plate with a straight edge beyond the hole that is perpendicular to the line of action of the applied load. If the edge of the plate is curved, the loss of shear area due to the curvature must be accounted for. Since the lift lug edge is curved and is symmetrical about an axis defined by the line of action of the applied load, then the loss of length of one shear plane, Z', is given by Equation C-2 [18]:

$$Z' = r - \sqrt{r^2 - \left(\frac{D_p}{2}\sin\varnothing\right)^2}$$

Where r is the radius of curvature of the edge of the plate, which equates to (R), the distance from the hole center to plate edge.

It follows that the distance (a) to the edge of the pinhole is given by:

$$a = R - \frac{D_h}{2} - Z'$$

Given the above strength checks and provided the detailed methodology in Section 3-3.3.1 of ASME BTH-1 [18], the allowable strength values of both the minimum and maximum condition drop-in weight assemblies is determined. Spreadsheet CALC-30201251-000.xlsx identified in Section 6.1 provides the detailed computations and Table 5-20 summarizes the Strength Allowables for P_t, P_b, P_v, and P_{bear}.

Table 5-20: Allowable Strength of Lift Lugs per ASME BTH-1

Strength Checks	Minimum Condition Lug Profile (kips)	Maximum Condition Lug Profile (kips)
P_t = Allowable Tensile Strength through the pinhole	37.70	128.76
P_b = Allowable Single Plane Fracture Strength beyond the pinhole	27.15	95.41
P_v = Allowable Double Plane Shear Strength beyond the pinhole	26.74	94.80
P_{bear} = Allowable Bearing Strength	30.94	139.22

Based on the Table 5-20 strength allowables and the required strengths determined in Table 5-21, the margins from the allowables are determined also in Table 5-21. Since all margins are positive, the design of both the minimum and maximum condition lift lugs for all ASME BTH-1 strength requirements is acceptable.

Table 5-21: Lifting Load Strength Requirements and Margins to Allowable Strengths

Drop-In Weight Identifier	Load Requirements			Margins			
	Drop-in Weight from Table 5-16 (pounds)	Dynamic Lift Factor	Lifted Force Requirement (kips)	P_t	P_b	P_v	P_{bear}
Min. Drop-In #1 (self)	16041	1.15	18.4	51%	32%	31%	40%
Min. Drop-In #2 (self)	19095	1.15	22.0	42%	19%	18%	29%
Max. Drop-In #1	40472	1.15	46.5	64%	51%	51%	67%
Max. Drop-In #2	63896	1.15	73.5	43%	23%	22%	47%
Max. Drop-In #3	68125	1.15	78.3	39%	18%	17%	44%
Max. Drop-In #4	67806	1.15	78.0	39%	18%	18%	44%

5.3.1.2 Weld Stress

The weld design for the lug doubler complies with the requirements of paragraph 3-3.4.3 of ASME BTH-1 [18]. As called out in Section 4.1, the doubler round bar material is specified as ASTM A108, Grade 1018 with a 45-ksi minimum yield strength and a 55-ksi minimum tensile strength. Since the minimum tensile strength of the ASTM A108 material [15] is lower than that of the ASTM A36 material [12] (58-ksi), the bounding 55-ksi for ASTM A108 is used in the computation. The design factor for fracture is used (i.e., $N_d = 2.4$) from Section 4.3.1.

The ¾-in. fillet welds on both sides of the lug join the round bar to the vertical plate (See Sheet 3 of [2]). These welds would have to fail in shear before the lug would shear out of the plate. The following weld evaluation shows the adequacy of the connection:

Tensile Strength: $F_u = 55\ ksi$

Allowable Shear Stress per Equation 3-55 [18]: $F_v = \dfrac{.6\ F_u}{1.2\ N_d} = \dfrac{.6\ (55)}{1.2\ (2.4)} = 11.46\ ksi$

Nominal Weld Size: $h = .75\ in.$

Weld Pattern Radius (See Figure 5-10): $r = 2.125\ in.$

Weld Area: $A = 2(1.414)\pi \times h \times r = 2(1.414)\pi \times .75 \times 2.125 = 14.16\ in.^2$

Lift Lug Load: $F = 71 kip \times 1.15 = 81.65\ kip$

Shear Stress from Vertical Load: $\tau_s = \dfrac{F}{A} = \dfrac{81.65}{14.16} = 5.76\ ksi$

Margin: $\dfrac{F_v - \tau_s}{F_v} = \dfrac{11.46 - 5.76}{11.46} = 50\%$

5.3.2 Strongback Main Beam Lifting

The central beam assembly (strongback main beam) is designed for the heaviest condition lift using slings configured in a choker configuration in the designated lift zones marked on the central beam (see drawing 3020935 [33] and Figure 5-12). The beam may be configured with the maximum amount of drop-in weights as shown in Figure 5-12. Other configurations, with lesser quantities of drop-in weights are also authorized.

CAUTION: The Maximum Drop-in Weight Assembly #4 must be removed when lifting this maximum allowable lifting configuration (i.e., Assembly A5 from drawing 3020460 [2]).

The only credible failure method for the central beam is due to bending or buckling. As indicated, the worst-case lifting load case placed on the central beam weldment occurs with the maximum test load configuration and Assembly A5 removed (i.e., Maximum Drop-in Weight Assembly #4). As shown in Figure 5-13, the maximum total load in this condition is 349.3 kips with a CG located within an inch of the half-beam length (i.e., .85-in. along X-axis). Consider a maximum sling spacing location between the lift points as 236-in. This offset along the X-axis will conservatively be included in the bending moment applied to the beam. It follows that the lifting load with consideration for the 1.15 dynamic lifting factor is:

$$W = 1.15(349.3) = 401.7\ kips$$

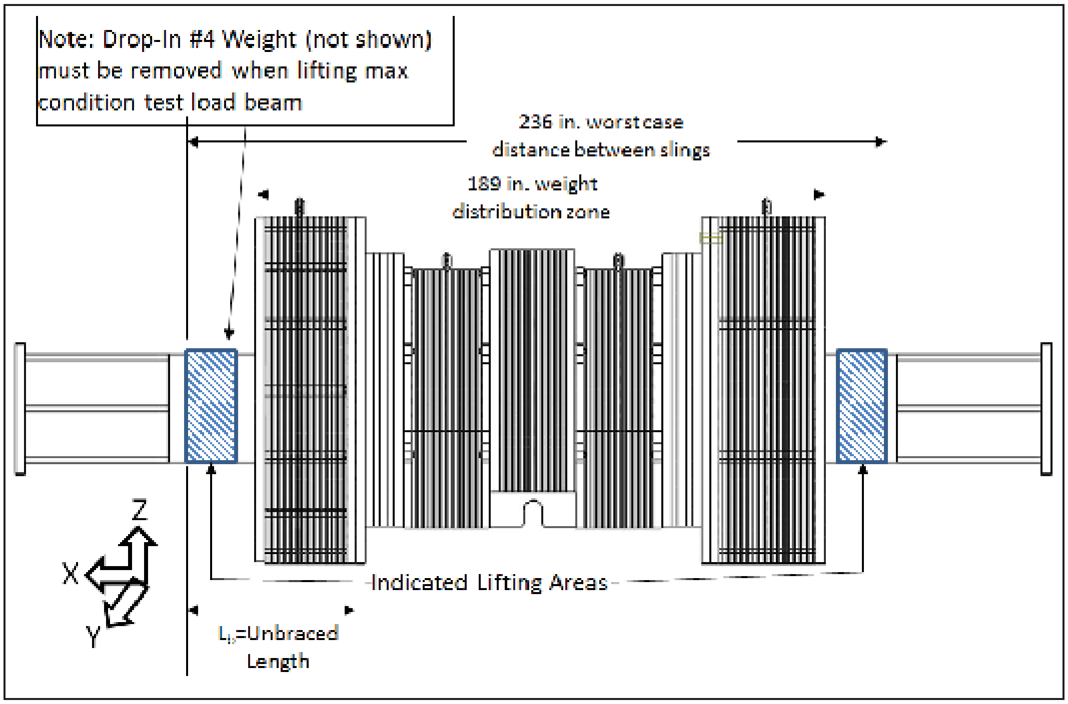


Figure 5-12: Maximum Allowable Lifted Test Load Configuration

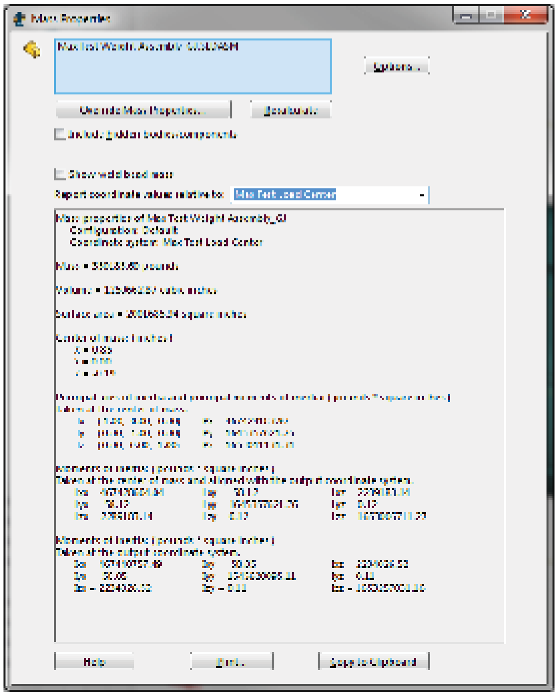
Assuming that the beam is simply supported by the slings, the maximum bending moment in the beam is calculated conservatively assuming the entire assembly weight is partially distributed uniformly over the central 189-in. section of the beam (defined as length *b*) (See Figure 2 of [32]). Then the maximum moment (M_{max}) in the beam is determined, given that the 189-in. weight distribution is shifted .85-in. within the 236 inches lift zone length (*l*). R_1 is the reaction load at the left end of the beam and (*a*) is the end offset distance from the left end as: ((236-(189+.85))/2 = 23.075 inches). It then follows that the offset distance (*c*) from the right end is 23.925 inches. It follows that R_1 is (Figure 2 of [32]):

$$R_1 = \frac{wb}{2l}(2c + b) = \frac{\left({}^{401.7}/_{189}\right)189}{2(236)}(2(23.925) + 189) = 201.6kips$$

And it follows that M_{max} is:

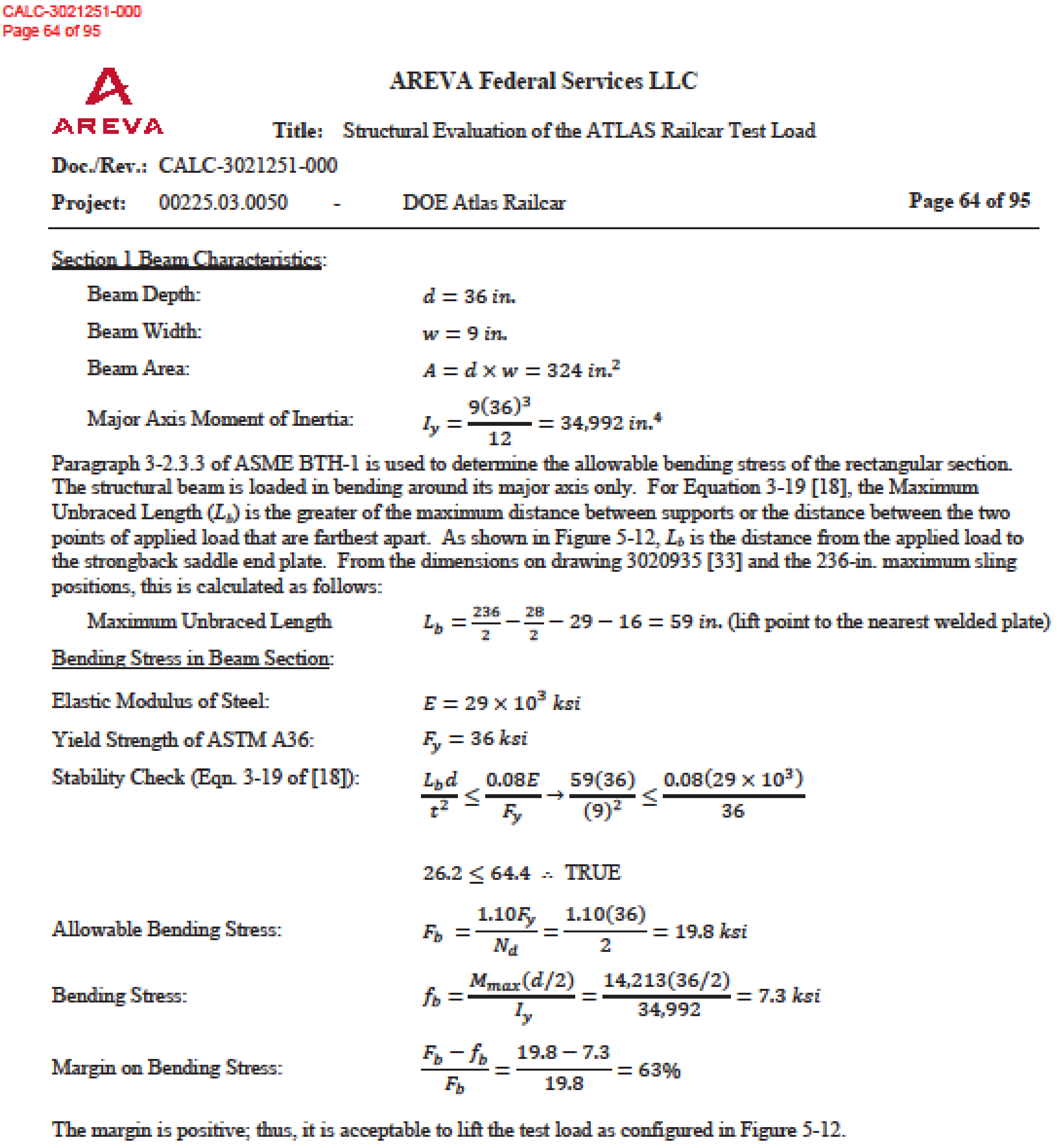
$$M_{max} = R_1\left(a + \frac{R_1}{2w}\right) = 201.6\left(23.075 + \frac{201.6}{2\left({}^{401.7}/_{189}\right)}\right) = 14{,}213\ kip \cdot in$$

The ASTM A36 beam is made up of three 3-in. thick plates welded together. The minimum cross section of the central beam sub-weldment is 9 inches wide (*t*) and 36 inches deep (*d*) [33]. This cross section is conservatively evaluated for the maximum bending moment at the beam center.



Mass properties of Max Test Weight Assembly_GJ
Configuration: Default
Coordinate system: Max Test Load Center

Figure 5-13: Mass Properties of Maximum Allowable Lifted Test Load Configuration



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Section 1 Beam Characteristics:

Beam Depth: $d = 36\ in.$

Beam Width: $w = 9\ in.$

Beam Area: $A = d \times w = 324\ in.^2$

Major Axis Moment of Inertia: $I_y = \frac{9(36)^3}{12} = 34{,}992\ in.^4$

Paragraph 3-2.3.3 of ASME BTH-1 is used to determine the allowable bending stress of the rectangular section. The structural beam is loaded in bending around its major axis only. For Equation 3-19 [18], the Maximum Unbraced Length (L_b) is the greater of the maximum distance between supports or the distance between the two points of applied load that are farthest apart. As shown in Figure 5-12, L_b is the distance from the applied load to the strongback saddle end plate. From the dimensions on drawing 3020935 [33] and the 236-in. maximum sling positions, this is calculated as follows:

Maximum Unbraced Length $L_b = \frac{236}{2} - \frac{28}{2} - 29 - 16 = 59\ in.$ (lift point to the nearest welded plate)

Bending Stress in Beam Section:

Elastic Modulus of Steel: $E = 29 \times 10^3\ ksi$

Yield Strength of ASTM A36: $F_y = 36\ ksi$

Stability Check (Eqn. 3-19 of [18]): $\frac{L_b d}{t^2} \leq \frac{0.08E}{F_y} \rightarrow \frac{59(36)}{(9)^2} \leq \frac{0.08(29 \times 10^3)}{36}$

$26.2 \leq 64.4\ \therefore$ TRUE

Allowable Bending Stress: $F_b = \frac{1.10F_y}{N_d} = \frac{1.10(36)}{2} = 19.8\ ksi$

Bending Stress: $f_b = \frac{M_{max}(d/2)}{I_y} = \frac{14{,}213(36/2)}{34{,}992} = 7.3\ ksi$

Margin on Bending Stress: $\frac{F_b - f_b}{F_b} = \frac{19.8 - 7.3}{19.8} = 63\%$

The margin is positive; thus, it is acceptable to lift the test load as configured in Figure 5-12.

5.4 Weld Evaluations

Of note, due to the large base metal cross-sections and some scoping evaluations of the base metal component's available strengths, only the weld joints themselves are analyzed in the following subsections, as these are the controlling strength elements of interest. Therefore, the weld metal strength allowables are exclusively employed in verification checks. This is consistent with strength checks under AISC code and Table J2.5 of the SCM [17] for partial penetration groove welds and fillet welds under shear loading.

5.4.1 Saddle Strongback End Stop Welds

The maximum test load configuration is restrained longitudinally in both directions by the two large End Stop weldments (See Figure 2-3) attached to the railcar on both ends. Wood shoring is placed between the end stop plates of the test load (See Figure 2-1) and these weldments. Six 2-in. thick gussets (end stop support ribs) act to reinforce a 3-in. beam section transferring loads to the end stop plates. Three of these end stop support ribs are located on each side of the 3-in. thick beam.

48-in. long fillet welds attach the beam to the center rib and the inside joints of the upper and lower ribs (See Sheet 3 of [33]). 48-in. long groove welds on either side of the 3-in. thick beam plate connect the outside joints of the upper and lower ribs. Check the weld size of these welds for adequacy. These welded joints are loaded in compression along the weld axis. Assuming the fillets take the load, according to AISC code (Table J2.5 of [17]), compression loads in parts joined parallel to a fillet weld axis need not be considered in the design. Therefore, these joints do not require an evaluation.

Next, review the welded connection of the central 3-in. strongback beam plate to the outer 3-in. central beam plates (See central beam weldment detail view on Sheet 3 of [33]). Since load is transferred through the central strongback plate and the ribs, there is no horizontal shear transfer through these connecting welds. They simply allow a portion of the applied load to pass into the outer plates of the central beam. Therefore, the minimum size is not checked.

Next, review the welded connection of the rib gussets to the 3-in. thick end stop plate. The 3-in. end stop plate is attached to each of the six rib plates with fillet welds along the 22.5-in. long edge of the rib plate. The longitudinal inertial load will act in shear transverse to the weld axis. The total area of each of the six rib plates welds treating as a line is given as:

$$A = 2(22.5in.)(6) = 270\ in.$$

The maximum longitudinal load applied to the weld group is provided in Table 4-2 as 1386.3 kips. Therefore, the required strength per inch of weld is:

$$f_w = \frac{1386.3kips}{270\ in.} = 5.13\frac{kips}{in.}$$

From Table 3.2 of [35] for Group I base metals (i.e., ASTM A36), the minimum matching strength filler metal is an E60XX electrode with minimum 60-ksi tensile strength. The minimum allowable weld shear stress in accordance with AWS D1.1 [35], Table 2.3 is 0.3 x classification tensile strength of the filler metal.

Therefore, the minimum fillet weld size is equal to:

$$w = \frac{5.13\ kips/in}{0.707(0.3)(60ksi)} = .40in.$$

Therefore, given the minimum fillet weld size of .40-in., then it follows that a minimum ½-in. fillet weld joining these rib plates to the end stop plate is adequate. Since sheet 3 of drawing 3020935 [33] calls out a 3/4-in. wide fillet weld, the weld group connecting the ribs to the end stop plate is acceptable with a 47% margin.

In addition, fillet welds have a minimum leg size for thick plates due to the fast cooling and greater restraint. This minimum size is checked given Table 3 of [34]. For plates within the range 2-1/4 to 6 inches, the minimum fillet weld size is ½-in. Since the end plate thickness is 3 inches, then ½-in. is the minimum required weld size. Since sheet 3 of drawing 3020935 [33] calls out a 3/4-in. wide fillet weld, the size check is acceptable with a 50% margin.

5.4.2 Central Assembly Circular Plate Attachment Welds

All of the drop-in plate bundle assemblies that are permanently fixed to the strongback beam (see sub-assembly A3 and A4 on [33]) are welded to the central beam with four fillet welds that are 20-in. long each. The bottom-end Saddle Bundle Assembly (A4) will experience the highest loading since it supports the full weight of the test load as it rests on the cradle, and support the Drop-in #3 and #4 heavy weights in the maximum test load condition (See Figure 2-7). Since the welds are all identical in size and length, the bottom-end Saddle Bundle Assembly fillet weld connections will bound the welded connection strength on the top end Saddle Bundle Assembly and the central Shear Key Weight weldment to the strongback main beam.

5.4.2.1 Primary Shear from the Total Test Load Weight

First check the weld size for primary shear stress on a single vertical plane applied to the fillet weld joint at the outside of the strongback endcap saddle plate (See Figure 2-1). The most conservative loading occurs when the test load is in its maximum test load configuration, and a 2g lateral inertial load is applied. The maximum shear forces on the weld occur at the outside of the strongback endcap saddle plate on the beam end securing the Drop-in #3 and #4 heavy weights. From Section 5.2.6, the shear load occurring at this particular weld plane is 325.7 kips. From Section D-D of drawing 3020935 [33], the length of one weld pass is 20 inches. Then, the total length of strongback endcap saddle plate welds treating as a line, with one weld on each side of the beam is given as:

$$A = 2(20in.) = 40\ in.$$

The maximum lateral load applied to the weld group is provided in Section 5.2.6 as 325.7 kips. Therefore, the required strength per inch of weld is:

$$f_w = \frac{325.7kips}{40\ in.} = 8.14\frac{kips}{in.}$$

From Table 3.2 of [35] for Group I base metals (i.e., ASTM A36), the minimum matching strength filler metal is an E60XX electrode with minimum 60-ksi tensile strength. The minimum allowable weld shear stress in accordance with AWS D1.1 [35], Table 2.3 is 0.3 x classification tensile strength of the filler metal.

Therefore, the minimum fillet weld size is equal to:

$$w = \frac{8.14\ kips/in}{0.707(0.3)(60ksi)} = .64in.$$

Therefore, given the minimum weld size of .64-in., then it follows that a minimum 1-in. fillet weld joining the strongback endcap saddle plate to the beam is adequate (See drawing 3020935 [33]). Therefore, the welds on this plane connecting the strongback endcap saddle plate to the central beam sub-weldment are adequate for this load with a 36% margin.

5.4.2.2 Loading from Drop-in Weight #3 and #4 and Saddle Bundle Assemblies

Next, the two welds analyzed in Section 5.4.2.1, along with the welds on the other side of the saddle bundle assembly are also analyzed as a separate, combined weld group. The load case evaluated includes the combined weight from Maximum Drop-in Weights #3 and #4 applied to the neutral axis of the welds (See Figure 5-14). This loading condition is congruent with that evaluated for the strongback endcap saddle plate bolt pattern in Section 5.2.2 and includes a weight contribution from the Saddle Bundle itself. However, in contrast to Section 5.4.3.1, the remaining weight of the strongback is not normalized as a separate load applied to the weld group.

Both the moment from the load induced at the welds and the shear force are applied to the welds, including the contributing shear force from the saddle bundle weight itself. In a lateral 2g load case, these Drop-in Weight assemblies apply a bending load in the weak axis of the weld group. Of note, the bottom-end Drop-in Weight #1 is also bolted to the strongback endcap saddle plate, but provides a countervailing torque, so its counteracting moment on the weld group is conservatively omitted from the weld evaluation.

These drop-in plate bundle assemblies A4 and A5 of [2] are bolted to the saddle weldment. As shown in CALC-30201251-000.xlsx spreadsheet identified in Section 6.1, the distance from the centroid of the combined weight to the bolting surface is 28.97 inches. The distance from this surface to the centroid of the weld group is the plate thickness (3-in.) plus half the 16-in. saddle bundle assembly stack height (Sheet 5 of [33]). This value is 11 inches. The combined weight of the two drop-in assemblies listed in Table 5-16 is conservatively rounded up to 140 kips (68.1 kips + 67.8). Therefore, the torsional moment applied to the weld group is as follows:

$$M_z = 140kips(28.97 + 11in.) = 5595.8\ kip - in$$

The total length of the saddle end plate welds, treating as a line, with two welds on each side of the saddle bundle is given as:

$$A = 2(20in.)(2) = 80\ in.$$

The maximum distance from the center of the neutral axis to the weld is the sum of the square root of the distance *b* between the weld joints (16−1.25×2=13.5-in.), the length of the welds (*d* = 20-in.) and the depth of the beam section which is 9 inches (See Figure 5-14). Then, the maximum distance to the top of the weld is given as:

$$c_w = \sqrt{\left(\frac{13.5}{2}\right)^2 + \left(\frac{20}{2}\right)^2 + \left(\frac{9}{2}\right)^2} = 12.9in.$$

The polar moment inertia of the weld group is given as:

$$J = \frac{d}{6}(3b^2 + d^2) \times 2\ joints = \frac{20}{6}(3 \times 13.5^2 + 20^2) \times 2 = 6311.7in.^3$$

The combined shear force acting on the weld is the drop-in weights and the saddle bundle weight of 26.9 kips (See Section 6.1 spreadsheet CALC-30201251-000.xlsx) acting on the weld group as follows:

$$f_s = \frac{140kips + 26.9kips}{80\ in.} = 2.09\frac{kip}{in.}$$

The torsional load on the weld group around the z-axis from the moment is:

$$f_z = \frac{M_z \times c_w}{J} = \frac{5595.8\ \times 12.9}{6311.7} = 11.44\frac{kip}{in.}$$

The resultant load on the weld group is given as:

$$f_r = \sqrt{f_s^{\,2} + f_z^{\,2}} = \sqrt{2.09^2 + 11.44^2} = 11.63\frac{kip}{in.}$$

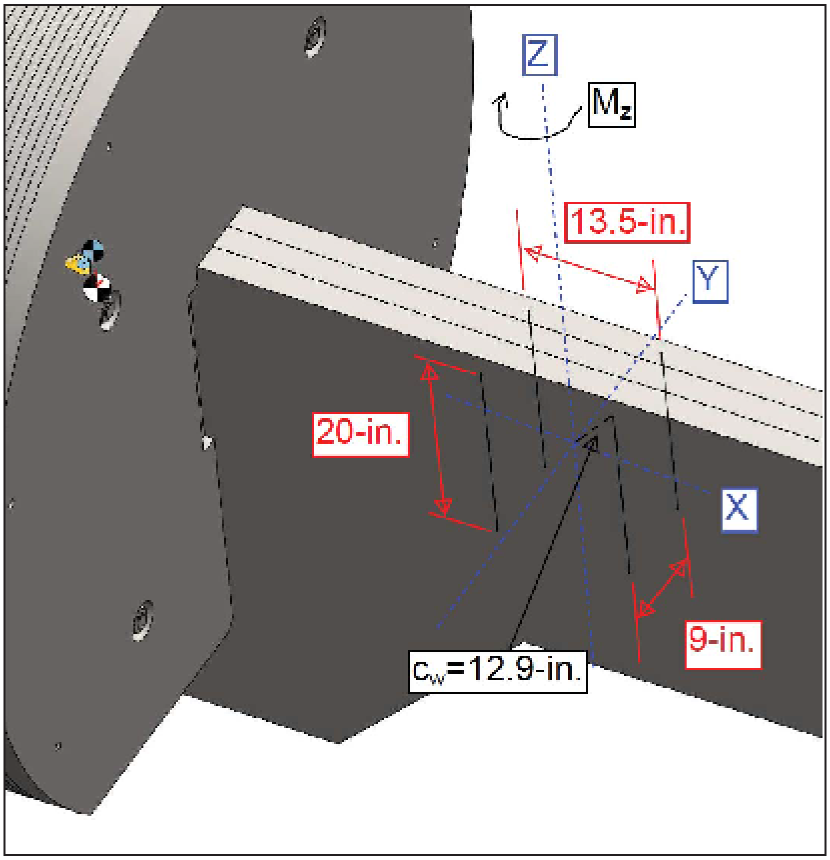


Figure 5-14: Weld Group attaching saddle bundle assembly to strongback beam

From Table 3.2 of [35] for Group I base metals (i.e., ASTM A36), the minimum matching strength filler metal is an E60XX electrode with minimum 60-ksi tensile strength. The minimum allowable weld shear stress in accordance with AWS D1.1 [35], Table 2.3 is 0.3 x classification tensile strength of the filler metal.

Therefore, the minimum fillet weld size is equal to:

$$w = \frac{11.63\ kips/in}{0.707(0.3)(60ksi)} = .914in.$$

Therefore, given the minimum weld size of .914-in., then it follows that a minimum 1-in. fillet weld joining these rib plates to the beam is adequate with a 8.6% margin. Since the drawing 3020935 [33] calls out 1-in. wide fillet welds, the weld groups connecting the saddle bundles to the central beam sub-weldment are adequate for this load case.

5.5 Wood End Chocking Evaluation

This optional structural evaluation section provides minimum strength requirements for lumber used as chocking between the end stop weldments and the end stop plate for the maximum condition test load. While the ultimate decision on any wood cribbing and chocking is DOE's, the guidance in this section may be used for sizing and selection. This evaluation is based on National Design Specification® (NDS®) for Wood Construction design procedures [36]. Allowable Stress Design (ASD) methodology is used. A bearing stress evaluation is used to check the compression stress is within the adjusted compression design value for the maximum longitudinal inertial loading criteria provided in Table 4-2. It is assumed that that the chocks will be loaded perpendicular to the grain, since this is a more conservative allowable strength requirement (parallel to the grain compressive stress limits are higher).

Therefore, the basic equation for design verification checks of compression members is: $f_{c\perp} \leq F_{c\perp}'$

Where,

$F_{c\perp}'$ = adjusted compression perpendicular to grain capacity, psi

$f_{c\perp}$ = required compression perpendicular to grain, psi

The adjusted design value ($F_{c\perp}'$) is the reference compression perpendicular to grain design value ($F_{c\perp}$) multiplied by adjustment factors. The reference compression perpendicular to grain ($F_{c\perp}$) is tabulated in Tables 4A-4F of [37]. ($F_{c\perp}$) applies at a deformation level of .04-in. (Section 4.2.6 of [36]) which is acceptable for this application, since there is an offset between the impact limiter and the cradle strap of .50-in. This indicates the deflection limit occurs with no engagement of the cradle strap during longitudinal loading. In accordance with Table 4.3.1 of NDS [36], the adjusted compression perpendicular to the grain is provided by:

$$F_{c\perp}' = F_{c\perp} \times C_M \times C_t \times C_i \times C_b$$

Where,

C_M = Wet Service Factor (0.67 for Tables 4A-4F of NDS Supplement [37])

C_t = Temperature Factor (1.0 for Temperatures $\leq$ 100°F, Table 2.3.3 of [36])

Note: 100°F is an acceptable maximum per § 2.5.8 of [6]

C_i = Incising Factor (1.00 for perpendicular to grain compression, Table 4.3.8 of [36])

C_b = Bearing Area Factor (1.00 for bearing length 6-in. or more) (Table 3.10.4 of [36])

It follows that, $F_{c\perp}' = F_{c\perp} \times 0.67 \times 1.0 \times 1.00 \times 1.00 = F_{c\perp} \times .67$

From Table 4-2, the maximum condition inertial load (P_{req}) is 1386.3 kips. The nominal test load end plate dimensions are 56-in. x 44-in. from drawing 3020935 [33], then the bearing area (A) = 2464in^2. However, assuming the chocking will extend beyond the edges of the end stop plate, the effective area of load distribution may be slightly increased. According to Section 6 of [38], a minimum 30 mm extension to each end of the contact area may be applied. Assume this 30 mm is limited to an inch per side of end stop plate, then the effective total area (A_{ef}) is increased to 58-in. x 46-in. = 2668in^2. Therefore, the compressive stress is as follows:

$$f_{c\perp} = P_{req} / A_{ef}$$

$$f_{c\perp} = 1386.3 \text{ kips} / 2668 \text{ in}^2 = .52 \text{ ksi}$$

Therefore, it follows that, $F_{c\perp} \times .67 \geq 520$ psi. As a result, $F_{c\perp} \geq 775.5$ psi

As long as the wood is rated to a compression perpendicular to the grain ($F_{c\perp}$) of 775.5 psi or higher, then the wood may be used. From Tables 4A-4F of [37], qualified species would be any grade of mixed oak, northern red oak, red oak or white oak.

5.6 Test Load Modal Analysis

Modal analyses of the test loads are discussed in this section. The natural frequencies of the test loads' bending modes are related to both the stiffness and mass of each of the test loads (minimum and maximum conditions shown in Figure 2-5 and Figure 2-3, respectively). Of note, the test load should be rigid enough that the test load's lowest bending frequency is not excited by the railcar test inputs. The actual TTCI dynamic testing program will be performed at 75mph over vertical and lateral track perturbations of a 39-foot wavelength. This corresponds to an input frequency of 2.82 Hz [39]. As stated in § 2.2.4.3 of the DBRD [6], the lowest bending frequency of the test load must be at least 3-5 times the lowest bending frequency of the loaded railcar or at least 3-5 times the input frequency (i.e., 3-5 times 2.82 Hz). Because the bending frequency of the loaded railcar is unavailable, the minimum allowable limit will be taken as 5 × 2.82 Hz or 14.1 Hz. Incidentally, according to [39], the test load's bending frequency will not significantly affect the first order vertical, lateral, and torsional bending frequency of a loaded railcar.

ANSYS® Mechanical Workbench, Version 17.1 is used to perform a modal analysis of the minimum and maximum weight condition test loads via a Finite Element Analysis (FEA) solution. To limit the computational resources required to perform the analysis, a half-scale model of the stated weight condition test loads was adopted. In addition, the test load cradles are not within the scope of the analysis (See § 2.2.4.3 of [6]) and therefore are not modeled in this analysis.

Symmetry plane boundary conditions were applied to the central plate, and three center beam faces, as highlighted in red in Figure 5-15 and Figure 5-16 for the minimum and maximum condition test loads, respectively. All contacts between the plates are of the "bonded" constraint type, indicating all degrees of freedom have been fixed for both translation and rotation.

All components in the model use ASTM A36 [12] material with the following mechanical property input values:

- Density: 0.28 lb/in^3
- Young's Modulus: 29.4×10^6 psi
- Poisson's Ratio: 0.3

For the Minimum Condition Test Load a fine mesh (620,548 elements) with global element size of 1.0-in. is adopted for all components with characteristics as shown in Figure 5-17. As shown in Figure 5-15, the blue-colored bottom cylindrical plate surfaces (labelled "A") are in bearing contact with the saddle cylindrical support on the cradle. The boundary conditions for this support are fixed in the radial and tangential direction, and free in the axial direction. All other surfaces are free. The resultant modes and associated natural frequencies are shown in Table 5-22.

The Maximum Condition Test Load was modelled with a medium mesh (334,471 elements) with a global element size of 2.0-in. for all components with characteristics as shown in Figure 5-18. As shown in Figure 5-16, the blue-colored bottom cylindrical plate surfaces (labelled "A") are in bearing contact with the saddle cylindrical support on the cradle. The boundary conditions for this support are fixed in the radial and tangential directions, and free in the axial direction. All other surfaces are free. The resultant modes and associated natural frequencies are shown in Table 5-22.

Table 5-22 shows that the lowest mode frequency is 15.471 Hz and 40.038 Hz for the minimum and maximum condition test loads, respectively.

The results of the modal analysis from Table 5-22 show that the first order bending frequencies of the minimum and maximum condition test loads are 15.471 and 40.038 Hz, respectively. These values are greater than the allowable minimum of 14.1 Hz (See Table 4-4) by a margin of 9.7% and 84% for the minimum and maximum test loads, respectively. As a result, the design of the test load's lowest bending frequency is not excited by the railcar test inputs.

Table 5-22: Minimum and Maximum Condition Test Load Modes and Natural Frequency Results

Mode	Minimum Condition Test Load	Maximum Condition Test Load
	Frequency (Hz)	Frequency (Hz)
1	15.471	40.038
2	40.284	53.889
3	44.788	83.152
4	48.573	106.67
5	56.815	142.02
6	91.9	158

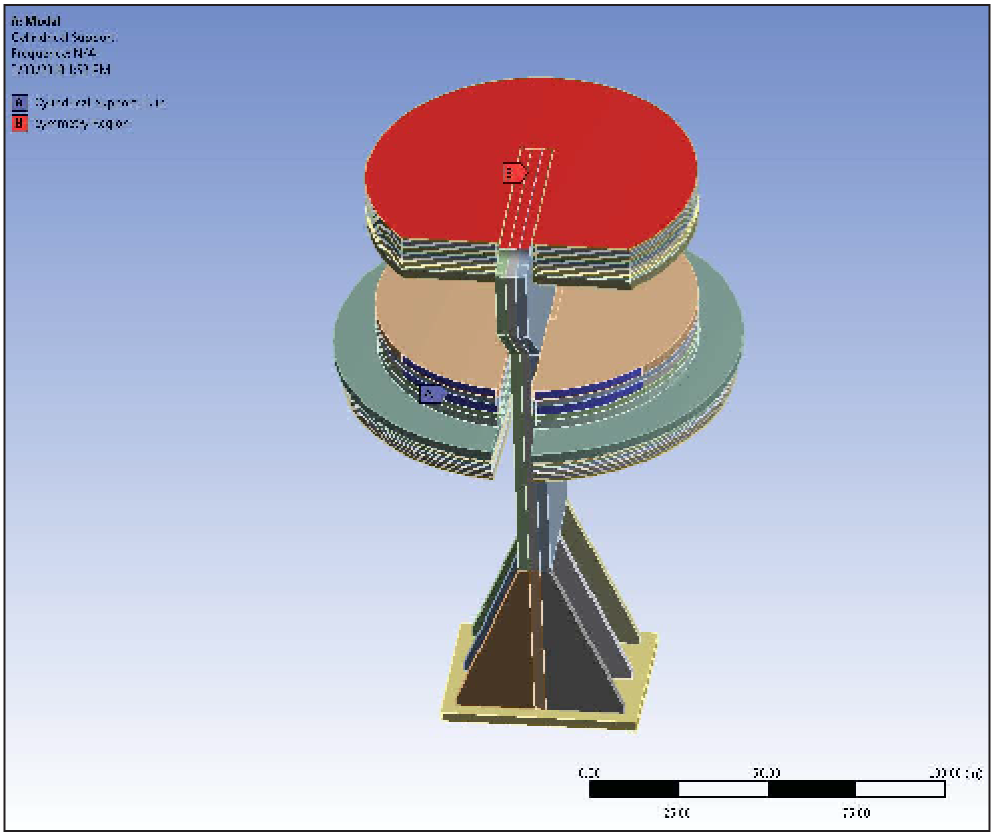


Figure 5-15: Minimum Condition Test Load, Half-Symmetry Boundary Conditions

Note: (red) Symmetry Plane and (blue) cylindrical support [radial fixed, axial free, tangential fixed]

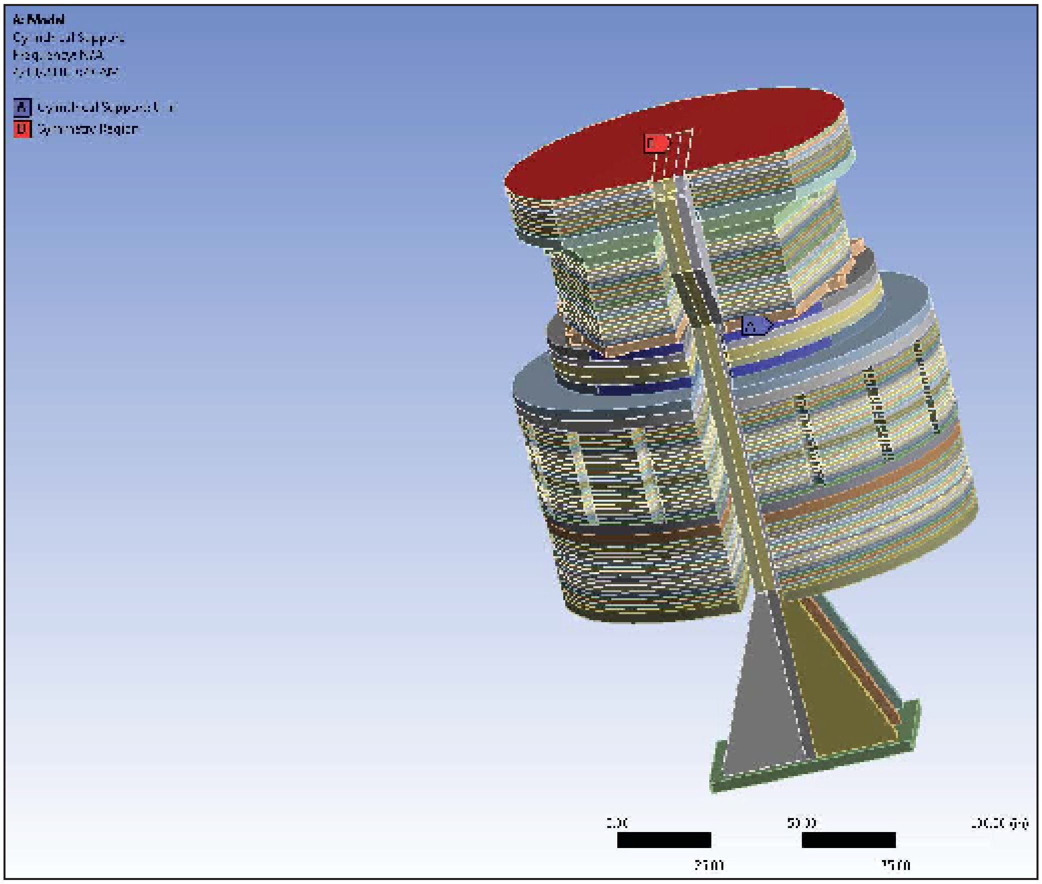
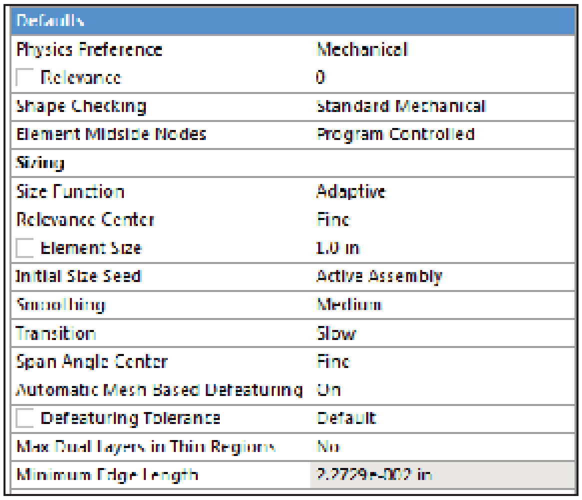


Figure 5-16: Maximum Condition Test Load, Half-Symmetry Boundary Conditions

Note: (red) Symmetry Plane and (blue) cylindrical support [radial fixed, axial free, tangential fixed]



Defaults	
Physics Preference	Mechanical
☐ Relevance	0
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Sizing	
Size Function	Adaptive
Relevance Center	Fine
☐ Element Size	1.0 in
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Slow
Span Angle Center	Fine
Automatic Mesh Based Defeaturing	On
☐ Defeaturing Tolerance	Default
Max Dual Layers in Thin Regions	No
Minimum Edge Length	2.2729e-002 in

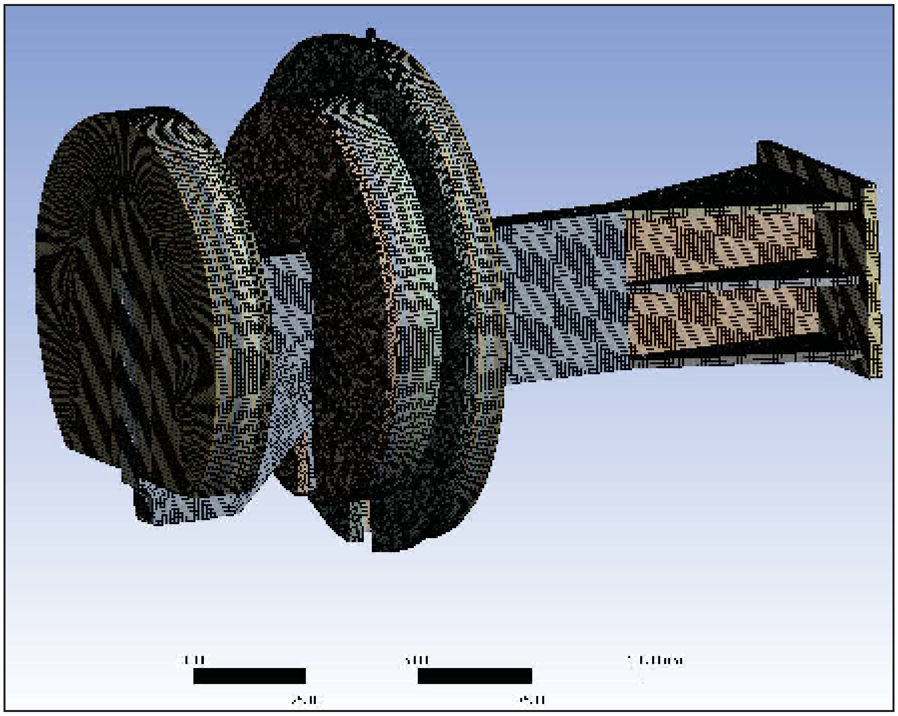
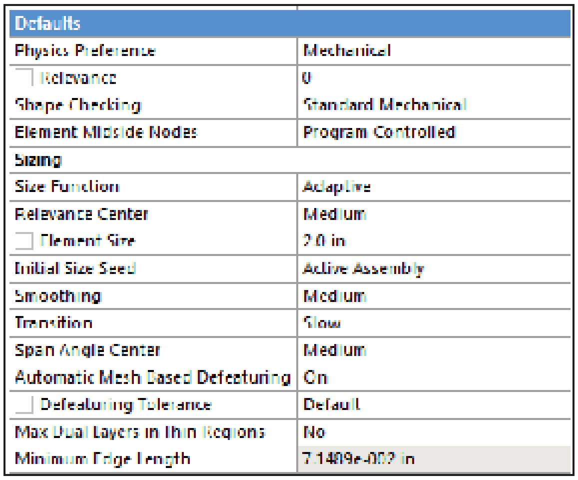


Figure 5-17: Minimum Condition Test Load Half-Symmetry Mesh with Characteristics and Values



Defaults	
Physics Preference	Mechanical
☐ Relevance	0
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Sizing	
Size Function	Adaptive
Relevance Center	Medium
☐ Element Size	2.0 in
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Slow
Span Angle Center	Medium
Automatic Mesh Based Defeaturing	On
☐ Defeaturing Tolerance	Default
Max Dual Layers in Thin Regions	No
Minimum Edge Length	7.1409e-002 in

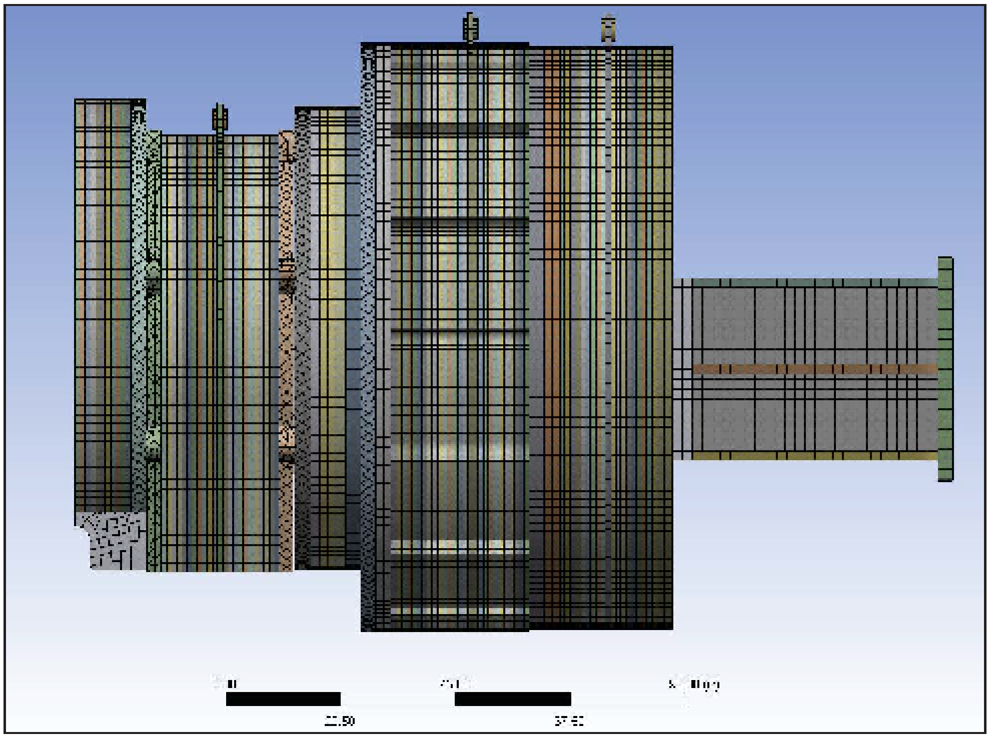


Figure 5-18: Maximum Condition Test Load Half-Symmetry Mesh with Characteristics and Values

6.0 COMPUTER SOFTWARE USAGE

Hand calculations are used through the support of Microsoft Excel® as identified in Section 6.1. In addition, Solidworks® Premium 2016 CAD software is used for determinations of basic component geometry, density, weight, CG, and MMI. SW File listings are output as a directory listing and included in Appendix B. File listings include date and time of most recent save, file size in bytes, and file name. Each Solidworks® calculation model consists of a large number of part models as well as associated assembly models. In addition, weights, CG assessments, and MMI determinations are output from the SW models. The outputted results of each SW MMI and CG computation are saved in the spreadsheet Mass Props Tables.xlsx identified in Section 6.1 The tables within the calculation where inertial output information is reported include: Table 5-2, Table 5-3, Table 5-4, Table 5-5, Table 5-6, Table 5-7, Table 5-9, Table 5-10, Table 5-11, Table 5-12, Table 5-13, Table 5-14, Figure 5-13, Table A-1, Table A-2, Table A-3, and Table A-4. Solidworks® Premium 2016 has been dedicated as documented in Software Release Authorization SD-SOLIDWORKS-2016-SRA-3019536-000 [42] and qualification report SD-SOLIDWORKS-2016-CALC-3019535 [40]. There are no error notices for Solidworks® Premium 2016 requiring review.

In Section 5.6, ANSYS® Mechanical Workbench Version 17.1 is used to resolve the FEA solutions for the minimum and maximum condition test load modal analyses. ANSYS has been validated for the modal analysis solutions evaluated herein, as documented in Software Release Authorization SD-ANSYS-17.1-SRA-3018359-000 [41]. The computer run records used in this analysis are included in Table 6-2 and Table 6-3. In accordance with Section 5.1.5 of AFS-EN-PRC-013 [1], in-use test run cases were solved in Section 6.2.2. Error Notices in ANSYS® Mechanical Workbench were reviewed for applicability and none apply.

6.1 Non-Engineering Application Software

Computations were tabulated using Microsoft Excel® Version 14.0.7194.5000 (32-bit) on the same hardware and software configuration used for SW and identified in Table 6-1. One file was generated for this calculation to calculate the tie-rod and bolt loads and margins from allowables, the main strongback beam shear forces, and the lift lug strength verification checks. The file is identified as follows:

Filename	Purpose	Date and Time	Size
CALC-30201251-000.xlsx	See Above	4/30/2018 6:01 PM	1,453 kB
Mass Props Tables.xlsx	See Above	3/28/2018 7:43 PM	85 kB

Table 6-1: Computer Run Record for SW Applicability

COMPUTER RUN RECORD	
Run description	See input/output file names in Appendix B and the discussions in the body of the calculation
Software used	Solidworks® Premium 2016 x64 Edition, SP 5.0
Software Verification	Verified under AFS-EN-PRC-013 Software Release Authorization Document ID: SD-SOLIDWORKS-2016-SRA-3019536-000 [42]
Computer name	CBACKUS3
Hardware Description	Intel® Xeon® CPU E5-1620 v2 @ 3.70 GHz, 16GB RAM
Operating System	64-bit Windows 7 Enterprise, 2009, Service Pack 1
Unique run identifier / List of output files	See input/output file names in Appendix B with associated date/time stamps
Disk Storage Description	All files stored in Coldstor along with calculation

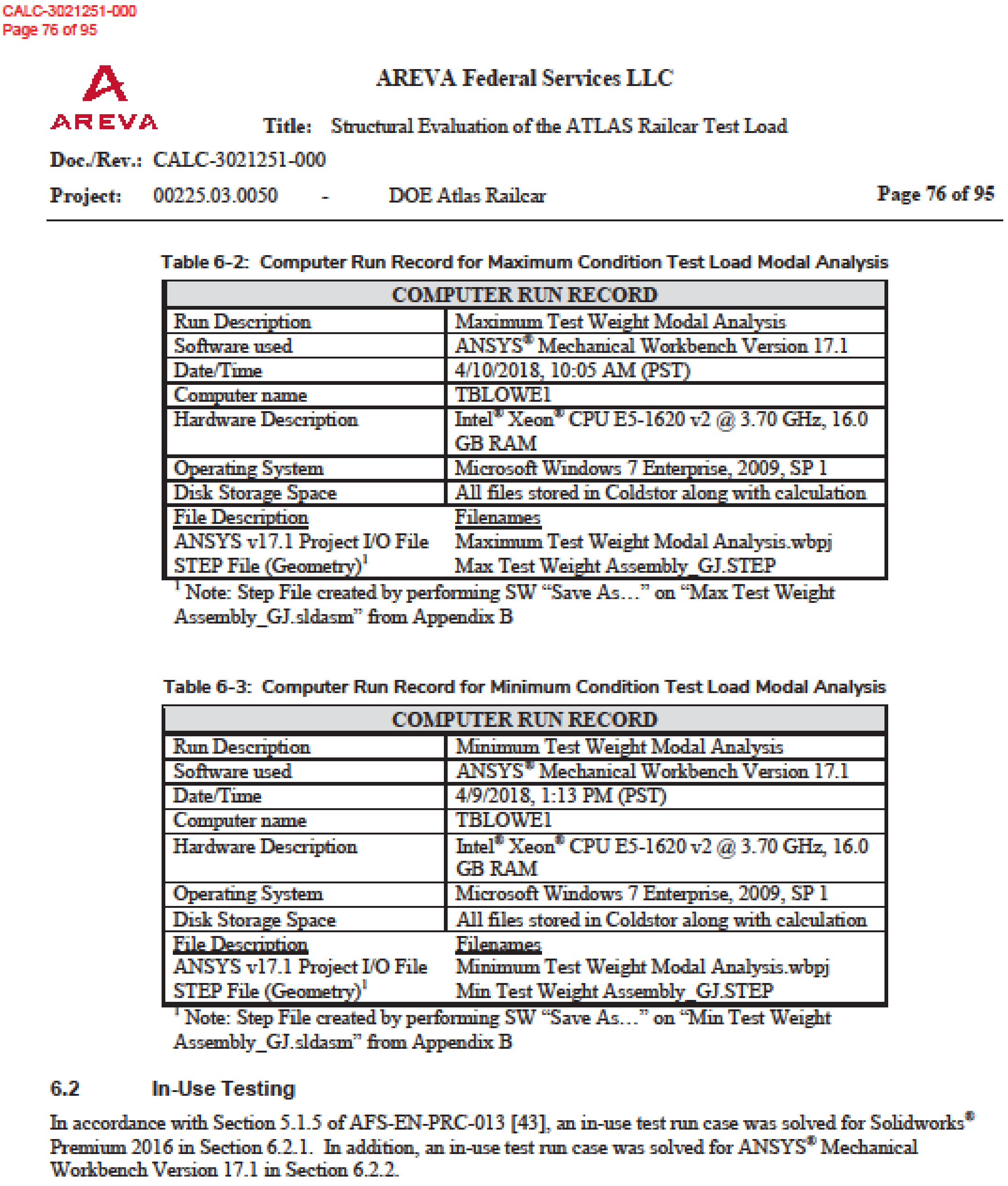


Table 6-2: Computer Run Record for Maximum Condition Test Load Modal Analysis

COMPUTER RUN RECORD	
Run Description	Maximum Test Weight Modal Analysis
Software used	ANSYS® Mechanical Workbench Version 17.1
Date/Time	4/10/2018, 10:05 AM (PST)
Computer name	TBLOWE1
Hardware Description	Intel® Xeon® CPU E5-1620 v2 @ 3.70 GHz, 16.0 GB RAM
Operating System	Microsoft Windows 7 Enterprise, 2009, SP 1
Disk Storage Space	All files stored in Coldstor along with calculation
<u>File Description</u>	<u>Filenames</u>
ANSYS v17.1 Project I/O File	Maximum Test Weight Modal Analysis.wbpj
STEP File (Geometry)[1]	Max Test Weight Assembly_GJ.STEP

[1] Note: Step File created by performing SW "Save As…" on "Max Test Weight Assembly_GJ.sldasm" from Appendix B

Table 6-3: Computer Run Record for Minimum Condition Test Load Modal Analysis

COMPUTER RUN RECORD	
Run Description	Minimum Test Weight Modal Analysis
Software used	ANSYS® Mechanical Workbench Version 17.1
Date/Time	4/9/2018, 1:13 PM (PST)
Computer name	TBLOWE1
Hardware Description	Intel® Xeon® CPU E5-1620 v2 @ 3.70 GHz, 16.0 GB RAM
Operating System	Microsoft Windows 7 Enterprise, 2009, SP 1
Disk Storage Space	All files stored in Coldstor along with calculation
<u>File Description</u>	<u>Filenames</u>
ANSYS v17.1 Project I/O File	Minimum Test Weight Modal Analysis.wbpj
STEP File (Geometry)[1]	Min Test Weight Assembly_GJ.STEP

[1] Note: Step File created by performing SW "Save As…" on "Min Test Weight Assembly_GJ.sldasm" from Appendix B

6.2 In-Use Testing

In accordance with Section 5.1.5 of AFS-EN-PRC-013 [43], an in-use test run case was solved for Solidworks® Premium 2016 in Section 6.2.1. In addition, an in-use test run case was solved for ANSYS® Mechanical Workbench Version 17.1 in Section 6.2.2.

6.2.1 Solidworks® Premium 2016 In-Use Testing Record

Test case number 1 (Test Shape 1.sldprt) from [40] was chosen for this in-use test, since it includes a check for all of the as-used inertial properties: weight, CG, and MMI. The qualification of SW on computer CBACKUS3 (hardware configuration listed in Table 6-1) by the calculation preparer validate the software for use in this calculation. The computer run record for the in-use test is included in Table 6-4. The mass properties of the part model and section properties of the front face were computed using the SW "Evaluate/Mass Properties" and "Evaluate/Section Properties" functionality within the SW program. The results from running these two functions produced the output reports shown in Figure 6-1 and Figure 6-2, respectively. Comparing these results with Section 5.1.1 of [40] computations for the identical information, shows there is 0% discrepancy between the two datasets, showing acceptability for use on computer name: CBACKUS3.

Table 6-4: CALC-3019535 SW Test Case 1 - Computer Run Record for In-Use testing

Run Identifier:	Test Case 1 from SD-SOLIDWORKS-2016-CALC-3019535 (Section 5.1.1 of [40])
Date/Time:	3/27/2018, 7:09 PM (PST)
Computer:	cbackus3.adom.ad.corp
Description:	Inertial Properties of Test Shape 1
Hardware Description:	Intel® Xenon® CPU E5-1620 v2 @ 3.70GHz, 16GB RAM
Operating System:	Microsoft Windows 7 Enterprise, 2009, SP 1
Filenames:	Directory: Mode LastWriteTime Length Name -a--- 3/27/2018 7:09 PM 59345 Test Shape 1.SLDPRT

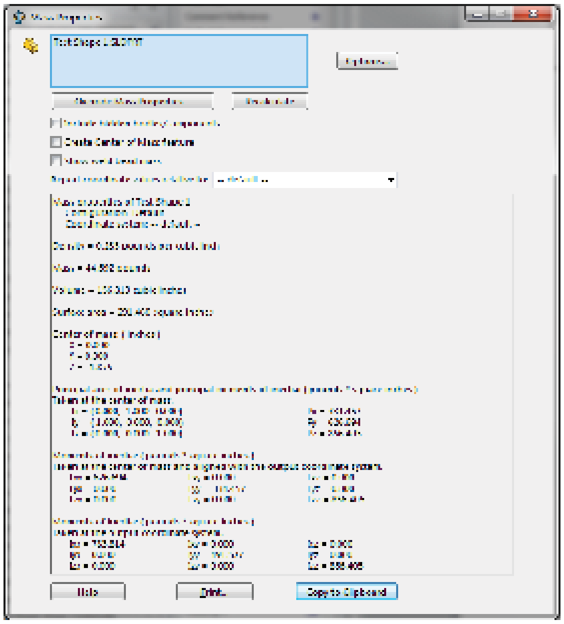


Figure 6-1: Test Shape 1 Mass Properties

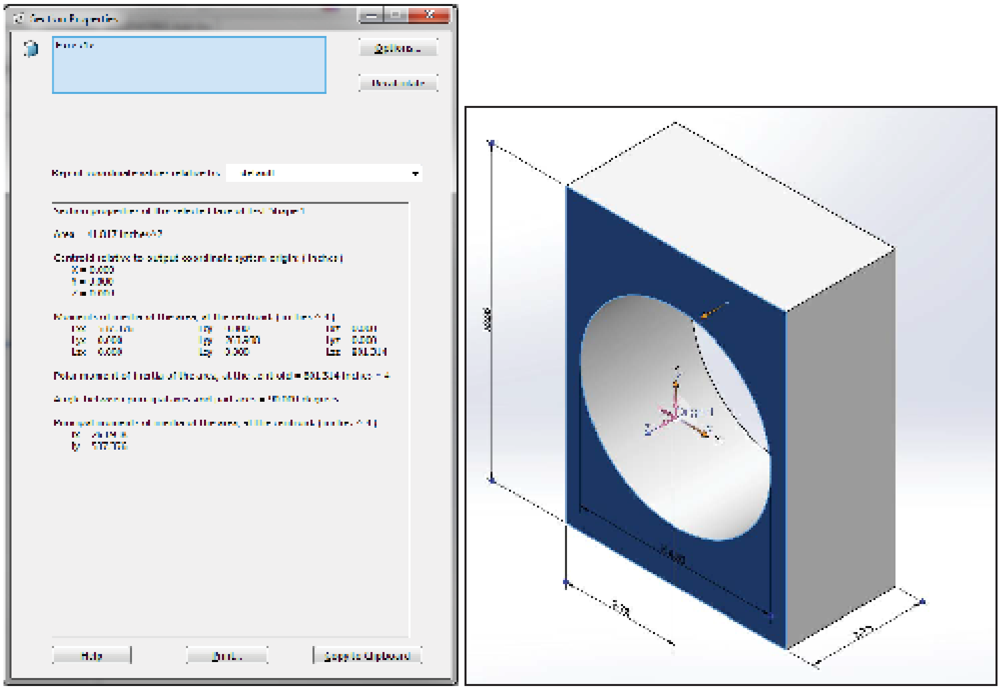


Figure 6-2: Test Shape 1 Section Properties of Front Face

6.2.2 ANSYS® Mechanical Workbench 17.1 In-Use Testing Record

Test case VMMECH003 from the ANSYS® Mechanical Workbench Verification Manual [44] was selected for the in-use test because of the similarity of the test schematic and use of a cylindrical boundary condition with respect to the test load annular test plates. The test case consists of an assembly of three annular plates having cylindrical supports (fixed in the radial, tangential, and axial directions) applied on cylindrical surfaces of a hole. Sizing control with element size of 0.5-in. is applied to the cylindrical surface of the hole. The first six modes of natural frequencies are determined. The target results of the test case are listed in the ANSYS® Mechanical Workbench Verification Manual [44]. These results were replicated by computer run ID VMMECH003_Test on computer TBLOWE1. Therefore, the software remains acceptable for use, since the in-use results (See Table 6-6) for the test case correspond to the target test case from [44]. The computer files for test case VMMECH003_Test are listed in Table 6-5.

Table 6-5: ANSYS® Mechanical Workbench Computer Run Record for In-Use Testing

Run Identifier:	VMMECH003_TEST
Date/Time:	4/11/2018, 8:58 AM (PST)
Computer:	TBLOWE1
Description:	Modal Analysis of Annular Plate
Hardware Description:	Intel® Xeon® CPU E5-1620 v2 @ 3.70 GHz, 16.0 GB RAM
Operating System:	Microsoft Windows 7 Enterprise, 2009, SP 1
Filenames:	

Name	Date modified	Type	Size
VMMECH003_TEST_files	4/11/2018 8:58 AM	File folder	
VMMECH003.STEP	4/10/2018 3:49 PM	STEP File	51 KB
VMMECH003_TEST	4/11/2018 8:58 AM	ANSYS v171 .wbpj File	414 KB

Table 6-6: ANSYS® Mechanical Workbench Test Case VMMECH003 Results

Results	Target Case [44]	Target Case Ansys® Mechanical VMMECH003_TEST on TBLOWE1	Error (%)
1st Frequency Mode (Hz)	310.911	311.04	0.04
2nd Frequency Mode (Hz)	318.086	316.5	-0.50
3rd Frequency Mode (Hz)	318.086	316.54	-0.49
4th Frequency Mode (Hz)	351.569	347.77	-1.08
5th Frequency Mode (Hz)	351.569	347.78	-1.08
6th Frequency Mode (Hz)	442.451	436.19	-1.42

7.0 RESULTS/CONCLUSIONS

7.1 Inertial Properties Assessment

Table 7-1 below shows the comparison between the inertial property requirement from Table 4-6 and the computed value for each inertial property for the minimum condition test load cask/cradle combination (See Figure 5-1). The left column lists the requirement, while the middle column reports the computed value, and the right-hand column lists the variance from nominal and a compliance statement. Similarly, data comparisons are reported in Table XY, for the maximum condition test load cask/cradle combination.

All inertial properties comply with the comparison requirements from the design phase, except for the following:

- Maximum (Loaded) Cask/Cradle Weight (lb)

In the case of the weight of the maximum condition test load and cradle, the minimum requirement is 433,137 pounds, but the computed value is at 430,858 pounds. This 2,279 pound variance (-0.5%) is in fact desirable to reach in this calculation, as the actual weight of the test load will be greater than that computed (due to Justified Assumption 3.2.7). The DBRD [6] requirement states in § 2.2.4.2.a that the tolerance is for the "fabricated maximum test load", not the as-modelled maximum test load with cradle design. Therefore, post-fabrication, the actual weight will increase, and will meet the 433,137 to 446,131 pound range required. If necessary, the ability to add material to the test loads to adjust for overall target weight is allowed per flag note 12 in [2].

For the overall railcar maximum condition vertical CG assessment, Section 5.1.2.1 calculated this value. For the overall railcar vertical CG location from the rails, the value is 95.19 inches. Per Section 4.3.2.2, the maximum acceptable overall CG from the rail tracks is 98 inches. Therefore, the test load on railcar maximum vertical CG location complies with the requirement.

Table 7-1: Test Load Inertial Property Comparison Assessment from Design Phase Requirement - Minimum Condition Test Load Cask/Cradle Combination

Inertial Property	Comparator Minimum Condition Cask/Cradle (Empty MP-197 Cask on Cradle) (See Table 4-6)	Calculated Test Load Cask/Cradle Value (See Figure 5-1)	Tabulated Variance	Complies with Requirement?
Minimum (Empty) Cask/Cradle Weight (lb)	≥ -5% of 201,076	195,186	-3%	Yes
Vertical CG from railcar deck (inches)	±.25-in. of 56.96	56.97	+0.01	Yes
Lateral CG from railcar center (inches)	±.50-in. of -0.028	-0.0001	+0.0279	Yes
Longitudinal CG from railcar center (inches)	±.50-in. of 1.07	1.01	-0.06	Yes
Rotational MMI Vertical Axis (lb × in^2)	±10% of 807,993,293	838,840,049	+3.8%	Yes
Rotational MMI Lateral Axis (lb × in^2)	±10% of 824,202,094	853,287,506	+3.5%	Yes
Rotational MMI Longitudinal Axis (lb × in^2)	±10% of 278,839,838	275,276,750	-1.3%	Yes

Table 7-2: Test Load Inertial Property Comparison Assessment from Design Phase Requirement - Maximum Condition Test Load Cask/Cradle Combination

Inertial Property	Comparator Maximum Condition Cask/Cradle (Loaded HI-Star 190 XL Cask on Cradle) (See Table 4-7)	Calculated Test Load Cask/Cradle Value (See Figure 5-2)	Tabulated Variance	Complies with Requirement?
Maximum (Loaded) Cask/Cradle Weight (lb)	≤ +5% of 433,137	430,858	2,279	No
Vertical CG from railcar deck (inches)	±.25-in. of 63.73	63.78	+0.05	Yes
Lateral CG from railcar center (inches)	±.50-in. of 0	0	0	Yes
Longitudinal CG from railcar center (inches)	±.50-in. of 17.19	17.136	-0.054	Yes
Rotational MMI Vertical Axis (lb × in^2)	±10% of 2,451,205,788	2,379,956,039	-2.9%	Yes
Rotational MMI Lateral Axis (lb × in^2)	±10% of 2,462,970,267	2,379,821,658	-3.4%	Yes
Rotational MMI Longitudinal Axis (lb × in^2)	±10% of 647,686,241	633,502,857	-2.2%	Yes

7.2 Test Load Structural Assessment

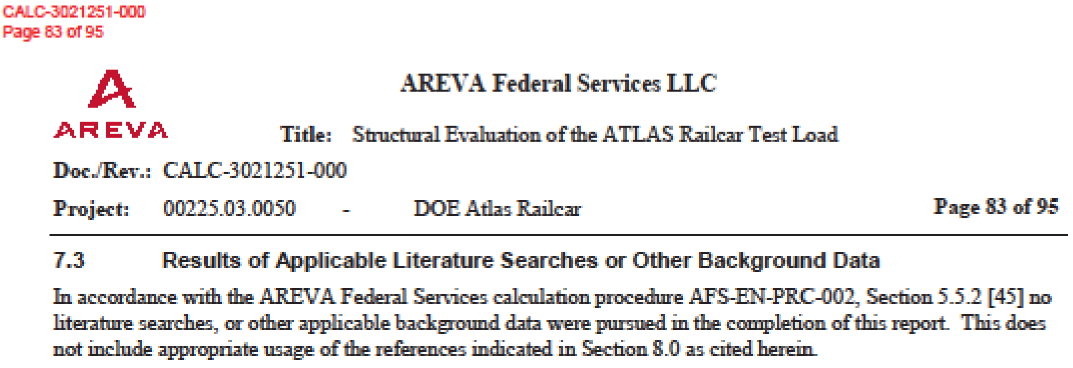
Table 7-3 below lists the results of the structural assessments conducted for the test loads. The results include the margin results for various structural analyses from the allowable requirements. All results show positive margin.

In Section 5.6, the results of the modal analysis from Table 5-22 show that the first order bending frequencies of the minimum and maximum condition test loads are 15.471 and 40.038 Hz, respectively. These values are greater than the allowable minimum of 14.1 Hz (See Table 4-4) by a margin of 9.7% and 84% for the minimum and maximum test loads, respectively. As a result, the design of the test load's lowest bending frequency is not excited by the railcar test inputs (See Table 7-3).

Table 7-3: Test Load Structural Evaluations and Margins from Allowables

Component Analyzed and Property Evaluated	Loading Condition	Margin from Allowable	Source
Slip Resistance for Tie-Rods on Drop-In Weight Bundles	Lateral or Vertical Inertial	Range: 60-90%	Table 5-16
Shear Strength for Tie-Rods on Drop-In Weight Bundles	Lateral or Vertical Inertial	Range: 15-80%	Table 5-16
Tensile Strength for Tie-Rods on Drop-In Weight Bundles	Longitudinal Inertial	Range: 32-84%	Table 5-16
Slip Resistance for Bolts on Drop-In Weight Bundles	Lateral Inertial	Range: 63-89%	Table 5-19
Slip Resistance for Bolts on Drop-In Weight Bundles	Vertical Inertial	Range: 64-89%	Table 5-19
Shear Strength for Bolts on Drop-In Weight Bundles	Lateral Inertial	Range: 26-76%	Table 5-19
Shear Strength for Bolts on Drop-In Weight Bundles	Vertical Inertial	Range: 27-77%	Table 5-19

Component Analyzed and Property Evaluated	Loading Condition	Margin from Allowable	Source
Tensile Strength for Bolts on Drop-In Weight Bundles	Longitudinal Inertial	Range: 39-81%	Table 5-19
Internal Thread Shear for Bolts on Drop-In Weight Bundles	All Inertial	53% Minimum	Section 5.2.2.1
Bearing Stress on Shear Key Reaction Zone of Strongback	Longitudinal Inertial	63%	Section 5.2.3
Combined Shear and Bending Stress on Strongback End Stop Plate	Longitudinal Inertial	62%	Section 5.2.4
Compressive Stress on Strongback End Stop Support Rib Plate	Longitudinal Inertial	73%	Section 5.2.5
Shear Stress in Strongback Beam Shear Keys	Vertical Inertial	307%	Section 5.2.6
Shear Stress in Strongback Beam Shear Keys	Longitudinal Inertial	15%	Section 5.2.6
Tensile strength through lift lug at plane tangent to bottom of doubler	Lifting	45.6%	Section 5.3.1.1
Tensile Strength through the lift lug pinhole on Drop-In Weight Bundles	Lifting	Range: 39-64%	Table 5-21
Single Plane Fracture Strength beyond the lift lug pinhole on Drop-In Weight Bundles	Lifting	Range: 18-51%	Table 5-21
Double Plane Shear Strength beyond the lift lug pinhole on Drop-In Weight Bundles	Lifting	Range: 17-51%	Table 5-21
Bearing Strength through the lift lug pinhole on Drop-In Weight Bundles	Lifting	Range: 29-67%	Table 5-21
Weld Strength for the lift lug doubler	Lifting	50%	Section 5.3.1.2
Bending Stress in Strongback Beam	Lifting	63%	Section 5.3.2
Shear Stress in End Stop Rib Gusset Fillet Welds to End Stop Plate	Longitudinal Inertial	47%	Section 5.4.1
End Stop Rib Gusset to End Stop Fillet Weld Size Check	N/A	50%	Section 5.4.1
Primary Shear Strength in Bottom-End Saddle Bundle Assembly Fillet Weld connection to Strongback Beam	Lateral Inertial	36%	Section 5.4.2.1
Combined Loading Capacity in Bottom-End Saddle Bundle Assembly Fillet Weld connection to Strongback Beam	Lateral Inertial	8.6%	Section 5.4.2.2
Minimum Condition Test Load First Order Mode Natural Frequency	Modal Analysis	9.7%	Section 5.6
Maximum Condition Test Load First Order Mode Natural Frequency	Modal Analysis	84%	Section 5.6



7.3 Results of Applicable Literature Searches or Other Background Data

In accordance with the AREVA Federal Services calculation procedure AFS-EN-PRC-002, Section 5.5.2 [45] no literature searches, or other applicable background data were pursued in the completion of this report. This does not include appropriate usage of the references indicated in Section 8.0 as cited herein.

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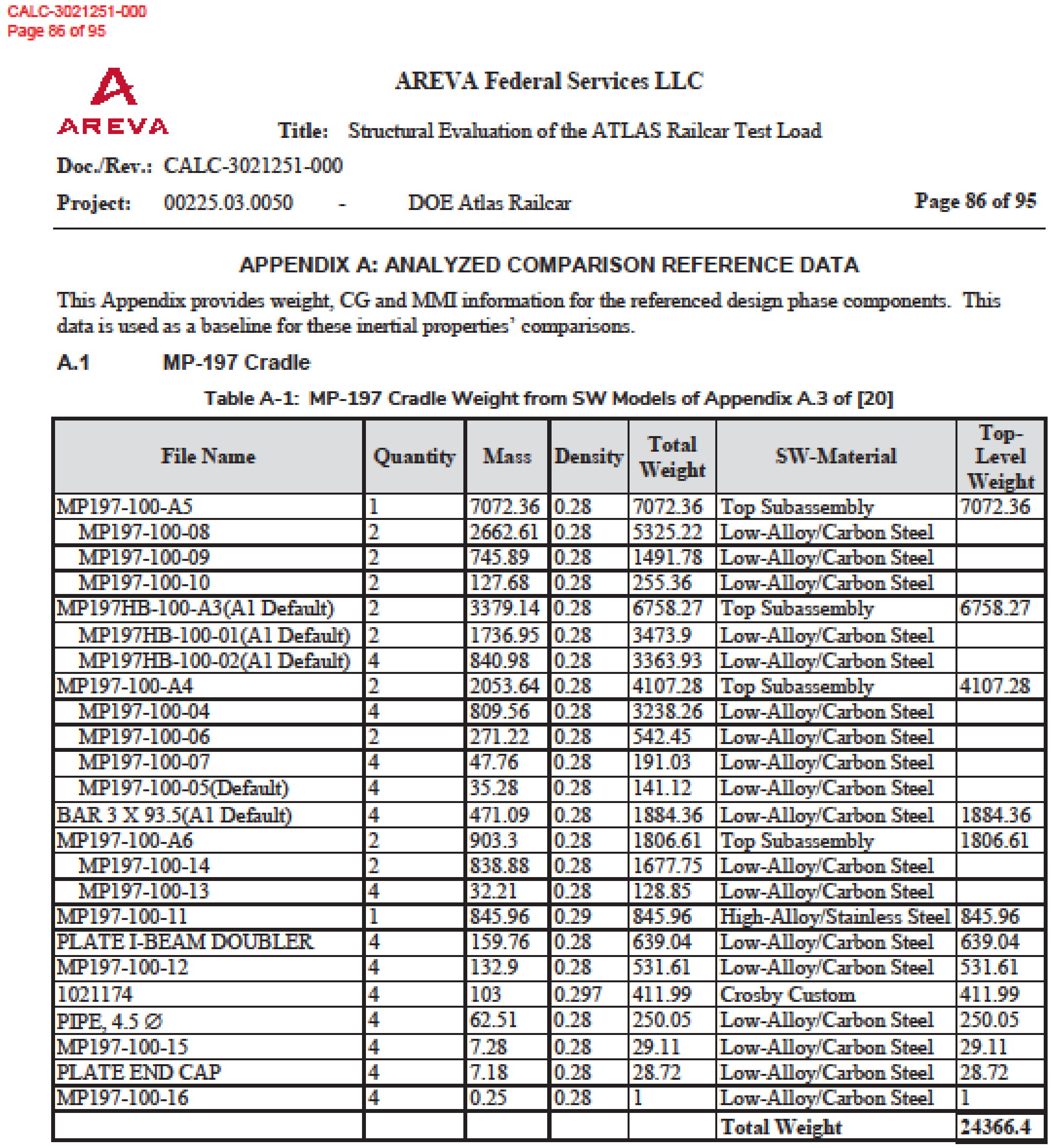

APPENDIX A: ANALYZED COMPARISON REFERENCE DATA

This Appendix provides weight, CG and MMI information for the referenced design phase components. This data is used as a baseline for these inertial properties' comparisons.

A.1 MP-197 Cradle

Table A-1: MP-197 Cradle Weight from SW Models of Appendix A.3 of [20]

File Name	Quantity	Mass	Density	Total Weight	SW-Material	Top-Level Weight
MP197-100-A5	1	7072.36	0.28	7072.36	Top Subassembly	7072.36
MP197-100-08	2	2662.61	0.28	5325.22	Low-Alloy/Carbon Steel	
MP197-100-09	2	745.89	0.28	1491.78	Low-Alloy/Carbon Steel	
MP197-100-10	2	127.68	0.28	255.36	Low-Alloy/Carbon Steel	
MP197HB-100-A3(A1 Default)	2	3379.14	0.28	6758.27	Top Subassembly	6758.27
MP197HB-100-01(A1 Default)	2	1736.95	0.28	3473.9	Low-Alloy/Carbon Steel	
MP197HB-100-02(A1 Default)	4	840.98	0.28	3363.93	Low-Alloy/Carbon Steel	
MP197-100-A4	2	2053.64	0.28	4107.28	Top Subassembly	4107.28
MP197-100-04	4	809.56	0.28	3238.26	Low-Alloy/Carbon Steel	
MP197-100-06	2	271.22	0.28	542.45	Low-Alloy/Carbon Steel	
MP197-100-07	4	47.76	0.28	191.03	Low-Alloy/Carbon Steel	
MP197-100-05(Default)	4	35.28	0.28	141.12	Low-Alloy/Carbon Steel	
BAR 3 X 93.5(A1 Default)	4	471.09	0.28	1884.36	Low-Alloy/Carbon Steel	1884.36
MP197-100-A6	2	903.3	0.28	1806.61	Top Subassembly	1806.61
MP197-100-14	2	838.88	0.28	1677.75	Low-Alloy/Carbon Steel	
MP197-100-13	4	32.21	0.28	128.85	Low-Alloy/Carbon Steel	
MP197-100-11	1	845.96	0.29	845.96	High-Alloy/Stainless Steel	845.96
PLATE I-BEAM DOUBLER	4	159.76	0.28	639.04	Low-Alloy/Carbon Steel	639.04
MP197-100-12	4	132.9	0.28	531.61	Low-Alloy/Carbon Steel	531.61
1021174	4	103	0.297	411.99	Crosby Custom	411.99
PIPE, 4.5 ∅	4	62.51	0.28	250.05	Low-Alloy/Carbon Steel	250.05
MP197-100-15	4	7.28	0.28	29.11	Low-Alloy/Carbon Steel	29.11
PLATE END CAP	4	7.18	0.28	28.72	Low-Alloy/Carbon Steel	28.72
MP197-100-16	4	0.25	0.28	1	Low-Alloy/Carbon Steel	1
					Total Weight	**24366.4**

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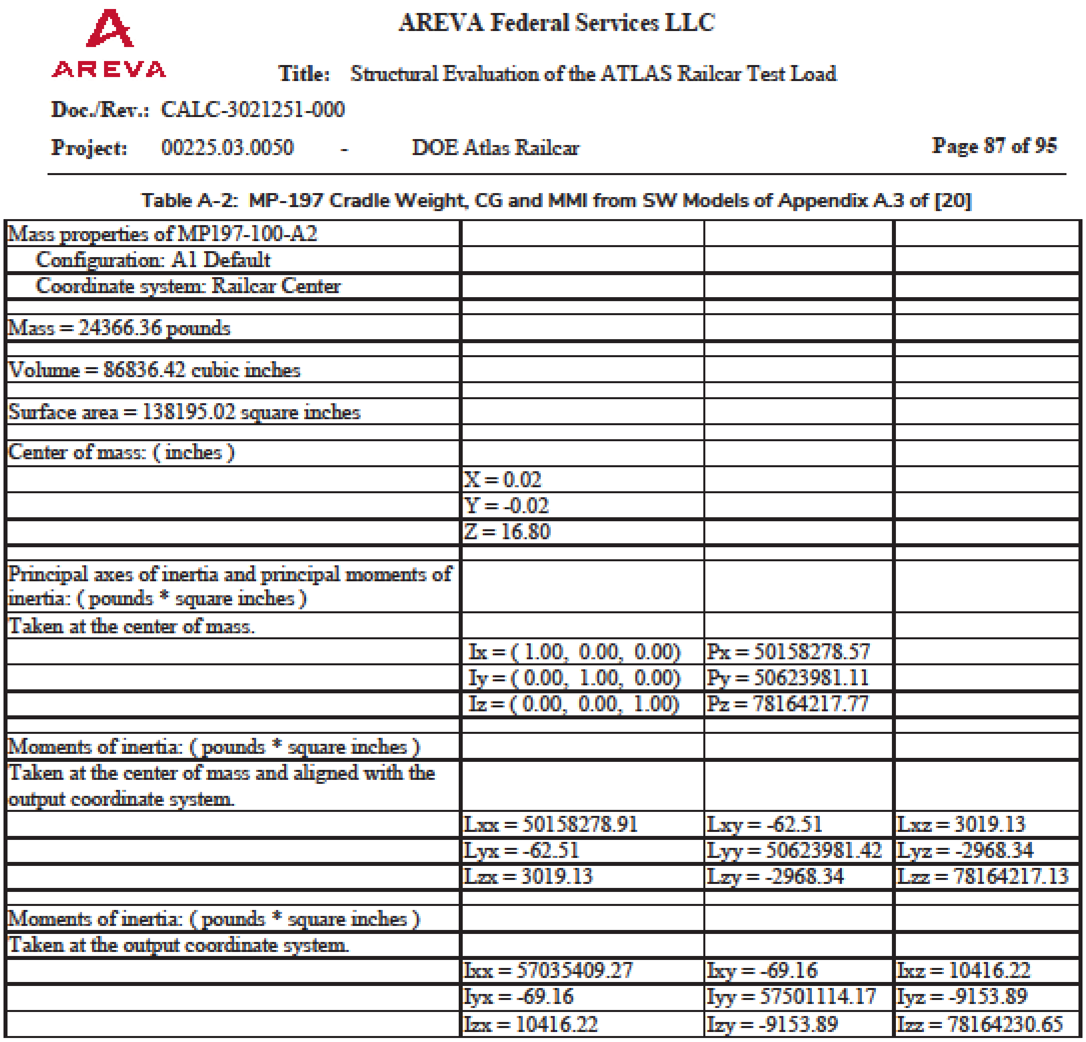

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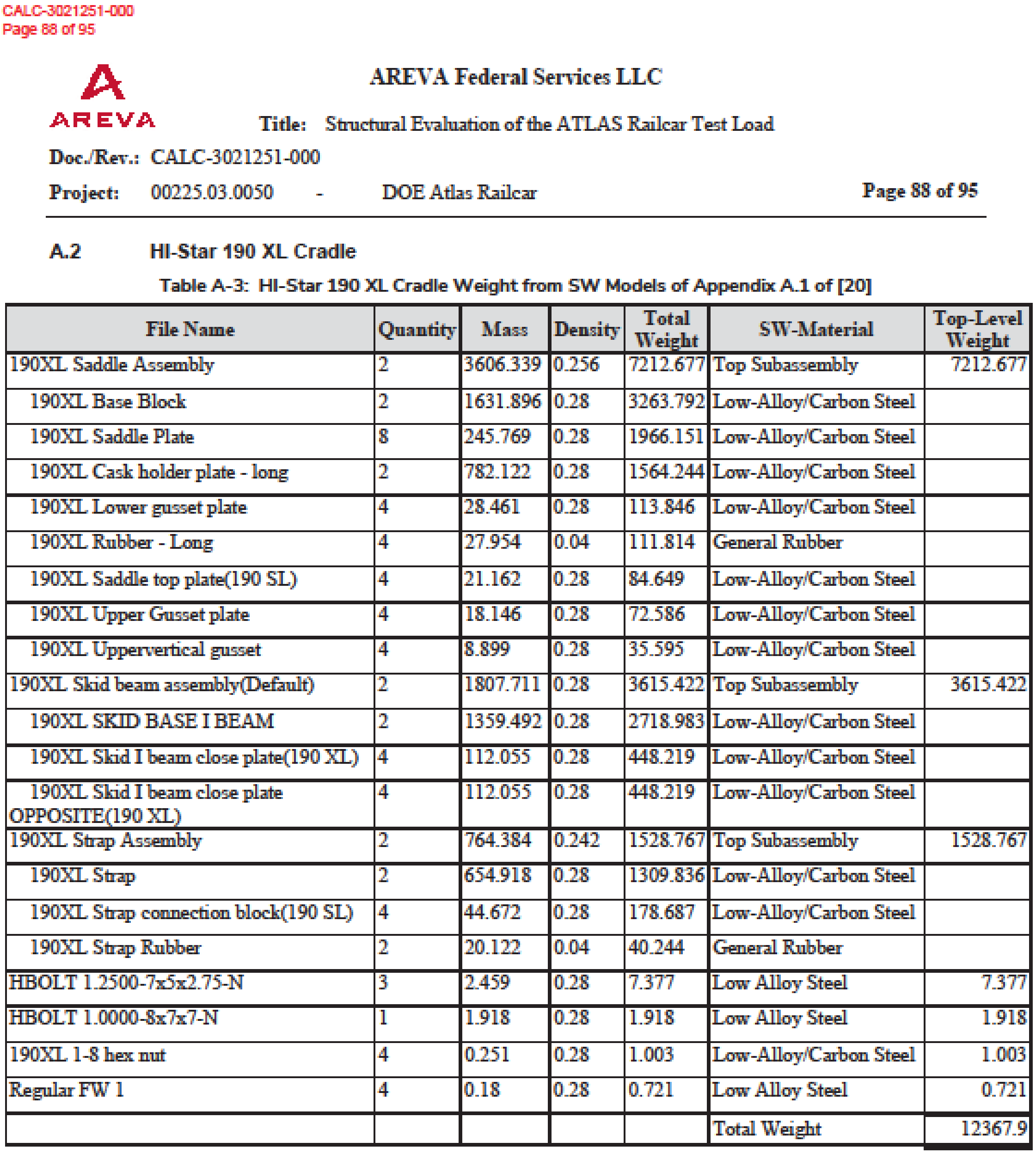
Table A-2: MP-197 Cradle Weight, CG and MMI from SW Models of Appendix A.3 of [20]

Mass properties of MP197-100-A2			
Configuration: A1 Default			
Coordinate system: Railcar Center			
Mass = 24366.36 pounds			
Volume = 86836.42 cubic inches			
Surface area = 138195.02 square inches			
Center of mass: (inches)			
	X = 0.02		
	Y = -0.02		
	Z = 16.80		
Principal axes of inertia and principal moments of inertia: (pounds * square inches)			
Taken at the center of mass.			
	Ix = (1.00, 0.00, 0.00)	Px = 50158278.57	
	Iy = (0.00, 1.00, 0.00)	Py = 50623981.11	
	Iz = (0.00, 0.00, 1.00)	Pz = 78164217.77	
Moments of inertia: (pounds * square inches)			
Taken at the center of mass and aligned with the output coordinate system.			
	Lxx = 50158278.91	Lxy = -62.51	Lxz = 3019.13
	Lyx = -62.51	Lyy = 50623981.42	Lyz = -2968.34
	Lzx = 3019.13	Lzy = -2968.34	Lzz = 78164217.13
Moments of inertia: (pounds * square inches)			
Taken at the output coordinate system.			
	Ixx = 57035409.27	Ixy = -69.16	Ixz = 10416.22
	Iyx = -69.16	Iyy = 57501114.17	Iyz = -9153.89
	Izx = 10416.22	Izy = -9153.89	Izz = 78164230.65



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A.2 HI-Star 190 XL Cradle

Table A-3: HI-Star 190 XL Cradle Weight from SW Models of Appendix A.1 of [20]

File Name	Quantity	Mass	Density	Total Weight	SW-Material	Top-Level Weight
190XL Saddle Assembly	2	3606.339	0.256	7212.677	Top Subassembly	7212.677
190XL Base Block	2	1631.896	0.28	3263.792	Low-Alloy/Carbon Steel	
190XL Saddle Plate	8	245.769	0.28	1966.151	Low-Alloy/Carbon Steel	
190XL Cask holder plate - long	2	782.122	0.28	1564.244	Low-Alloy/Carbon Steel	
190XL Lower gusset plate	4	28.461	0.28	113.846	Low-Alloy/Carbon Steel	
190XL Rubber - Long	4	27.954	0.04	111.814	General Rubber	
190XL Saddle top plate(190 SL)	4	21.162	0.28	84.649	Low-Alloy/Carbon Steel	
190XL Upper Gusset plate	4	18.146	0.28	72.586	Low-Alloy/Carbon Steel	
190XL Uppervertical gusset	4	8.899	0.28	35.595	Low-Alloy/Carbon Steel	
190XL Skid beam assembly(Default)	2	1807.711	0.28	3615.422	Top Subassembly	3615.422
190XL SKID BASE I BEAM	2	1359.492	0.28	2718.983	Low-Alloy/Carbon Steel	
190XL Skid I beam close plate(190 XL)	4	112.055	0.28	448.219	Low-Alloy/Carbon Steel	
190XL Skid I beam close plate OPPOSITE(190 XL)	4	112.055	0.28	448.219	Low-Alloy/Carbon Steel	
190XL Strap Assembly	2	764.384	0.242	1528.767	Top Subassembly	1528.767
190XL Strap	2	654.918	0.28	1309.836	Low-Alloy/Carbon Steel	
190XL Strap connection block(190 SL)	4	44.672	0.28	178.687	Low-Alloy/Carbon Steel	
190XL Strap Rubber	2	20.122	0.04	40.244	General Rubber	
HBOLT 1.2500-7x5x2.75-N	3	2.459	0.28	7.377	Low Alloy Steel	7.377
HBOLT 1.0000-8x7x7-N	1	1.918	0.28	1.918	Low Alloy Steel	1.918
190XL 1-8 hex nut	4	0.251	0.28	1.003	Low-Alloy/Carbon Steel	1.003
Regular FW 1	4	0.18	0.28	0.721	Low Alloy Steel	0.721
					Total Weight	12367.9

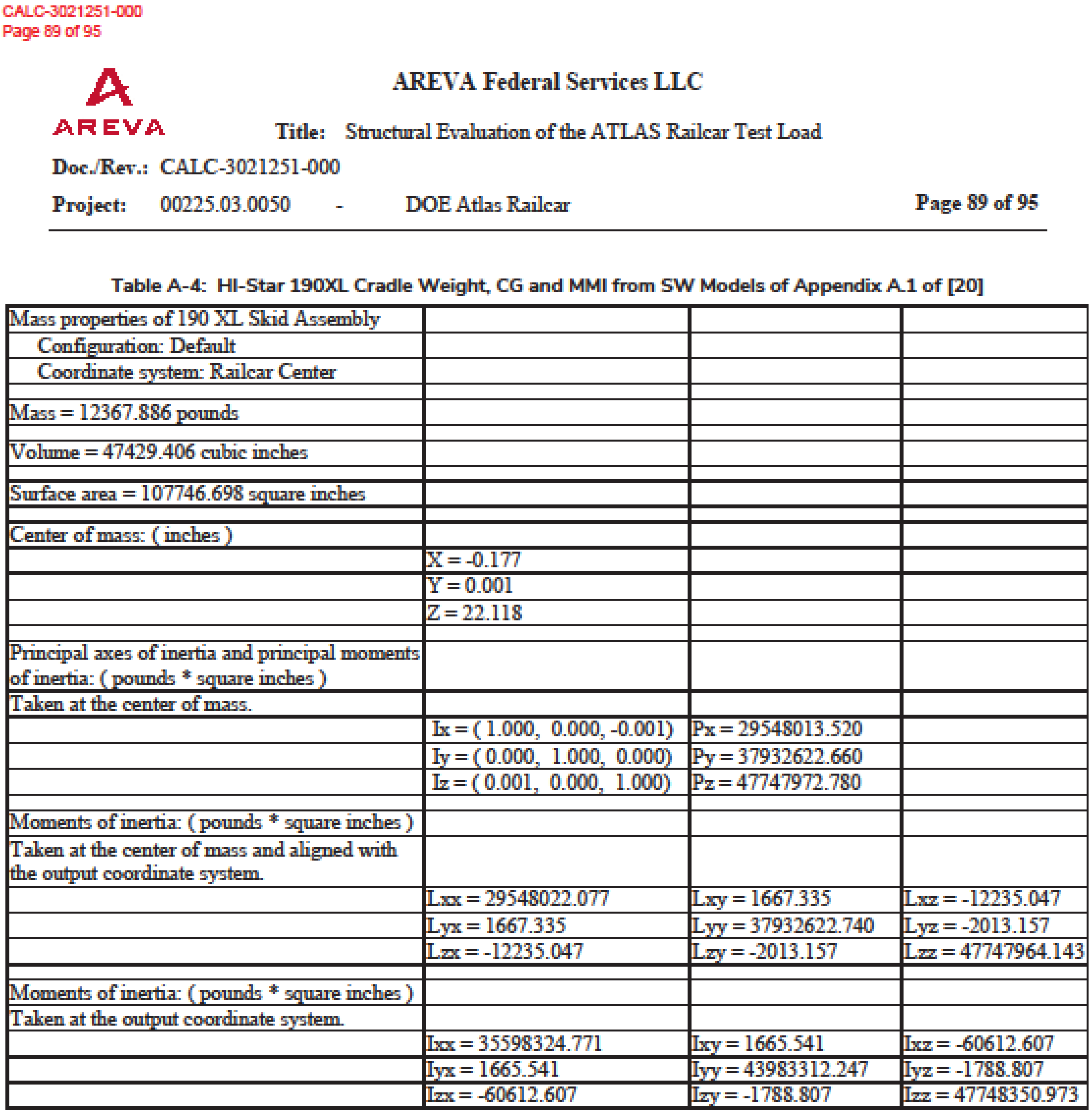


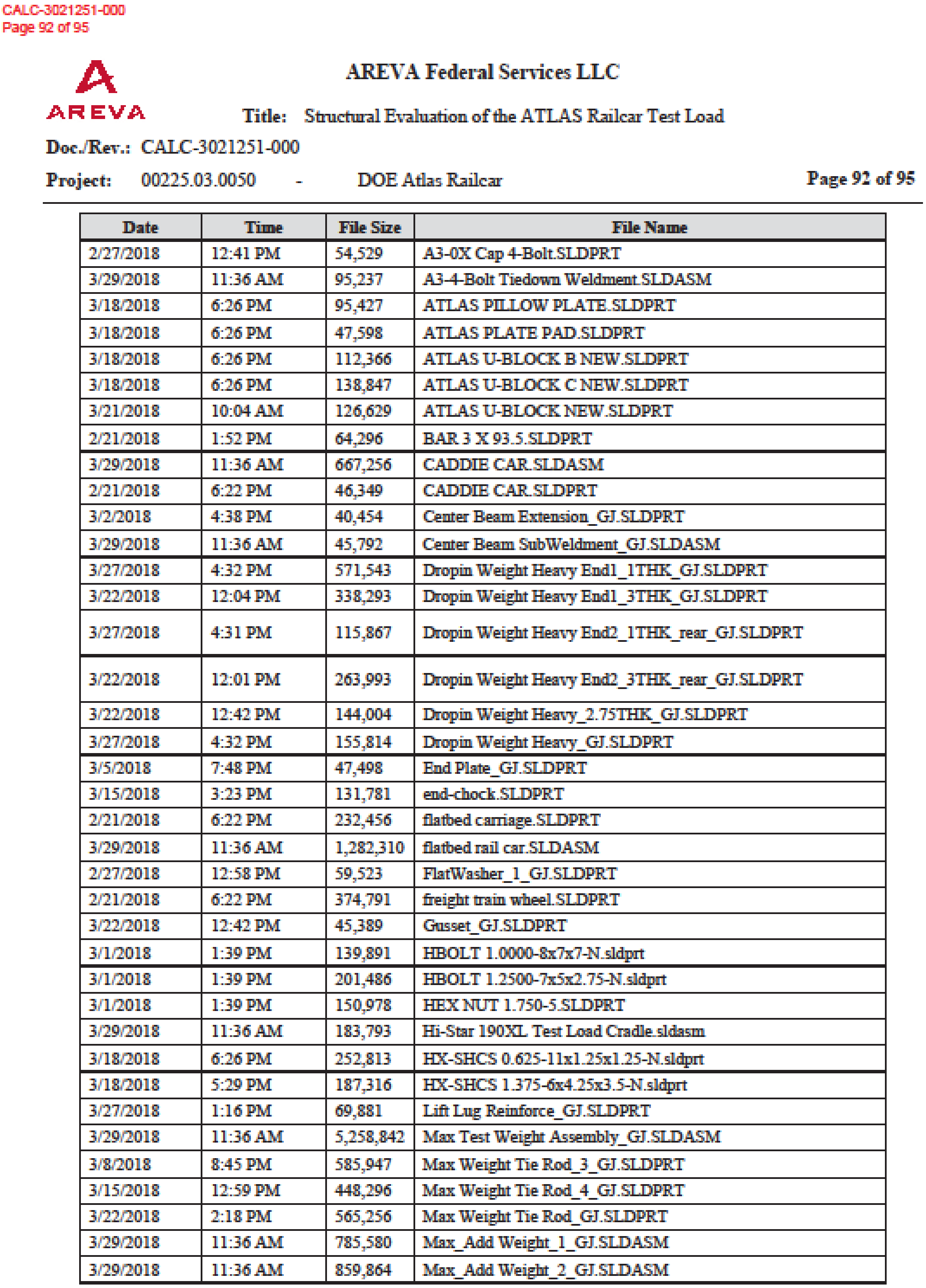
Table A-4: HI-Star 190XL Cradle Weight, CG and MMI from SW Models of Appendix A.1 of [20]

Mass properties of 190 XL Skid Assembly			
Configuration: Default			
Coordinate system: Railcar Center			
Mass = 12367.886 pounds			
Volume = 47429.406 cubic inches			
Surface area = 107746.698 square inches			
Center of mass: (inches)			
	X = -0.177		
	Y = 0.001		
	Z = 22.118		
Principal axes of inertia and principal moments of inertia: (pounds * square inches)			
Taken at the center of mass.			
	Ix = (1.000, 0.000, -0.001)	Px = 29548013.520	
	Iy = (0.000, 1.000, 0.000)	Py = 37932622.660	
	Iz = (0.001, 0.000, 1.000)	Pz = 47747972.780	
Moments of inertia: (pounds * square inches)			
Taken at the center of mass and aligned with the output coordinate system.			
	Lxx = 29548022.077	Lxy = 1667.335	Lxz = -12235.047
	Lyx = 1667.335	Lyy = 37932622.740	Lyz = -2013.157
	Lzx = -12235.047	Lzy = -2013.157	Lzz = 47747964.143
Moments of inertia: (pounds * square inches)			
Taken at the output coordinate system.			
	Ixx = 35598324.771	Ixy = 1665.541	Ixz = -60612.607
	Iyx = 1665.541	Iyy = 43983312.247	Iyz = -1788.807
	Izx = -60612.607	Izy = -1788.807	Izz = 47748350.973

APPENDIX B: SW MODELS LISTING

Date	Time	File Size	File Name
2/21/2018	1:52 PM	484,612	1021174.SLDPRT
2/27/2018	12:16 PM	47,392	190 SL - XL Base Block.SLDPRT
3/1/2018	6:34 PM	61,738	190 SL - XL Saddle top plate.SLDPRT
3/1/2018	6:34 PM	89,800	190 SL - XL SKID BASE I BEAM.SLDPRT
3/1/2018	6:34 PM	65,501	190 SL - XL Skid I beam close plate OPPOSITE.SLDPRT
3/1/2018	6:34 PM	99,509	190 SL - XL Skid I beam close plate.SLDPRT
3/29/2018	11:36 AM	85,907	190 SL - XL Strap Assembly.SLDASM
3/1/2018	6:34 PM	61,258	190 SL - XL Strap connection block.SLDPRT
3/1/2018	6:34 PM	90,598	190 SL - XL Strap.SLDPRT
3/29/2018	11:36 AM	118,568	190 SL - XL TN-40 Saddle Assembly.SLDASM
3/1/2018	6:34 PM	47,743	190 SL - XL Uppervertical gusset.SLDPRT
3/1/2018	6:34 PM	73,723	190 SL - XLCask holder plate - long.SLDPRT
3/1/2018	6:34 PM	55,598	190 SL - XLLower Gusset plate.SLDPRT
3/29/2018	11:36 AM	83,351	190 SL - XLTN-40 Skid beam assembly.SLDASM
3/29/2018	11:36 AM	68,360	190 SL - XLUpper Gusset plate.SLDPRT
3/14/2018	4:56 PM	67,913	190 SL = XL Saddle Plate.SLDPRT
3/16/2016	8:06 AM	189,952	190 SL-XLHi-Star 100 Middle plate.SLDPRT
3/29/2018	11:36 AM	120,180	190 XL end stop assembly.SLDASM
3/29/2018	11:36 AM	1,136,984	190 XL Skid Assembly.SLDASM
2/26/2018	3:02 PM	1,033,867	190XL 1-8 hex nut.SLDPRT
3/29/2018	11:36 AM	54,201	190XL Align plate.SLDPRT
3/29/2018	11:36 AM	45,382	190XL Base Block.SLDPRT
3/29/2018	11:36 AM	58,929	190XL Cask holder plate - long.SLDPRT
3/28/2018	5:58 PM	157,950	190XL Cask.SLDPRT
3/29/2018	11:36 AM	89,268	190XL Center high gusset.SLDPRT
3/1/2018	4:14 PM	41,461	190XL end stop attched.SLDPRT
3/1/2018	4:14 PM	42,151	190XL end stop front plate.SLDPRT
3/29/2018	11:36 AM	51,306	190XL Gusset plate.SLDPRT
3/29/2018	11:36 AM	43,841	190XL Lower gusset plate.SLDPRT
3/3/2017	9:56 AM	106,496	190XL Middle plate.SLDPRT
3/29/2018	11:36 AM	56,858	190XL Rubber - Long.SLDPRT
3/3/2017	9:56 AM	124,928	190XL Rubber - Short.SLDPRT
3/29/2018	11:36 AM	97,411	190XL Saddle Assembly.SLDASM
2/26/2018	3:02 PM	54,295	190XL Saddle Plate.SLDPRT
2/26/2018	3:02 PM	59,633	190XL Saddle top plate.SLDPRT
2/26/2018	3:02 PM	87,363	190XL SKID BASE I BEAM.SLDPRT
3/29/2018	11:36 AM	62,161	190XL Skid beam assembly.SLDASM

Date	Time	File Size	File Name
2/26/2018	3:02 PM	119,716	190XL Skid I beam close plate OPPOSITE.SLDPRT
2/26/2018	3:02 PM	82,593	190XL Skid I beam close plate.SLDPRT
3/29/2018	11:36 AM	76,128	190XL Strap Assembly.SLDASM
2/26/2018	3:02 PM	58,956	190XL Strap connection block.SLDPRT
2/26/2018	3:02 PM	58,138	190XL Strap Rubber.SLDPRT
3/1/2018	12:20 PM	73,397	190XL Strap.SLDPRT
3/29/2018	11:36 AM	43,843	190XL Upper Gusset plate.SLDPRT
3/29/2018	11:36 AM	39,593	190XL Uppervertical gusset.SLDPRT
3/1/2018	4:14 PM	50,606	190XL VERTICAL PLATE.SLDPRT
3/1/2018	4:14 PM	125,129	190XLGusset short.SLDPRT
3/29/2018	11:36 AM	120,240	190XLStop end assembly.SLDASM
3/15/2018	3:17 PM	1,555,235	91571A340_STEEL HEAVY HEX HEAD STRUCTURAL BOLT_GJ.SLDPRT
3/14/2018	12:52 PM	1,036,079	91583A359_GALVANIZED STL HEAVY HEX HEAD STRUCTURAL BOLT_GJ.SLDPRT
3/1/2018	1:41 PM	460,905	94485A038_GRADE 7 ALLOY STEEL HEX NUT_GJ.SLDPRT
3/1/2018	1:41 PM	489,631	98427A600_HEX NUT FOR ASTM A325 STRUCTURAL BOLTS_GJ.SLDPRT
2/27/2018	12:41 PM	85,297	A1-14 Key.SLDPRT
3/29/2018	11:36 AM	219,234	A1-Min Load Test Cradle Assy.SLDASM
2/27/2018	12:41 PM	83,030	A2-01 W 18 X 119.SLDPRT
2/27/2018	12:41 PM	41,224	A2-02 Plate .13 X 19 X 11.3.SLDPRT
2/27/2018	12:41 PM	52,836	A2-03 Plate 1.0 X 178.1 X 16.9.SLDPRT
2/27/2018	12:41 PM	39,044	A2-04 Plate 1.0 X 24.0 X 15.5.SLDPRT
3/20/2018	4:37 PM	65,635	A2-05 Plate 1.0 X 112.0X 50.0.SLDPRT
2/27/2018	12:41 PM	73,661	A2-06 Plate 1.0 X 122.5 X 8.25.SLDPRT
2/27/2018	12:41 PM	41,848	A2-10 Plate 2.0 X 24.0 X 15.5.SLDPRT
2/27/2018	12:41 PM	80,666	A2-11 Plate 2.0 X 14.7 X 6.25.SLDPRT
2/27/2018	12:41 PM	124,596	A2-12 Plate 3.0 X 93.5 X 37.75.SLDPRT
2/27/2018	12:41 PM	43,261	A2-13 Plate 3.0 X 93.5 X 9.5.SLDPRT
2/27/2018	12:41 PM	42,022	A2-15 Plate 3.0 X 6.0 X 93.5.SLDPRT
2/27/2018	12:41 PM	63,907	A2-16 Round 6.5 DIA X 11.25.SLDPRT
3/29/2018	11:36 AM	135,133	A2-Base Weldment Assembly.SLDASM
3/29/2018	11:36 AM	51,279	A2-Beam Weldment.SLDASM
3/29/2018	11:36 AM	56,489	A2-Key Sub assy.SLDASM
3/29/2018	11:36 AM	116,147	A2-Saddle Sub Weldment.SLDASM
2/27/2018	12:41 PM	81,311	A3-07 Plate 4-Bolt.SLDPRT
2/27/2018	12:41 PM	61,296	A3-08 Plate 4-Bolt.SLDPRT
2/27/2018	12:41 PM	144,749	A3-09 4-Bolt.SLDPRT



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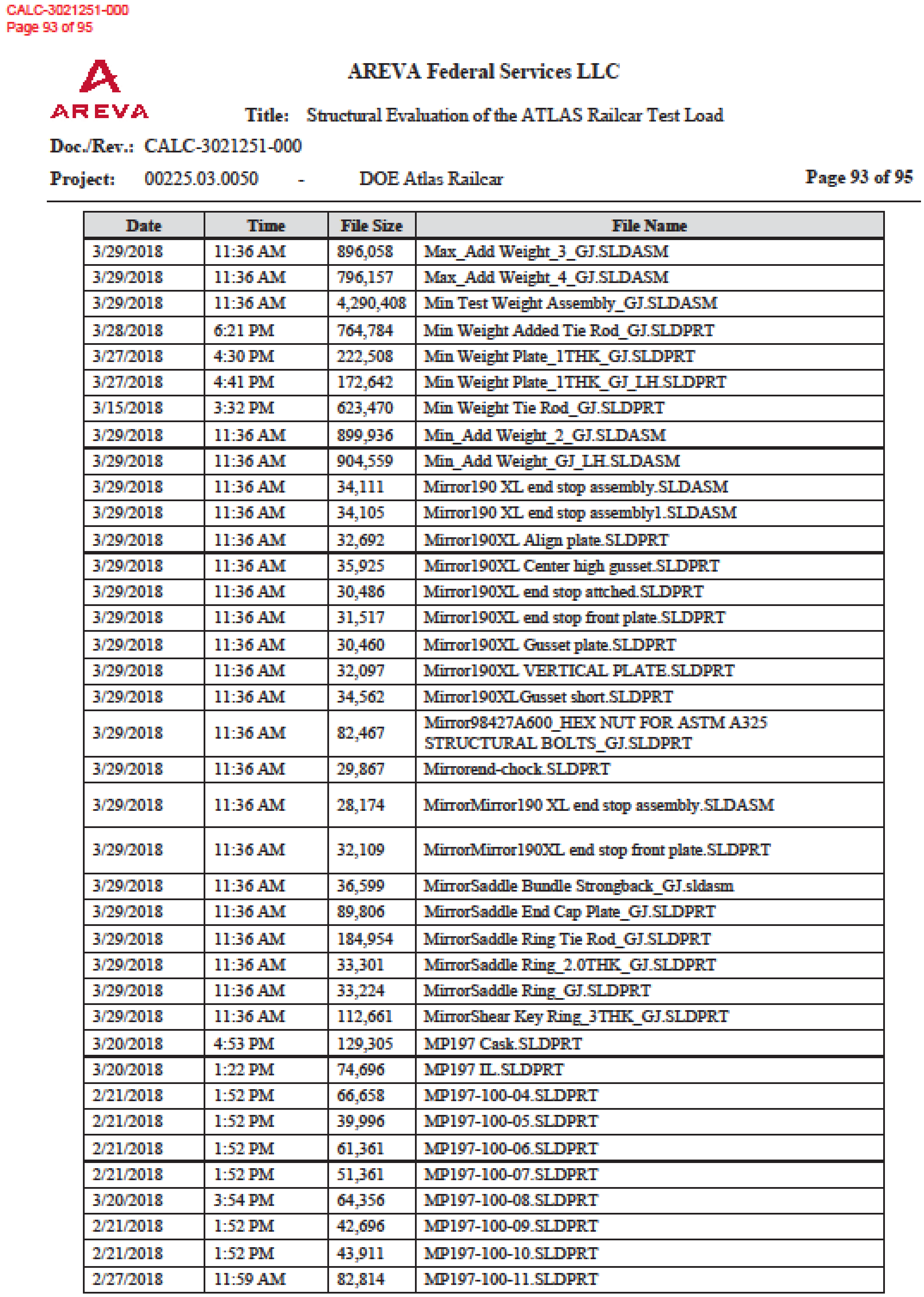
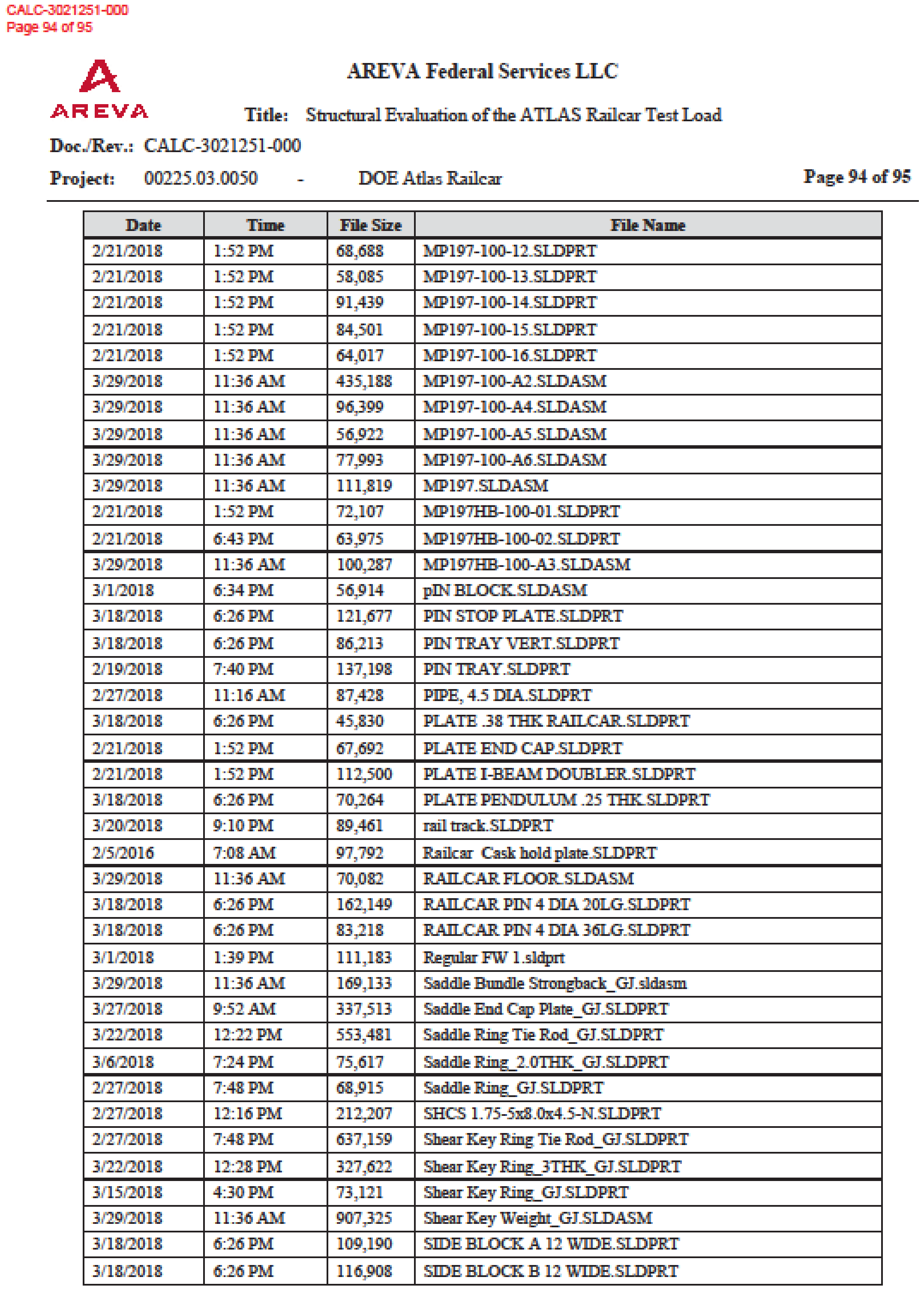
Date	Time	File Size	File Name
2/27/2018	12:41 PM	54,529	A3-0X Cap 4-Bolt.SLDPRT
3/29/2018	11:36 AM	95,237	A3-4-Bolt Tiedown Weldment.SLDASM
3/18/2018	6:26 PM	95,427	ATLAS PILLOW PLATE.SLDPRT
3/18/2018	6:26 PM	47,598	ATLAS PLATE PAD.SLDPRT
3/18/2018	6:26 PM	112,366	ATLAS U-BLOCK B NEW.SLDPRT
3/18/2018	6:26 PM	138,847	ATLAS U-BLOCK C NEW.SLDPRT
3/21/2018	10:04 AM	126,629	ATLAS U-BLOCK NEW.SLDPRT
2/21/2018	1:52 PM	64,296	BAR 3 X 93.5.SLDPRT
3/29/2018	11:36 AM	667,256	CADDIE CAR.SLDASM
2/21/2018	6:22 PM	46,349	CADDIE CAR.SLDPRT
3/2/2018	4:38 PM	40,454	Center Beam Extension_GJ.SLDPRT
3/29/2018	11:36 AM	45,792	Center Beam SubWeldment_GJ.SLDASM
3/27/2018	4:32 PM	571,543	Dropin Weight Heavy End1_1THK_GJ.SLDPRT
3/22/2018	12:04 PM	338,293	Dropin Weight Heavy End1_3THK_GJ.SLDPRT
3/27/2018	4:31 PM	115,867	Dropin Weight Heavy End2_1THK_rear_GJ.SLDPRT
3/22/2018	12:01 PM	263,993	Dropin Weight Heavy End2_3THK_rear_GJ.SLDPRT
3/22/2018	12:42 PM	144,004	Dropin Weight Heavy_2.75THK_GJ.SLDPRT
3/27/2018	4:32 PM	155,814	Dropin Weight Heavy_GJ.SLDPRT
3/5/2018	7:48 PM	47,498	End Plate_GJ.SLDPRT
3/15/2018	3:23 PM	131,781	end-chock.SLDPRT
2/21/2018	6:22 PM	232,456	flatbed carriage.SLDPRT
3/29/2018	11:36 AM	1,282,310	flatbed rail car.SLDASM
2/27/2018	12:58 PM	59,523	FlatWasher_1_GJ.SLDPRT
2/21/2018	6:22 PM	374,791	freight train wheel.SLDPRT
3/22/2018	12:42 PM	45,389	Gusset_GJ.SLDPRT
3/1/2018	1:39 PM	139,891	HBOLT 1.0000-8x7x7-N.sldprt
3/1/2018	1:39 PM	201,486	HBOLT 1.2500-7x5x2.75-N.sldprt
3/1/2018	1:39 PM	150,978	HEX NUT 1.750-5.SLDPRT
3/29/2018	11:36 AM	183,793	Hi-Star 190XL Test Load Cradle.sldasm
3/18/2018	6:26 PM	252,813	HX-SHCS 0.625-11x1.25x1.25-N.sldprt
3/18/2018	5:29 PM	187,316	HX-SHCS 1.375-6x4.25x3.5-N.sldprt
3/27/2018	1:16 PM	69,881	Lift Lug Reinforce_GJ.SLDPRT
3/29/2018	11:36 AM	5,258,842	Max Test Weight Assembly_GJ.SLDASM
3/8/2018	8:45 PM	585,947	Max Weight Tie Rod_3_GJ.SLDPRT
3/15/2018	12:59 PM	448,296	Max Weight Tie Rod_4_GJ.SLDPRT
3/22/2018	2:18 PM	565,256	Max Weight Tie Rod_GJ.SLDPRT
3/29/2018	11:36 AM	785,580	Max_Add Weight_1_GJ.SLDASM
3/29/2018	11:36 AM	859,864	Max_Add Weight_2_GJ.SLDASM



Date	Time	File Size	File Name
3/29/2018	11:36 AM	896,058	Max_Add Weight_3_GJ.SLDASM
3/29/2018	11:36 AM	796,157	Max_Add Weight_4_GJ.SLDASM
3/29/2018	11:36 AM	4,290,408	Min Test Weight Assembly_GJ.SLDASM
3/28/2018	6:21 PM	764,784	Min Weight Added Tie Rod_GJ.SLDPRT
3/27/2018	4:30 PM	222,508	Min Weight Plate_1THK_GJ.SLDPRT
3/27/2018	4:41 PM	172,642	Min Weight Plate_1THK_GJ_LH.SLDPRT
3/15/2018	3:32 PM	623,470	Min Weight Tie Rod_GJ.SLDPRT
3/29/2018	11:36 AM	899,936	Min_Add Weight_2_GJ.SLDASM
3/29/2018	11:36 AM	904,559	Min_Add Weight_GJ_LH.SLDASM
3/29/2018	11:36 AM	34,111	Mirror190 XL end stop assembly.SLDASM
3/29/2018	11:36 AM	34,105	Mirror190 XL end stop assembly1.SLDASM
3/29/2018	11:36 AM	32,692	Mirror190XL Align plate.SLDPRT
3/29/2018	11:36 AM	35,925	Mirror190XL Center high gusset.SLDPRT
3/29/2018	11:36 AM	30,486	Mirror190XL end stop attched.SLDPRT
3/29/2018	11:36 AM	31,517	Mirror190XL end stop front plate.SLDPRT
3/29/2018	11:36 AM	30,460	Mirror190XL Gusset plate.SLDPRT
3/29/2018	11:36 AM	32,097	Mirror190XL VERTICAL PLATE.SLDPRT
3/29/2018	11:36 AM	34,562	Mirror190XLGusset short.SLDPRT
3/29/2018	11:36 AM	82,467	Mirror98427A600_HEX NUT FOR ASTM A325 STRUCTURAL BOLTS_GJ.SLDPRT
3/29/2018	11:36 AM	29,867	Mirrorend-chock.SLDPRT
3/29/2018	11:36 AM	28,174	MirrorMirror190 XL end stop assembly.SLDASM
3/29/2018	11:36 AM	32,109	MirrorMirror190XL end stop front plate.SLDPRT
3/29/2018	11:36 AM	36,599	MirrorSaddle Bundle Strongback_GJ.sldasm
3/29/2018	11:36 AM	89,806	MirrorSaddle End Cap Plate_GJ.SLDPRT
3/29/2018	11:36 AM	184,954	MirrorSaddle Ring Tie Rod_GJ.SLDPRT
3/29/2018	11:36 AM	33,301	MirrorSaddle Ring_2.0THK_GJ.SLDPRT
3/29/2018	11:36 AM	33,224	MirrorSaddle Ring_GJ.SLDPRT
3/29/2018	11:36 AM	112,661	MirrorShear Key Ring_3THK_GJ.SLDPRT
3/20/2018	4:53 PM	129,305	MP197 Cask.SLDPRT
3/20/2018	1:22 PM	74,696	MP197 IL.SLDPRT
2/21/2018	1:52 PM	66,658	MP197-100-04.SLDPRT
2/21/2018	1:52 PM	39,996	MP197-100-05.SLDPRT
2/21/2018	1:52 PM	61,361	MP197-100-06.SLDPRT
2/21/2018	1:52 PM	51,361	MP197-100-07.SLDPRT
3/20/2018	3:54 PM	64,356	MP197-100-08.SLDPRT
2/21/2018	1:52 PM	42,696	MP197-100-09.SLDPRT
2/21/2018	1:52 PM	43,911	MP197-100-10.SLDPRT
2/27/2018	11:59 AM	82,814	MP197-100-11.SLDPRT



CALC-3021251-000
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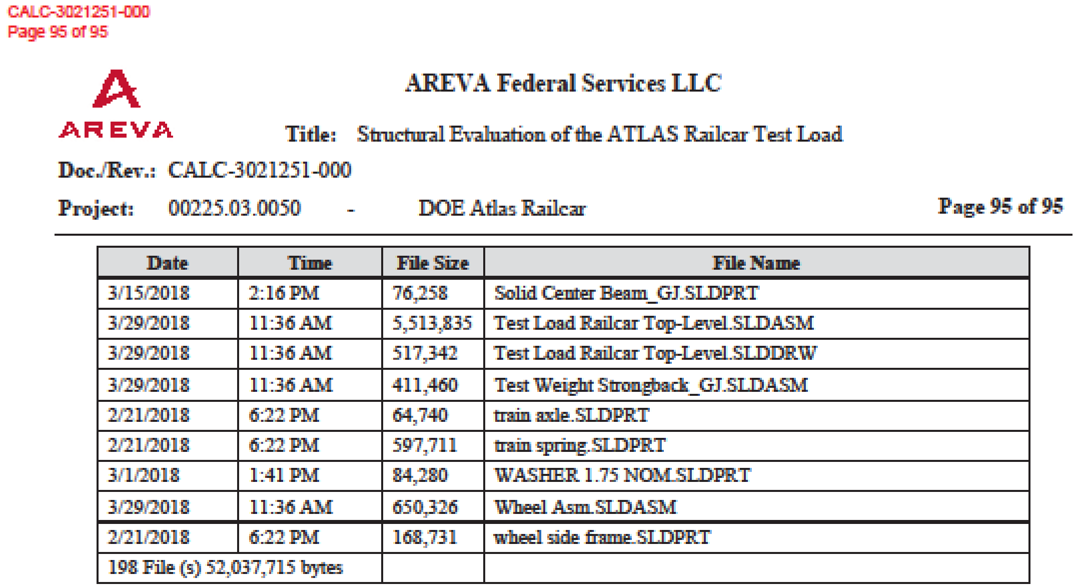
AREVA Federal Services LLC

Title: Structural Evaluation of the ATLAS Railcar Test Load

Doc./Rev.: CALC-3021251-000

Project: 00225.03.0050 - DOE Atlas Railcar **Page 94 of 95**

Date	Time	File Size	File Name
2/21/2018	1:52 PM	68,688	MP197-100-12.SLDPRT
2/21/2018	1:52 PM	58,085	MP197-100-13.SLDPRT
2/21/2018	1:52 PM	91,439	MP197-100-14.SLDPRT
2/21/2018	1:52 PM	84,501	MP197-100-15.SLDPRT
2/21/2018	1:52 PM	64,017	MP197-100-16.SLDPRT
3/29/2018	11:36 AM	435,188	MP197-100-A2.SLDASM
3/29/2018	11:36 AM	96,399	MP197-100-A4.SLDASM
3/29/2018	11:36 AM	56,922	MP197-100-A5.SLDASM
3/29/2018	11:36 AM	77,993	MP197-100-A6.SLDASM
3/29/2018	11:36 AM	111,819	MP197.SLDASM
2/21/2018	1:52 PM	72,107	MP197HB-100-01.SLDPRT
2/21/2018	6:43 PM	63,975	MP197HB-100-02.SLDPRT
3/29/2018	11:36 AM	100,287	MP197HB-100-A3.SLDASM
3/1/2018	6:34 PM	56,914	pIN BLOCK.SLDASM
3/18/2018	6:26 PM	121,677	PIN STOP PLATE.SLDPRT
3/18/2018	6:26 PM	86,213	PIN TRAY VERT.SLDPRT
2/19/2018	7:40 PM	137,198	PIN TRAY.SLDPRT
2/27/2018	11:16 AM	87,428	PIPE, 4.5 DIA.SLDPRT
3/18/2018	6:26 PM	45,830	PLATE .38 THK RAILCAR.SLDPRT
2/21/2018	1:52 PM	67,692	PLATE END CAP.SLDPRT
2/21/2018	1:52 PM	112,500	PLATE I-BEAM DOUBLER.SLDPRT
3/18/2018	6:26 PM	70,264	PLATE PENDULUM .25 THK.SLDPRT
3/20/2018	9:10 PM	89,461	rail track.SLDPRT
2/5/2016	7:08 AM	97,792	Railcar Cask hold plate.SLDPRT
3/29/2018	11:36 AM	70,082	RAILCAR FLOOR.SLDASM
3/18/2018	6:26 PM	162,149	RAILCAR PIN 4 DIA 20LG.SLDPRT
3/18/2018	6:26 PM	83,218	RAILCAR PIN 4 DIA 36LG.SLDPRT
3/1/2018	1:39 PM	111,183	Regular FW 1.sldprt
3/29/2018	11:36 AM	169,133	Saddle Bundle Strongback_GJ.sldasm
3/27/2018	9:52 AM	337,513	Saddle End Cap Plate_GJ.SLDPRT
3/22/2018	12:22 PM	553,481	Saddle Ring Tie Rod_GJ.SLDPRT
3/6/2018	7:24 PM	75,617	Saddle Ring_2.0THK_GJ.SLDPRT
2/27/2018	7:48 PM	68,915	Saddle Ring_GJ.SLDPRT
2/27/2018	12:16 PM	212,207	SHCS 1.75-5x8.0x4.5-N.SLDPRT
2/27/2018	7:48 PM	637,159	Shear Key Ring Tie Rod_GJ.SLDPRT
3/22/2018	12:28 PM	327,622	Shear Key Ring_3THK_GJ.SLDPRT
3/15/2018	4:30 PM	73,121	Shear Key Ring_GJ.SLDPRT
3/29/2018	11:36 AM	907,325	Shear Key Weight_GJ.SLDASM
3/18/2018	6:26 PM	109,190	SIDE BLOCK A 12 WIDE.SLDPRT
3/18/2018	6:26 PM	116,908	SIDE BLOCK B 12 WIDE.SLDPRT



CALC-3021251-000
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AREVA Federal Services LLC

Title: Structural Evaluation of the ATLAS Railcar Test Load

Doc./Rev.: CALC-3021251-000

Project: 00225.03.0050 - DOE Atlas Railcar **Page 95 of 95**

Date	Time	File Size	File Name
3/15/2018	2:16 PM	76,258	Solid Center Beam_GJ.SLDPRT
3/29/2018	11:36 AM	5,513,835	Test Load Railcar Top-Level.SLDASM
3/29/2018	11:36 AM	517,342	Test Load Railcar Top-Level.SLDDRW
3/29/2018	11:36 AM	411,460	Test Weight Strongback_GJ.SLDASM
2/21/2018	6:22 PM	64,740	train axle.SLDPRT
2/21/2018	6:22 PM	597,711	train spring.SLDPRT
3/1/2018	1:41 PM	84,280	WASHER 1.75 NOM.SLDPRT
3/29/2018	11:36 AM	650,326	Wheel Asm.SLDASM
2/21/2018	6:22 PM	168,731	wheel side frame.SLDPRT
198 File (s) 52,037,715 bytes			

APPENDIX I-2 DWG-3020457-001, BALLAST TEST LOAD

DWG-3020457-001
Page 1 of 6

DWG NO 3020457 REV 1 SH 1

NOTES, UNLESS OTHERWISE SPECIFIED:

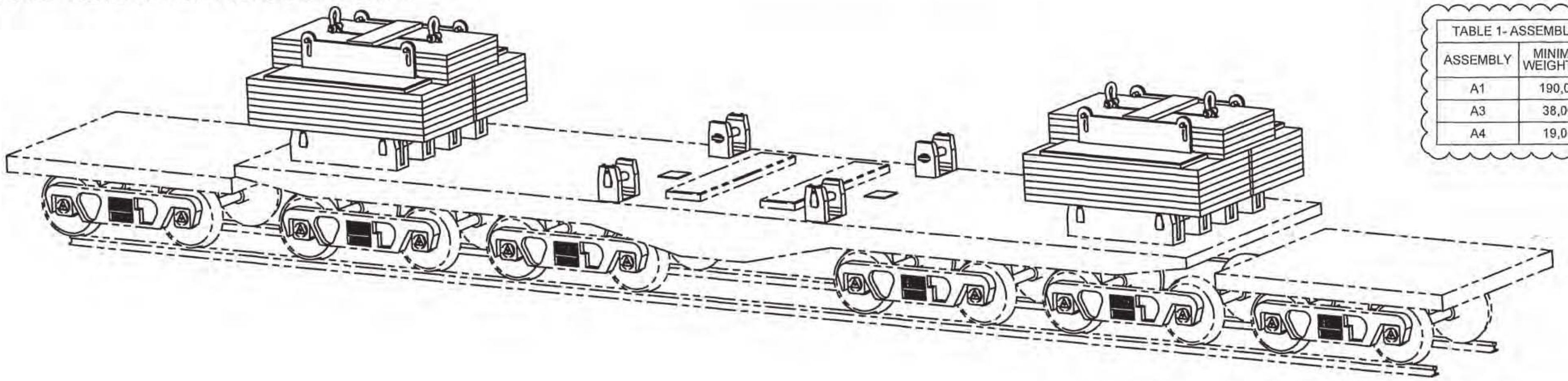
1. ALL WELDS ARE FULL PENETRATION WELDS UNLESS OTHERWISE SPECIFIED.
2. WELDING SHALL BE PERFORMED IN ACCORDANCE WITH AWS D1.1.
3. FABRICATE IN ACCORDANCE WITH SPECIFICATION PKG-GF-SPC-003.
4. VERIFY ALIGNMENT BY INSERTING A 4.06 DIA ROUND BAR EXTENDING THRU BOTH PLATES.
5. ALTERNATE MATERIALS MAY BE USED WITH THE APPROVAL OF THE DESIGN AUTHORITY.
6. GRIND WELDS AS REQUIRED TO ACHIEVE ASSEMBLY FIT-UP BETWEEN ITEM 4 AND ASSEMBLY A4.
7. TWO SHACKLES (ITEM 13) ARE REQUIRED TO LIFT EACH A3 OR A4 WELDMENTS.
8. STENCIL THE FOLLOWING USING 1" HIGH LETTERS: "WARNING: MAX LIFTING LOAD 44.1 KIP OVER 2 ATTACHMENTS. DO NOT LIFT A2 AS ONE ASSEMBLY, LIFT A3 AND A4 AS SEPERATE ASSEMBLIES ONLY." "REMOVE A5 PRIOR TO LIFTING".
9. LENGTH AND WIDTH DIMENSIONS FOR RAW MATERIAL IN THE LIST OF MATERIALS DESCRIPTION COLUMN ARE FOR REFERENCE ONLY, WITH THE EXCEPTION OF THE STOCK PLATE ITEMS 1, 3, 7 & 8. MANUFUFACTURER SHALL CONFIRM ACTUAL REQUIREMENTS PRIOR TO FABRICATION.
10. THE WEIGHTS OF THE A1, A3, AND A4 ASSEMBLIES MUST MEET THE LIMITS SHOWN IN TABLE1. WEIGH EACH A3, A4, AND A5 ASSEMBLY. STENCIL CORRESPONDING WEIGHT ON EACH ASSEMBLY USING 1" HIGH LETTERS IN THE APPROXIMATE AREA SHOWN.
11. ALL TEST LOAD PLATE SURFACES SHALL BE BLAST CLEANED PER SSPC-SP6. AFTER ASSEMBLY, SHOP PRIMER SHALL BE APPLIED TO THE EXPOSED SURFACES OF THE TEST LOAD ASSEMBLIES PER COATING MANUFACTURER'S INSTRUCTIONS.

LIST OF MATERIALS

S/D	QTY A5	QTY A4	QTY A3	QTY A2	QTY A1	ITEM NO	PART NO	DESCRIPTION	SPECIFICATION
						A1		BALLAST TEST LOAD	
					2	A2		UNIT BALLAST TEST LOAD ASSEMBLY	
				2		A3		MAIN BALLAST LOAD WELDMENT	
				1		A4		TOP BALLAST LOAD WELDMENT	
				4		A5		TIE DOWN WELDMENT	
NITS			1			1		PLATE, 2.5 THK X 85 X 48	ASTM A588
NITS		3	7			2		PLATE, 3.5 THK X 106 X 48	ASTM A588
NITS			2			3		PLATE, 2.5 THK X 64 X 15.5	ASTM A588
NITS			1			4		PLATE, 1.5 THK X 68 X 46.4	ASTM A588
NITS		1				5		PLATE, 1.5 THK X 68X 19.3	ASTM A588
NITS		1				6		PLATE, 2.5 THK X 106 X 48	ASTM A588
NITS		2				7		PLATE, 2.5 THK X 10 X 48	ASTM A588
NITS		1				8		PLATE, 2.5 THK X 15 X 48	ASTM A588
NITS	1					9		PLATE, 2.0 THK X 2 X 6	ASTM A588
NITS	2					10		PLATE, .5 THK X 1 X 3	ASTM A588
NITS				4		11	94975A488	18-8 STAINLESS STEEL QUICK RELEASE PIN & LANYARD, Ø5/16, 2.5 USABLE LENGTH	McMASTER-CARR
NITS				4		12	92185A240	SOCKET HEAD CAP SCR, 10-24 UNC-2A X .38	McMASTER-CARR
7 NITS				AR		13	1019659	SHACKLE, 1-3/4, 25T WLL	CROSBY

TABLE 1- ASSEMBLY WEIGHT LIMITS

ASSEMBLY	MINIMUM WEIGHT (LB)	MAXIMUM WEIGHT (LB)
A1	190,000	210,000
A3	38,000	42,000
A4	19,000	21,000



REVISION HISTORY

REV	DESCRIPTION
1	ECN NO. 3020457R0-E1
0	INITIAL RELEASE

	NAME/SIGNATURE	DATE
EM	DSH AS Hillstrom	7/11/18
RE	S. Klen	7/11/18
TECH CHK	S. Klen	7/11/18
DFTG CHK	D. WICK	7/11/18
DRAWN	T.E. MARTIN	7/09/2018

NA	NA
NEXT ASSY	FINAL ASSY

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED:
INTERPRET DRAWINGS & TOLERANCES PER ASME Y14.5-2009
(REVISION OF ASME Y14.5M-1994)
INTERPRET WELD CALLOUTS PER ANSI/AWS A2.4
DIMENSIONS ARE IN INCHES

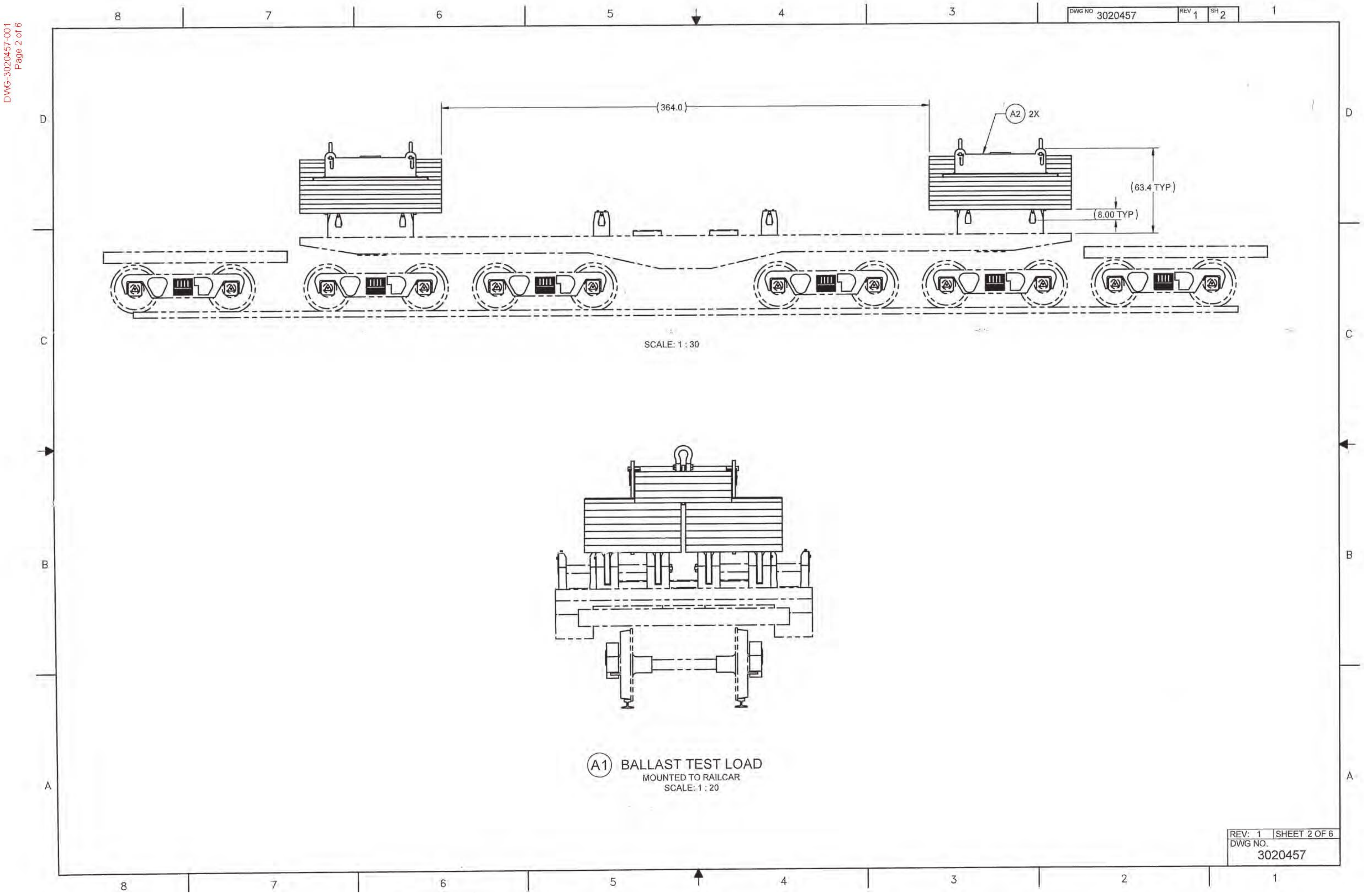
orano
Orano Federal Services LLC
Packaging Projects
Federal Way, WA 98003

DWG TITLE
BALLAST TEST LOAD
ATLAS RAILCAR TEST LOADS

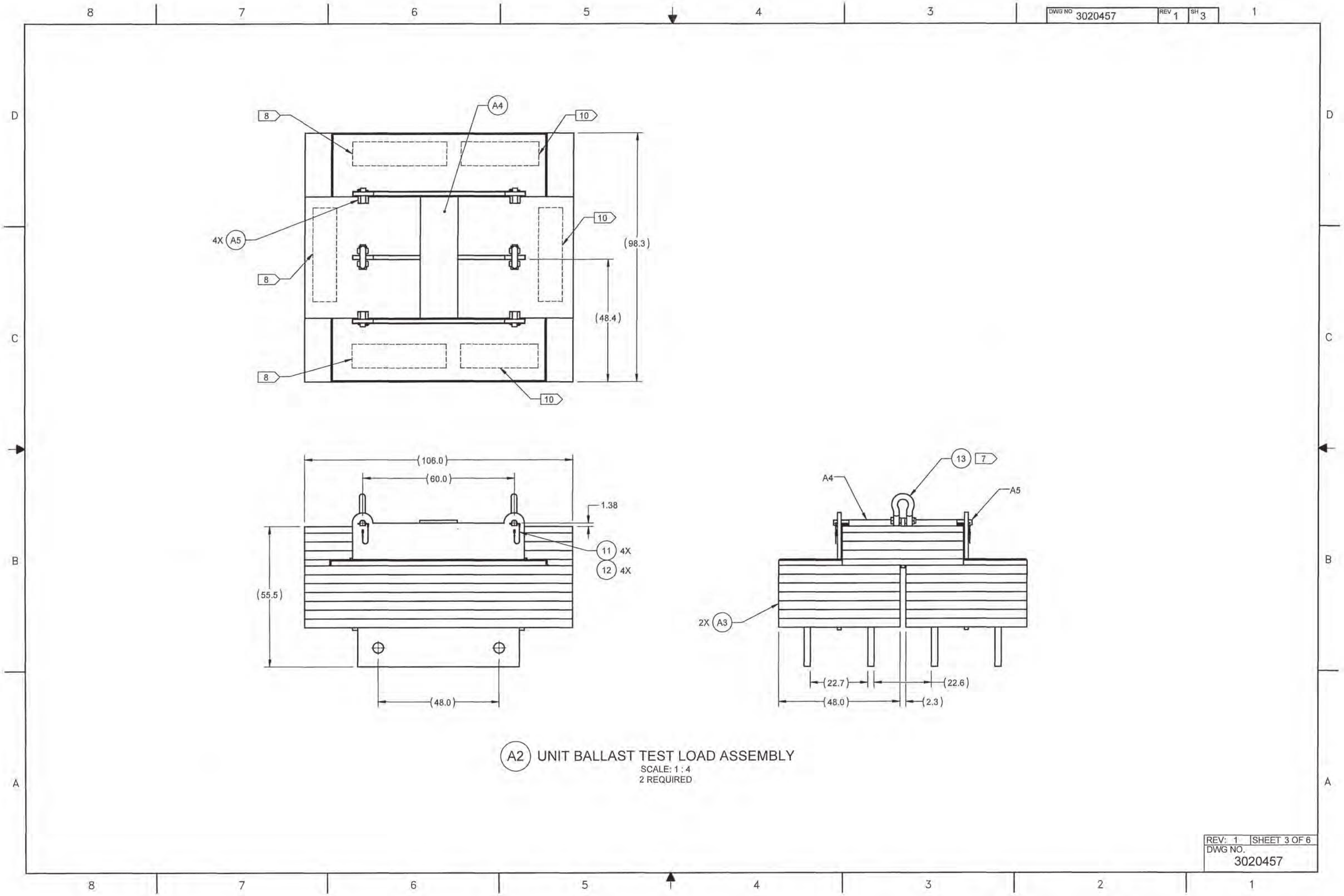
TOLERANCE BLOCK
FRACTIONS ± 3/16
ANGLES ± 1°
3 PLACE DECIMALS ± .010
2 PLACE DECIMALS ± .06
1 PLACE DECIMALS ± .1

SCALE: SHOWN
WT. ~
REV: 1
SHEET 1 OF 6
DWG SIZE D
DWG NO. 3020457
CADFILE: 3020457R1.SLDDRW
DWG-3020457-001

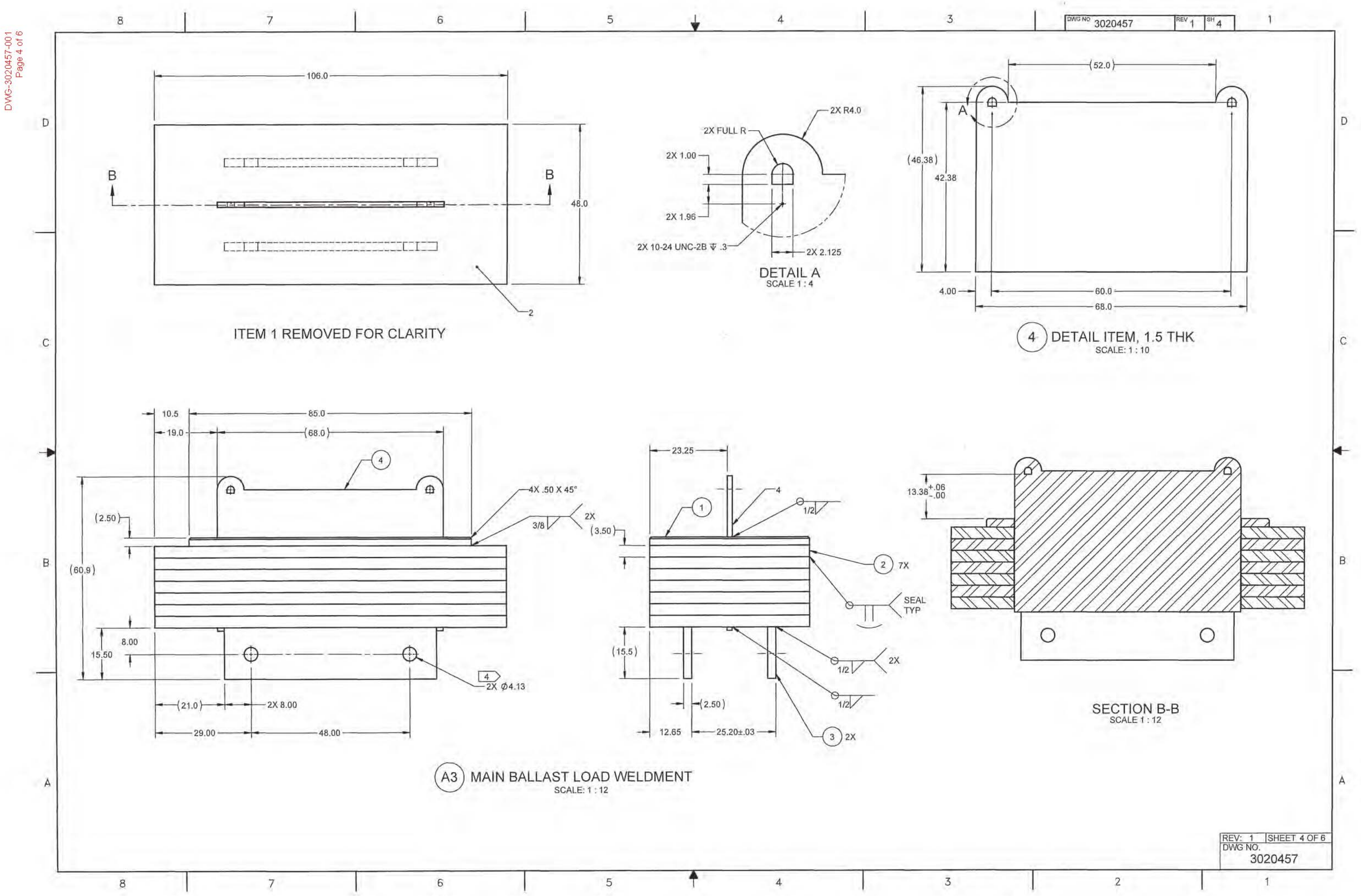
Orano Federal Services
July 11, 2018
Records Management

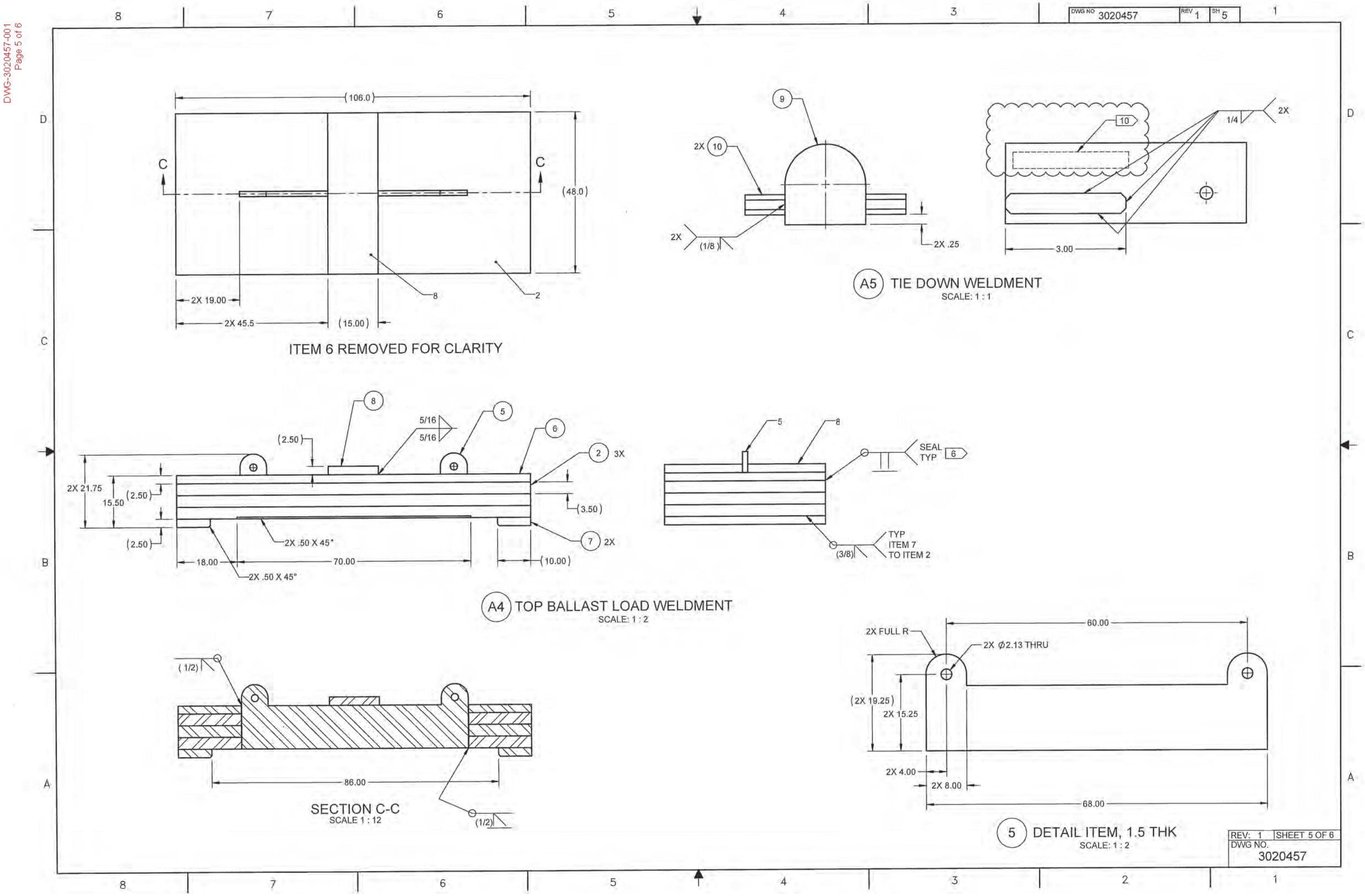

DWG-3020457-001
Page 2 of 6
DWG NO 3020457
REV 1
SH 2
8
7
6
5
4
3
2
1
D
C
B
A
(364.0)
A2 2X
(63.4 TYP)
(8.00 TYP)
SCALE: 1 : 30
A1 BALLAST TEST LOAD
MOUNTED TO RAILCAR
SCALE: 1 : 20
REV: 1
SHEET 2 OF 6
DWG NO.
3020457

DWG-3020457-001
Page 3 of 6



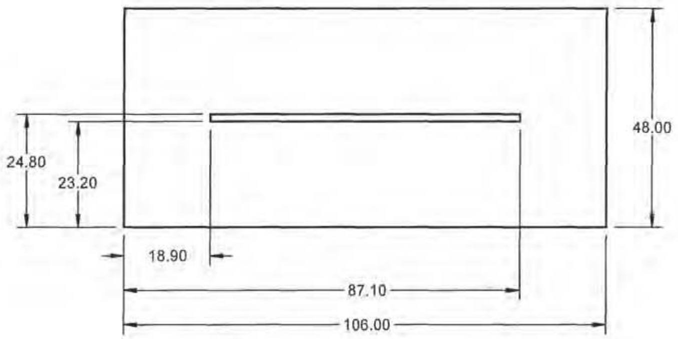
A2 UNIT BALLAST TEST LOAD ASSEMBLY
SCALE: 1 : 4
2 REQUIRED


DWG-3020457-001
Page 4 of 6
DWG NO 3020457
REV 1
SH 4
106.0
48.0
B
B
2
ITEM 1 REMOVED FOR CLARITY
2X R4.0
2X FULL R
2X 1.00
2X 1.96
2X 10-24 UNC-2B ⊽ .3
2X 2.125
DETAIL A
SCALE 1 : 4
(52.0)
A
(46.38)
42.38
4.00
60.0
68.0
4 DETAIL ITEM, 1.5 THK
SCALE: 1 : 10
10.5
85.0
19.0
(68.0)
4
4X .50 X 45°
3/8
2X
(2.50)
(60.9)
8.00
15.50
4
2X Ø4.13
(21.0)
2X 8.00
29.00
48.00
23.25
1
4
1/2
(3.50)
2 7X
SEAL TYP
(15.5)
2X
1/2
1/2
(2.50)
12.65
25.20±.03
3 2X
13.38 +.06 -.00
SECTION B-B
SCALE 1 : 12
A3 MAIN BALLAST LOAD WELDMENT
SCALE: 1 : 12
REV: 1
SHEET 4 OF 6
DWG NO.
3020457

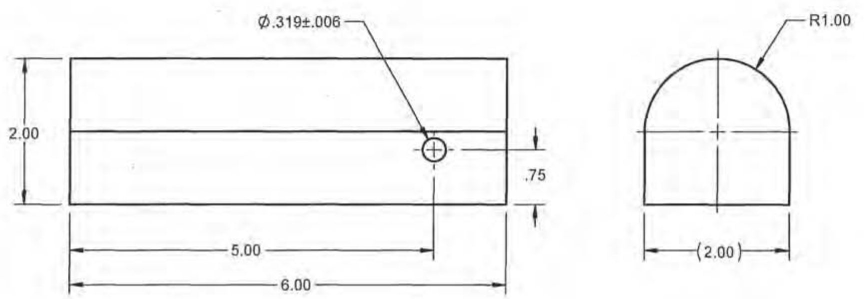

DWG-3020457-001
Page 5 of 6
DWG NO 3020457
REV 1
SH 5
(106.0)
C
C
(48.0)
2X 19.00
2X 45.5
(15.00)
8
2
ITEM 6 REMOVED FOR CLARITY
9
2X 10
2X
(1/8)
2X .25
A5 TIE DOWN WELDMENT
SCALE: 1 : 1
10
1/4
2X
3.00
8
5/16
5/16
5
6
(2.50)
2 3X
2X 21.75
15.50
(2.50)
(3.50)
(2.50)
2X .50 X 45°
7 2X
18.00
70.00
(10.00)
2X .50 X 45°
A4 TOP BALLAST LOAD WELDMENT
SCALE: 1 : 2
5
8
SEAL TYP 6
(3/8)
TYP
ITEM 7
TO ITEM 2
(1/2)
86.00
SECTION C-C
SCALE 1 : 12
(1/2)
60.00
2X FULL R
2X Ø2.13 THRU
(2X 19.25)
2X 15.25
2X 4.00
2X 8.00
68.00
5 DETAIL ITEM, 1.5 THK
SCALE: 1 : 2
REV: 1
SHEET 5 OF 6
DWG NO.
3020457
8
7
6
5
4
3
2
1
D
C
B
A

DWG-3020457-001
Page 6 of 6

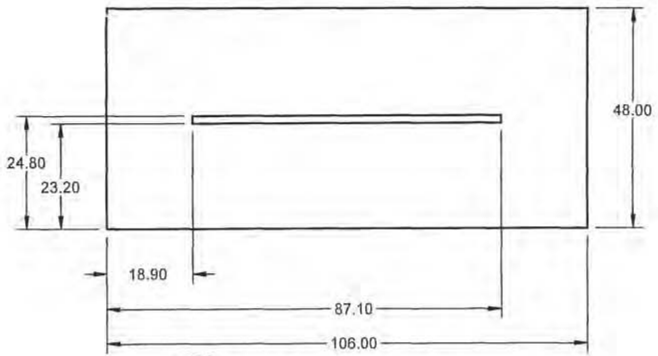
DWG NO 3020457 REV 1 SH 6



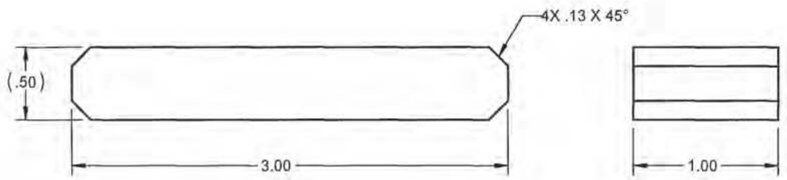
2 DETAIL ITEM, 3.5 THK
SCALE: 1 : 16



9 DETAIL ITEM, 2 THK
SCALE: 1 : 1



6 DETAIL ITEM, 2.5 THK
SCALE: 1 : 16



10 DETAIL ITEM, .50 THK
SCALE: 2 : 1

REV: 1 SHEET 6 OF 6
DWG NO.
3020457

APPENDIX I-3 DWG-3020458-001, MINIMUM TEST LOAD

DWG-3020458-001
Page 1 of 4

DWG NO 3020458 REV 1 SH 1

NOTES, UNLESS OTHERWISE SPECIFIED:

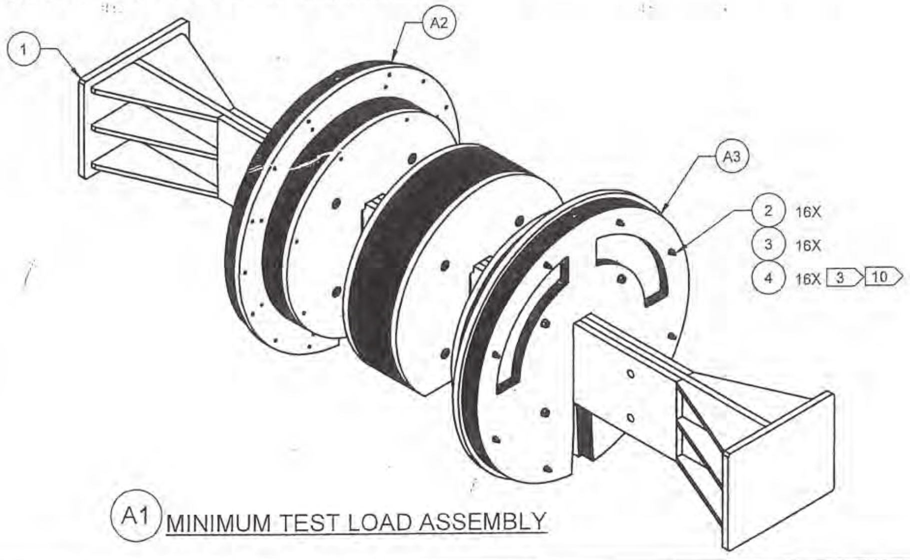
1. FABRICATE IN ACCORDANCE WITH SPECIFICATION PKG-GF-SPC-003.
2. MATERIAL SIZES LISTED IN THE DESCRIPTION COLUMN ARE FOR REFERENCE ONLY. MANUFACTURER SHALL CONFIRM ACTUAL REQUIREMENTS PRIOR TO FABRICATION.
3. INSTALL FASTENERS USING TURN-OF-NUT METHOD. AFTER SNUG TIGHT, 1/2 TURN FOR ITEM 12, 2/3 TURN FOR ITEM 4.
4. FASTENERS MAY BE REUSED ONLY IF THE NUT CAN BE THREADED BY HAND AFTER INITIAL USAGE, OTHERWISE REPLACE FASTENER.
5. ALL PLATE SURFACES SHALL BE BLAST CLEANED PER SSPC-SP6.
6. THE LIFT POINTS SHALL BE LOAD TESTED TO 125% OF THE RATED LOAD (21 KIP X 1.25 = 26.25 KIP) FOR DURATION OF AT LEAST 10 MINUTES. THE MATERIAL ADJACENT TO THE LIFT POINT SHALL BE VISUALLY INSPECTED TO ENSURE THERE ARE NO CRACKS OR DEFORMATION AFTER THE LOAD TEST.
7. STENCIL THE FOLLOWING USING 1 INCH HIGH LETTERS: "LIFTING ATTACHMENTS RATED FOR 21 KIPS". INSTALL WITH PAINT FACING OUTWARDS. USE EPOXY PAINT. COLOR SHALL BE HIGH CONTRAST WITH BASE PRIMER COAT.
8. ALTERNATE MATERIAL MAY BE USED WITH THE APPROVAL OF THE DESIGN AUTHORITY.
9. ALTERNATE ANCHOR ROD MATERIAL SHALL HAVE A YIELD STRENGTH OF AT LEAST 105 KSI.
10. APPLY LOCTITE 2047 TO ALL FASTENERS BEFORE INSTALLATION.
11. FOR LIFTING, A SCREW PIN SHACKLE WITH 1-3/8 PIN DIAMETER AND 12 TON WORKING LOAD LIMIT IS ACCEPTABLE (USE CROSBY PART NO. 1018570 OR EQUIVALENT).
12. ASSEMBLIES A2 AND A3 MAY BE FABRICATED BY ALTERNATE MANUFACTURING METHODS SUCH AS CASTING, OR THE PLATE THICKNESS ALTERED IN THE EXISTING DESIGN TO ACHIVE THE OVERALL ASSEMBLY WEIGHT, AS APPROVED BY THE DESIGN AUTHORITY.
13. THE WEIGHTS OF THE A1, A2, AND A3 ASSEMBLIES MUST MEET THE LIMITS SHOWN IN TABLE 1. THE WEIGHTS OF THE A2 AND A3 ASSEMBLIES SHALL BE ADJUSTED WITHIN THEIR RESPECTIVE RANGES TO MEET THE WEIGHT RANGE FOR THE A1 ASSEMBLY. WEIGH AND MARK THE A2 AND A3 ASSEMBLY WITH THE DRAWING ASSEMBLY NUMBER AND WEIGHT USING 1-INCH HIGH LETTERS LOCATED APPROXIMATELY AS SHOWN.
14. DELETED.
15. DELETED.
16. INSTALL ITEM 2 WITH THE SHORTER THREADED LENGTH GOING INTO THE CENTRAL ASSEMBLY PLATES. A THIN HEX NUT (E.G. McMASTER-CARR PART 95010A175) MAY BE USED AS A JAM NUT TO INSTALL THE ANCHOR ROD.
17. AFTER ASSEMBLY, SHOP PRIMER SHALL BE APPLIED TO THE EXPOSED SURFACES OF TEST LOAD ASSEMBLIES A2 AND A3 PER COATING MANUFACTURER'S INSTRUCTIONS, WITH THE EXCEPTION OF INSIDE SURFACES OF BOLT HOLES AND THE INDICATED SURFACES IN CONTACT WITH THE CENTRAL ASSEMBLY.

LIST OF MATERIALS

	S/D	QTY A3	QTY A2	QTY A1	ITEM NO	PART NO	DESCRIPTION	SPECIFICATION
				╳	A1		MINIMUM TEST LOAD ASSEMBLY	
			╳	1	A2		MINIMUM WEIGHT 7 PLATE ASSEMBLY	
		╳		1	A3		MINIMUM WEIGHT 8 PLATE ASSEMBLY	
	NITS			1	1	3020935	CENTRAL ASSEMBLY	
16 9	NITS			16	2		ANCHOR ROD, Ø1-8 X 13.0 LG	ASTM A193, GRADE B7
	NITS			16	3		HARDENED WASHER, 1	ASTM F436, TYPE 1
	NITS			16	4		HEAVY HEX NUT, 1-8 UNC-2B	ASTM A563, GRADE DH
	NITS	1	1		5		PLATE WITH LUG, 1 THK X Ø112.0 X 116.0	ASTM A36
	NITS	3			6		PLATE NO LUG, 1 THK X Ø112.0	ASTM A36
	NITS		6		7		PLATE, 1 THK X Ø112.0	ASTM A36
	NITS	4			8		PLATE, 1 THK X Ø112.0	ASTM A36
9	NITS	4			9		ANCHOR ROD, Ø 1 1/2 X 12.0 LG	ASTM A193, GRADE B7
9	NITS		4		10		ANCHOR ROD, Ø 1 1/2 X 11.0 LG	ASTM A193, GRADE B7
	NITS	8	8		11		HARDENED WASHER, 1 1/2	ASTM F436, TYPE 1
	NITS	8	8		12		HEAVY HEX NUT, 1 1/2-6 UNC-2B	ASTM A563, GRADE DH

TABLE 1-ASSEMBLY WEIGHT LIMITS

ASSEMBLY	MINIMUM WEIGHT (LB)	MAXIMUM WEIGHT (LB)
A1	163,500	176,710
A2	15,000	16,300
A3	18,000	19,400



A1 MINIMUM TEST LOAD ASSEMBLY

Orano Federal Services
July 11, 2018
Records Management

REV	DESCRIPTION
1	ECN NO. 3020458R0-E1
0	INITIAL RELEASE

REVISION HISTORY

	NAME/SIGNATURE	DATE
EM	DSH D Hillstrom	7/11/18
RE	S. Klein	7/11/18
TECH CHK	S. Klein	7/11/18
DFTG CHK	D. WICK	7/11/18
DRAWN	T.E. MARTIN	7/09/2018

NA	NA
NEXT ASSY	FINAL ASSY

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED:
INTERPRET DRAWINGS & TOLERANCES PER ASME Y14.5-2009
(REVISION OF ASME Y14.5M-1994)
INTERPRET WELD CALLOUTS PER ANSI/AWS A2.4
DIMENSIONS ARE IN INCHES

orano
Orano Federal Services LLC
Packaging Projects
Federal Way, WA 98003

DWG TITLE
MINIMUM TEST LOAD
ATLAS RAILCAR TEST LOADS

TOLERANCE BLOCK
FRACTIONS ± NA
ANGLES ± 1°
3 PLACE DECIMALS ± .010
2 PLACE DECIMALS ± .05
1 PLACE DECIMALS ± .1

SCALE: SHOWN
WT. –
REV: 1
SHEET 1 OF 4
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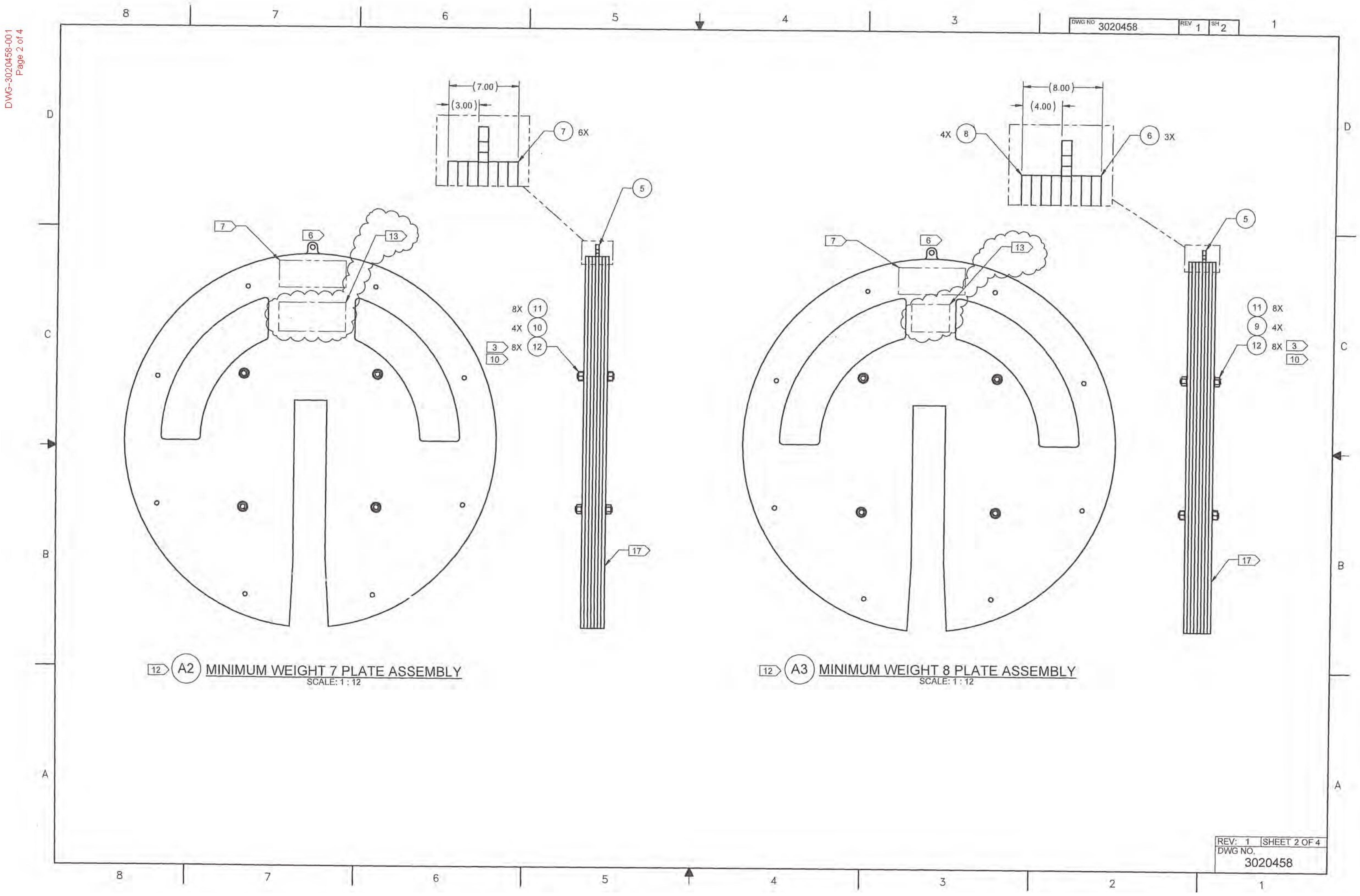
DWG-3020458-001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(3.00)
7 6X
5
7
6
13
8X 11
4X 10
3 8X 12
10
17
(8.00)
(4.00)
4X 8
6 3X
5
7
6
13
11 8X
9 4X
12 8X 3
10
17
12 A2 MINIMUM WEIGHT 7 PLATE ASSEMBLY
SCALE: 1 : 12
12 A3 MINIMUM WEIGHT 8 PLATE ASSEMBLY
SCALE: 1 : 12
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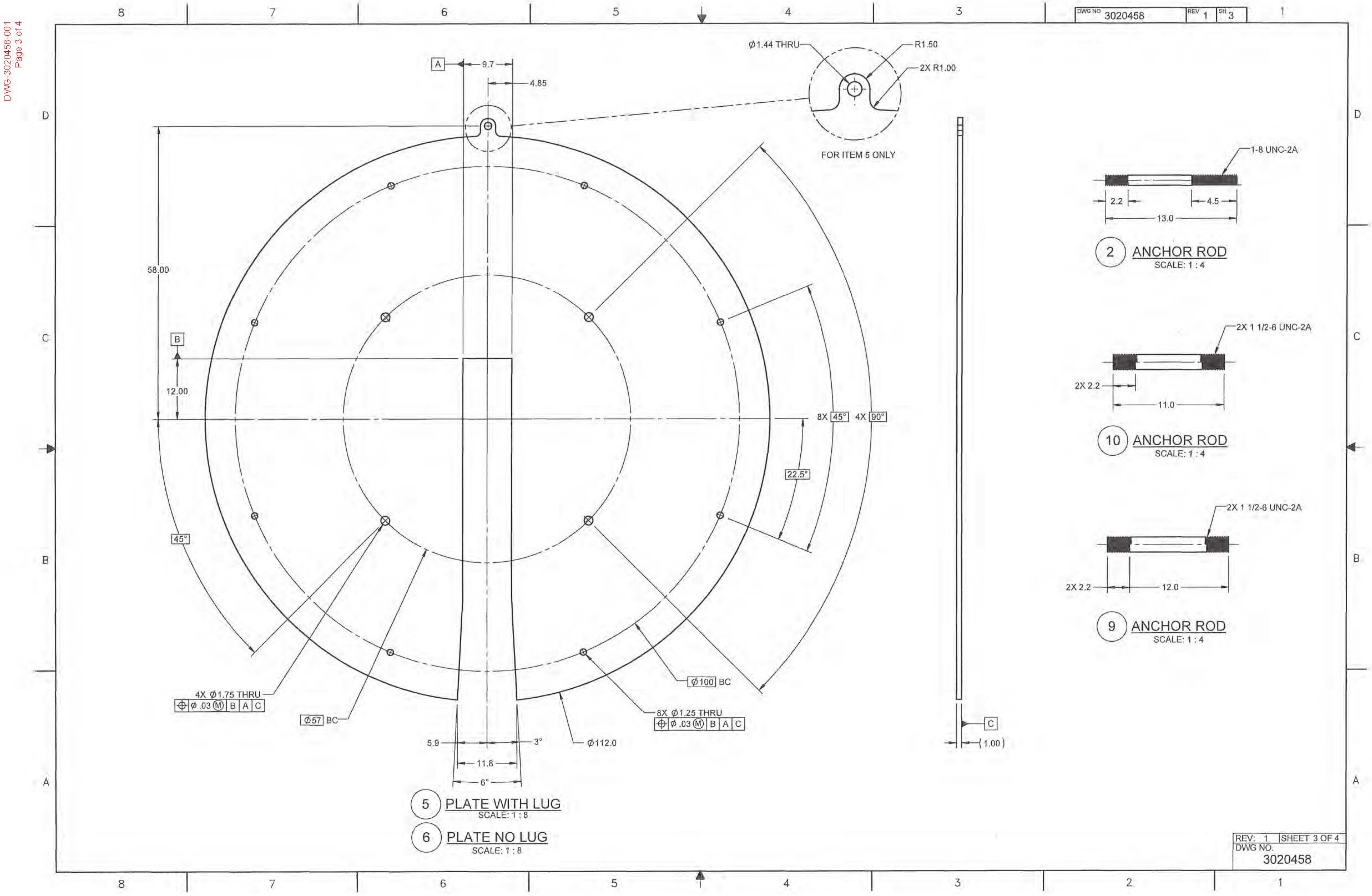
DWG NO.
3020458
8 7 6 5 4 3 2 1
D C B A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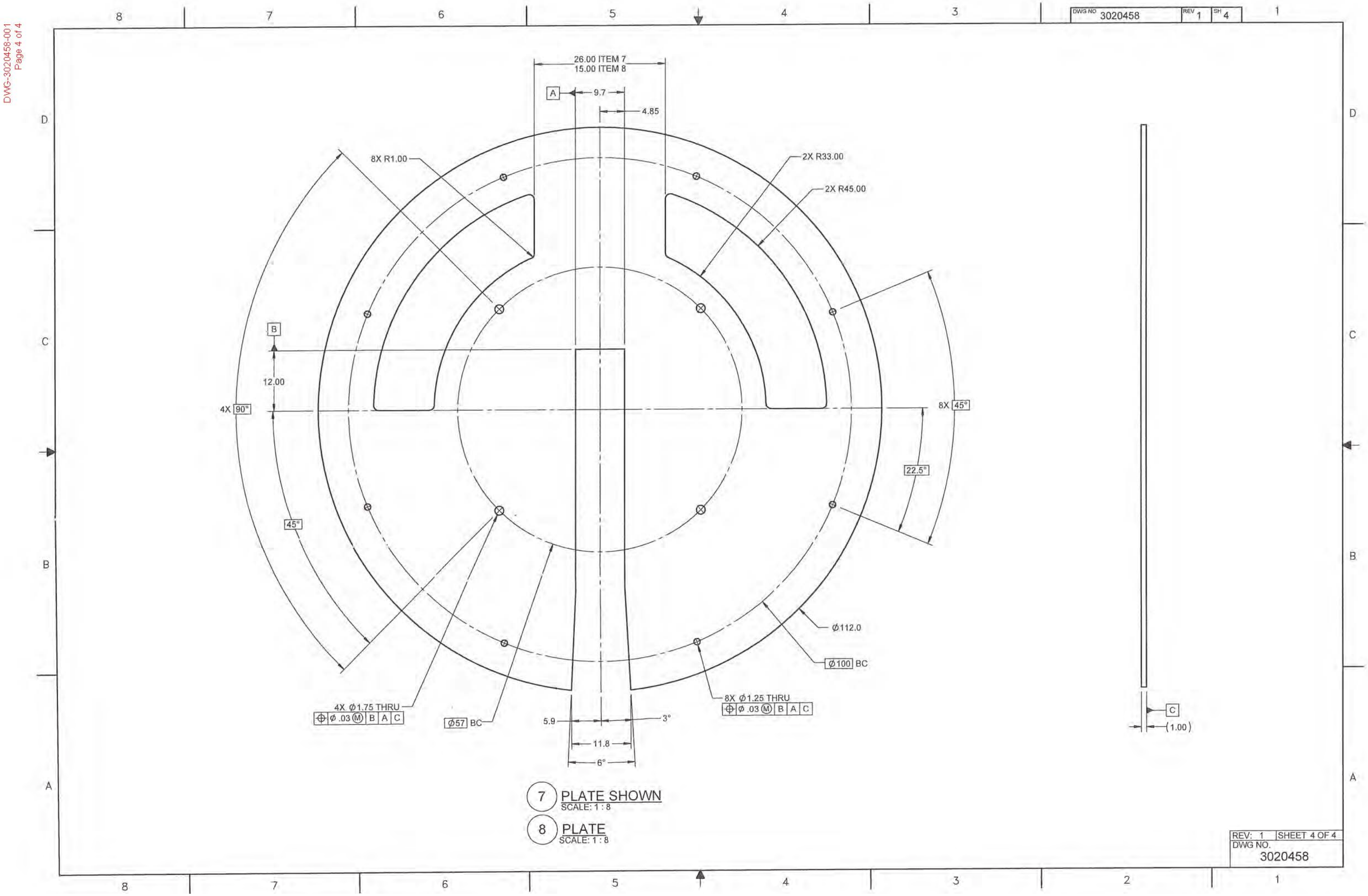
Page 3 of 4
DWG NO 3020458
REV 1
SH 3
A
9.7
4.85
Ø1.44 THRU
R1.50
2X R1.00
FOR ITEM 5 ONLY
58.00
B
12.00
8X 45°
4X 90°
22.5°
45°
4X Ø1.75 THRU
⊕ Ø .03 Ⓜ B A C
Ø57 BC
Ø100 BC
8X Ø1.25 THRU
⊕ Ø .03 Ⓜ B A C
5.9
3°
11.8
6°
Ø112.0
C
(1.00)
5 PLATE WITH LUG
SCALE: 1 : 8
6 PLATE NO LUG
SCALE: 1 : 8
1-8 UNC-2A
2.2
4.5
13.0
2 ANCHOR ROD
SCALE: 1 : 4
2X 1 1/2-6 UNC-2A
2X 2.2
11.0
10 ANCHOR ROD
SCALE: 1 : 4
2X 1 1/2-6 UNC-2A
2X 2.2
12.0
9 ANCHOR ROD
SCALE: 1 : 4
REV: 1
SHEET 3 OF 4
DWG NO.
3020458
8
7
6
5
4
3
2
1
D
C
B
A


DWG-3020458-001
Page 4 of 4
DWG NO 3020458
REV 1
SH 4
26.00 ITEM 7
15.00 ITEM 8
A
9.7
4.85
8X R1.00
2X R33.00
2X R45.00
B
12.00
4X 90°
8X 45°
22.5°
45°
Ø112.0
Ø100 BC
4X Ø1.75 THRU
⌖ Ø .03 Ⓜ B A C
Ø57 BC
5.9
3°
11.8
6°
8X Ø1.25 THRU
⌖ Ø .03 Ⓜ B A C
C
(1.00)
7 PLATE SHOWN
SCALE: 1 : 8
8 PLATE
SCALE: 1 : 8
REV: 1
SHEET 4 OF 4
DWG NO.
3020458
8
7
6
5
4
3
2
1
D
C
B
A

APPENDIX I-4 DWG-3020459-001, MINIMUM TEST LOAD CRADLE

DWG-3020459-001
Page 1 of 5

DWG NO 3020459 REV 1 SH 1

NOTES, UNLESS OTHERWISE SPECIFIED:

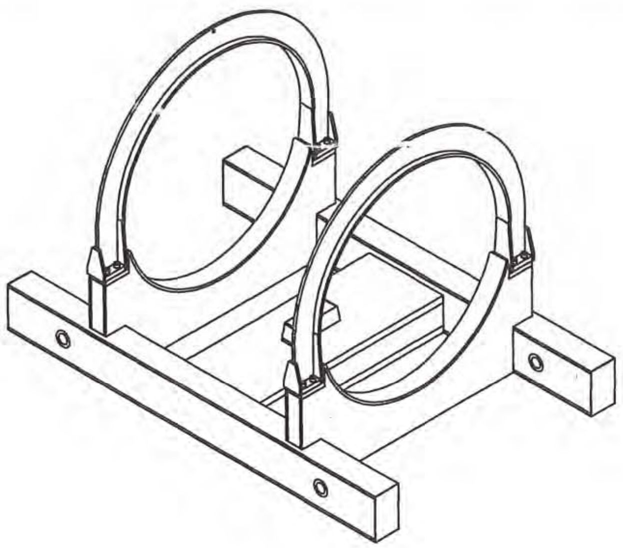
1. ALL WELDS VISUALLY INSPECTED PER AWS D1.1.
2. WELDING SHALL BE PERFORMED IN ACCORDANCE WITH AWS D1.1.
3. STRAIGHTEN AND OR MACHINE BEAM TO ACHIEVE DIMENSIONS SHOWN. REMOVE NO MORE THAN .19 INCHES FROM ANY SURFACE. THE BEAM MAY BE OPTIONALLY FABRICATED FROM PLATES OF EQUAL THICKNESS AND MATERIALS OF EQUAL OR GREATER YIELD STRENGTH. FABRICATED BEAMS SHALL UTILIZE FULL PENETRANT WELDS.
4. ALL SURFACES OF THE CRADLE, EXCEPT FOR LIFTING HOLES AND THE 4.13 DIAMETER HOLES SHALL BE BLAST CLEANED PER SSPC-SP-6 AND COATED WITH SELF-PRIMING ENAMEL, 2 COATS. THE NON-PAINTED WELDMENT SURFACES SHALL BE LIGHTLY COATED WITH NUCLEAR GRADE 'NEVER SEEZ' GREASE.
5. OVERALL CAMBER IN BEAM AFTER WELDING SHALL BE LIMITED FROM .0 TO .13 INCHES.
6. FABRICATE IN ACCORDANCE WITH SPECIFICATION PKG-GF-SPC-003.
7. LENGTH AND WIDTH DIMENSIONS FOR RAW MATERIAL IN THE LIST OF MATERIALS DESCRIPTION COLUMN ARE FOR REFERENCE ONLY, WITH THE EXCEPTION OF THE STOCK PLATE ITEMS 5, 6, 12 & 15. MANFUFACTURER SHALL CONFIRM ACTUAL REQUIREMENTS PRIOR TO FABRICATION.
8. MINIMUM TEST LOAD CRADLE BASED ON MP197 CONCEPUAL DESIGN. DRAWING 3015139-000.
9. DIMENSIONS SHALL MEET ANSI/ASME B18.3.
10. VERIFY ALIGNMENT BY INSERTING A 4.06 DIA ROUND BAR EXTENDING THRU BOTH BEAMS.
11. MAY BE FABRICATED FROM MULTIPLE PIECES USING FULL PENETRATION WELDS.
12. DIMENSION APPLIES FROM DATUM LINES F THRU G AND H THRU J.
13. TO BE USED FOR LIFTING ASSEMBLY A3 ONLY.
14. THE WEIGHT OF THE A1 ASSEMBLY MUST MEET THE LIMITS SHOWN IN TABLE 1. STENCIL THE CORRESPONDING WEIGHT ON THE ASSEMBLY USING 1" HIGH LETTERS IN THE APPROXIMATE AREA AS SHOWN BELOW:
    ORANO DWG 3020459 A1 ASSEMBLY
    WEIGHT: XX,XXX LBS
    WHERE XX,XXX IS CORRESPONDING ASSEMBLY WEIGHT.

LIST OF MATERIALS

	S/D	QTY A3	QTY A2	QTY A1	ITEM NO	PART NO	DESCRIPTION	SPECIFICATION
					A1		MINIMUM TEST LOAD CRADLE	
				1	A2		BASE WELDMENT	
				2	A3		TIE DOWN WELDMENT	
	NITS			1	1		PLATE, 6.0 THK X 22.5 X 22.1	ASTM A564 XM-16 H900
9	NITS			18	2	91251A773	SOCKET HEAD CAP SCREW, 1 3/8-6 UNC-2A X 6 LG	McMASTER-CARR
	NITS		1		3		PLATE, 3.0 THK X 35.8 X 93.5	ASTM A514
	NITS		1		4		PLATE, 3.0 THK X 35.8 X 93.5	ASTM A514
	NITS		2		5		PLATE, 3.0 THK X 9.5 X 93.5	ASTM A514
	NITS		2		6		PLATE, 2.0 THK X 9.5 X 24	ASTM A514
3	NITS		2		7		W 18 X 119, 178.2 LG	ASTM A992
	NITS		4		8		PLATE, 1.0 THK x 16.9 X 178.2	ASTM A514
	NITS		4		9		PLATE, .13 X 11.3 X 19.0	ASTM A514
	NITS		4		10		BAR, Ø6.25 X 11.3 LG	ASTM A276, TYPE 304
	NITS		4		11		PLATE, 1.0 THK X 112.0 X 46.5	ASTM A514
	NITS		4		12		PLATE, 1.0 THK X 6.0 x 21.0	ASTM A514
	NITS		4		13		PLATE, 2.0 THK X 8.0 X 14.75	ASTM A514
	NITS		2		14		PLATE, 1.0 THK X 120.0 X 8.0	ASTM A514
	NITS		2		15		PLATE, 1.5 THK X 6.0 X 93.5	ASTM A514
11	NITS	1			16		PLATE, 1.0 THK X 187.0 X 8.0	ASTM A514
	NITS	1			17		PLATE, 1.13 THK X 112.0 X 74.0	ASTM A514
	NITS	2			18		PLATE, 2.0 THK X 8.0 X 9.3	ASTM A514
	NITS	2			19		PLATE, 1.0 THK X 12.0 X 8.0	ASTM A514

TABLE 1-ASSEMBLY WEIGHT LIMITS

ASSEMBLY	MINIMUM WEIGHT (LB)	MAXIMUM WEIGHT (LB)
A1	20,300	22,900



Orano Federal Services
July 11, 2018
Records Management

REVISION HISTORY

REV	DESCRIPTION
1	ECN NO. 3020459R0-E1
0	INITIAL RELEASE

			NAME/SIGNATURE	DATE
		EM	DSH	7/11/18
		RE	S. Klein	7/11/18
		TECH CHK	S. Klein	7/11/18
NA	NA	DFTG CHK	D. Wick	7/11/18
NEXT ASSY	FINAL ASSY	DRAWN	T.E. MARTIN	7/10/2018

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED:
INTERPRET DRAWINGS & TOLERANCES PER ASME Y14.5-2009
(REVISION OF ASME Y14.5M-1994)
INTERPRET WELD CALLOUTS PER ANSI/AWS A2.4
DIMENSIONS ARE IN INCHES

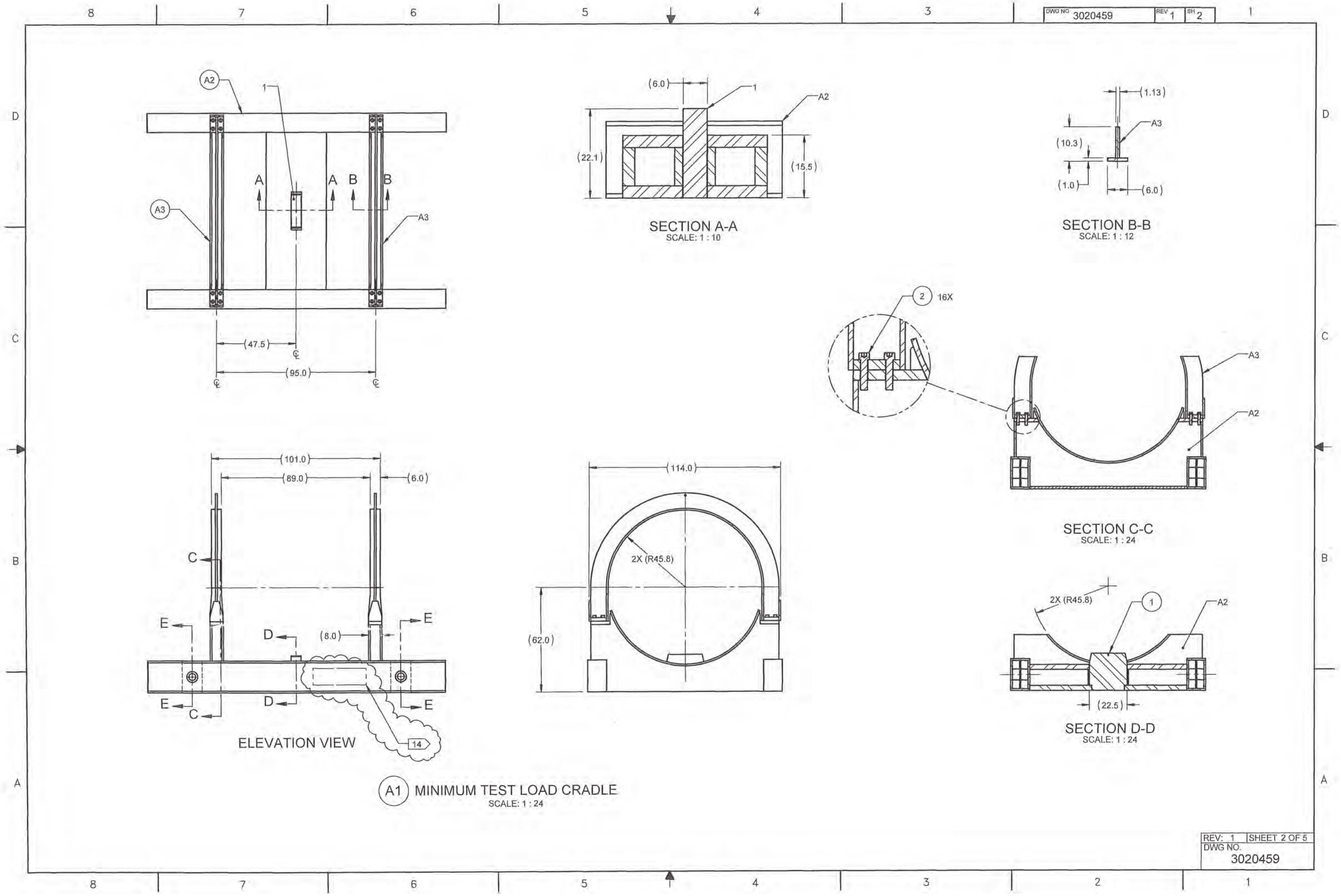
orano
Orano Federal Services LLC
Packaging Projects
Federal Way, WA 98003

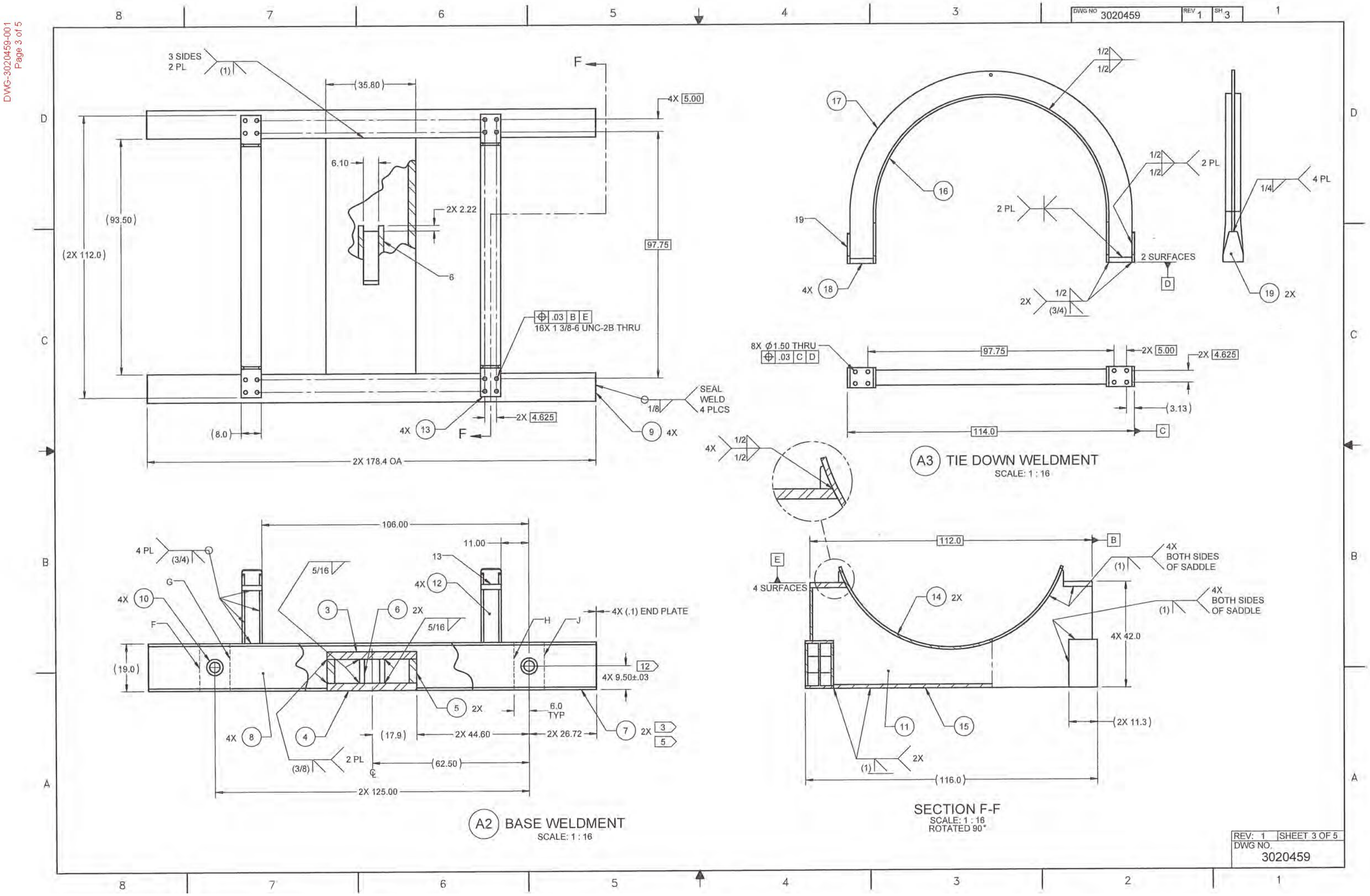
DWG TITLE
MINIMUM TEST LOAD CRADLE
ATLAS RAILCAR TEST LOADS

TOLERANCE BLOCK
FRACTIONS ± 3/16
ANGLES ± 1°
3 PLACE DECIMALS ± .030
2 PLACE DECIMALS ± .06
1 PLACE DECIMALS ± .1

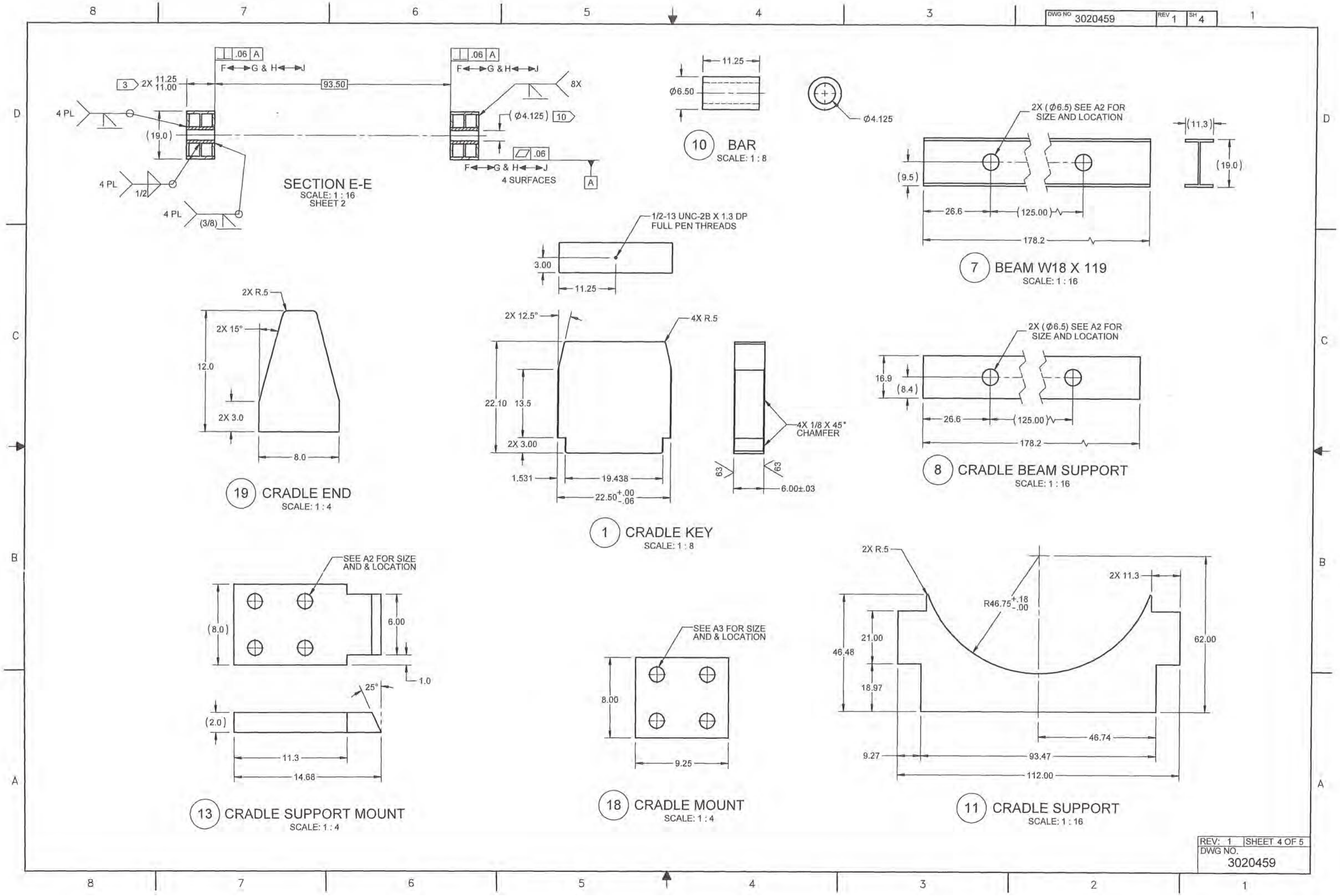
SCALE: SHOWN
WT. ~
REV: 1
SHEET 1 OF 5
DWG SIZE D
DWG NO. 3020459
CADFILE: 3020459R1.SLDDRW
DWG-3020459-001

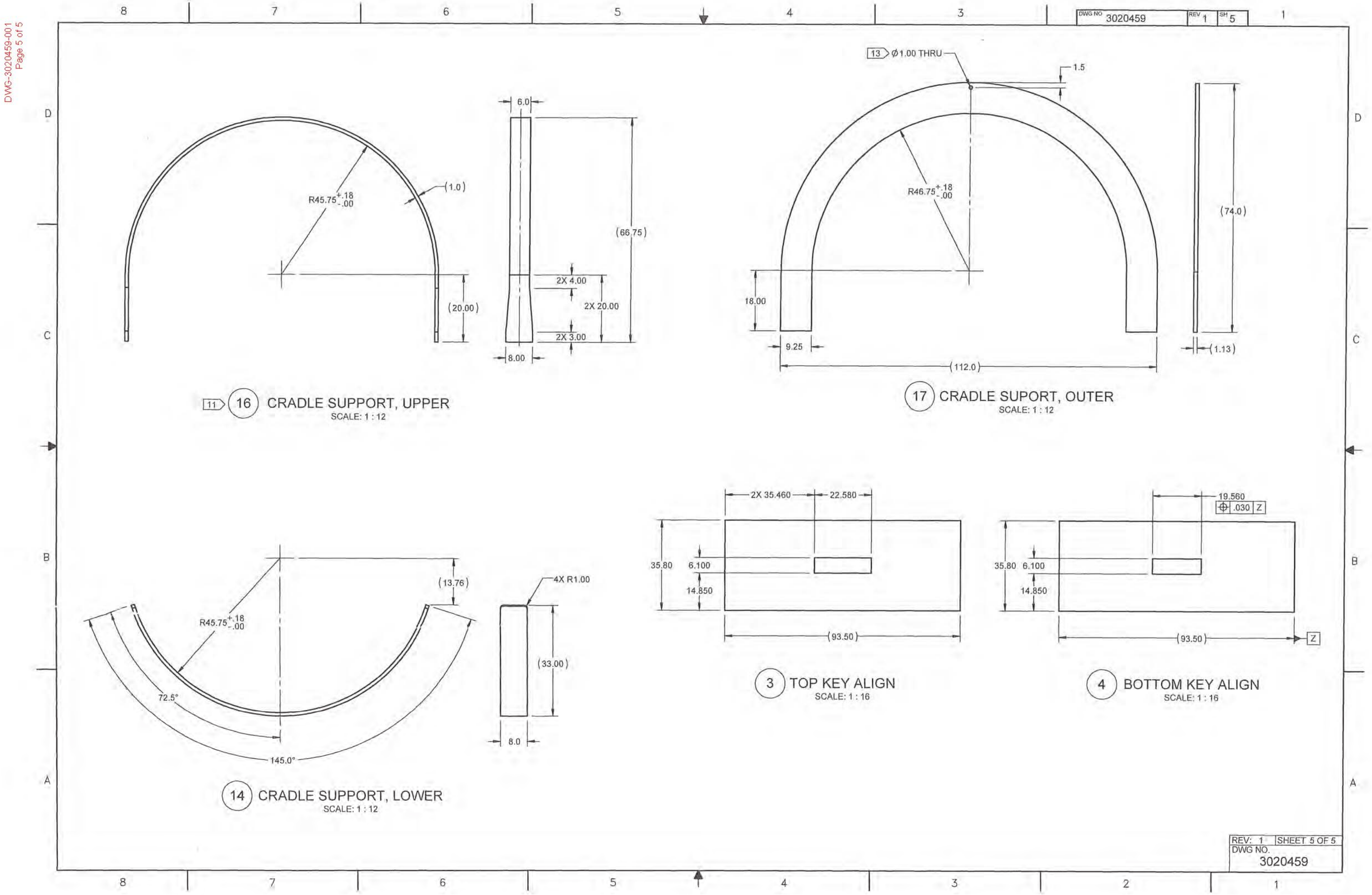
DWG-3020459-001
Page 2 of 5



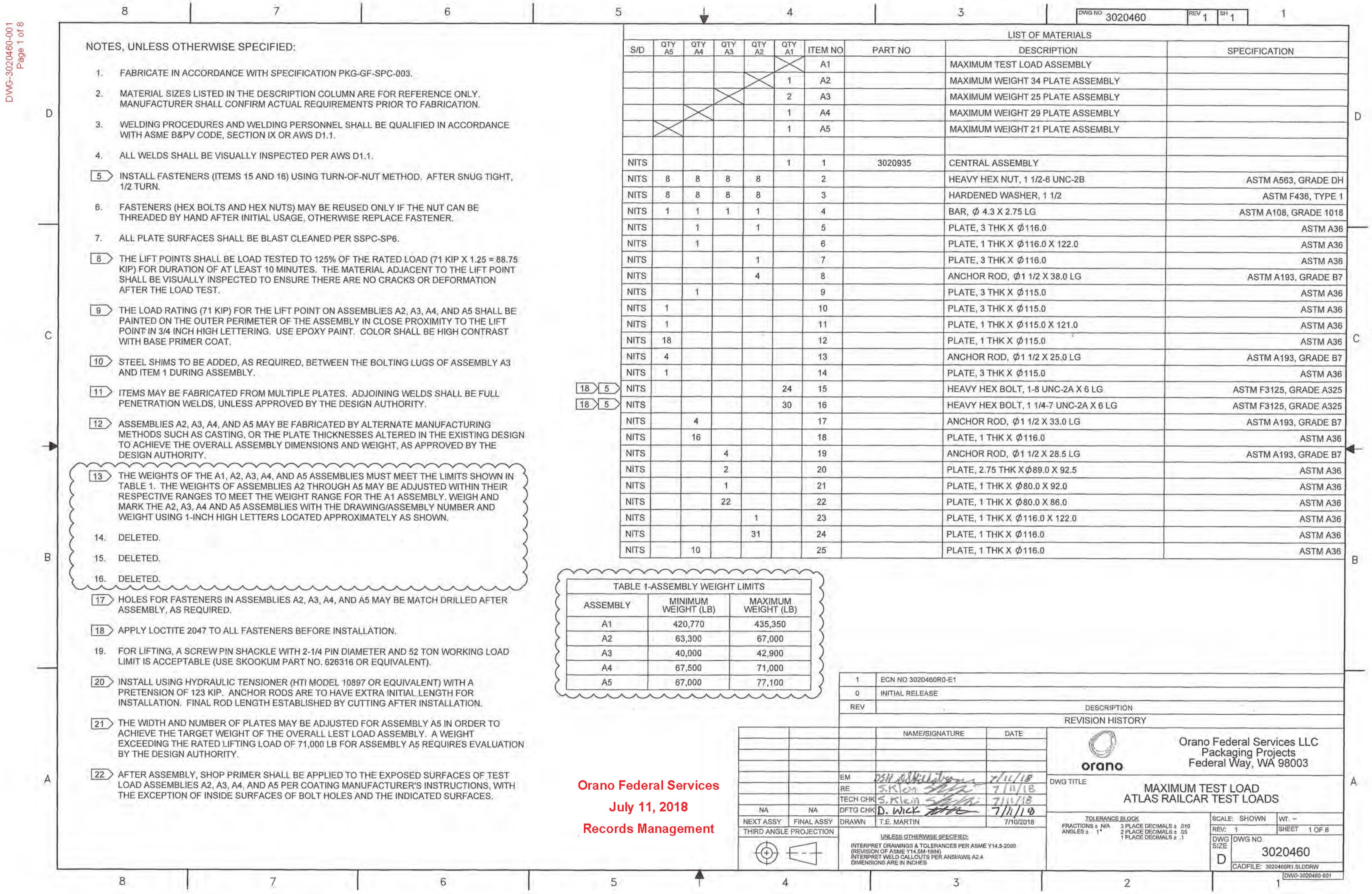

DWG-3020459-001
Page 3 of 5
DWG NO 3020459
REV 1
SH 3
3 SIDES
2 PL
(1)
35.80
F
4X 5.00
6.10
2X 2.22
(93.50)
(2X 112.0)
97.75
6
.03 B E
16X 1 3/8-6 UNC-2B THRU
SEAL WELD 4 PLCS
1/8
(8.0)
4X 13
F
2X 4.625
9 4X
2X 178.4 OA
17
1/2
1/2
16
2 PL
4 PL
1/4
19
2 SURFACES
D
4X 18
2X
(3/4)
19 2X
8X Ø1.50 THRU
.03 C D
97.75
2X 5.00
2X 4.625
(3.13)
114.0
C
4X
A3 TIE DOWN WELDMENT
SCALE: 1 : 16
106.00
11.00
4 PL
(3/4)
13
G
5/16
4X 12
4X 10
3
6 2X
5/16
H
J
4X (.1) END PLATE
F
(19.0)
12
4X 9.50±.03
5 2X
6.0 TYP
4X 8
4
(17.9)
2X 44.60
2X 26.72
7 2X
3
5
2 PL
(3/8)
(62.50)
2X 125.00
A2 BASE WELDMENT
SCALE: 1 : 16
112.0
B
E
4 SURFACES
4X BOTH SIDES OF SADDLE
(1)
14 2X
4X 42.0
11
15
(2X 11.3)
(1)
2X
(116.0)
SECTION F-F
SCALE: 1 : 16
ROTATED 90°
REV: 1
SHEET 3 OF 5
DWG NO.
3020459

DWG-3020459-001
Page 4 of 5




DWG-3020459-001
Page 5 of 5
DWG NO 3020459 REV 1 SH 5
13 Ø1.00 THRU
1.5
6.0
R45.75 +.18 -.00
(1.0)
(66.75)
2X 4.00
2X 20.00
2X 3.00
(20.00)
8.00
R46.75 +.18 -.00
(74.0)
18.00
9.25
(112.0)
(1.13)
11 16 CRADLE SUPPORT, UPPER
SCALE: 1 : 12
17 CRADLE SUPORT, OUTER
SCALE: 1 : 12
2X 35.460
22.580
35.80
6.100
14.850
(93.50)
3 TOP KEY ALIGN
SCALE: 1 : 16
19.560
.030 Z
35.80
6.100
14.850
(93.50)
Z
4 BOTTOM KEY ALIGN
SCALE: 1 : 16
(13.76)
4X R1.00
R45.75 +.18 -.00
(33.00)
72.5°
145.0°
8.0
14 CRADLE SUPPORT, LOWER
SCALE: 1 : 12
REV: 1 SHEET 5 OF 5
DWG NO.
3020459

APPENDIX I-5 DWG-3020460-001, MAXIMUM TEST LOAD



DWG-3020460-001
Page 1 of 8

DWG NO 3020460 REV 1 SH 1

NOTES, UNLESS OTHERWISE SPECIFIED:

1. FABRICATE IN ACCORDANCE WITH SPECIFICATION PKG-GF-SPC-003.
2. MATERIAL SIZES LISTED IN THE DESCRIPTION COLUMN ARE FOR REFERENCE ONLY. MANUFACTURER SHALL CONFIRM ACTUAL REQUIREMENTS PRIOR TO FABRICATION.
3. WELDING PROCEDURES AND WELDING PERSONNEL SHALL BE QUALIFIED IN ACCORDANCE WITH ASME B&PV CODE, SECTION IX OR AWS D1.1.
4. ALL WELDS SHALL BE VISUALLY INSPECTED PER AWS D1.1.
5. INSTALL FASTENERS (ITEMS 15 AND 16) USING TURN-OF-NUT METHOD. AFTER SNUG TIGHT, 1/2 TURN.
6. FASTENERS (HEX BOLTS AND HEX NUTS) MAY BE REUSED ONLY IF THE NUT CAN BE THREADED BY HAND AFTER INITIAL USAGE, OTHERWISE REPLACE FASTENER.
7. ALL PLATE SURFACES SHALL BE BLAST CLEANED PER SSPC-SP6.
8. THE LIFT POINTS SHALL BE LOAD TESTED TO 125% OF THE RATED LOAD (71 KIP X 1.25 = 88.75 KIP) FOR DURATION OF AT LEAST 10 MINUTES. THE MATERIAL ADJACENT TO THE LIFT POINT SHALL BE VISUALLY INSPECTED TO ENSURE THERE ARE NO CRACKS OR DEFORMATION AFTER THE LOAD TEST.
9. THE LOAD RATING (71 KIP) FOR THE LIFT POINT ON ASSEMBLIES A2, A3, A4, AND A5 SHALL BE PAINTED ON THE OUTER PERIMETER OF THE ASSEMBLY IN CLOSE PROXIMITY TO THE LIFT POINT IN 3/4 INCH HIGH LETTERING. USE EPOXY PAINT. COLOR SHALL BE HIGH CONTRAST WITH BASE PRIMER COAT.
10. STEEL SHIMS TO BE ADDED, AS REQUIRED, BETWEEN THE BOLTING LUGS OF ASSEMBLY A3 AND ITEM 1 DURING ASSEMBLY.
11. ITEMS MAY BE FABRICATED FROM MULTIPLE PLATES. ADJOINING WELDS SHALL BE FULL PENETRATION WELDS, UNLESS APPROVED BY THE DESIGN AUTHORITY.
12. ASSEMBLIES A2, A3, A4, AND A5 MAY BE FABRICATED BY ALTERNATE MANUFACTURING METHODS SUCH AS CASTING, OR THE PLATE THICKNESSES ALTERED IN THE EXISTING DESIGN TO ACHIEVE THE OVERALL ASSEMBLY DIMENSIONS AND WEIGHT, AS APPROVED BY THE DESIGN AUTHORITY.
13. THE WEIGHTS OF THE A1, A2, A3, A4, AND A5 ASSEMBLIES MUST MEET THE LIMITS SHOWN IN TABLE 1. THE WEIGHTS OF ASSEMBLIES A2 THROUGH A5 MAY BE ADJUSTED WITHIN THEIR RESPECTIVE RANGES TO MEET THE WEIGHT RANGE FOR THE A1 ASSEMBLY. WEIGH AND MARK THE A2, A3, A4 AND A5 ASSEMBLIES WITH THE DRAWING/ASSEMBLY NUMBER AND WEIGHT USING 1-INCH HIGH LETTERS LOCATED APPROXIMATELY AS SHOWN.
14. DELETED.
15. DELETED.
16. DELETED.
17. HOLES FOR FASTENERS IN ASSEMBLIES A2, A3, A4, AND A5 MAY BE MATCH DRILLED AFTER ASSEMBLY, AS REQUIRED.
18. APPLY LOCTITE 2047 TO ALL FASTENERS BEFORE INSTALLATION.
19. FOR LIFTING, A SCREW PIN SHACKLE WITH 2-1/4 PIN DIAMETER AND 52 TON WORKING LOAD LIMIT IS ACCEPTABLE (USE SKOOKUM PART NO. 626316 OR EQUIVALENT).
20. INSTALL USING HYDRAULIC TENSIONER (HTI MODEL 10897 OR EQUIVALENT) WITH A PRETENSION OF 123 KIP. ANCHOR RODS ARE TO HAVE EXTRA INITIAL LENGTH FOR INSTALLATION. FINAL ROD LENGTH ESTABLISHED BY CUTTING AFTER INSTALLATION.
21. THE WIDTH AND NUMBER OF PLATES MAY BE ADJUSTED FOR ASSEMBLY A5 IN ORDER TO ACHIEVE THE TARGET WEIGHT OF THE OVERALL LEST LOAD ASSEMBLY. A WEIGHT EXCEEDING THE RATED LIFTING LOAD OF 71,000 LB FOR ASSEMBLY A5 REQUIRES EVALUATION BY THE DESIGN AUTHORITY.
22. AFTER ASSEMBLY, SHOP PRIMER SHALL BE APPLIED TO THE EXPOSED SURFACES OF TEST LOAD ASSEMBLIES A2, A3, A4, AND A5 PER COATING MANUFACTURER'S INSTRUCTIONS, WITH THE EXCEPTION OF INSIDE SURFACES OF BOLT HOLES AND THE INDICATED SURFACES.

LIST OF MATERIALS

	S/D	QTY A5	QTY A4	QTY A3	QTY A2	QTY A1	ITEM NO	PART NO	DESCRIPTION	SPECIFICATION
						X	A1		MAXIMUM TEST LOAD ASSEMBLY	
					X	1	A2		MAXIMUM WEIGHT 34 PLATE ASSEMBLY	
				X		2	A3		MAXIMUM WEIGHT 25 PLATE ASSEMBLY	
			X			1	A4		MAXIMUM WEIGHT 29 PLATE ASSEMBLY	
		X				1	A5		MAXIMUM WEIGHT 21 PLATE ASSEMBLY	
	NITS					1	1	3020935	CENTRAL ASSEMBLY	
	NITS	8	8	8	8		2		HEAVY HEX NUT, 1 1/2-6 UNC-2B	ASTM A563, GRADE DH
	NITS	8	8	8	8		3		HARDENED WASHER, 1 1/2	ASTM F436, TYPE 1
	NITS	1	1	1	1		4		BAR, Ø 4.3 X 2.75 LG	ASTM A108, GRADE 1018
	NITS		1		1		5		PLATE, 3 THK X Ø116.0	ASTM A36
	NITS		1				6		PLATE, 1 THK X Ø116.0 X 122.0	ASTM A36
	NITS				1		7		PLATE, 3 THK X Ø116.0	ASTM A36
	NITS				4		8		ANCHOR ROD, Ø1 1/2 X 38.0 LG	ASTM A193, GRADE B7
	NITS		1				9		PLATE, 3 THK X Ø115.0	ASTM A36
	NITS	1					10		PLATE, 3 THK X Ø115.0	ASTM A36
	NITS	1					11		PLATE, 1 THK X Ø115.0 X 121.0	ASTM A36
	NITS	18					12		PLATE, 1 THK X Ø115.0	ASTM A36
	NITS	4					13		ANCHOR ROD, Ø1 1/2 X 25.0 LG	ASTM A193, GRADE B7
	NITS	1					14		PLATE, 3 THK X Ø115.0	ASTM A36
18 5	NITS					24	15		HEAVY HEX BOLT, 1-8 UNC-2A X 6 LG	ASTM F3125, GRADE A325
18 5	NITS					30	16		HEAVY HEX BOLT, 1 1/4-7 UNC-2A X 6 LG	ASTM F3125, GRADE A325
	NITS		4				17		ANCHOR ROD, Ø1 1/2 X 33.0 LG	ASTM A193, GRADE B7
	NITS		16				18		PLATE, 1 THK X Ø116.0	ASTM A36
	NITS			4			19		ANCHOR ROD, Ø1 1/2 X 28.5 LG	ASTM A193, GRADE B7
	NITS			2			20		PLATE, 2.75 THK X Ø89.0 X 92.5	ASTM A36
	NITS			1			21		PLATE, 1 THK X Ø80.0 X 92.0	ASTM A36
	NITS			22			22		PLATE, 1 THK X Ø80.0 X 86.0	ASTM A36
	NITS				1		23		PLATE, 1 THK X Ø116.0 X 122.0	ASTM A36
	NITS				31		24		PLATE, 1 THK X Ø116.0	ASTM A36
	NITS		10				25		PLATE, 1 THK X Ø116.0	ASTM A36

TABLE 1-ASSEMBLY WEIGHT LIMITS

ASSEMBLY	MINIMUM WEIGHT (LB)	MAXIMUM WEIGHT (LB)
A1	420,770	435,350
A2	63,300	67,000
A3	40,000	42,900
A4	67,500	71,000
A5	67,000	77,100

REVISION HISTORY

REV	DESCRIPTION
1	ECN NO 3020460R0-E1
0	INITIAL RELEASE

	NAME/SIGNATURE	DATE
EM	DSH	7/11/18
RE	S.Klein	7/11/18
TECH CHK	S.Klein	7/11/18
DFTG CHK	D. WICK	7/11/18
DRAWN	T.E. MARTIN	7/10/2018

NA	NA
NEXT ASSY	FINAL ASSY

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED:
INTERPRET DRAWINGS & TOLERANCES PER ASME Y14.5-2009
(REVISION OF ASME Y14.5M-1994)
INTERPRET WELD CALLOUTS PER ANSI/AWS A2.4
DIMENSIONS ARE IN INCHES

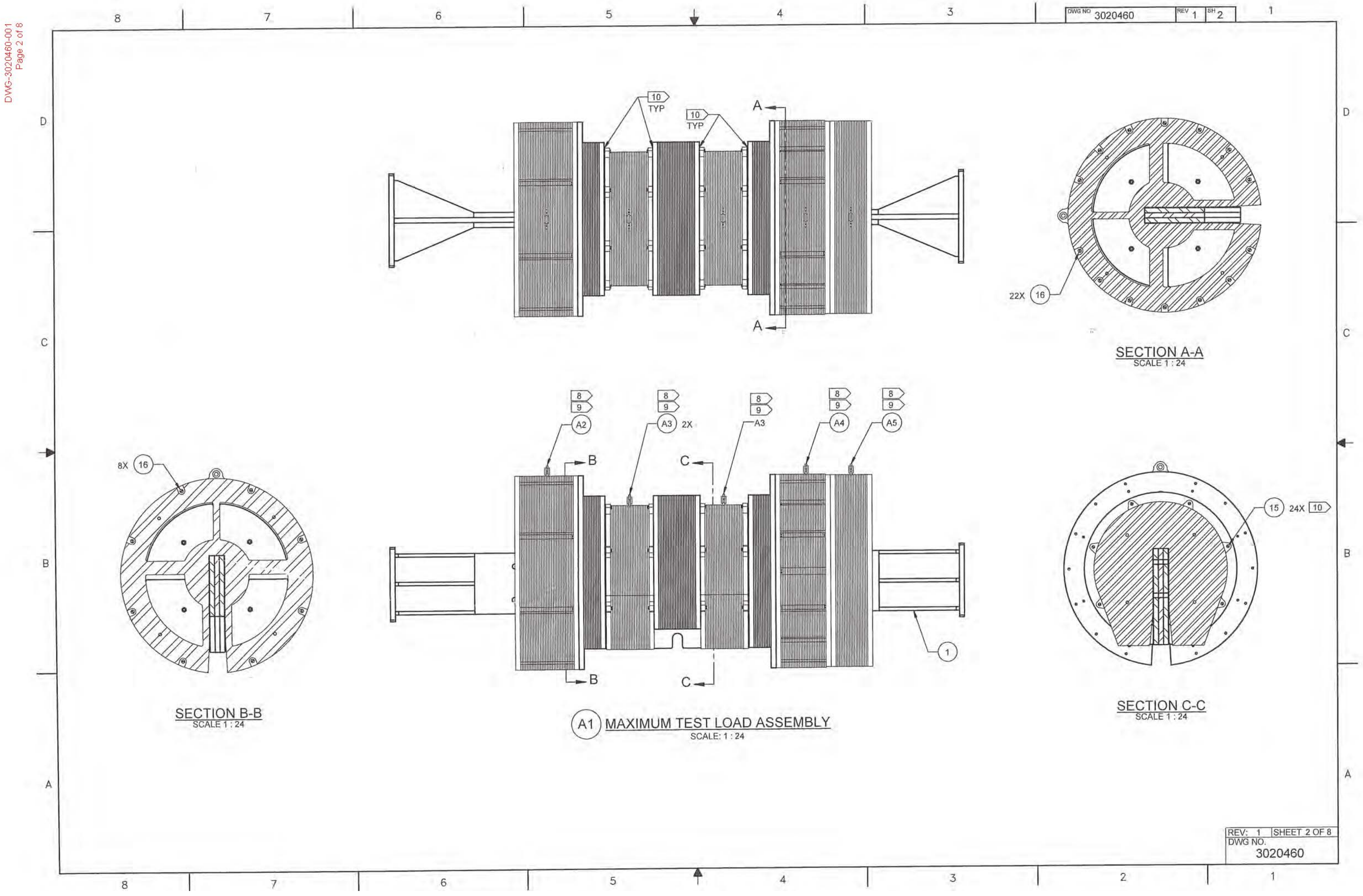
Orano Federal Services LLC
Packaging Projects
Federal Way, WA 98003

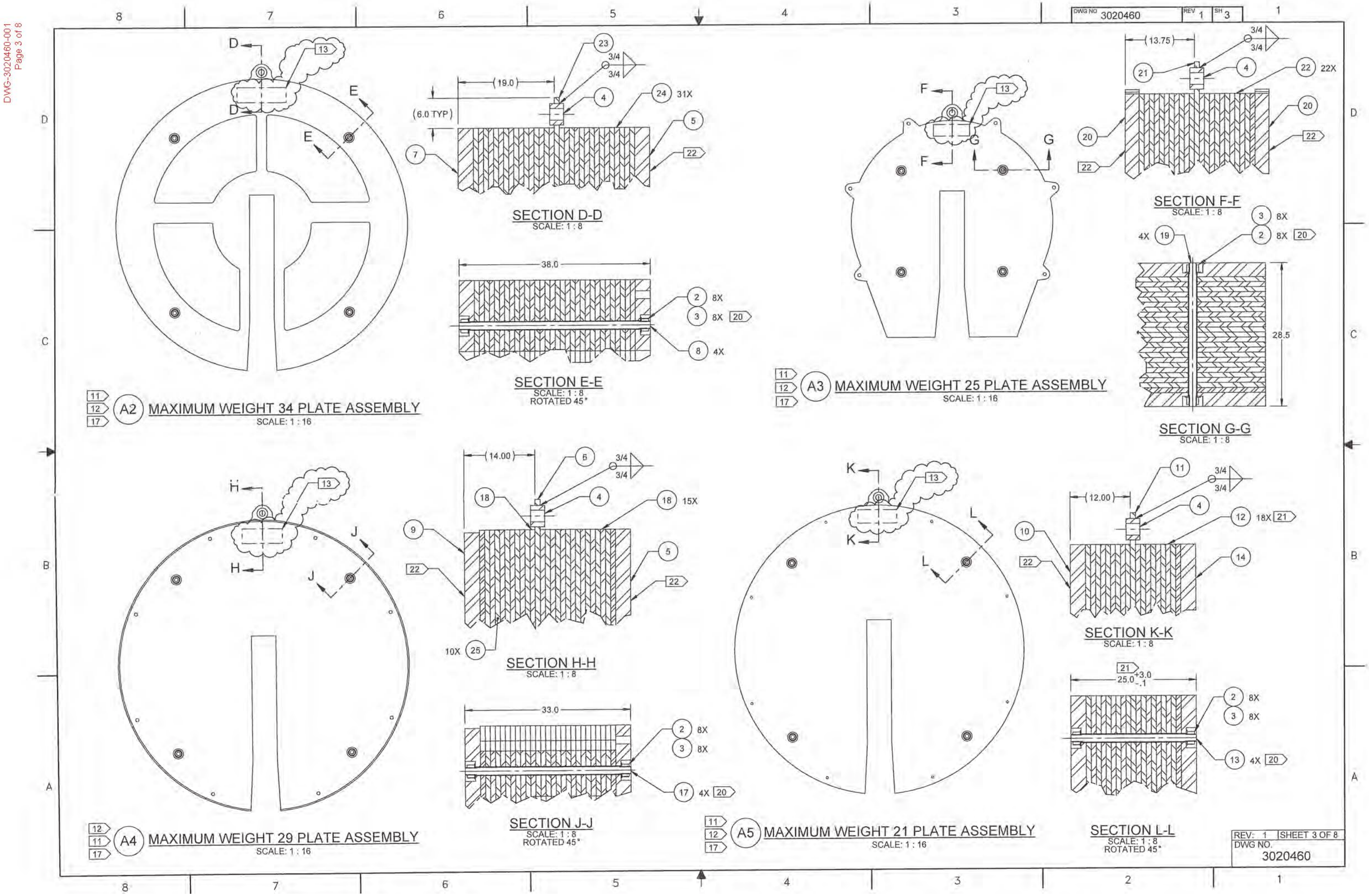
DWG TITLE
MAXIMUM TEST LOAD
ATLAS RAILCAR TEST LOADS

TOLERANCE BLOCK
FRACTIONS ± N/A
ANGLES ± 1°
3 PLACE DECIMALS ± .010
2 PLACE DECIMALS ± .05
1 PLACE DECIMALS ± .1

SCALE: SHOWN
WT. ~
REV: 1
SHEET 1 OF 8
DWG SIZE D
DWG NO. 3020460
CADFILE: 3020460R1.SLDDRW
DWG-3020460-001

Orano Federal Services
July 11, 2018
Records Management


DWG-3020460-001
Page 2 of 8
DWG NO 3020460
REV 1
SH 2
10 TYP
10 TYP
A
A
22X 16
SECTION A-A
SCALE 1 : 24
8 9 A2
8 9 A3 2X
8 9 A3
8 9 A4
8 9 A5
8X 16
B
B
C
C
15 24X 10
1
SECTION B-B
SCALE 1 : 24
A1 MAXIMUM TEST LOAD ASSEMBLY
SCALE: 1 : 24
SECTION C-C
SCALE 1 : 24
REV: 1 SHEET 2 OF 8
DWG NO.
3020460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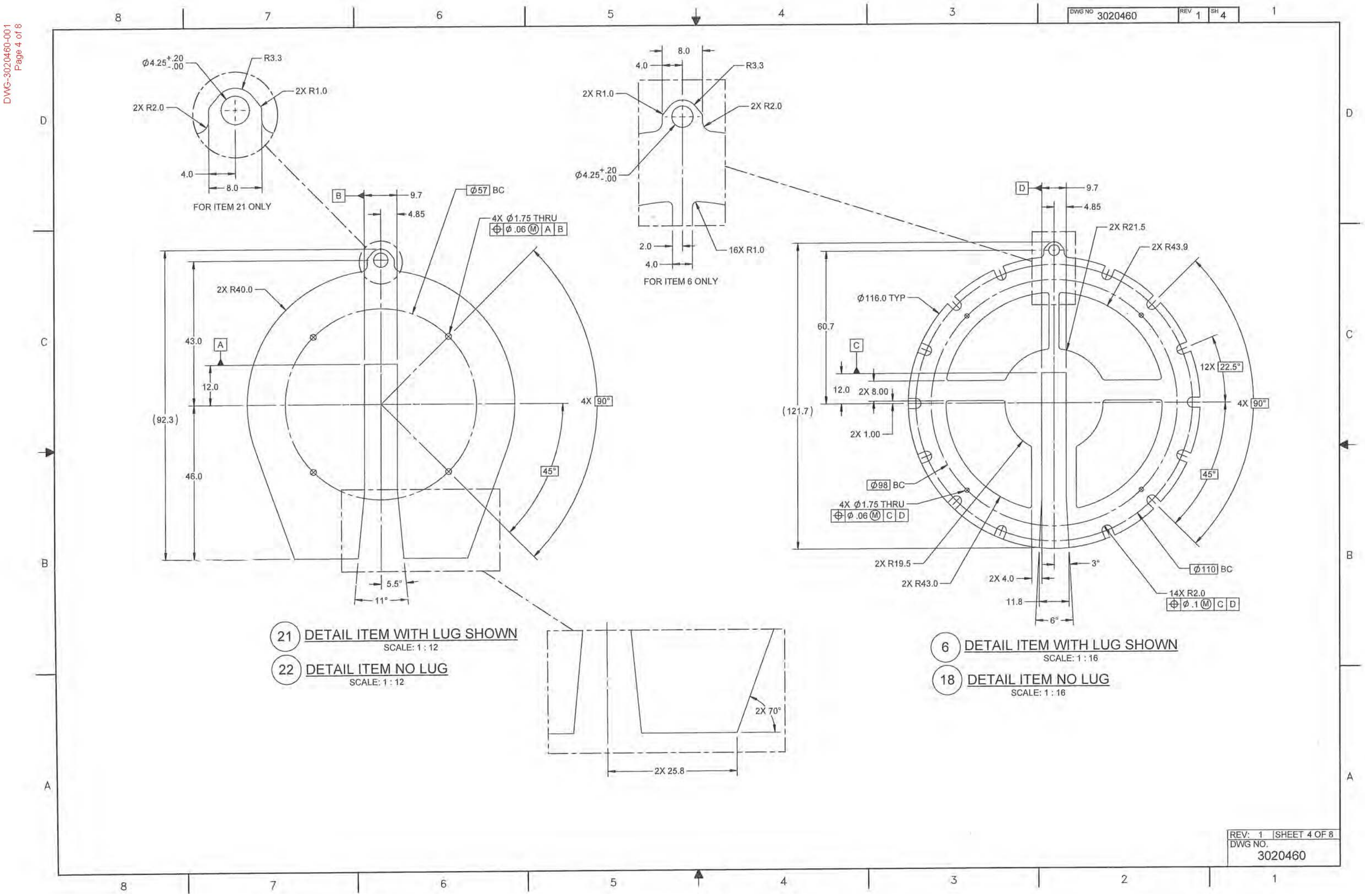
Page 3 of 8
DWG NO 3020460 REV 1 SH 3
A2 MAXIMUM WEIGHT 34 PLATE ASSEMBLY
SCALE: 1 : 16
SECTION D-D
SCALE: 1 : 8
(19.0)
(6.0 TYP)
3/4
31X
SECTION E-E
SCALE: 1 : 8
ROTATED 45°
38.0
8X
4X
A3 MAXIMUM WEIGHT 25 PLATE ASSEMBLY
SCALE: 1 : 16
SECTION F-F
SCALE: 1 : 8
(13.75)
22X
SECTION G-G
SCALE: 1 : 8
28.5
A4 MAXIMUM WEIGHT 29 PLATE ASSEMBLY
SCALE: 1 : 16
SECTION H-H
SCALE: 1 : 8
(14.00)
15X
10X
SECTION J-J
SCALE: 1 : 8
ROTATED 45°
33.0
A5 MAXIMUM WEIGHT 21 PLATE ASSEMBLY
SCALE: 1 : 16
SECTION K-K
SCALE: 1 : 8
(12.00)
18X
SECTION L-L
SCALE: 1 : 8
ROTATED 45°
25.0 +3.0 -.1
REV: 1 SHEET 3 OF 8
DWG NO. 3020460


DWG-3020460-001
Page 4 of 8
DWG NO 3020460 REV 1 SH 4
Ø4.25 +.20 -.00
R3.3
2X R1.0
2X R2.0
4.0
8.0
FOR ITEM 21 ONLY
B
9.7
4.85
Ø57 BC
4X Ø1.75 THRU
⊕ Ø .06 Ⓜ A B
2X R40.0
43.0
A
12.0
(92.3)
46.0
4X 90°
45°
5.5°
11°
2X 70°
2X 25.8
21 DETAIL ITEM WITH LUG SHOWN
SCALE: 1 : 12
22 DETAIL ITEM NO LUG
SCALE: 1 : 12
16X R1.0
2.0
FOR ITEM 6 ONLY
D
2X R21.5
2X R43.9
Ø116.0 TYP
60.7
C
12X 22.5°
2X 8.00
(121.7)
2X 1.00
Ø98 BC
4X Ø1.75 THRU
⊕ Ø .06 Ⓜ C D
2X R19.5
2X R43.0
2X 4.0
3°
11.8
6°
Ø110 BC
14X R2.0
⊕ Ø .1 Ⓜ C D
6 DETAIL ITEM WITH LUG SHOWN
SCALE: 1 : 16
18 DETAIL ITEM NO LUG
SCALE: 1 : 16
REV: 1 SHEET 4 OF 8
DWG NO.
3020460

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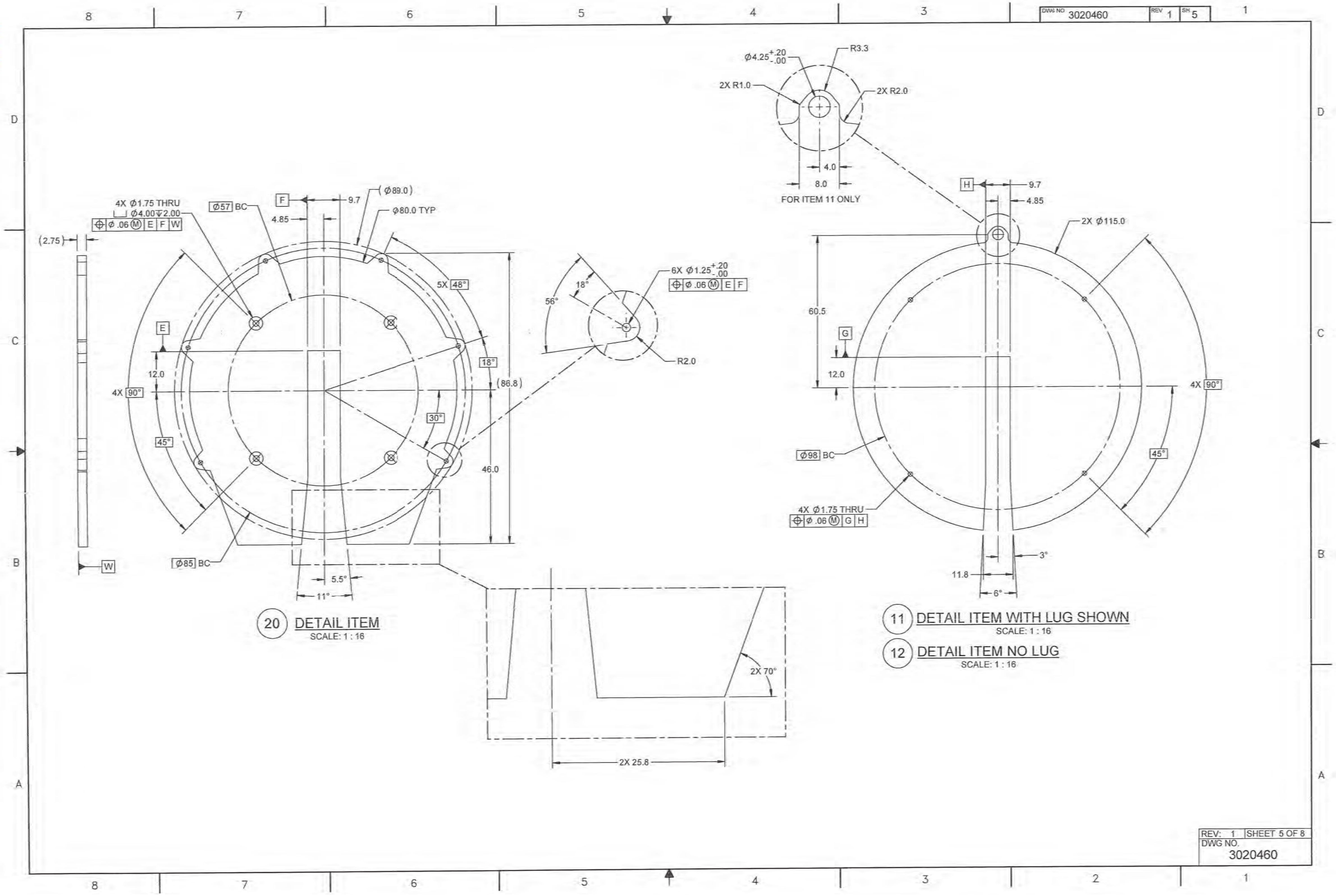
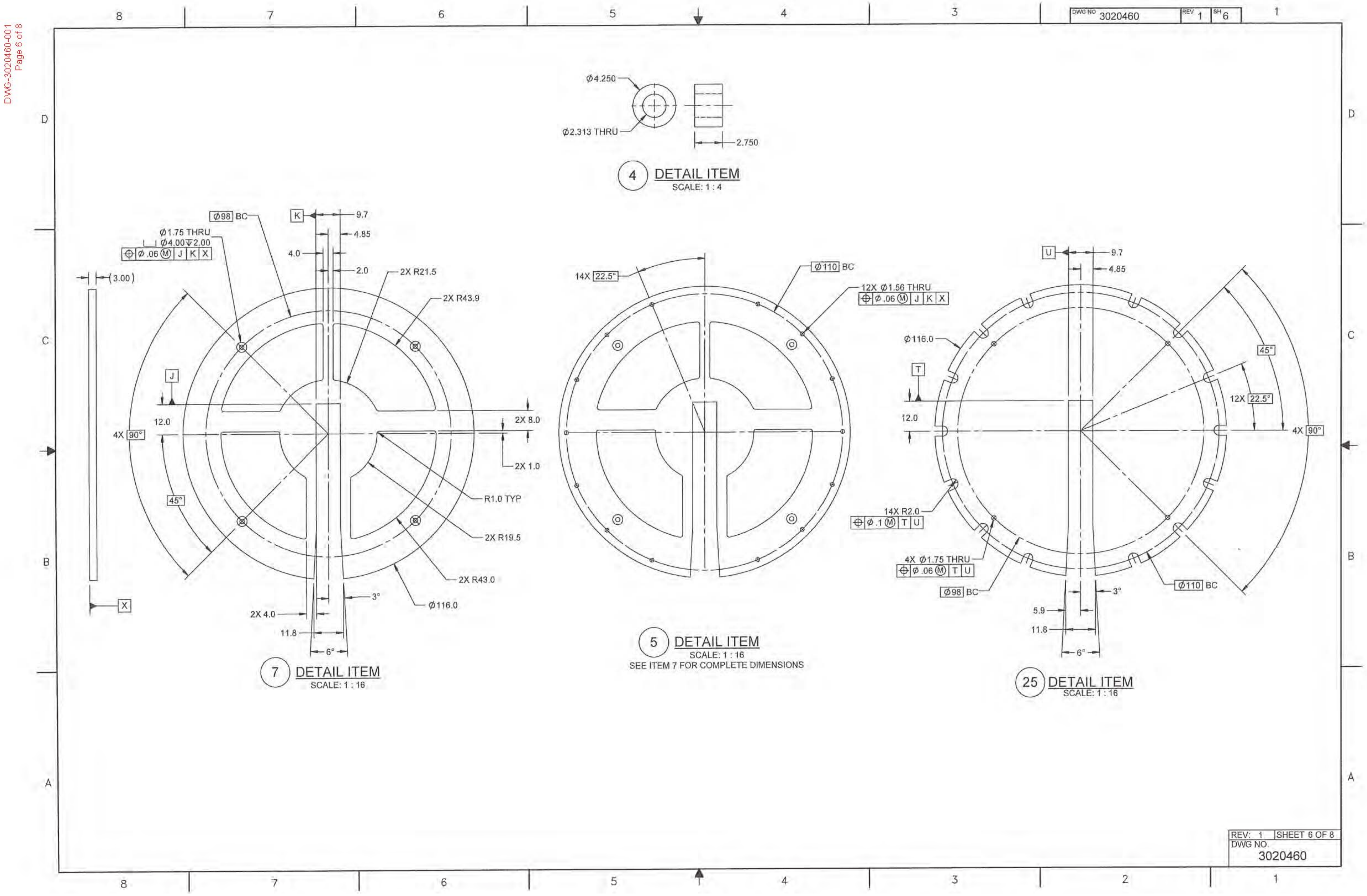
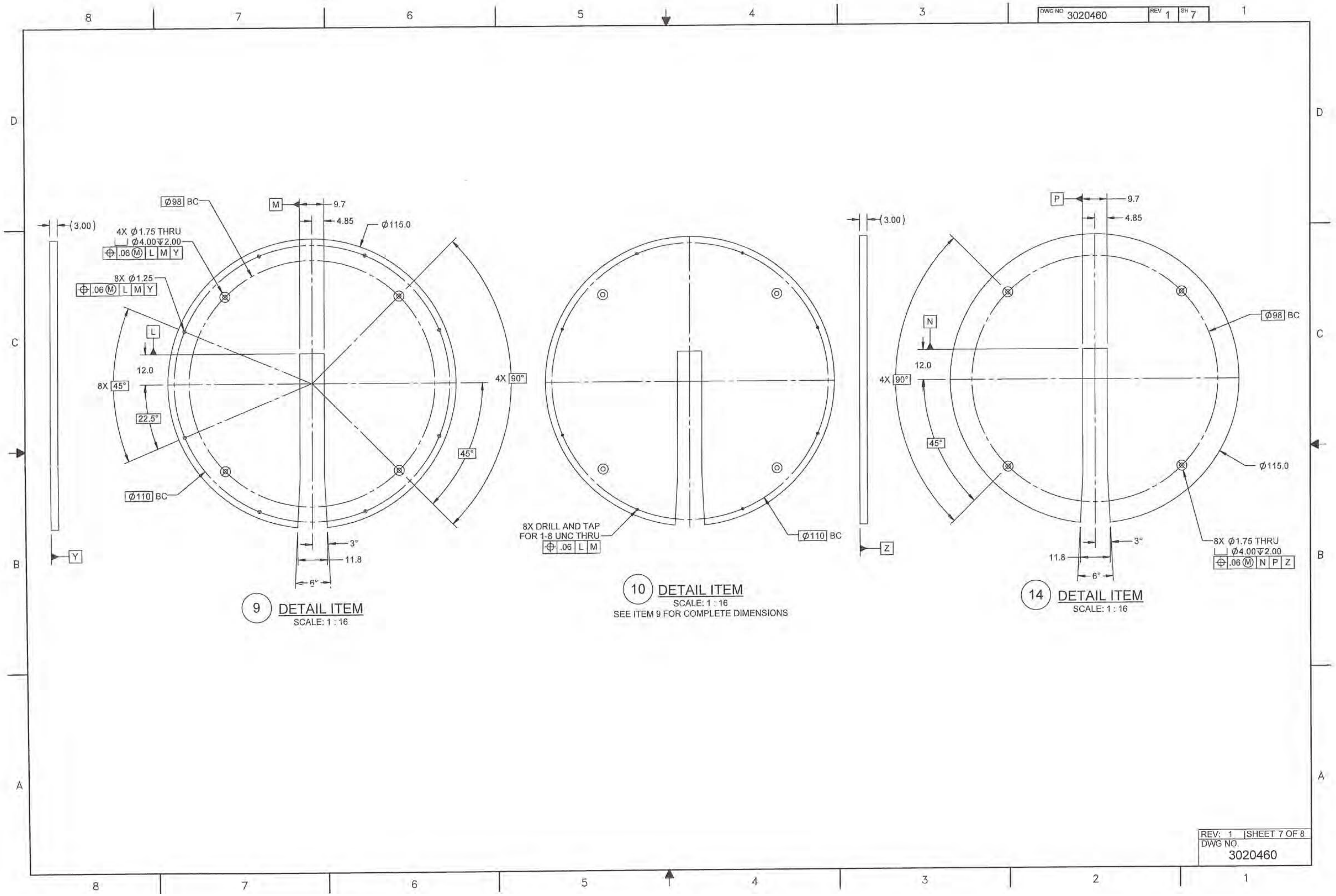
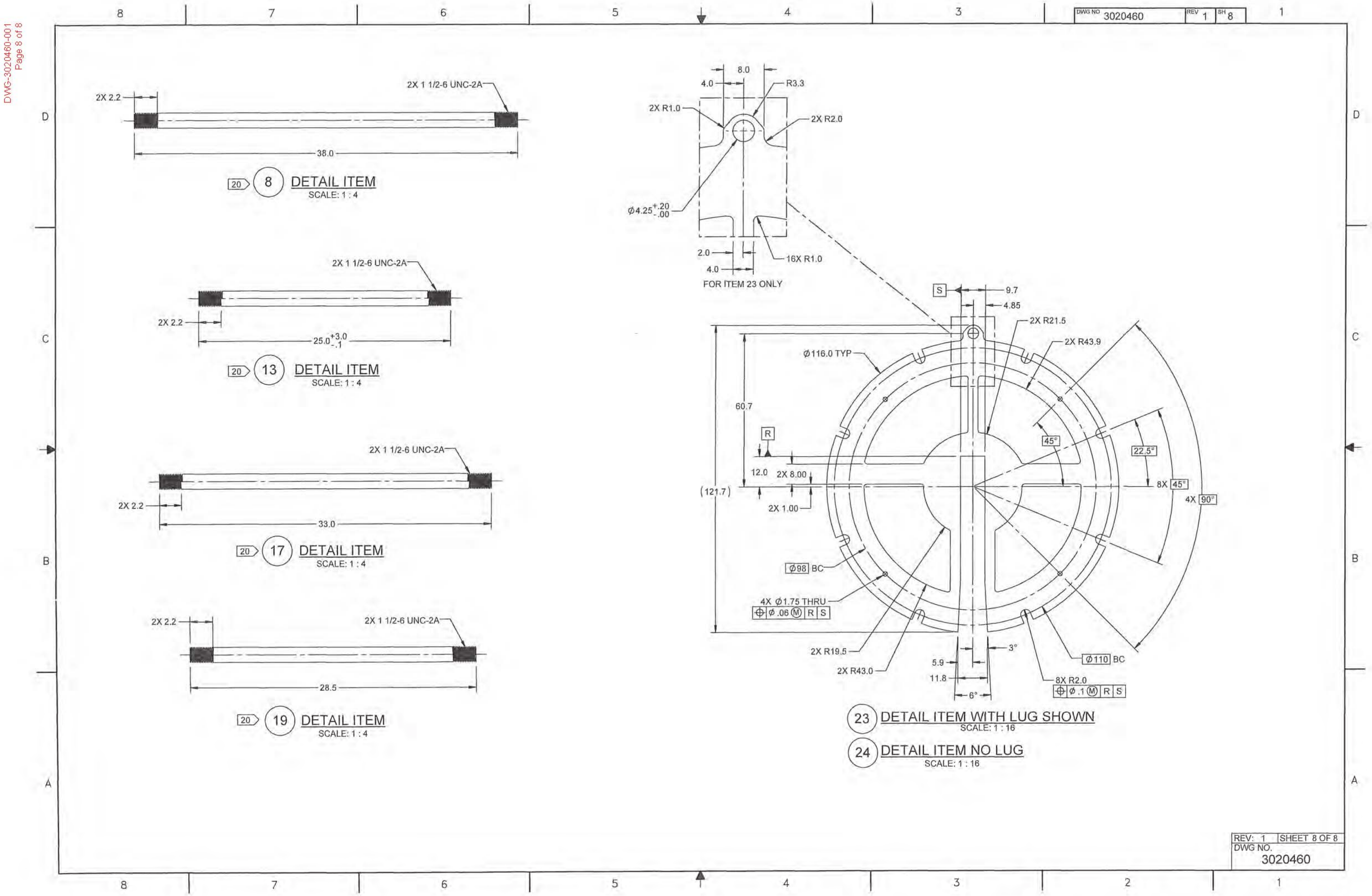
Page 5 of 8




DWG-3020460-001
Page 6 of 8
DWG NO 3020460 REV 1 SH 6
8 7 6 5 4 3 2 1
D C B A
Ø4.250
Ø2.313 THRU
2.750
4 DETAIL ITEM
SCALE: 1 : 4
Ø98 BC
K
9.7
4.85
Ø1.75 THRU
⌴ Ø4.00↧2.00
⊕ Ø .06 Ⓜ J K X
4.0
2.0
2X R21.5
2X R43.9
(3.00)
J
12.0
4X 90°
45°
2X 8.0
2X 1.0
R1.0 TYP
2X R19.5
2X R43.0
Ø116.0
X
3°
2X 4.0
11.8
6°
7 DETAIL ITEM
SCALE: 1 : 16
14X 22.5°
Ø110 BC
12X Ø1.56 THRU
⊕ Ø .06 Ⓜ J K X
5 DETAIL ITEM
SCALE: 1 : 16
SEE ITEM 7 FOR COMPLETE DIMENSIONS
U
9.7
4.85
Ø116.0
T
12.0
45°
12X 22.5°
4X 90°
14X R2.0
⊕ Ø .1 Ⓜ T U
4X Ø1.75 THRU
⊕ Ø .06 Ⓜ T U
Ø98 BC
Ø110 BC
3°
5.9
11.8
6°
25 DETAIL ITEM
SCALE: 1 : 16
REV: 1 SHEET 6 OF 8
DWG NO.
3020460

DWG-3020460-001
Page 7 of 8




DWG-3020460-001
Page 8 of 8
DWG NO 3020460
REV 1
SH 8
2X 2.2
2X 1 1/2-6 UNC-2A
38.0
20
8
DETAIL ITEM
SCALE: 1 : 4
2X 1 1/2-6 UNC-2A
2X 2.2
25.0 +3.0 -.1
20
13
DETAIL ITEM
SCALE: 1 : 4
2X 1 1/2-6 UNC-2A
2X 2.2
33.0
20
17
DETAIL ITEM
SCALE: 1 : 4
2X 2.2
2X 1 1/2-6 UNC-2A
28.5
20
19
DETAIL ITEM
SCALE: 1 : 4
8.0
4.0
R3.3
2X R1.0
2X R2.0
Ø4.25 +.20 -.00
2.0
4.0
16X R1.0
FOR ITEM 23 ONLY
S
9.7
4.85
2X R21.5
2X R43.9
Ø116.0 TYP
60.7
R
45°
22.5°
12.0
2X 8.00
(121.7)
2X 1.00
8X 45°
4X 90°
Ø98 BC
4X Ø1.75 THRU
⊕ Ø .08 Ⓜ R S
2X R19.5
2X R43.0
5.9
11.8
6°
3°
Ø110 BC
8X R2.0
⊕ Ø .1 Ⓜ R S
23
DETAIL ITEM WITH LUG SHOWN
SCALE: 1 : 16
24
DETAIL ITEM NO LUG
SCALE: 1 : 16
REV: 1
SHEET 8 OF 8
DWG NO.
3020460
8
7
6
5
4
3
2
1
D
C
B
A

APPENDIX I-6 DWG-3020461-001, MAXIMUM TEST LOAD CRADLE

DWG-3020461-001
Page 1 of 7

DWG NO 3020461 REV 1 SH 1

NOTES, UNLESS OTHERWISE SPECIFIED:

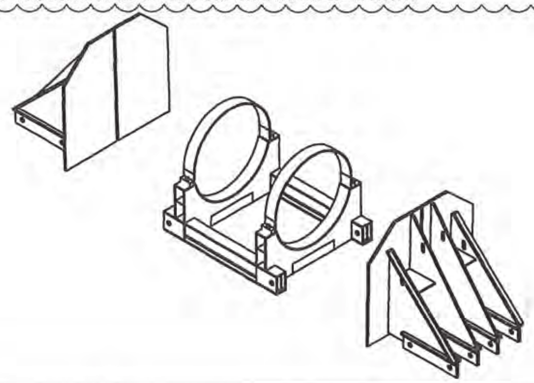
1. ALL WELDS VISUALLY INSPECTED PER AWS D1.1.
2. FABRICATION SHALL BE PERFORMED IN ACCORDANCE WITH SPECIFICATION PKG-GF-SPC-003.
3. LENGTH AND WIDTH DIMENSIONS FOR RAW MATERIAL IN THE LIST OF MATERIALS DESCRIPTION COLUMN ARE FOR REFERENCE ONLY, WITH THE EXCEPTION OF THE STOCK PLATE ITEMS 7, 8, 11 & 17. MANFUFACTURER SHALL CONFIRM ACTUAL REQUIREMENTS PRIOR TO FABRICATION.
4. ALL SURFACES OF THE CRADLE WELDMENT, EXCEPT FOR THREADED HOLES AND THE 4.13 DIAMETER HOLES, SHALL BE BLAST CLEANED PER SSPC-SP-6 AND COATED WITH SELF-PRIMING ENAMEL, 2 COATS. THE NON-PAINTED CRADLE WELDMENT SURFACES SHALL BE LIGHTLY COATED WITH NUCLEAR GRADE "NEVER-SEEZ" GREASE.
5. STRAIGHTEN AND OR MACHINE BEAM TO ACHIEVE DIMENSIONS SHOWN. REMOVE NO MORE THAN .19 INCHES FROM ANY SURFACES. THE BEAM MAY BE OPTIONALLY FABRICATED FROM PLATES OF EQUAL THICKNESS AND OF EQUAL OR GREATER YIELD STRENGTH. FABRICATED BEAMS SHALL UTILIZE FULL PENETRANT WELDS.
6. OVERALL CAMBER IN BEAM AFTER WELDING SHALL BE LIMITED FROM .0 TO .13 INCHES.
7. PRIOR TO TESTING, INSTALL SHIMS BETWEEN END STOPS AND CENTRAL ASSEMBLY END PLATES TO CLOSE GAP.
8. USE SLOTTED HOLES AT THE LOCATIONS SHOWN AND INSTALL ENDLESS STRAPS FOR LIFTING END STOP WELDMENT ASSEMBLIES A3 AND A4.
9. VERIFY ALIGNMENT BY INSERTING A 4.06 DIA ROUND BAR EXTENDING THRU BOTH BEAMS OR END STOP WELDMENT, AS APPLICABLE.
10. MAXIMUM TEST LOAD CRADLE BASED ON HI-STAR 190XL CONCEPTUAL DRAWING, 3015137-001.
11. FOR REFERANCE OF CRADLE ATTACHMENT SEE DRAWING 3015278-002.
12. WELDING SHALL BE PERFORMED IN ACCORDANCE WITH AWS D1.1.
13. THE WEIGHTS OF THE A2, A3, A4, AND A5 ASSEMBLIES MUST MEET THE LIMITS SHOWN IN TABLE 1.
14. ADDITIONAL MATERIAL MAY BE ADDED TO THE A2 ASSEMBLY TO MEET THE WEIGHT REQUIREMENTS OF TABLE 1. ORANO APPROVAL IS REQUIRED FOR ALL MATERIAL ADDITIONS.
15. WEIGH AND STENCIL THE CORRESPONDING COMBINED WEIGHT OF THE A2 AND BOTH A5 ASSEMBLIES USING 1" HIGH LETTERS IN THE APPROXIMATE AREA AS SHOWN BELOW:
    ORANO DWG 3020461
    CENTRAL CRADLE ASSEMBLY
    WEIGHT: XX,XXX LBS
    WHERE XX,XXX IS THE CORRESPONDING ASSEMBLY WEIGHT.
16. WEIGH AND STENCIL THE CORRESPONDING COMBINED WEIGHT OF THE A3 ASSEMBLY USING 1" HIGH LETTERS IN THE APPROXIMATE AREA AS SHOWN BELOW:
    ORANO DWG 3020461 A3 ASSEMBLY
    WEIGHT: XX,XXX LBS
    WHERE XX,XXX IS THE CORRESPONDING ASSEMBLY WEIGHT.
17. WEIGH AND STENCIL THE CORRESPONDING COMBINED WEIGHT OF THE A4 ASSEMBLY USING 1" HIGH LETTERS IN THE APPROXIMATE AREA AS SHOWN BELOW:
    ORANO DWG 3020461 A4 ASSEMBLY
    WEIGHT: XX,XXX LBS
    WHERE XX,XXX IS THE CORRESPONDING ASSEMBLY WEIGHT.

LIST OF MATERIALS

S/D	QTY A5	QTY A4	QTY A3	QTY A2	QTY A1	ITEM NO	PART NO	DESCRIPTION	SPECIFICATION
						A1		MAXIMIM TEST LOAD CRADLE	
					1	A2		MAX CRADLE WELDMENT	
					2	A3		END STOP WELDMENT (LH)	
					2	A4		END STOP WELDMENT (RH)	
					2	A5		TIE DOWN WELDMENT	
NITS					4	1	90044A215	SHCS, 1-3/4-5 UNC-2A X 8.0 LG	McMASTER-CARR
NITS					4	2	98119A112	WASHER, 1-3/4 NOM	McMASTER-CARR
NITS					4	3	91845A044	HEX NUT, 1-3/4-5 UNC-2B	McMASTER-CARR
NITS		1	1			4		PLATE, 2 THK X 62.0 X 116.0	ASTM A572, GR 50
NITS		1	1			5		PLATE, 2 THK X 83.0 X 88.25	ASTM A572, GR 50
NITS		1	1			6		PLATE, 2 THK X 83.0 X 112.0	ASTM A572, GR 50
NITS		4	4			7		PLATE, 2 X 3.25 X 64	ASTM A572, GR 50
NITS		1	1			8		PLATE, 1 THK X 23.25 X 30.5	ASTM A572, GR 50
NITS		4	4			9		PLATE, 1.25 THK X 12.0 X 64.0	ASTM A572, GR 50
NITS		1	1			10		PLATE, 2 THK X 4.0 X 111.75	ASTM A572, GR 50
5 NITS				2		11		BEAM W18X119 X 137 LG	ASTM A992
NITS				8		12		PLATE, 1.0 THK X 16,9 X 24.5	ASTM A572, GR 50
NITS				4		13		PLATE, 1 THK X 52.5 X 116.0	ASTM A572, GR 50
NITS				4		14		PLATE, 1 THK X 12.9 X 12.0	ASTM A572, GR 50
NITS				2		15		PLATE, 1 THK X 12.0 X 125	ASTM A572, GR 50
NITS				4		16		PLATE, .50 THK X 10.0 X 20.3	ASTM A572, GR 50
NITS				2		17		BAR, 10 X 12.0 X 50.7	ASTM A36
NITS				4		18		PLATE, .50 THK X 10.0 X 21.5	ASTM A572, GR 50
NITS				4		19		PLATE, .50 THK X 12.6 X 10.0	ASTM A572, GR 50
NITS	1					20		PLATE, 1 THK X 12.0 X 193.5	ASTM A572, GR 50
NITS	2					21		BAR, 4.0 X 4.3 X 12.0	ASTM A572, GR 50

TABLE 1-ASSEMBLY WEIGHT LIMITS

ASSEMBLY	MINIMUM WEIGHT (LB)	MAXIMUM WEIGHT (LB)
A2	12,380	13,580
A3	10,000	11,000
A4	10,000	11,000
A5	630	700
A2 AND BOTH A5 COMBINED	13,640	14,980



REVISION HISTORY

REV	DESCRIPTION
1	ECN NO.3020461R0-E1
0	INITIAL RELEASE

	NAME/SIGNATURE	DATE
EM	DJH D.J. Hillstrom	7/11/18
RE	S. Klein	7/11/18
TECH CHK	S. Klein	7/11/18
DFTG CHK	D. WICK	7/11/18
DRAWN	T.E. MARTIN	7/10/2018

NA	NA
NEXT ASSY	FINAL ASSY

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED:
INTERPRET DRAWINGS & TOLERANCES PER ASME Y14.5-2009 (REVISION OF ASME Y14.5M-1994)
INTERPRET WELD CALLOUTS PER ANSI/AWS A2.4
DIMENSIONS ARE IN INCHES

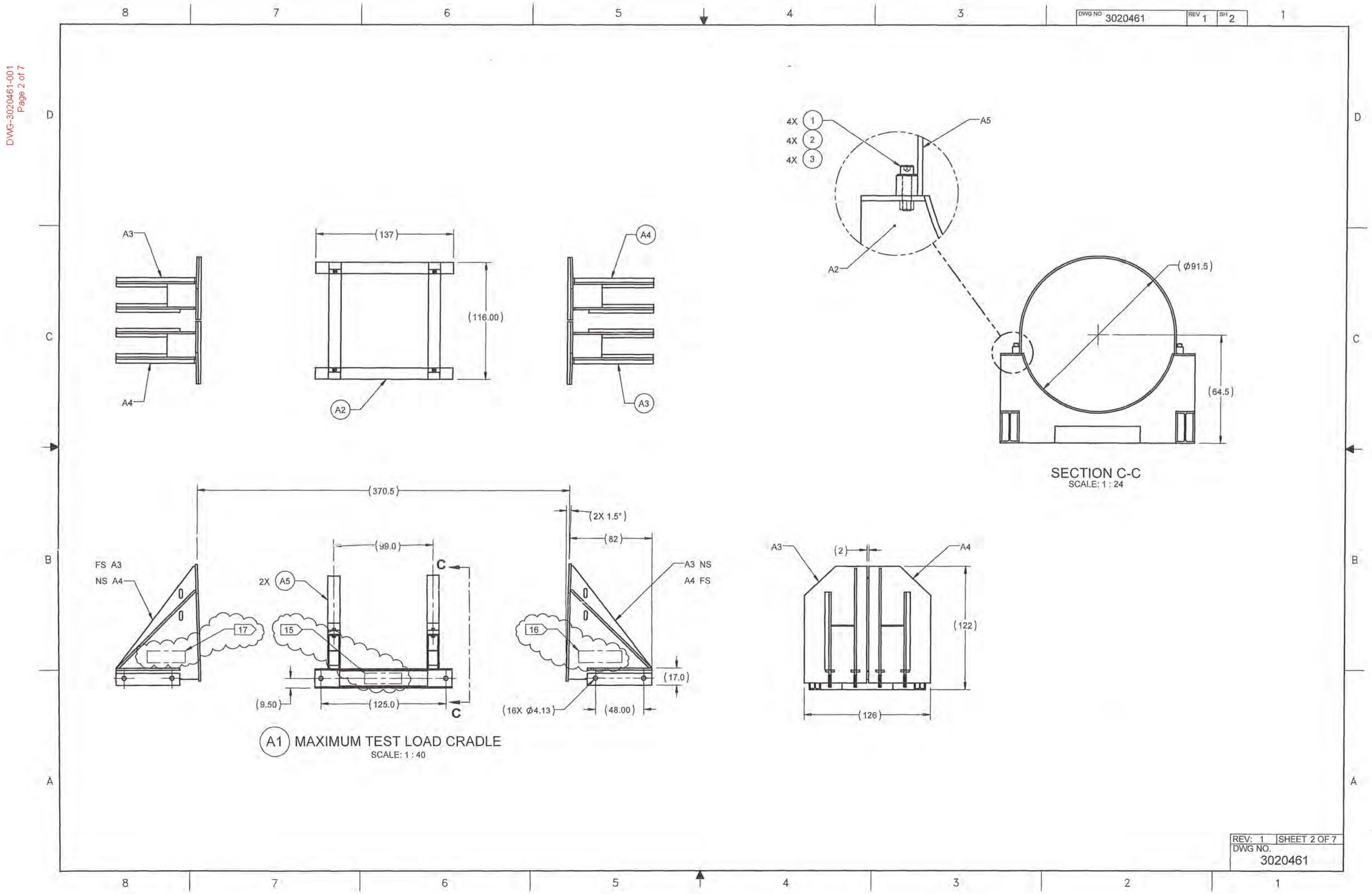
orano
Orano Federal Services LLC
Packaging Projects
Federal Way, WA 98003

DWG TITLE
MAXIMUM TEST LOAD CRADLE
ATLAS RAILCAR TEST LOADS

TOLERANCE BLOCK
FRACTIONS ± 3/16
ANGLES ± 1°
3 PLACE DECIMALS ± .030
2 PLACE DECIMALS ± .06
1 PLACE DECIMALS ± .1

SCALE: SHOWN
WT: ~
REV: 1
SHEET 1 OF 7
DWG SIZE D
DWG NO. 3020461
CADFILE: 3020461R1.SLDDRW
DWG-3020461-001

Orano Federal Services
July 11, 2018
Records Management



A1 MAXIMUM TEST LOAD CRADLE
SCALE: 1 : 40

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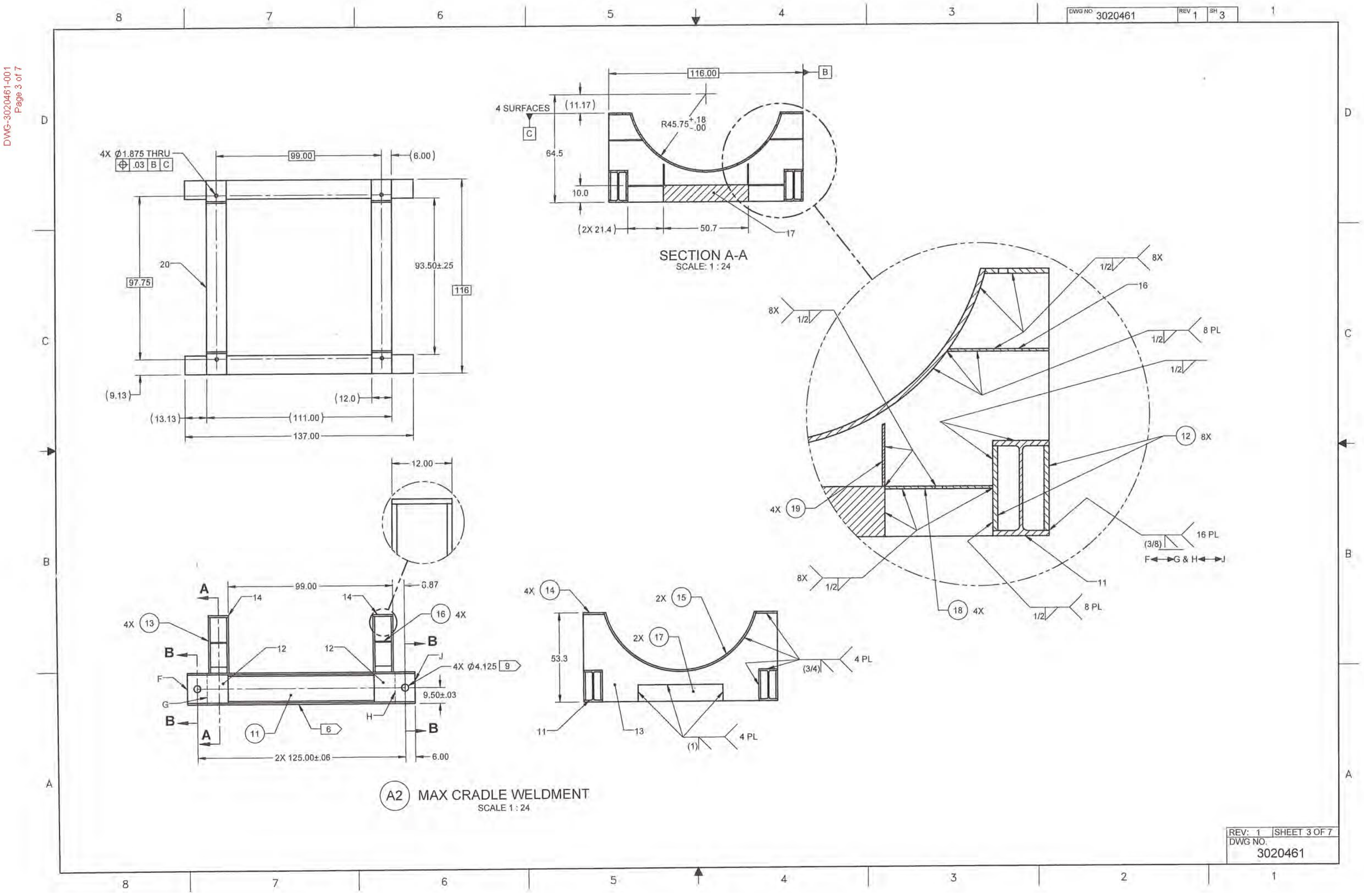

A2 MAX CRADLE WELDMENT
SCALE 1 : 24

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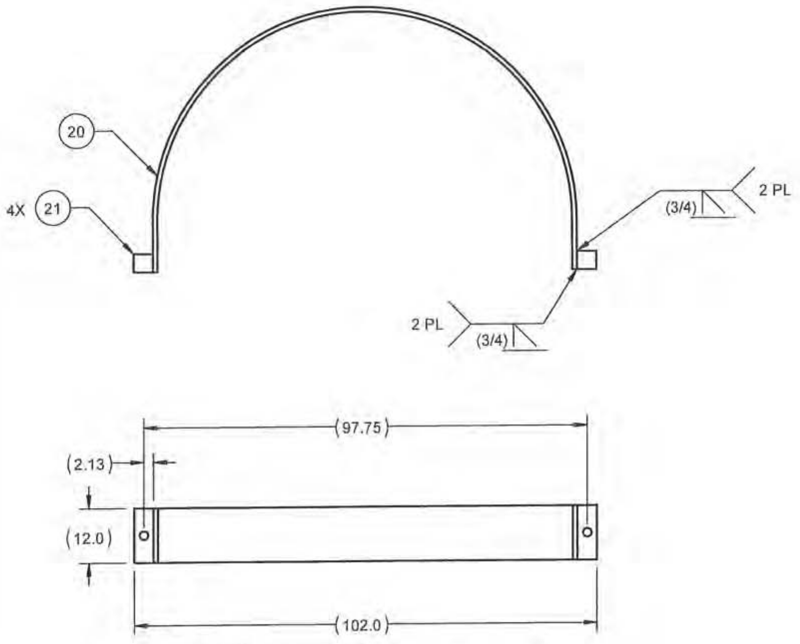
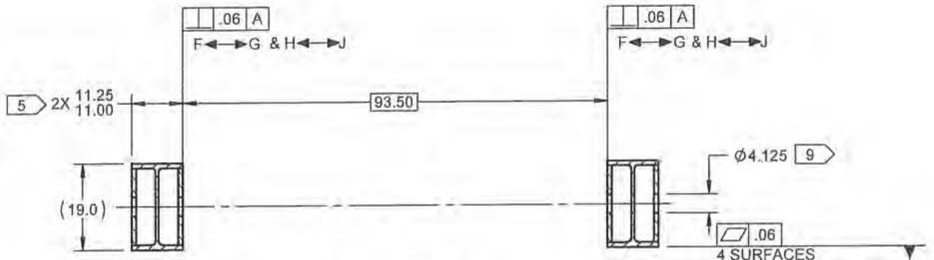
DWG NO 3020461 REV 1 SH 4

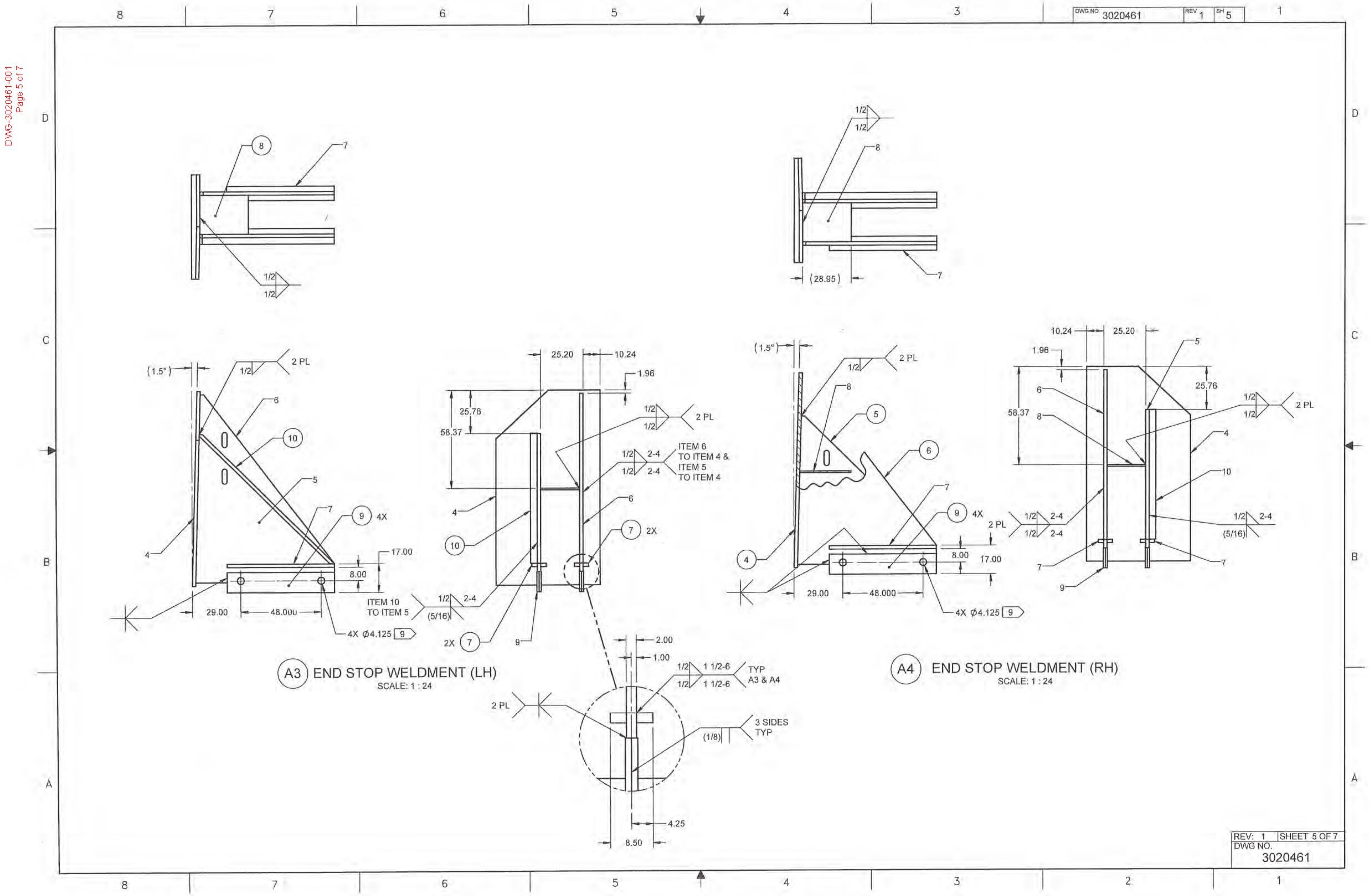


A5 TIE DOWN WELDMENT
SCALE 1 : 16



SECTION B-B
SCALE: 1 : 16
SHEET 3

REV: 1 SHEET 4 OF 7
DWG NO.
3020461


DWG NO 3020461 REV 1 SH 5
DWG-3020461-001
Page 5 of 7
8
7
1/2
1/2
(28.95)
(1.5°)
2 PL
6
10
5
4
9 4X
17.00
8.00
29.00
48.000
4X Ø4.125 9
ITEM 10 TO ITEM 5
1/2 2-4
(5/16)
2X 7
25.20
10.24
1.96
25.76
58.37
ITEM 6 TO ITEM 4 & ITEM 5 TO ITEM 4
1/2 2-4
7 2X
2.00
1.00
1/2 1 1/2-6
TYP A3 & A4
(1/8)
3 SIDES TYP
4.25
8.50
A3 END STOP WELDMENT (LH)
SCALE: 1 : 24
A4 END STOP WELDMENT (RH)
SCALE: 1 : 24
REV: 1 SHEET 5 OF 7
DWG NO.
3020461

DWG NO 3020461 REV 1 SH 6

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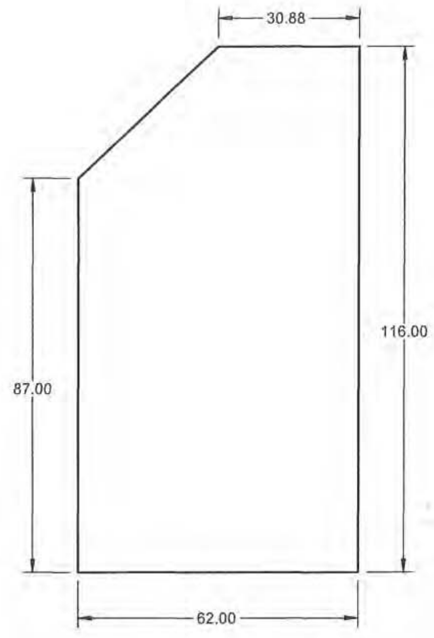
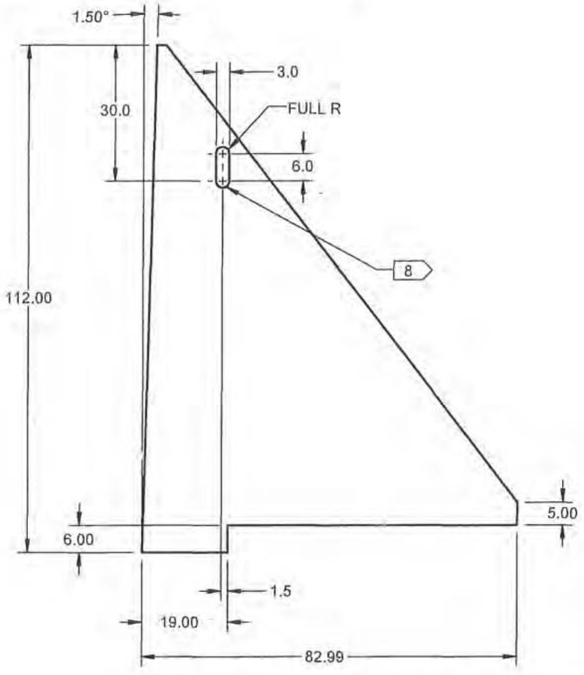
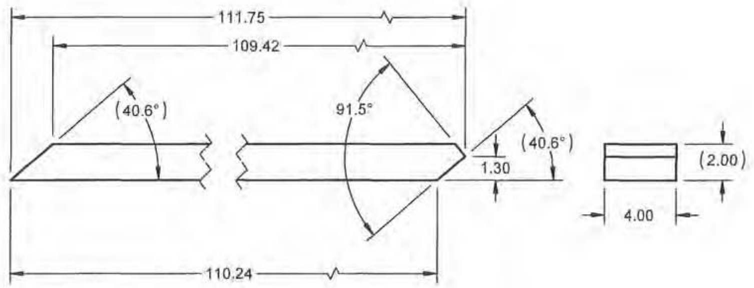


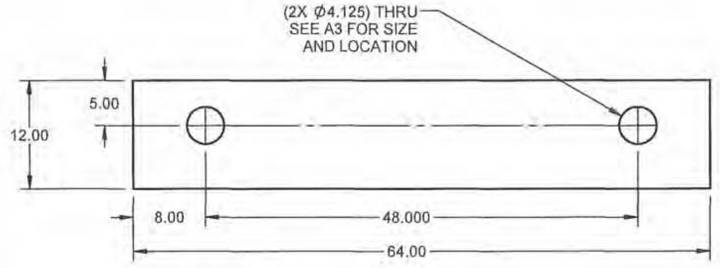
4 END STOP BACK, 2 THK
SCALE 1 : 16



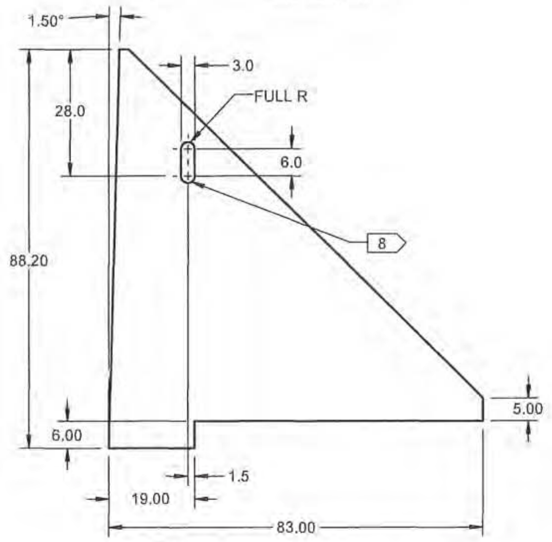
6 LARGE GUSSET, 2 THK
SCALE 1 : 16



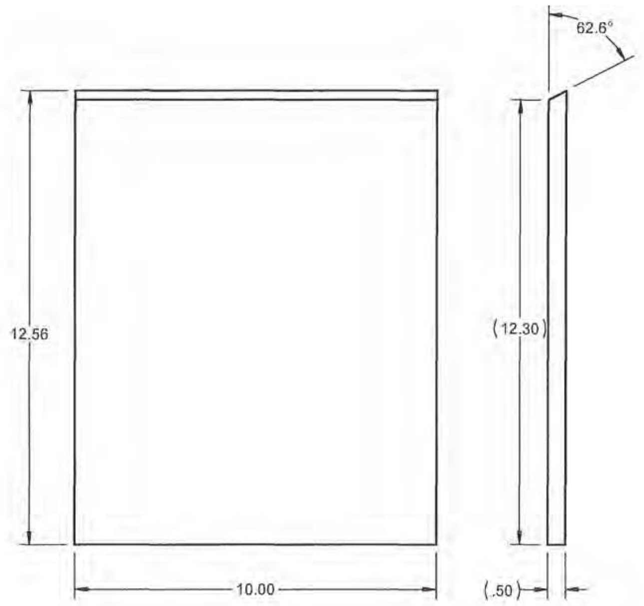
10 END STOP ALIGN PLATE, 2 THK
SCALE 1 : 4



9 END STOP BRACKET, 1 1/4 THK
SCALE 1 : 8



5 SMALL GUSSET, 2 THK
SCALE 1 : 16



19 VERTICAL CRADLE SUPPORT, .50 THK
SCALE 1 : 4

REV: 1 SHEET 6 OF 7
DWG NO.
3020461

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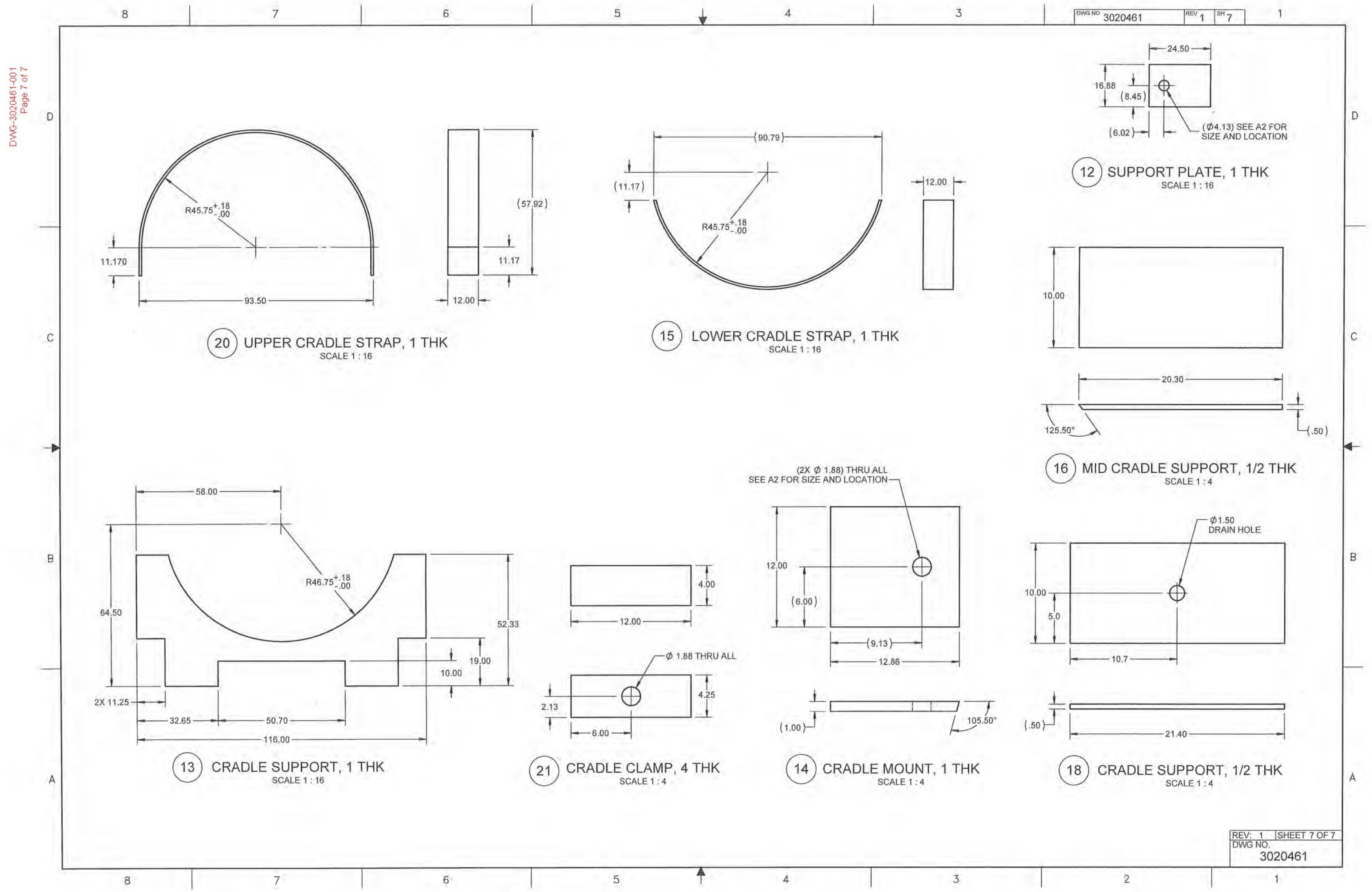
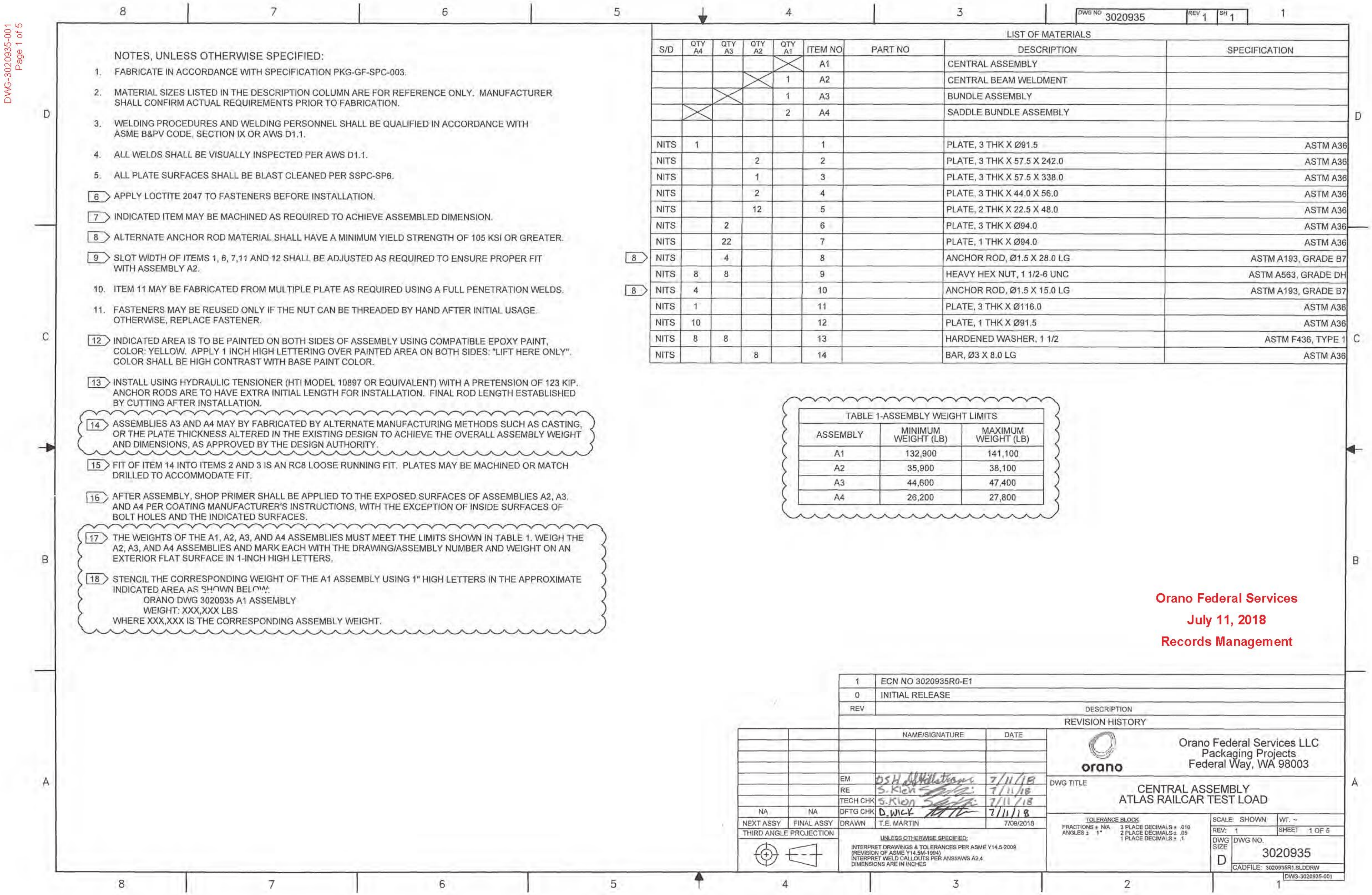


APPENDIX I-7 DWG-3020935-001. CENTRAL ASSEMBLY



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Page 1 of 5

DWG NO 3020935 REV 1 SH 1

NOTES, UNLESS OTHERWISE SPECIFIED:

1. FABRICATE IN ACCORDANCE WITH SPECIFICATION PKG-GF-SPC-003.
2. MATERIAL SIZES LISTED IN THE DESCRIPTION COLUMN ARE FOR REFERENCE ONLY. MANUFACTURER SHALL CONFIRM ACTUAL REQUIREMENTS PRIOR TO FABRICATION.
3. WELDING PROCEDURES AND WELDING PERSONNEL SHALL BE QUALIFIED IN ACCORDANCE WITH ASME B&PV CODE, SECTION IX OR AWS D1.1.
4. ALL WELDS SHALL BE VISUALLY INSPECTED PER AWS D1.1.
5. ALL PLATE SURFACES SHALL BE BLAST CLEANED PER SSPC-SP6.
6. APPLY LOCTITE 2047 TO FASTENERS BEFORE INSTALLATION.
7. INDICATED ITEM MAY BE MACHINED AS REQUIRED TO ACHIEVE ASSEMBLED DIMENSION.
8. ALTERNATE ANCHOR ROD MATERIAL SHALL HAVE A MINIMUM YIELD STRENGTH OF 105 KSI OR GREATER.
9. SLOT WIDTH OF ITEMS 1, 6, 7,11 AND 12 SHALL BE ADJUSTED AS REQUIRED TO ENSURE PROPER FIT WITH ASSEMBLY A2.
10. ITEM 11 MAY BE FABRICATED FROM MULTIPLE PLATE AS REQUIRED USING A FULL PENETRATION WELDS.
11. FASTENERS MAY BE REUSED ONLY IF THE NUT CAN BE THREADED BY HAND AFTER INITIAL USAGE. OTHERWISE, REPLACE FASTENER.
12. INDICATED AREA IS TO BE PAINTED ON BOTH SIDES OF ASSEMBLY USING COMPATIBLE EPOXY PAINT, COLOR: YELLOW. APPLY 1 INCH HIGH LETTERING OVER PAINTED AREA ON BOTH SIDES: "LIFT HERE ONLY". COLOR SHALL BE HIGH CONTRAST WITH BASE PAINT COLOR.
13. INSTALL USING HYDRAULIC TENSIONER (HTI MODEL 10897 OR EQUIVALENT) WITH A PRETENSION OF 123 KIP. ANCHOR RODS ARE TO HAVE EXTRA INITIAL LENGTH FOR INSTALLATION. FINAL ROD LENGTH ESTABLISHED BY CUTTING AFTER INSTALLATION.
14. ASSEMBLIES A3 AND A4 MAY BY FABRICATED BY ALTERNATE MANUFACTURING METHODS SUCH AS CASTING, OR THE PLATE THICKNESS ALTERED IN THE EXISTING DESIGN TO ACHIEVE THE OVERALL ASSEMBLY WEIGHT AND DIMENSIONS, AS APPROVED BY THE DESIGN AUTHORITY.
15. FIT OF ITEM 14 INTO ITEMS 2 AND 3 IS AN RC8 LOOSE RUNNING FIT. PLATES MAY BE MACHINED OR MATCH DRILLED TO ACCOMMODATE FIT.
16. AFTER ASSEMBLY, SHOP PRIMER SHALL BE APPLIED TO THE EXPOSED SURFACES OF ASSEMBLIES A2, A3, AND A4 PER COATING MANUFACTURER'S INSTRUCTIONS, WITH THE EXCEPTION OF INSIDE SURFACES OF BOLT HOLES AND THE INDICATED SURFACES.
17. THE WEIGHTS OF THE A1, A2, A3, AND A4 ASSEMBLIES MUST MEET THE LIMITS SHOWN IN TABLE 1. WEIGH THE A2, A3, AND A4 ASSEMBLIES AND MARK EACH WITH THE DRAWING/ASSEMBLY NUMBER AND WEIGHT ON AN EXTERIOR FLAT SURFACE IN 1-INCH HIGH LETTERS.
18. STENCIL THE CORRESPONDING WEIGHT OF THE A1 ASSEMBLY USING 1" HIGH LETTERS IN THE APPROXIMATE INDICATED AREA AS SHOWN BELOW:
    ORANO DWG 3020935 A1 ASSEMBLY
    WEIGHT: XXX,XXX LBS
    WHERE XXX,XXX IS THE CORRESPONDING ASSEMBLY WEIGHT.

LIST OF MATERIALS

	S/D	QTY A4	QTY A3	QTY A2	QTY A1	ITEM NO	PART NO	DESCRIPTION	SPECIFICATION
						A1		CENTRAL ASSEMBLY	
					1	A2		CENTRAL BEAM WELDMENT	
					1	A3		BUNDLE ASSEMBLY	
					2	A4		SADDLE BUNDLE ASSEMBLY	
	NITS	1				1		PLATE, 3 THK X Ø91.5	ASTM A36
	NITS			2		2		PLATE, 3 THK X 57.5 X 242.0	ASTM A36
	NITS			1		3		PLATE, 3 THK X 57.5 X 338.0	ASTM A36
	NITS			2		4		PLATE, 3 THK X 44.0 X 56.0	ASTM A36
	NITS			12		5		PLATE, 2 THK X 22.5 X 48.0	ASTM A36
	NITS		2			6		PLATE, 3 THK X Ø94.0	ASTM A36
	NITS		22			7		PLATE, 1 THK X Ø94.0	ASTM A36
8	NITS		4			8		ANCHOR ROD, Ø1.5 X 28.0 LG	ASTM A193, GRADE B7
	NITS	8	8			9		HEAVY HEX NUT, 1 1/2-6 UNC	ASTM A563, GRADE DH
8	NITS	4				10		ANCHOR ROD, Ø1.5 X 15.0 LG	ASTM A193, GRADE B7
	NITS	1				11		PLATE, 3 THK X Ø116.0	ASTM A36
	NITS	10				12		PLATE, 1 THK X Ø91.5	ASTM A36
	NITS	8	8			13		HARDENED WASHER, 1 1/2	ASTM F436, TYPE 1
	NITS			8		14		BAR, Ø3 X 8.0 LG	ASTM A36

TABLE 1-ASSEMBLY WEIGHT LIMITS

ASSEMBLY	MINIMUM WEIGHT (LB)	MAXIMUM WEIGHT (LB)
A1	132,900	141,100
A2	35,900	38,100
A3	44,600	47,400
A4	26,200	27,800

Orano Federal Services
July 11, 2018
Records Management

REVISION HISTORY

REV	DESCRIPTION
1	ECN NO 3020935R0-E1
0	INITIAL RELEASE

	NAME/SIGNATURE	DATE
EM	DSH	7/11/18
RE	S. Klein	7/11/18
TECH CHK	S. Klein	7/11/18
DFTG CHK	D. WICK	7/11/18
DRAWN	T.E. MARTIN	7/09/2018

NEXT ASSY	FINAL ASSY
NA	NA

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED:
INTERPRET DRAWINGS & TOLERANCES PER ASME Y14.5-2009
(REVISION OF ASME Y14.5M-1994)
INTERPRET WELD CALLOUTS PER ANSI/AWS A2.4
DIMENSIONS ARE IN INCHES

orano
Orano Federal Services LLC
Packaging Projects
Federal Way, WA 98003

DWG TITLE
CENTRAL ASSEMBLY
ATLAS RAILCAR TEST LOAD

TOLERANCE BLOCK
FRACTIONS ± N/A
ANGLES ± 1°
3 PLACE DECIMALS ± .010
2 PLACE DECIMALS ± .05
1 PLACE DECIMALS ± .1

SCALE: SHOWN
WT. ~
REV: 1
SHEET 1 OF 5
DWG SIZE D
DWG NO. 3020935
CADFILE: 3020935R1.SLDDRW
DWG-3020935-001

DWG-3020935-001
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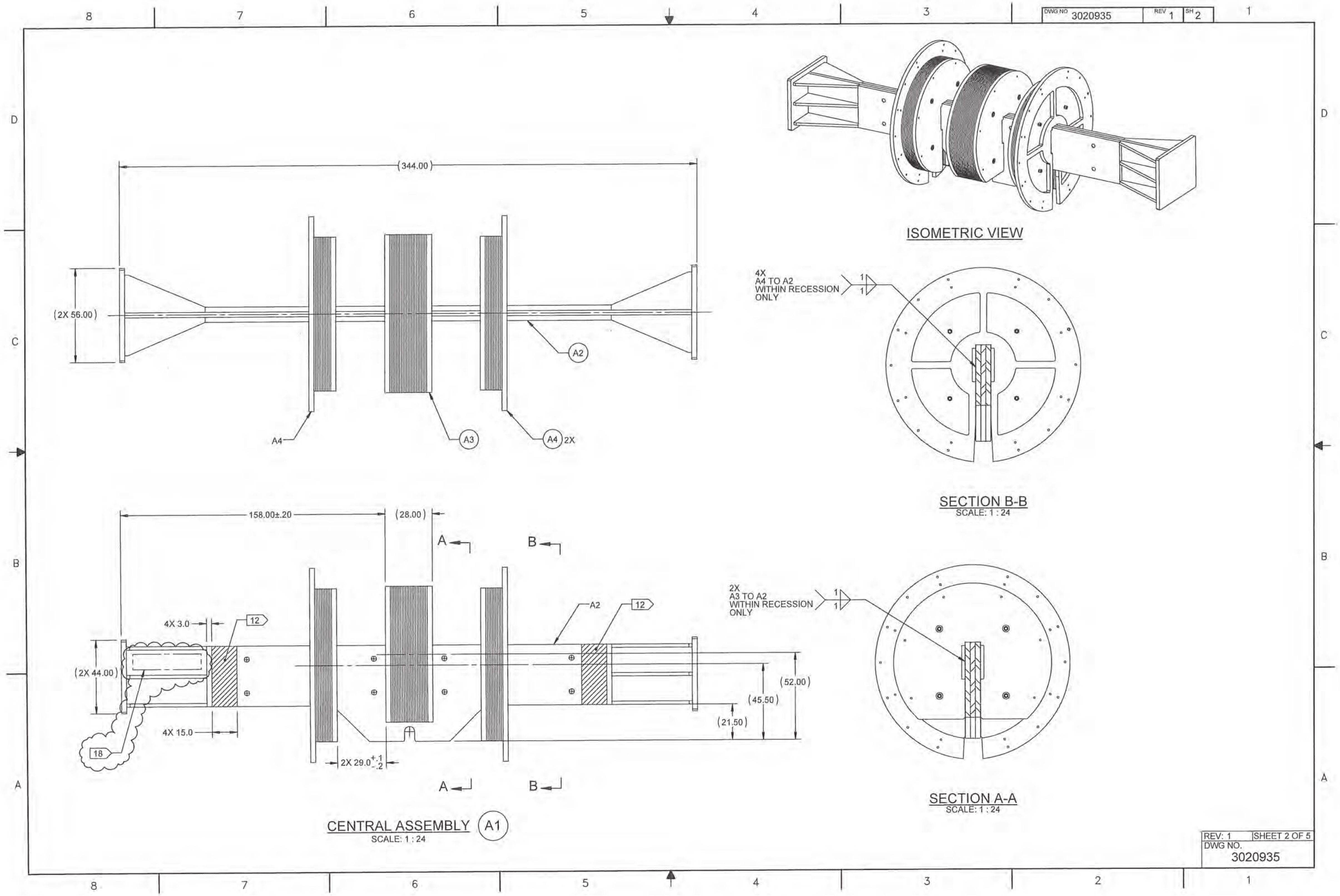
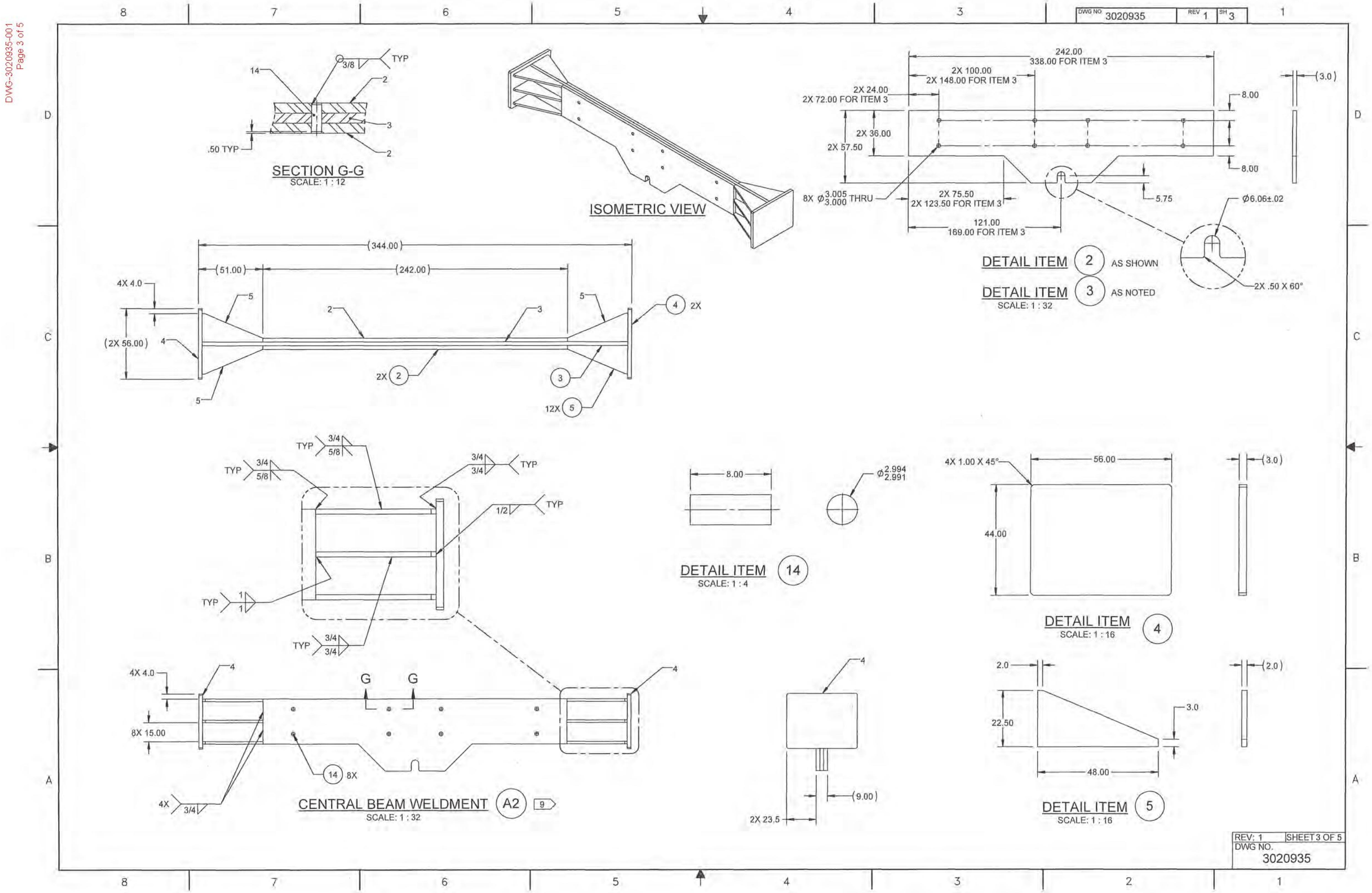
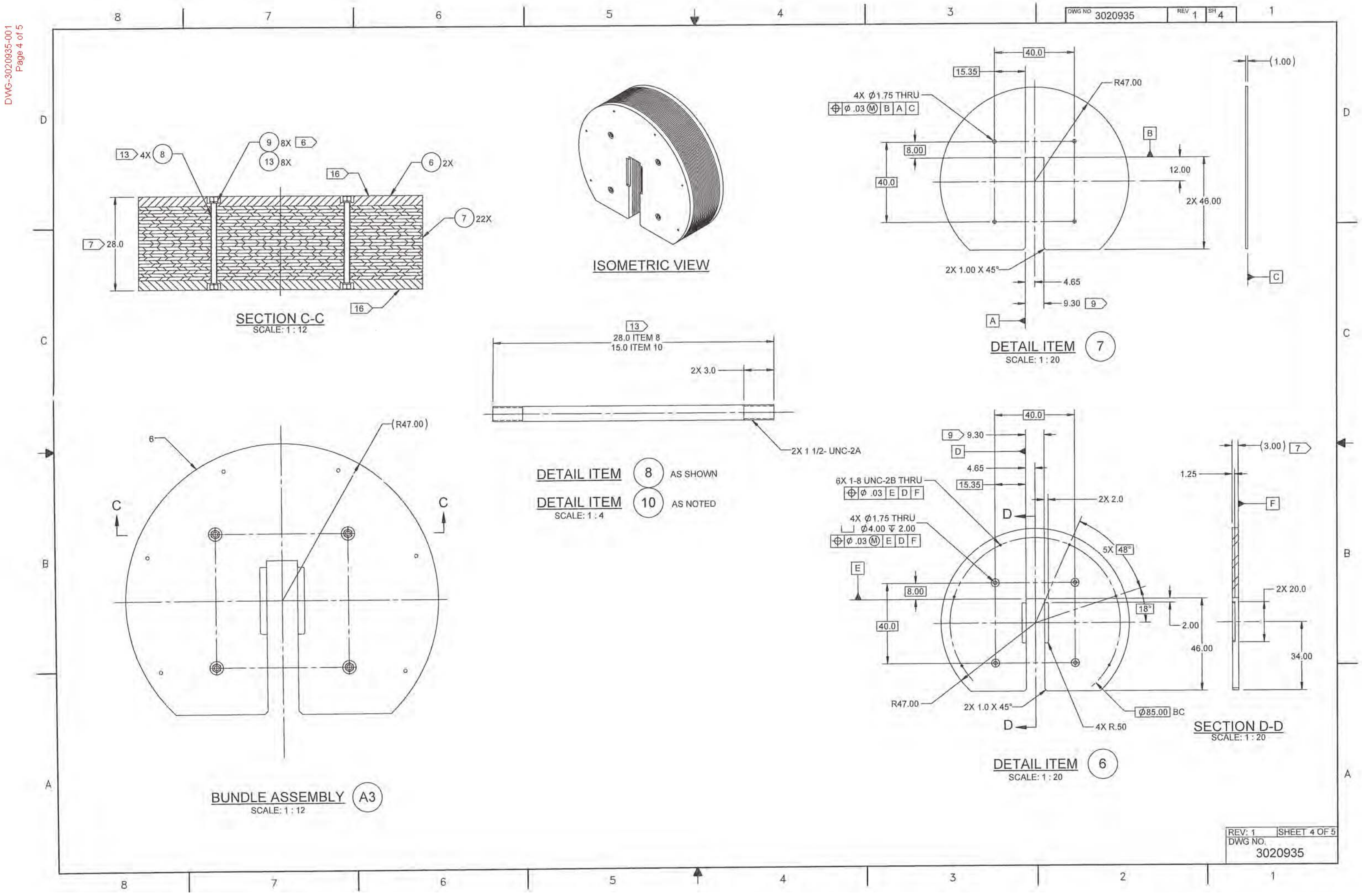



DWG-3020935-001
Page 3 of 5
DWG NO 3020935
REV 1
SH 3
SECTION G-G
SCALE: 1 : 12
14
3/8
TYP
2
3
.50 TYP
ISOMETRIC VIEW
242.00
338.00 FOR ITEM 3
2X 100.00
2X 148.00 FOR ITEM 3
2X 24.00
2X 72.00 FOR ITEM 3
2X 36.00
2X 57.50
8X ∅3.005/3.000 THRU
2X 75.50
2X 123.50 FOR ITEM 3
121.00
169.00 FOR ITEM 3
8.00
5.75
(3.0)
∅6.06±.02
2X .50 X 60°
DETAIL ITEM 2 AS SHOWN
DETAIL ITEM 3 AS NOTED
SCALE: 1 : 32
(344.00)
(51.00)
(242.00)
4X 4.0
(2X 56.00)
4 2X
2X 2
3
12X 5
5
TYP
3/4
5/8
3/4
1/2
1
DETAIL ITEM 14
SCALE: 1 : 4
∅2.994/2.991
4X 1.00 X 45°
56.00
44.00
DETAIL ITEM 4
SCALE: 1 : 16
G G
4X 4.0
8X 15.00
14 8X
4X 3/4
CENTRAL BEAM WELDMENT A2 9
SCALE: 1 : 32
(9.00)
2X 23.5
2.0
(2.0)
22.50
48.00
DETAIL ITEM 5
SCALE: 1 : 16
REV: 1
SHEET 3 OF 5
DWG NO.
3020935


DWG-3020935-001
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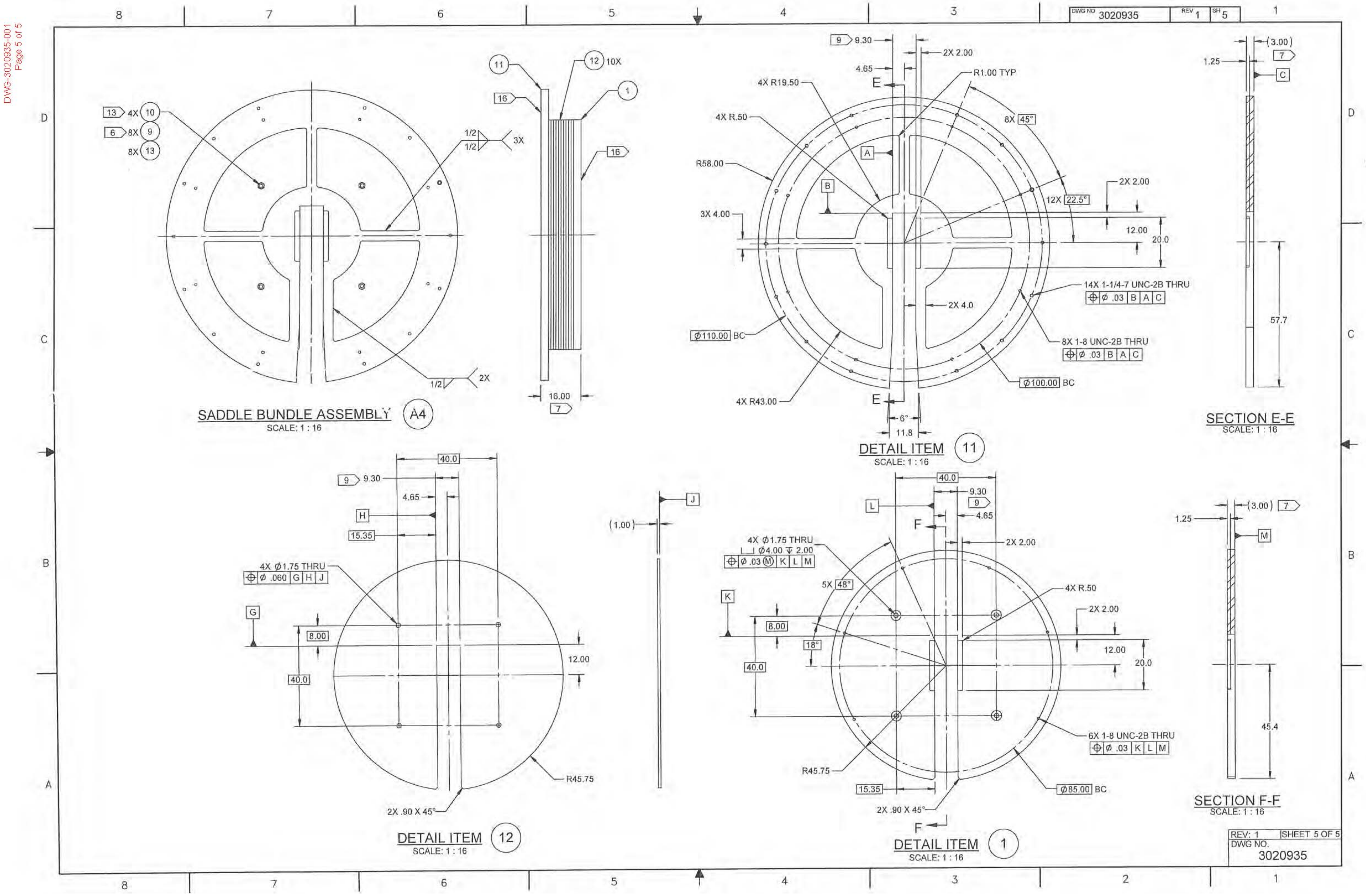
DWG NO 3020935
REV 1
SH 4
13 4X 8
9 8X 6
13 8X
16
6 2X
7 22X
7 28.0
16
SECTION C-C
SCALE: 1 : 12
ISOMETRIC VIEW
13
28.0 ITEM 8
15.0 ITEM 10
2X 3.0
2X 1 1/2- UNC-2A
DETAIL ITEM 8 AS SHOWN
DETAIL ITEM 10 AS NOTED
SCALE: 1 : 4
6
(R47.00)
C
C
BUNDLE ASSEMBLY A3
SCALE: 1 : 12
40.0
15.35
4X Ø1.75 THRU
⊕ Ø .03 Ⓜ B A C
R47.00
(1.00)
B
8.00
40.0
12.00
2X 46.00
2X 1.00 X 45°
4.65
9.30 9
A
C
DETAIL ITEM 7
SCALE: 1 : 20
40.0
9 9.30
D
4.65
15.35
6X 1-8 UNC-2B THRU
⊕ Ø .03 E D F
4X Ø1.75 THRU
⌴ Ø4.00 ↧ 2.00
⊕ Ø .03 Ⓜ E D F
D
2X 2.0
5X 48°
E
8.00
40.0
18°
2.00
46.00
R47.00
2X 1.0 X 45°
D
4X R.50
Ø85.00 BC
(3.00) 7
1.25
F
2X 20.0
34.00
SECTION D-D
SCALE: 1 : 20
DETAIL ITEM 6
SCALE: 1 : 20
REV: 1
SHEET 4 OF 5
DWG NO.
3020935



SADDLE BUNDLE ASSEMBLY (A4)
SCALE: 1 : 16

DETAIL ITEM (11)
SCALE: 1 : 16

SECTION E-E
SCALE: 1 : 16

DETAIL ITEM (12)
SCALE: 1 : 16

DETAIL ITEM (1)
SCALE: 1 : 16

SECTION F-F
SCALE: 1 : 16