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PNNL Coal Gasifier Transportation Logistics

DJ Reid AD Guzman

April 2011

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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

This report provides Pacific Northwest National laboratory (PNNL) craftspeople with the necessary information and suggested configurations to transport PNNL's coal gasifier from its current location at the InEnTec facility in Richland, Washington, to PNNL's Laboratory Support Warehouse (LSW) for short-term storage. A method of securing the gasifier equipment is provided that complies with the tie-down requirements of the Federal Motor Carrier Safety Administration's Cargo Securement Rules.

Acronyms and Abbreviations

ft	foot(feet)
in.	inch(es)
lb	pound(s)
LSW	Laboratory Support Warehouse
POC	point of contact

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1.0 Introduction

One of Pacific Northwest National Laboratory's (PNNL's) Laboratory Directed Research and Development projects has involved a coal gasifier that was built and operated at the InEnTec facility (InEnTec LLC, 2011) in Richland, Washington. The gasifier is no longer being operated, so it is time to relocate the equipment in a PNNL storage facility. The fully assembled gasifier is too tall and heavy to move easily in its upright position. The InEnTec staff disassembled the three heavy spool pieces from the frame to allow for more modular transport. The frame will be laid down to prevent any over height transportation issues. All of the equipment will be transported to PNNL's LSW for short-term storage. PNNL craftspeople (Crafts) are required to place the Bosch frame upright in a standing position inside the LSW.

The ensuing sections briefly describe the source and destination facilities; the assumptions and requirements related to equipment handling, securement, and conveyance; and a proposed tie-down configuration. Appendix A contains related photos and equipment drawings.

2.0 InEnTec and LSW Facilities

The gasifier frame, three palletized spool pieces, two empty palletized spool pieces, a palletized coal auger and miscellaneous hardware, and a palletized boiler reside in the warehouse at the InEnTec facility and will be transported to PNNL's LSW located north of Horn Rapids Road and PNNL's north campus facilities (see Figure A.1 in Appendix A). Figure A.2 shows the exterior of the InEnTec facility. Figure A.3 shows the laydown yard where the components will be loaded onto a trailer. The ground is moderately flat and consists of a gravel/asphalt mix. The entryway to the north campus LSW consists of gravel. Figure A.4 shows the open dimensions of the LSW doors. Figure A.5 shows the entryway transition "step" that may provide a challenge for unloading the components and transporting them into the LSW. Figure A.6 shows the interior of the LSW.

3.0 Assumptions and Requirements

The specific tie-down methodology and conveyance used for transportation of the equipment is up to the discretion of Crafts. The transportation route and time of day will also be Crafts' responsibility. Coordination for pick-up times shall be arranged with the PNNL point of contact (POC) to ensure InEnTec staff availability. PNNL Crafts shall provide the proposed shipping date to PNNL POC by April 20 for labor and planning purposes.

The following assumptions are applicable to lifting and tying down the PNNL gasifier when preparing it for transportation to the LSW (see Figures A.7 to A.11):

- InEnTec staff will be responsible for moving the equipment out of their facility and loading it onto the PNNL transportation vehicles.
- The move involves the gasifier Bosch frame and six wooden pallets.
- The top spool piece on the pallet is assumed to weigh 1,800 lb at most.
- The Bosch stand with spools removed is assumed to weigh 1,750 lb at most.
- Two pallets, each with one spool piece, are assumed to weigh 1,500 lb at most per pallet. (Figure A.7)
- Two additional spool pieces on one pallet is assumed to weigh 1,500 lb at most (Figure A.9).
- Miscellaneous hardware (hopper, auger, etc.) on a pallet is assumed to weigh 1,500 lb at most.
- The boiler (Figure A.11) on a pallet is assumed to weigh 1,500 lb at most.
- The attachment points on the trailer or conveyance are assumed to withstand imposed tie-down loads.
- An 8-ft-wide lowboy trailer or equivalent meeting tie-down equivalency criteria is acceptable for transport.
- The Bosch stand must be oriented as shown in Figure 4.1.
- 4x4 lumber may be used to shim up the Bosch stand to level its position on the trailer.
- Metal banding will be used to secure the spool pieces onto their associated pallet.
- A rubber mat will be placed under loaded pallets. All calculations were made given this assumption.

3.1 Tolerance Requirements

Placement of the equipment on the conveyance is critical for centering the load. The following requirements apply:

- The gasifier Bosch stand will be centered laterally on the trailer with a tolerance of +/-2 in.
- The spool pieces and pallets will be centered laterally with a tolerance of +/-2 in.
- Crafts shall provide a tie-down configuration for the remaining components.

3.2 Tie-Down Description and Equipment

The required hardware for the proposed tie down is as follows:

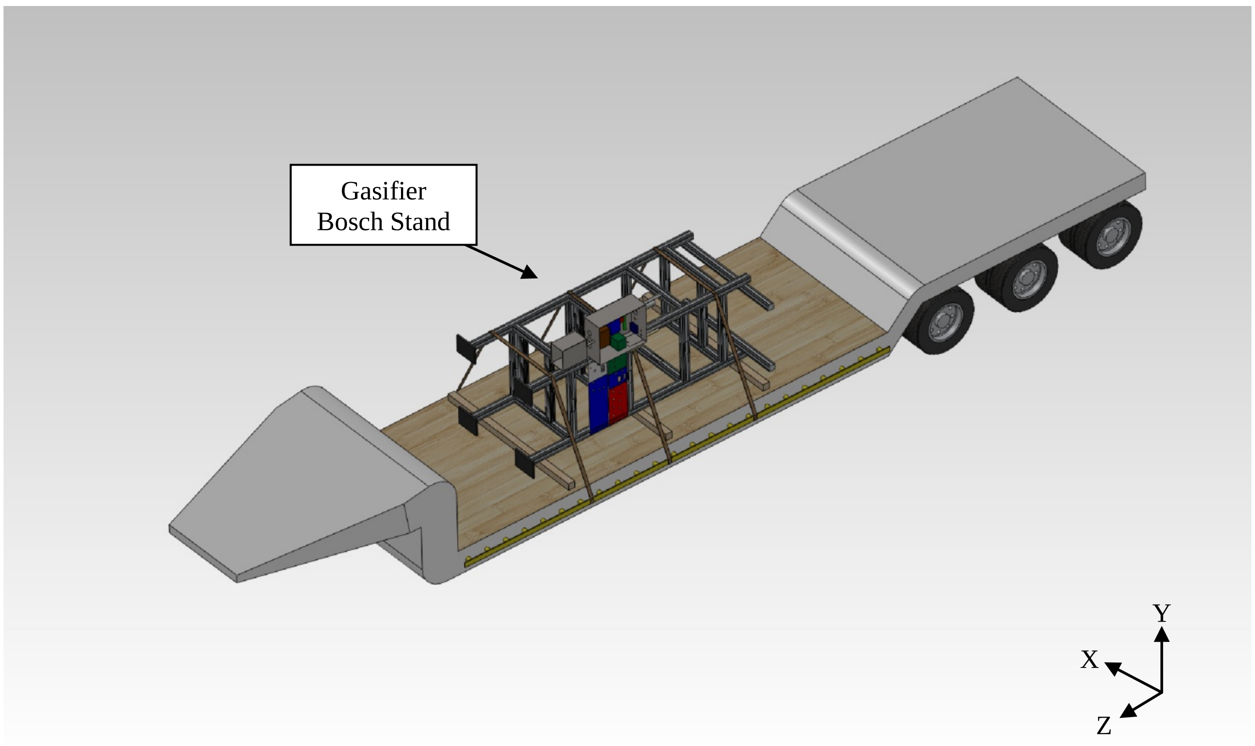
- Multiple chains or straps with a working load limit of 4,000 lb or greater.
- Rubber friction mats required between pallets and conveyance deck.

4.0 A Proposed Tie-Down Configuration

This section presents the layout and coordinate system and tie-down calculations for a proposed tie-down configuration for the gasifier components, as an example.

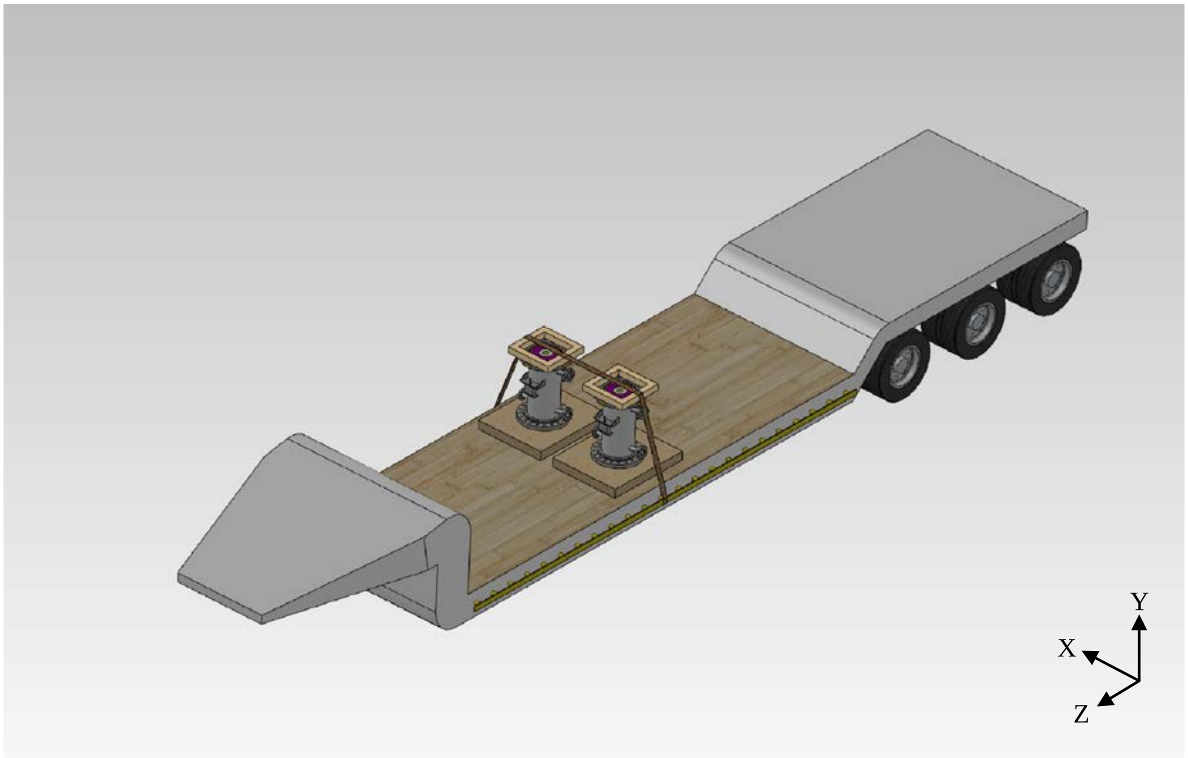
4.1 Layout and Coordinate System

Figure 4.1 and Figure 4.2 below have three reference axes for clarification when referring to the tie-down configuration.



X: Lateral **Y**: Vertical **Z**: Forward/Aft

Figure 4.1. Tie-Down Example for the Gasifier Bosch Stand



X: Lateral **Y**: Vertical **Z**: Forward/Aft

Figure 4.2. Example of the Tie-Down Configuration for Spool Pieces

4.2 Tie-Down Calculations

The calculations in this section apply to the tie-down configuration shown in Figure 4.2. Rubber mats are not shown in the figure but are required.

4.2.1 Forces

The total estimated weight of two spool pieces each supported by a typical pallet is

$$W_{system} := 2000 \cdot \text{lbf}$$

In accordance with the Federal Motor Carrier Safety Administration's Cargo Securement Rules (FMCSA 2011), the tie-down configuration shall restrain the load from a g-force of 0.8 in the forward direction, 0.5 in the aft/backward direction, 0.5 in the lateral direction, and 0.5 in the vertical direction.

The *CRC Handbook of Chemistry and Physics* (Lide 1991) reports friction factors ranging from 1 to 4 for rubber mats. A coefficient of friction of 0.4 is conservatively used. To ensure that a friction of at least this magnitude is always present a friction-enhancing load mat shall be placed under all pallets. This requirement is intended to restrict forward, aft, and lateral movement under the specified worst-case inertial loads.

Coefficient of friction (Lide 1991):

$$\mu := 0.4$$

Forward, aft, lateral, and vertical g-force values:

$$g_{forward} := 0.8$$

$$g_{aft} := 0.5$$

$$g_{lat} := g_{aft}$$

$$g_{vert} := 0.5$$

4.2.2 Strapping Setup

For a configuration with two spool pieces each supported on a typical wooden pallet, one strap or chain shall be placed across the top flanges similar to the setup shown in Figures 4.2 and 4.3. Use of a frame made of 4x4 lumber is also suggested (shown across the top).

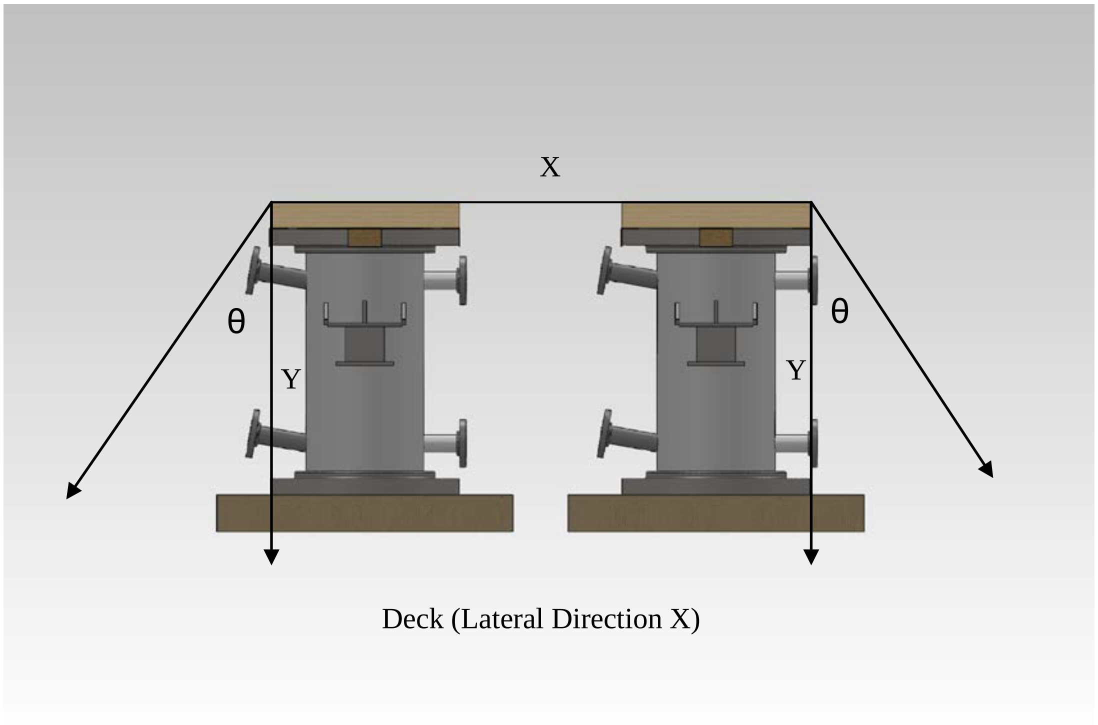


Figure 4.3. Angle Calculation Definition

Angle between strap and spool piece:

$$\theta_{strap} := 70.4 \cdot deg$$

4.2.3 Lateral Restraint Calculations

In Figure 4.2, the lateral direction is also called the X direction. Lateral restraint is provided by using a single strap or chain across the top flanges of both spool pieces. The ends of the strap are then secured to the conveyance. To avoid damage to the strap, any edge that comes in contact with the strap should be padded. Alternatively, more than one strap may be used.

Load in the lateral direction(s):

$$F_{lat} := W_{system} \cdot g_{lat}$$

Solving for tension in the chain or strap:

$$T_{lateral} := \frac{F_{lat}}{\sin(\theta_{strap})}$$

$$T_{lateral} = 1.062 \times 10^{3} \, \text{lbf}$$

The working load limit of one strap in the lateral direction must be 1,250 lb or greater.

4.2.4 Vertical Restraint Calculations

In Figure 4.2, the vertical direction is also called the Y direction. Vertical restraint is provided by using a single strap or chain across the top flanges of both spool pieces. The ends of the strap are then secured to the conveyance. To avoid damage to the strap, any edge that comes in contact with the strap should be padded.

Load in the vertical direction:

$$F_{vertical} := W_{system} \cdot g_{vert}$$

Solving for tension in the chain or strap:

$$T_{vertical} := \frac{\left(\frac{F_{vertical}}{2}\right)}{\cos(\theta_{strap})}$$

$$T_{vertical} = 1.491 \times 10^{3} \, \text{lbf}$$

The working load limit of one strap in the vertical direction must be 1,750 lb or greater.

4.2.5 Forward Restraint Calculations

In case chocking is not used for forward and aft restraint, the preload of straps can be calculated by balancing forward inertial load with opposing friction force. Forward restraint calculations are as follows (Hibbeler 2004):

Load in the forward direction:

$$F_{forward} := W_{system} \cdot g_{forward}$$

Friction force:

$$f = \mu \cdot N_{normal}$$

Force balance:

$$F_{forward} - f = 0$$

Solve for normal force:

$$g_{forward} \cdot W_{system} = \mu \cdot N_{normal}$$

$$N_{normal} := 2 \cdot W_{system}$$

$$N_{normal} = W_{system} + 2 \cdot Y_{down}$$

Tension of Y component in one strap:

$$Y_{down} := \frac{\left(N_{normal} - W_{system}\right)}{2}$$

$$Y_{down} = 1 \times 10^{3}\ \text{lbf}$$

Minimum preload required per strap:

$$T_{preload} := \frac{\left(Y_{down}\right)}{\cos\left(\theta_{strap}\right)}$$

$$T_{preload} = 2.981 \times 10^{3}\ \text{lbf}$$

To provide forward restraint, each strap or chain should be preloaded to at least 3,250 lb, requiring a strap working load limit of 4,000 lb or greater.

5.0 References

InEnTec Website. InEnTec LLC, 2011. http://www.inentec.com/ Accessed in March 2011.

Federal Motor Carrier Safety Administration Cargo Securement Rules. http://www.fmcsa.dot.gov/rules-regulations/truck/vehicle/cs-policy.htm Accessed in March 2011.

Hibbeler, RC. 2004. *Engineering Mechanics, Statics and Dynamics.* Tenth Edition, Pearson Prentice Hall, Upper Saddle River, New Jersey.

Lide, DR (ed.). 1991. *CRC Handbook of Chemistry and Physics*. 72nd revised edition, CRC Press Inc., Boca Raton, Florida.

Appendix A

Drawings and Figures

Appendix A – Drawings and Figures

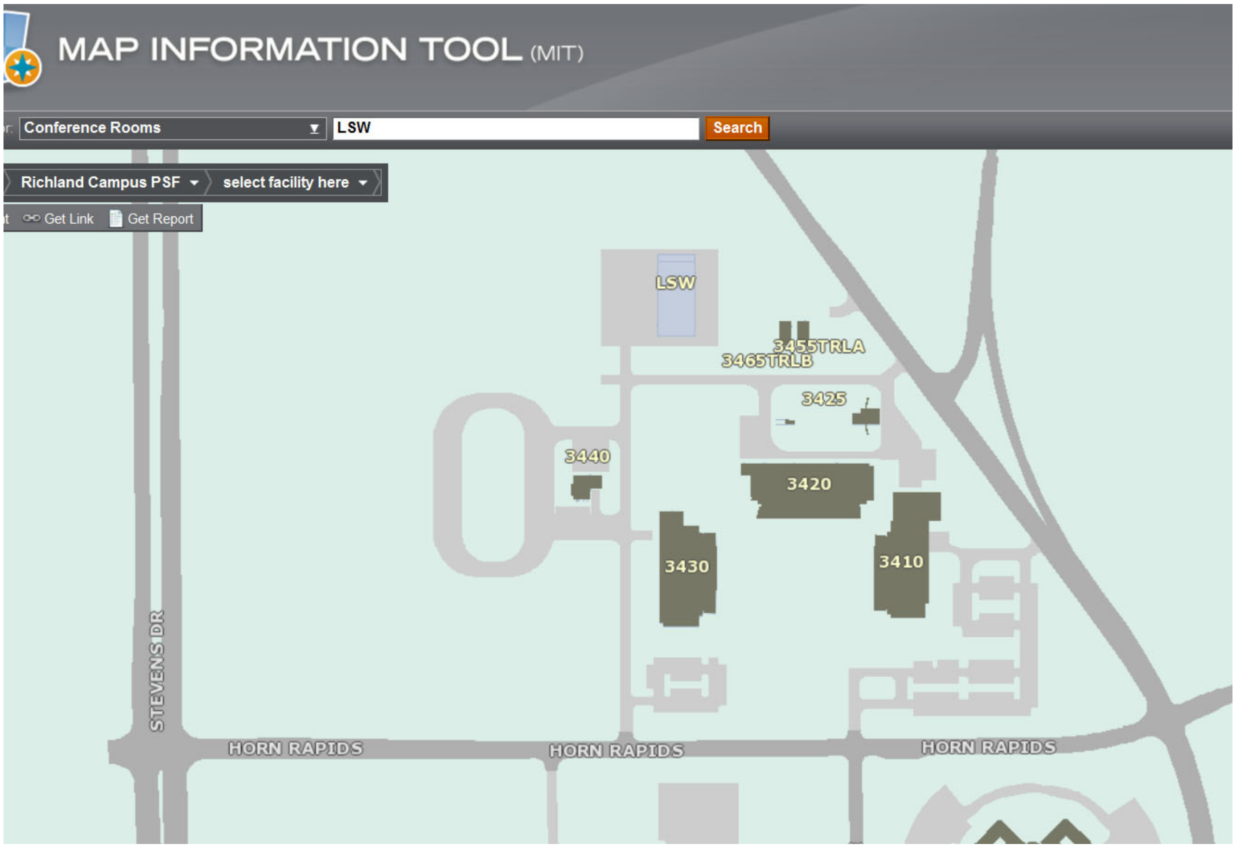


Figure A.1. Map of PNNL's North Campus Showing the Location of the LSW

Figure A.2. InEnTec Facility

Figure A.3. InEnTec Laydown Yard

Figure A.4. LSW Entry Way. Maximum height is 14 feet.

Figure A.5. LSW Entry Way "Step"

Figure A.1. Interior View of the LSW

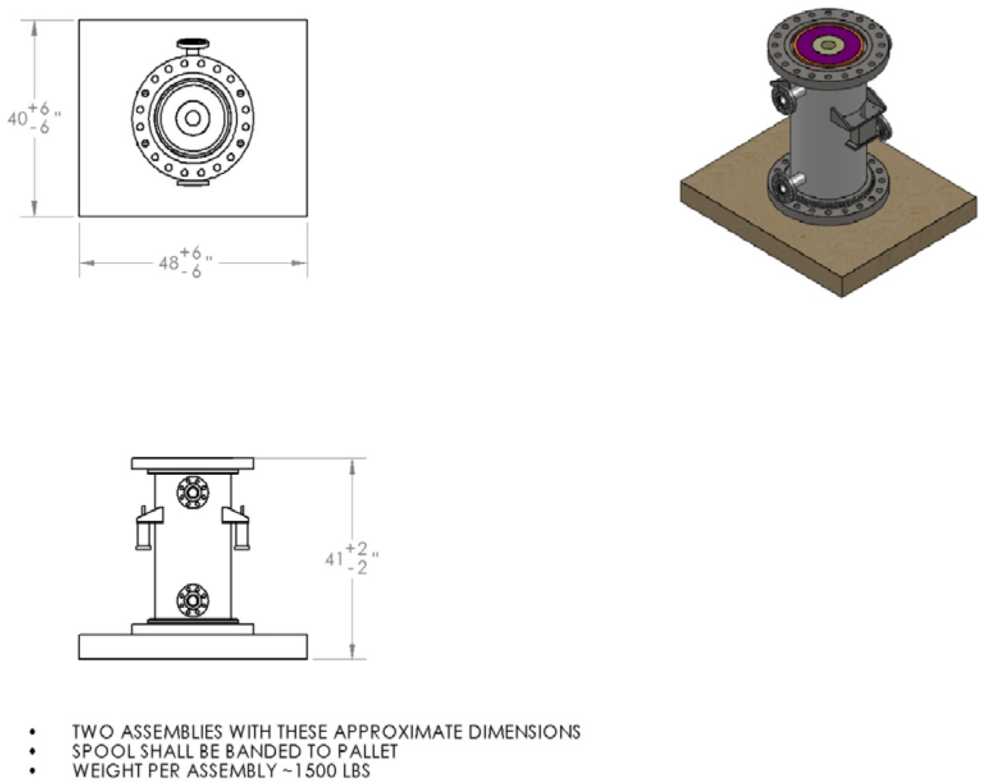
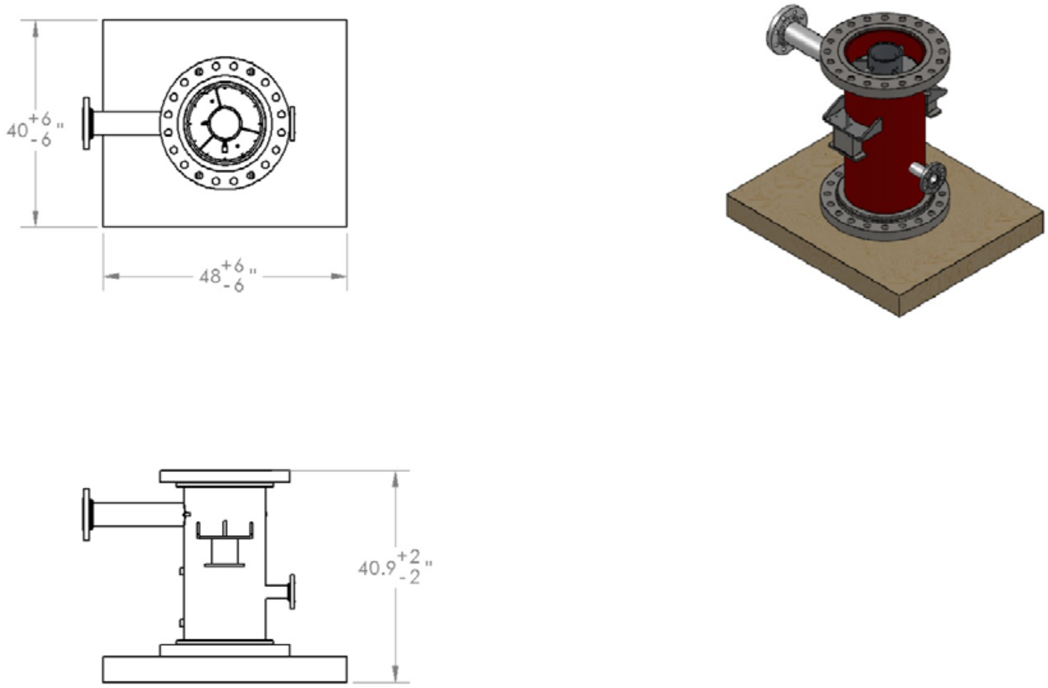


Figure A.7. Height and Footprint Dimensions of Middle and Upper Spool Pieces (in inches)



- SPOOL PIECE SHALL BE BANDED TO PALLET
- TOTAL WEIGHT OF SPOOL ~1000 LBS

Figure A.8. Height and Footprint Dimensions of Lower Spool Piece (in inches)

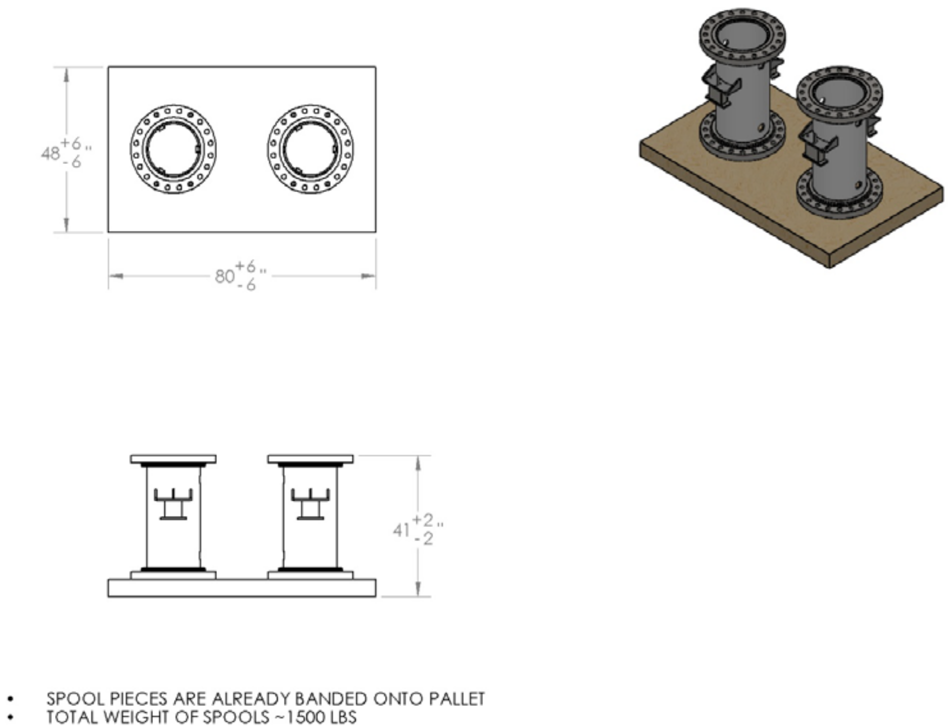


Figure A.9. Height and Footprint Dimensions of Extra Spool Pieces (in inches)

Figure A.10. Extra Spool Pieces Attached to Pallet at InEnTec

Figure A.11. Gasifier Boiler

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