**DOCUMENT RELEASE AND CHANGE FORM**

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08VR14800

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1. **Doc No:** RPP-CALC-60841  **Rev.:** 01

2. **Title:** AX Farm Pit Spray Ring Type 1 Lifting and Operational Evaluation

3. **Project Number:** T2R02

4. **Design Verification Required:** ☒ Yes  ☐ No

5. **USQ Number:** ☒ N/A  ☐ N/A-8

6. **PrHA Number**

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8. **Description of Change and Justification**

Section 8.6.1 revised to address chains. Section 8.6.3 added for the cover plate. CFR references updated in Sections 2.3.3 and 3.0. File names in Table 5-2 are updated. Updated terminology to refer to type 1 work platform in Section 1.0.

Added new sluicer (H-2-70030 and RPP-CALC-61723 to Design Inputs and References.

Because of the general service status of the equipment, a graded approach was applied and design verification was not performed as allowed by ARES quality assurance procedure 3.5, Design Verification.

9. **TBDs or Holds** ☒ N/A

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AX Farm Pit Spray Ring Type 1 Lifting and Operational Evaluation

Prepared by

T.F. Schmitt
ARES Corporation for Washington River Protection Solutions, LLC

Date Published
October 2017

Prepared for the U.S. Department of Energy
Office of River Protection

Contract No. DE-AC27-08RV14800
**Project No.**
054409.15.065

**Project Title:**
AX Equipment Removal Construction Support

**Client:**
Washington River Protection Solutions

**Title:**
AX Farm Spray Ring Type 1 Lifting and Operational Evaluation

**Purpose and Objective:**
The purpose of this calculation is to structurally evaluate the split spray ring type 1 with the type 1 work platform for lifting and operation. The ASME evaluation of the pressure components is performed in RPP-CALC-60810.

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**Revision Description (Revision Description/Affected Pages):**
Initial Release.

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**Revision Description (Revision Description/Affected Pages):**
Section 8.6.1 Revised to address chains. Section 8.6.3 added for the cover plate. CFR references updated in Sections 2.3.3 and 3.0. File names in Table 5-2 are updated. Update terminology to refer to type 1 work platform in Section 1.0.

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**Revision Description (Revision Description/Affected Pages):**
Revised Table 1-1 to remove pits AX-03D and AX-04B as they are not applicable to the Type 1 Work Platform or Spray Ring. Revised non-technical editorial comments throughout.
### CALCULATION COVER SHEET (Cont.)

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Revision Description (Revision Description/Affected Pages):
Added additional Sluicer (H-2-70030) and corresponding structural analysis RPP-CALC-61723 to Design Input 8 and References.
## RPP-CALC-60841, Rev. 1

### CALCULATION REVIEW CHECKLIST

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<td>2. Calculation sheet headers complete with calculation number, revision number, etc.</td>
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<td>3. Calculation sheet contents are legible, accurate, and complete per format.</td>
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<td>4. Listed attachments included.</td>
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<td>5. Calculation objective clearly described.</td>
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### Calculation Checking Method

1. Direct Step-by-Step Check
2. Reference Chart(s) or Book(s) Comparison
   (Append Documentation)
3. Alternate Calculation (Append Documentation)

### Comments:
None.

---

**Preparer (Print Name and Sign):**
TF Schmitt, PE

**Date:**
10/10/2017

---

**Checker (Print Name and Sign):**
GD Lawrence, PE

**Date:**
10/10/2017

Signatures obtained only after discrepancies are corrected and comments are resolved.
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**Prepared By:** T. F. Schmitt  
**Date:** 10/10/17  
**Checked By:** G. D. Lawrence  
**Date:** 10/10/17

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- **8.6.2 Seismic Stop Block Evaluation**
- **8.6.3 Cover Plate Evaluation**

### Attachments

1. **Attachment 1**
   - 1) Hoist Ring Rating When Used With ASTM A36 Material
   - 2) Email: Hoist Ring Derating Questions

2. **Attachment 2**
   - Actek Lifting Ring Data Sheets

3. **Attachment 3**
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4. **Attachment 4**
   - Load Runner Roller Cut Sheets

5. **Attachment 5**
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<td>77</td>
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</tr>
</tbody>
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Prepared By: T. F. Schmitt  Date: 10/10/17  Checked By: G. D. Lawrence  Date: 10/10/17

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Acronyms

AISC  American Institute of Steel Construction
ASME  American Society of Mechanical Engineers
BOM  Bill of Materials
DST  Double Shell Tank
FEA  Finite Element Analysis
FEM  Finite Element Model
OSHA  Occupational Safety & Health Administration
SST  Single Shell Tank
1.0 PURPOSE

Equipment must be removed from single shell tanks (SSTs) in the AX farms to allow for the upcoming transfer of waste to double shell tanks (DSTs). A total of eight pits will be accessed for equipment removal for type 1 work platform (listed in Table 1-1). When equipment (long length pumps, sluicers, screens, etc.) is removed, shielding must be in place and the equipment must be decontaminated by water washing with a spray ring. These spray rings contain a high pressure water system capable of cleaning/decontaminating the equipment.

A temporary work platform and spray ring will be put in place to facilitate the equipment removal and decontamination. The work platform will be lifted into place on top of the pit with or without the spray ring in place. If operations decide to lift the spray ring separately, it will be lifted in after the work platform base is in place. With the work platform open, the equipment will be lifted above the spray ring. The work platform will be closed, and the equipment will be lowered onto the top of the spray ring. A top hat with bagging material will be lowered onto the spray ring. The equipment will be slowly raised, rinsed, and bagged. When the equipment retrieval is complete, the spray ring will be bagged and lifted off the work platform for disposal.

The objective of the spray ring is to decontaminate the equipment and direct the rinse water back into the riser. The spray ring consists of 16 high pressure nozzles (10,000 psi) using a total of 34 gpm to rinse equipment as it is removed [Ref A1].

The purpose of this calculation is to structurally evaluate the split spray ring type 1 work platform for lifting and operation. The ASME evaluation of the pressure components is performed in RPP-CALC-60810 [Ref A11]. The different configurations are shown below in Table 1-1 as were presented for the conceptual design review. A basic illustration of the spray ring and work platform is shown below in Figure 1-1 and Figure 1-2.
Figure 1-1. Work Platform in Place on Pit in Closed Configuration
Figure 1-2. Work Platform in Place on Pit in Open Configuration (Spray Ring Not Shown)
<table>
<thead>
<tr>
<th>Split Spray Ring</th>
<th>Work Platform</th>
<th>Riser</th>
<th>Size</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>AX01D RISER 24</td>
<td>12</td>
<td>Transfer Pump</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>AX02D</td>
<td>12</td>
<td>P-10 Pump</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Salt Well Screen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>AX03B RISER 14</td>
<td>42</td>
<td>Sluicer</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>AX04C</td>
<td>34</td>
<td>Sluicer</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>AX04D</td>
<td>34</td>
<td>Sluicer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sluice Adapter Plate (not being cleaned)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>AX01B RISER 1B</td>
<td>34</td>
<td>Salt Well Screen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Salt Well Transfer Pump</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.0 METHODOLOGY

This calculation considers the following load case scenarios. Methodology for each scenario is detailed in the following subsections. All components not specifically listed are considered acceptable by inspection. This includes welds not specifically analyzed which are deemed acceptable due to the low stress results in the welded areas shown in the FEA.

Lifting Scenarios to be Considered

1. Lifting base plate onto or off of pits.
   A. This analysis is performed with the entire work platform to allow lifting of the components separately or as a complete platform.

2. Lifting a complete spray ring in the vertical position.
   A. This analysis bounds the cases of lifting a spray ring half or a complete spray ring because the lifting slings are out of plane in the configuration with a complete spray ring.

3. Lifting a complete spray ring in the horizontal position.
   A. This analysis bounds the case of lifting a spray ring half or a complete spray ring because only two lifting slings are used in either scenario.

Operational Scenarios to be Considered

1. Work platform with spray ring, equipment weight, and worker weight.

2.1 Lifting Evaluations

Lifting evaluations are performed in accordance with RPP-8360, Lifting Point Evaluation Process [Ref A7]. Paragraph 5.2.1.6 [Ref A7] direct acceptance criteria be taken from Manual of Steel Construction: Allowable Stress Design 1989 [Ref B1], or a more recent version of the code may be used if the allowable stress design (ASD) method is used. For this calculation, the 14th Edition [Ref B2] is used which includes the 2010 Specification for Structural Steel Buildings [Ref B3]. Allowable stress is taken from RPP-8360 paragraph 5.3.1 [Ref A7] whenever possible.

2.1.1 Lifting Base Plates

The base plates are lifted from four lifting rings using slings/chains/cables to a single point attachment. RPP-8360, Lifting Point Evaluation Process [Ref A7] details the methodology to be used for lifting analysis. A weight contingency factor of 5% is added to the calculated weight as specified in 5.2.1.2 [Ref A7]. A dynamic loading factor of 25% is applied as specified in 5.2.1.3 [Ref A7]. The minimum sling angle of 45° is used for the evaluation as specified in 5.2.1.6(c) [Ref A7]. RPP-8360 paragraph 5.2.1.6(d) [Ref A7] requires only 3
lifting points to be considered for the whole load when evaluating the lifting component ratings so the calculated load for evaluating the pick point is multiplied by 4/3 to meet this requirement.

2.1.2 **Lifting Spray Ring in Vertical Position**

The methodology is similar to Section 2.1.1. There are 4 lift points so the calculated loads on the lift points are factored.

2.1.3 **Lifting Spray Ring in the Horizontal Position**

The methodology is similar to Section 2.1.1. The spray ring is considered with 2 slings attached and contact with the ground at the bottom to provide vertical support. There are only 2 lift points, so the loads are not factored.

2.1.4 **Lifting Sliding Plates**

The spray ring and top hat have a combined weight of approximately 2,672 lb. The largest sliding plate has a mass of 2,676 lbm. The analysis of the spray ring for the horizontal and vertical conditions is reasonably bounding for the sliding plates and hoist rings since the sliding plates are thicker than the spray ring flanges.

2.2 **Operational Evaluations**

Operational evaluations consider equipment weight, worker weight, and self-weight of the work platform. The 5% weight contingency factor discussed in Section 2.1.1 is still included in the operational evaluation. The same allowable stress criteria from Section 2.1 for the work platform and spray ring are used for operational evaluations. A nominal worker and equipment weight of 3,000 lbs is included in the applicable load cases. This load is listed on the drawing [Ref A1] and is a similar value used in previous work platform designs. The work platform is seismic category PC-1/2 (1 over 2), which means their failure (sliding or breaking and falling into the pits) could affect PC-2 equipment (piping inside the pits). Therefore, they are subjected to the same seismic loads as PC-2 equipment which is specified in TFC-ENG-STD-06, *Design Loads for Tank Farm Facilities* [Ref A6]. The seismic load is used to evaluate the seismic restraint blocks.

2.2.1 **Work Platform Loaded with Worker Weight, Equipment Weight, and Spray Ring in the Middle**

This case evaluates the worst case loading when the equipment is placed on top of the spray ring. A 25% dynamic load factor is applied to the equipment (similar to the lifting analysis) to account for the equipment being placed on the spray ring.

2.2.2 **Seismic Load on the Stop Block**

The bottom plate of the work platform has four seismic stop blocks on its underside to prevent the work platform from sliding into the pit during a seismic event. The seismic stop block welds are evaluated for seismic loading by conservatively applying a lateral seismic load of 1.0g to one seismic stop block.
2.3 Purchased Component Evaluations

2.3.1 Actek Hoist Rings

The rated load of the hoist rings are compared to the calculated lifting loads described above. In order to use A36 carbon steel with Actek hoist rings, without derating the load capacity of the hoist rings, the five requirements of Attachment 1 must be met. Each Attachment 1 requirement will be checked for acceptability.

The material thickness is evaluated to determine if it meets the requirements given in Attachment 1 and Attachment 2. Attachment 1 requires the material thickness to be at least 1.5 times the hoist ring screw diameter. Attachment 2 requires the material thickness to be at least 1.89” or 0.78” thick depending on the hoist ring model (the hoist ring screw protrusion length). The tool proper material thickness is acceptable when it is greater than the requirements given in Attachments 1 and 2.

The screw protrusion length (given in Attachment 2) of each hoist ring is evaluated to determine if it is at least 1.5 times the hoist ring screw diameter (Attachment 1). If the screw protrusion length does not meet the requirement given in Attachment 1, the required thread engagement length for an Actek hoist ring placed in an ASTM A36 base material will be determined using ASME B1.1 [Ref B6]. The required thread engagement length will be compared to the screw protrusion length given in Attachment 2. If the required thread engagement length is less than or equal to the screw protrusion length given in Attachment 2 the screw protrusion length is acceptable.

2.3.2 Rollers

The calculated loads on the rollers are compared to the catalog rated values listed in Attachment 4. The load on the work platform is compared to the allowable bearing load for A-36 steel computed with the roller bearings treated as an expansion rocker using AISC [Ref B3] methodology.

2.3.3 Handrails

The handrails are evaluated against OSHA requirements in 29 CFR 1910.29 [Ref B7]. Kee Clamp has performed tests demonstrating the strength of the handrails and fittings [Attachment 5]. The bolts anchoring the handrails are analyzed for the required 200 lb load acting laterally on the weak axis of a single post. The tensile load in the bolts is calculated considering the base prying at its outer edge. Thread engagement in the base plate is also verified.
3.0 DESIGN INPUTS

Material properties are taken from ASME Section II-D [Ref B4].

1. Modulus of Elasticity of carbon steel (C ≤ 0.30%) at 70°F is 29.4 x 10^6 psi [Ref B4, Table TM-1].

2. Yield Strength of A-36 is 36 ksi [Ref B4, Table Y-1].

3. Tensile Strength of A-36 is 58 ksi [Ref B4, Table U-1].

4. Density of carbon steel is 0.280 lb/in^3 [Ref B4, Table PRD].

5. Poisson’s Ratio of carbon steel is 0.30 [Ref B4, Table PRD].

6. Weight contingency factor for lifting is 5% [Ref A7, para. 5.2.1.2].

7. Dynamic loading factor for lifting is 25% [Ref A7, para. 5.2.1.3].

8. A bounding equipment weight of 3,000 lbs is used in the analysis.
   a. Saltwell Pump assembly is 700 lbs as listed in RPP-CALC-57731 [Ref A8, para. 8.1].
   b. Saltwell Casing/Screen weight is 1,515 lbs as calculated in RPP-CALC-57731 [Ref A8, para. 8.5.1].
   c. Sluicer (H-2-64527) weight is 2,664 lbs as listed in RPP-CALC-57866 [Ref A9, para. 8.1.2]
   d. Sluicer (H-2-70030) weight is 2,397 lbs as listed in RPP-CALC-61723 [Ref A12, para. 8.1.2]
   e. Transfer Pump (P-10) assembly weight is 2,133 lbs as calculated in RPP-CALC-57732 [Ref A10, para. 8.1].

9. Miscellaneous worker and tool weight of 3,000 lbs is used in the analysis [Ref A1].

10. Rollers are PLRE-3-1/2 (Plain Eccentric Stud Style Rollers) and VLR-3-1/2-16 (V-Grooved – Concentric Stud Style Rollers). The minimum rating for shear, bending, static limit, or 500 hour L_{10} life is 6,370 lbs for the plain end roller and 3,120 lbs radially and 3,150 lbs axially for the v-grooved roller [Attachment 4].

11. The railings are 1-1/2 SCH 40 with a nominal weight of 2.72 lb/ft [Ref B5]. To account for the two horizontals and the vertical posts, 8.16 lb/ft is applied around the perimeter. The perimeter of the handrails is 634 in, so 432 lb are applied to account for the handrails.

12. ASTM A325 bolts are considered AISC Group A when threads are not excluded from shear planes [Ref B3, para. J3.1] with nominal tensile strength of 90 ksi and nominal shear strength of 54 ksi [Ref B3, Table J3.2].
13. The bolts anchoring the handrail are analyzed for 200 lbs acting laterally per 29 CFR 1910.29(b)(3) [Ref B7] which states, “Guardrail systems are capable of withstanding, without failure, a force of at least 200 pounds applied in a downward or outward direction within 2 inches (5 cm) of the top edge, at any point along the top rail.”

14. ASTM A193 B7 bolts (≤ 2-1/2in) have a tensile strength of 125 ksi and yield strength of 105 ksi [Ref B4, Table 3]. Allowable stress is taken for threaded parts meeting the requirements of AISC 360 Section A3.4 with threads not excluded from the shear plane (0.75F_u and 0.45F_u) [Ref B3, Table J3.2].

4.0 ASSUMPTIONS

There are no unverified assumptions in this calculation. Engineering judgements are used and justified in the body of the calculation.
5.0 COMPUTER SOFTWARE

The following software is used in this calculation:

a) PTC Mathcad\textsuperscript{1} 15.0 – results from Mathcad are checked directly step-by-step using a hand held calculator.

b) ANSYS\textsuperscript{2} Workbench 16.0 was used for the FE analysis. The ANSYS program was verified by ARES Corporation, as documented in Verification No. VV-15-02-058. This verification was performed on an ARES computer (Computer ID: RL_C0314 / 70YL1R1) which is a DELL Precision T5500 running Microsoft Windows\textsuperscript{3} 7 Professional x64 Edition Version 2009 Service Pack 1.

A summary of the Software verification is shown in Table 5-1. The files used to generate this calculation are listed in Table 5-2.

No unverified computer software was used in this analysis.

<table>
<thead>
<tr>
<th>Program Name and Version:</th>
<th>Computer Type</th>
<th>Operating System</th>
<th>Verification No.</th>
<th>Computer ID:</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSYS Workbench 16.0</td>
<td>Dell PC</td>
<td>Windows 7 Professional x64 Service Pack 1</td>
<td>VV-15-02-058</td>
<td>70YL1R1</td>
</tr>
</tbody>
</table>

\textsuperscript{1} Mathcad\textsuperscript{®} is a registered trademark of Parametric Technology Corporation, 140 Kendrick St., Needham, MA 02494.

\textsuperscript{2} ANSYS\textsuperscript{®} is a registered trademark of ANSYS, Inc. Corporation, 2600 Ansys Dr. Canonsburg, PA 15317.

\textsuperscript{3} Microsoft Windows\textsuperscript{®} is a registered trademark of Microsoft Corporation, 1 Microsoft Way Redmond, WA 98052.
## Table 5-2. Computer Files

<table>
<thead>
<tr>
<th>File Name</th>
<th>Description of File</th>
<th>Computer Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>B Pit Rev 0.wbpz</td>
<td>ANSYS Workbench Project Archive File for the Work Platform</td>
<td>70YL1R1</td>
</tr>
<tr>
<td>AX-104 (B-PIT) ASSY For Analysis.sldprt</td>
<td>Solidworks geometry file for the Work Platform</td>
<td>N/A</td>
</tr>
<tr>
<td>Rev 1 Sec 8.1.xmcd</td>
<td>Mathcad Worksheet File</td>
<td>70SV1R1</td>
</tr>
<tr>
<td>Rev 1 Sec 8.2.5.xmcd</td>
<td>Mathcad Worksheet File</td>
<td>70SV1R1</td>
</tr>
<tr>
<td>Rev 1 Sec 8.3.5.xmcd</td>
<td>Mathcad Worksheet File</td>
<td>70SV1R1</td>
</tr>
<tr>
<td>Rev 1 Sec 8.4.5.xmcd</td>
<td>Mathcad Worksheet File</td>
<td>70SV1R1</td>
</tr>
<tr>
<td>Rev 1 Sec 8.5.5.xmcd</td>
<td>Mathcad Worksheet File</td>
<td>70SV1R1</td>
</tr>
<tr>
<td>Rev 1 Sec 8.6.xmcd</td>
<td>Mathcad Worksheet File</td>
<td>70SV1R1</td>
</tr>
</tbody>
</table>
6.0 RESULTS

A summary of the results is shown below. Detailed results are given in the sections listed in the tables. The split work platform is acceptable.

Table 6-1. Results Summary

<table>
<thead>
<tr>
<th>Item</th>
<th>DCR</th>
<th>Result</th>
<th>Calculation Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Stress in the Work Platform</td>
<td>0.82</td>
<td>Acceptable</td>
<td>8.2.5</td>
</tr>
<tr>
<td>Operational Load on the Rollers</td>
<td>0.98</td>
<td>Acceptable</td>
<td>8.2.5</td>
</tr>
<tr>
<td>Operation Load Shear on the Spray Ring Bolts</td>
<td>0.28</td>
<td>Acceptable</td>
<td>8.2.5</td>
</tr>
<tr>
<td>Operation Load Tension and Shear on the Spray Ring Bolts</td>
<td>0.35</td>
<td>Acceptable</td>
<td>8.2.5</td>
</tr>
<tr>
<td>Operation Load Bearing on the Spray Ring Bolt Holes</td>
<td>0.06</td>
<td>Acceptable</td>
<td>8.2.5</td>
</tr>
<tr>
<td>Lifting Stress in the Work Platform</td>
<td>0.74</td>
<td>Acceptable</td>
<td>8.3.5</td>
</tr>
<tr>
<td>Lifting Load on Bottom Plate Lift Rings</td>
<td>0.96*</td>
<td>Acceptable</td>
<td>8.3.5</td>
</tr>
<tr>
<td>Lifting Load Shear on the Spray Ring Bolts</td>
<td>0.19</td>
<td>Acceptable</td>
<td>8.3.5</td>
</tr>
<tr>
<td>Lifting Load Tension with Account for Shear on the Spray Ring Bolts</td>
<td>0.24</td>
<td>Acceptable</td>
<td>8.3.5</td>
</tr>
<tr>
<td>Lifting Load Bearing on the Spray Ring Bolt Holes</td>
<td>0.04</td>
<td>Acceptable</td>
<td>8.3.5</td>
</tr>
<tr>
<td>Lifting Stress in the Spray Ring (Vertical Lift)</td>
<td>0.62</td>
<td>Acceptable</td>
<td>8.4.5</td>
</tr>
<tr>
<td>Lifting Ring for Spray Ring Vertical Lift</td>
<td>0.67</td>
<td>Acceptable</td>
<td>8.4.5</td>
</tr>
<tr>
<td>Lifting Load Shear on the Spray Ring Bolts (Vertical Spray Ring Lift)</td>
<td>0.22</td>
<td>Acceptable</td>
<td>8.4.5</td>
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<td>Lifting Load Tension and Shear on the Spray Ring Bolts (Vertical Spray Ring Lift)</td>
<td>0.08</td>
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<td>8.4.5</td>
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<tr>
<td>Lifting Load Bearing on the Spray Ring Bolt Holes</td>
<td>0.05</td>
<td>Acceptable</td>
<td>8.4.5</td>
</tr>
<tr>
<td>Lifting Stress in the Spray Ring (Horizontal Lift)</td>
<td>0.47</td>
<td>Acceptable</td>
<td>8.5.5</td>
</tr>
<tr>
<td>Lifting Ring for Spray Ring Horizontal Lift</td>
<td>0.88</td>
<td>Acceptable</td>
<td>8.5.5</td>
</tr>
<tr>
<td>Lifting Load Shear on the Spray Ring Bolts (Horizontal Spray Ring Lift)</td>
<td>0.06</td>
<td>Acceptable</td>
<td>8.5.5</td>
</tr>
<tr>
<td>Lifting Load Tension and Shear on the Spray Ring Bolts (Horizontal Spray Ring Lift)</td>
<td>0.19</td>
<td>Acceptable</td>
<td>8.5.5</td>
</tr>
<tr>
<td>Lifting Load Bearing on the Spray Ring Bolt Holes</td>
<td>0.01</td>
<td>Acceptable</td>
<td>8.5.5</td>
</tr>
<tr>
<td>Handrail Anchor Bolts from Shear Loading</td>
<td>0.03</td>
<td>Acceptable</td>
<td>8.6.1</td>
</tr>
<tr>
<td>Handrail Anchor Bolts from Shear and Tensile Loading</td>
<td>0.43</td>
<td>Acceptable</td>
<td>8.6.1</td>
</tr>
<tr>
<td>Seismic Block Weld</td>
<td>0.62</td>
<td>Acceptable</td>
<td>8.6.2</td>
</tr>
<tr>
<td>Cover Plate</td>
<td>0.88</td>
<td>Acceptable</td>
<td>8.6.3</td>
</tr>
</tbody>
</table>

*The analyzed angle is 45°. To add an additional factor of safety, the specified lifting angle is 60°.
### 7.0 REFERENCES

**A. WRPS and ARES Documents**

- **A1.** H-14-110683, Rev 1, *AX Farm Pit Spray Ring & Work Platform Type 1* (Sheets 1-5), US Department of Energy, Richland, WA.
- **A2.** H-14-110682, Rev 2, *AX Farm Pit Split Spray Ring Handrail* (Sheet 1), US Department of Energy, Richland, WA.
- **A3.** H-14-110681, Rev 1, *AX Farm Pit Split Spray Ring Assembly* (Sheets 1-4), US Department of Energy, Richland, WA.
- **A4.** H-14-110680, Rev 1, *AX Farm Pit Spray Ring Base Plate Assembly* (Sheets 1-2), US Department of Energy, Richland, WA.
- **A5.** H-14-110679, Rev 1, *AX Farm Pit Spray Ring Sliding Plate Assemblies* (Sheets 1-5), US Department of Energy, Richland, WA.
- **A8.** RPP-CALC-57731, Rev 0, *241-AX Salt Well Lifting Analysis*, US Department of Energy, Richland, WA.
- **A9.** RPP-CALC-57866, Rev 0, *Removal of Sluicer (H-2-64527) from Various Risers in 241-AX Tank*, US Department of Energy, Richland, WA.
- **A10.** RPP-CALC-57732, Rev 0, *Structural and Lifting Analysis of Pump H-2-65054*, US Department of Energy, Richland, WA.
- **A11.** RPP-CALC-60810, Rev 0, *AX Farm Pit Spray Ring ASME Piping Analysis*, US Department of Energy, Richland, WA.
- **A12.** RPP-CALC-61723, Rev 0, *Removal of Sluicer (H-2-70030) from Various Risers in 241-AX Tank*, US Department of Energy, Richland, WA.
- **A13.** VV-15-02-058, *ANSYS® Release 16.0, Professional NLT including Workbench Verification and Validation*, ARES Corporation, Richland, WA.
B. Codes and Standards


C. Other References


### 8.0 Calculations

#### 8.1 Allowable Stress and Component Allowables

##### 8.1.1 Allowable Bearing Load at Rollers

- \( F_y := 36 \text{ksi} \)  
  Yield Strength of A-36 [Design Input 2]
- \( \Omega_B := 2.00 \)  
  Safety factor for bearing [Ref B3, pg. 16.1-131]
- \( l_b := 2.000\text{in} \)  
  Length of bearing (width of roller in Attachment 4)
- \( d := 3.5\text{in} \)  
  Roller diameter (flat roller in Attachment 4)

\[
R_n := \frac{1.2 \left( \frac{F_y}{\text{ksi}} - 13 \right) l_b}{20} \frac{d}{\text{in} \cdot \text{in}} = 9.66 \times 10^3 \text{lbf}
\]

Nominal bearing strength (\( d < 25 \text{ in} \)) [Ref B3, pg. 16.1-131, Eqn. J7-2]

\[
\frac{R_n}{\Omega_B} = 4.83 \times 10^3 \text{lbf}
\]

Allowable bearing strength [Ref B3, pg. 16.1-131]

The minimum rating for shear, bending, static limit, or 500 hour L10 life is 6,370 lbs for the plain end roller and 3,120 lbs radially and 3,150 lbs axially for the v-grooved roller [Design Input 10]. The bearing load governs the design for the flat roller, and the roller rating governs for the vee roller.
8.1.2 Allowable Stress in FEA

The allowable tensile, bending, and compressive stress is calculated below. The limiting stress is used to compare to the calculated stress in the FEM.

\[ E := 29.4 \times 10^6 \text{ psi} \]
\[ F_y := 36 \text{ksi} \]

Modulus of Elasticity of A-36 [Design Input 1]

Yield Strength of A-36 [Design Input 2]

Allowable Tensile Stress

\[ \Omega_t := 1.67 \]
\[ P_n := F_y = 36 \text{ksi} \]

Safety factor for tension [Ref B3, pg. 16.1-26]

Nominal tensile strength (in stress for a general area) [Ref B3, pg. 16.1-26]

\[ P_n \Omega_t = 21.557 \text{ksi} \]

Allowable tensile stress [Ref B3, pg. 16.1-26]

Allowable Bending Stress

\[ \Omega_b := 1.67 \]
\[ M_n := F_y = 36 \text{ksi} \]

Safety factor for bending [Ref B3, pg. 16.1-46]

Nominal bending strength of solid cross sections (in stress for a general area) [Ref B3, pg. 16.1-63]

\[ M_n \Omega_b = 21.557 \text{ksi} \]

Allowable bending stress [Ref B3, pg. 16.1-63]
Allowable Compressive Stress

The flanges on the spray ring are under the most severe compression so they are used for determining an allowable stress.

\[ w_{\text{flange}} := 26 \text{in} \]

\[ h_{\text{flange}} := 11.5 \text{in} \]

\[ t_{\text{flange}} := 0.5 \text{in} \]

\[ r_{\text{flange}} = \frac{\min(w_{\text{flange}}, h_{\text{flange}})}{\sqrt{12}} = 3.32 \text{in} \]  

Radius of gyration [Ref B2, Table 17-27]

\[ \Omega_c := 1.67 \]

Safety factor for compression [Ref B3, pg. 16.1-31]

\[ K := 1 \]

Stability factor conservatively taken for pinned supports [Ref B3, Table C-A-7.1]

\[ \frac{K \cdot h_{\text{flange}}}{r_{\text{flange}}} = 3.464 < 4.71 \cdot \frac{E}{F_y} = 134.599 \]  

Checking equation applicability [Ref B3, pg. 16.1-33]

\[ F_c := \frac{\pi^2 \cdot E}{(K \cdot h_{\text{flange}})^2} = 2.418 \times 10^4 \text{ksi} \]

Elastic buckling stress [Ref B3, pg. 16.1-33]

\[ \frac{F_{\text{cr}}}{F_y} = 0.658 \cdot F_y = 35.978 \text{ksi} \]  

Critical stress [Ref B3, pg. 16.1-33]

\[ P_n := F_{\text{cr}} = 35.978 \text{ksi} \]

Nominal compressive strength (computed as a stress) [Ref B3, pg. 16.1-33]

\[ \frac{P_n}{\Omega_c} = 21.543 \text{ksi} \]  

Allowable compressive stress [Ref B3, pg. 16.1-31]

**Allowable Stress for FEA**

\[ \min \left( \frac{P_n}{\Omega_c}, \frac{M_n}{\Omega_b}, \frac{P_n}{\Omega_f} \right) = 21.543 \text{ksi} \]  

Allowable stress used to compare to FEA results
8.1.3 Allowable Load on Spray Ring and Handrail Bolts

Allowable Shear and Tension on Spray Ring Bolts

\[ \Omega = 2.00 \]
\[ A_b = 0.1257 \text{in}^2 \]
\[ F_{nt} = 90 \text{ksi} \]
\[ F_{nv} = 54 \text{ksi} \]

For shear and tension, Section J3.7 is used [Ref B3]

\[ F'_{nt} = \min \left( 1.3 \cdot F_{nt} - \frac{\Omega \cdot F_{nt}}{F_{nv} \cdot F_{nt}} \right) \]

Nominal tensile stress modified to include the effects of shear stress [Ref B3, pg. 16.1-125]

\[ R_n = F'_{nt} \cdot A_b \]
\[ \frac{R_n}{\Omega} \]

Available tensile strength of the bolt [Ref B3, pg. 16.1-125]

\[ R_n = F_{nv} \cdot A_b = 6.788 \times 10^3 \text{lbf} \]
\[ \frac{R_n}{\Omega} = 3.394 \times 10^3 \text{lbf} \]

Allowable shear strength of 1/2 in bolt [Ref B3, pg. 16.1-125]

Allowable Shear and Tension on Handrail Bolts

\[ F_{nt} = 0.75 \cdot 125 \text{ksi} = 93.75 \text{ksi} \]
\[ F_{nv} = 0.45 \cdot 125 \text{ksi} = 56.25 \text{ksi} \]

For shear and tension, Section J3.7 is used [Ref B3] as shown above for the spray ring bolts.

\[ F'_{nt} = \min \left( 1.3 \cdot F_{nt} - \frac{\Omega \cdot F_{nt}}{F_{nv} \cdot F_{nt}} \right) \]

Nominal tensile stress modified to include the effects of shear stress [Ref B3, pg. 16.1-125]

\[ R_n = F'_{nt} \cdot A_b \]
\[ \frac{R_n}{\Omega} \]

Available tensile strength of the bolt [Ref B3, pg. 16.1-125]

\[ R_n = F_{nv} \cdot A_b = 7.071 \times 10^3 \text{lbf} \]
\[ \frac{R_n}{\Omega} = 3.535 \times 10^3 \text{lbf} \]

Allowable shear strength of 1/2 in bolt [Ref B3, pg. 16.1-125]
Allowable Bearing Stress at Spray Ring Bolt Holes

\[
\Omega := 2.00
\]

\[
d := \frac{1}{2} \text{ in}
\]

\[
l_c := 1 \text{ in} - 0.5 \cdot \frac{5}{8} \text{ in} = 0.688 \text{ in}
\]

\[
t := \frac{1}{2} \text{ in}
\]

\[
F_u := 58 \text{ ksi}
\]

\[
R_n := \min (1.5 \cdot l_c \cdot t \cdot F_u, 3.0 \cdot d \cdot t \cdot F_u) = 2.991 \times 10^4 \text{ lbf}
\]

\[
\frac{R_n}{\Omega} = 1.495 \times 10^4 \text{ lbf}
\]
8.1.4 Allowable Load on the Hoist Rings

The hoist rings are Actek hoist rings part numbers 46802 and 46644, (Attachment 2). These hoist rings are rated to 15,000 lbs and 2,500 lbs respectively with a safety factor of five (Attachment 2).

\[ F_{a.46802} := 15000 \text{ lbf} \]

Hoist Ring Allowable Strength (Attachment 2).

\[ F_{a.46644} := 2500 \text{ lbf} \]

Hoist Ring Allowable Strength (Attachment 2).

The 46802 hoist rings are screwed in to the bottom plate (2” thick [Ref A1]) and the 46644 hoist rings are screwed in to the sliding plates (1” thick [Ref A1]), and the top of the spray ring (1/2” thick [Ref A1]).

\[ d_{46802} := \frac{1}{4} \text{ in} \]

Thread diameter of the 46802 hoist ring

[Attachment 2]

\[ d_{46644} := \frac{1}{2} \text{ in} \]

Thread diameter of the 46644 hoist ring

[Attachment 2]

\[ p_{r46802} := 1.89 \text{ in} \]

Thread protrusion of the 46802 hoist ring

[Attachment 2]

\[ p_{r46644} := 0.78 \text{ in} \]

Thread protrusion of the 46644 hoist ring

[Attachment 2]

\[ t_{\text{plate}} := \begin{pmatrix} 2 \text{ in} \\ 1 \text{ in} \\ \frac{1}{2} \text{ in} \end{pmatrix} \]

Plate thickness the hoist rings screw in to (bottom plate, sliding plate, and spray ring) [Ref A1]

\[
\begin{align*}
t_{\text{req}} := & \begin{cases} 
\max(p_{r46802}, 1.5 \cdot d_{46802}) & \text{if } t_{\text{plate}} \geq t_{\text{req}} \\
\max(p_{r46644}, 1.5 \cdot d_{46644}) & \text{otherwise}
\end{cases} \\
& = \begin{cases} 
1.89 \text{ in} & \text{if } t_{\text{plate}} \geq t_{\text{req}} \\
0.78 \text{ in} & \text{otherwise}
\end{cases}
\end{align*}
\]

Required material thicknesses

\[
\text{Check} := \begin{cases} 
\text{"Bottom Plate OK" if } t_{\text{plate}} \geq t_{\text{req}} \\
\text{"Evaluate Bottom Plate Engagement" otherwise} \\
\text{"Sliding Plate OK" if } t_{\text{plate}} \geq t_{\text{req}} \\
\text{"Evaluate Sliding Plate Engagement" otherwise} \\
\text{"Spray Ring Plate Plate OK" if } t_{\text{plate}} \geq t_{\text{req}} \\
\text{"Evaluate Spray Ring Plate Engagement" otherwise}
\end{cases} \]

\[ = \begin{cases} 
\text{"Bottom Plate OK"} \\
\text{"Sliding Plate OK"} \\
\text{"Evaluate Spray Ring Plate Engagement"}
\end{cases} \]
From the above check, the spray ring plates do not meet the thickness requirement for the hoist ring attachment. The thread strength of the spray ring plate is evaluated below to confirm it is acceptable for lifting.

\[ d_{\min} = 0.4876 \text{in} \]

Minimum major diameter of external thread [Ref B6, Table 2]

\[ D_{\text{max}} = 0.4565 \text{in} \]

Maximum pitch diameter of internal thread [Ref B6, Table 2]

\[ n = \frac{3}{\text{in}} - 1 \]

Number of thread per inch for a 1/2" screw diameter [Ref B6, Table 2]

\[ D = \frac{1}{2} \text{in} \]

Nominal screw diameter

Minimum screw material tensile strength (Per Attachment 1, Ateck hoist rings are typically used in material with a tensile strength of 80,000 psi. As a material with this strength does not require an increased screw protrusion length, this value is used as the screw tensile strength).

\[ S_{\text{screw}} = 80 \text{ ksi} \]

Minimum tensile strength of ASTM A36 base material [Design Input 2]

\[ S_{\text{base}} = 58 \text{ ksi} \]

Calculate the allowable screw load using the given screw tensile strength and the nominal screw diameter:

\[ A_s \approx \frac{\pi}{4} \left( D - \frac{0.9743}{n} \right)^2 = 0.142 \text{ in}^2 \]

Tensile stress area equation from Section B-1 [ASME B1.1, Appendix B, Ref. B6].

\[ P_{\text{screw}} = S_{\text{screw}} A_s = 11.352 \text{ kip} \]

Tensile strength of screw from Section B-3 [ASME B1.1, Appendix B, Ref. B6].

\[ \frac{V_{\text{threads}}}{0.5 S_{\text{base}}} \]

Internal thread shear strength from Section B-3 [ASME B1.1, Appendix B, Ref. B6].
Using the two equations above and the first equation in Section B-2 [ASME B1.1, Appendix B, Ref. B6] calculate the required thread engagement for the internal thread when its shear strength \( V_{\text{threads}} \) is equal to the screw strength \( P_{\text{screw}} \):

\[
LE := \frac{P_{\text{screw}}}{0.5 \cdot S_{\text{base}}} = 0.348 \text{ in}
\]

Check if the required thread engagement is less than or equal to the given thread protrusion length for the #46644 Actek Swivel Hoist Ring (Attachment 2):

\[
\text{Check}_{LE} := \text{if}(LE \leq t_{\text{plate}}_3, \text{"Okay"}, \text{"Not Okay"}) = \text{"Okay"}
\]

The hoist rings can be used at their full strength.
8.2 Operational Evaluation of the Work Platform

8.2.1 Complete Work Platform Geometry

The Work Platform geometry is imported from the Solidworks model which was used to generate the drawing [Ref A1]. The surfaces of the solid parts are selected as shell elements for the FEM. Shell thicknesses are assigned in ANSYS and shown below in Figure 8-1 and Figure 8-2. The shell offset effects are shown in the mesh by displaying the shell elements as solids in Figure 8-3 and Figure 8-4. Note that the model nomenclature doesn’t exactly match the drawing nomenclature. This is due to naming in the model to help identify parts and abbreviate names.
Figure 8-1. Work Platform Shell Thickness View 1
Figure 8-3. Work Platform Mesh Side View
Figure 8-4. Work Platform Mesh Isometric View
8.2.2 Complete Work Platform Model Contacts

The Work Platform consists of 6 multi-body parts: the Base, Platform1, Platform2, Ring1, Ring2, and Top Hat. These parts are shown below in Figure 8-5. Where the bodies within the individual parts touch, they are bonded to each other. The other connections are shown and discussed below.
Title: AX Farm Spray Ring Type 1 Lifting and Operational Evaluation

Prepared By: T. F. Schmitt  Date: 10/10/17  Checked By: G. D. Lawrence  Date: 10/10/17

Figure 8-5. Work Platform Multibody Parts in ANSYS
As a conservative model, the spray ring halves are only held together at the bolt hole locations as shown below in Figure 8-6. This means the entire load transmitted between the spray ring halves is transmitted through the bolts in the model. Joints are used to simulate a typical hand calculation which only considers forces transmitted through each bolt.

**Figure 8-6. Spray Ring Bolt Contacts**

The top hat is attached to the spray ring at the bolt holes as shown in Figure 8-7. This means the entire load transmitted between the spray ring and top hat is transmitted through the bolts in the model.
Figure 8-7. Top Hat Bolt Contacts
The flanges on the spray ring are connected to the work platform using a no separation contact as shown below in Figure 8-8. The spray ring is only supported vertically by the work platforms. At the pin locations, the spray ring is bonded to the work platform to transmit lateral loads between the parts as shown in Figure 8-9.

Figure 8-8. Work Platform to Spray Ring No Separation Contact
Figure 8-9. Work Platform to Spray Ring Bonded Contact at Pin Locations
At the roller locations, the holes in the side plates are attached to the angle track or the base at the bearing area as used in the AISC [Ref B3] analysis for bearing. Translations in the x direction and rotations are free on all rollers. Translation in the z direction is also free on the flat rollers. The contact locations are shown below in Figure 8-10.
To keep the work platforms from rolling, pins go through the roller bars to the vertical bars mounted to the base. At these pin locations, translation is restrained in the x direction in the FEM. These locations are shown below in Figure 8-11.

Figure 8-11. Work Platform Pin Locations
8.2.3 Operational Model Restraints

The work platform sits on top of the pit. To simulate this for the operational case, an imprint of the pit wall is imprinted on the base of the work platform and is restrained vertically. The support location is shown below in a top view in Figure 8-12 with the rolling platforms hidden for clarity.
To stabilize the model for analysis, the centerlines of the base are restrained for translation as shown below in Figure 8-13 with the rolling platforms hidden for clarity.

**Figure 8-13. Base Centerline Restraints**
8.2.4 Operational Model Loads

For loading on the operational model, the mass of the equipment [Design Input 8], workers [Design Input 9], and handrails (which aren’t modeled) [Design Input 11] are attached to surfaces as shown below in Figure 8-14. The equipment load is eccentrically loaded to match the equipment in this scenario. This is consistent with most of the equipment as the pump heads are not directly in line with the piping. As a bounding condition, the worker load is placed on one roller platform. The largest platform produces the highest stress and roller loading, so it is used for analysis.
Figure 8-14. Applied Masses to the Operational Model
The model is loaded with an acceleration applied to the shell element masses and the added distributed loads discussed above. Similar to the lifting methodology as discussed in Section 2.1.1, 5% is added to the gravitational acceleration loading to account for miscellaneous weight. The applied acceleration is shown below in Figure 8-15.

**Figure 8-15. Applied Acceleration to the Operational Model**
8.2.5 Operational Model FEA Results

Results from the finite element analysis are shown below in this section. The allowable stress was calculated in Section 8.1.2. As can be seen in the image, most of the work platform is well below the allowable stress. The areas of high stress are in discontinuity areas where detailed modeling is required for meaningful results. These two main areas are the roller connections and the bolted connections between the spray ring halves. The forces from the model are extracted at these locations and evaluated below.

![Figure 8-16. Operating Condition Stress Results](image)

The allowable stress is 21,543 psi as calculated in Section 8.1.2. The DCR for the stress is 0.82. A more detailed view of the cross section is shown below in Figure 8-17.
Figure 8-17. Operating Condition Stress Results Cross Section
The roller loads are shown below in Table 8-1.

<table>
<thead>
<tr>
<th></th>
<th>Vertical Force</th>
<th>Maximum Vertical Force</th>
<th>Lateral Force</th>
<th>Maximum Lateral Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vee Roller</td>
<td>76</td>
<td>3,042</td>
<td>1,334</td>
<td>1,704</td>
</tr>
<tr>
<td>Vee Roller</td>
<td>3,042</td>
<td></td>
<td>1,085</td>
<td></td>
</tr>
<tr>
<td>Vee Roller</td>
<td>2,803</td>
<td></td>
<td>1,704</td>
<td></td>
</tr>
<tr>
<td>Vee Roller</td>
<td>1,585</td>
<td></td>
<td>1,454</td>
<td></td>
</tr>
<tr>
<td>Flat Roller</td>
<td>1,821</td>
<td>2,555</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Flat Roller</td>
<td>2,222</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Flat Roller</td>
<td>2,555</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Flat Roller</td>
<td>256</td>
<td></td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

As calculated in Section 8.1.1, the allowable vertical load is 4,299 lbs for the plain end roller and 3,120 lbs for the v-groove roller, and the allowable lateral load is 3,150 lbs for the v-groove roller. This gives a maximum DCR on the rollers of 0.98.

The loads on the bolts holding the spray ring halves are listed below in Table 8-2.

<table>
<thead>
<tr>
<th></th>
<th>Force X</th>
<th>Force Y</th>
<th>Shear Force</th>
<th>Force Z / Tensile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolt 1</td>
<td>69</td>
<td>538</td>
<td>543</td>
<td>241</td>
</tr>
<tr>
<td>Bolt 2</td>
<td>4</td>
<td>945</td>
<td>945</td>
<td>1,633</td>
</tr>
<tr>
<td>Bolt 3</td>
<td>125</td>
<td>443</td>
<td>461</td>
<td>526</td>
</tr>
<tr>
<td>Bolt 4</td>
<td>107</td>
<td>816</td>
<td>823</td>
<td>115</td>
</tr>
<tr>
<td>Bolt 5</td>
<td>65</td>
<td>85</td>
<td>107</td>
<td>347</td>
</tr>
<tr>
<td>Bolt 6</td>
<td>41</td>
<td>523</td>
<td>525</td>
<td>1,983</td>
</tr>
<tr>
<td>Bolt 7</td>
<td>35</td>
<td>60</td>
<td>69</td>
<td>1,897</td>
</tr>
<tr>
<td>Bolt 8</td>
<td>49</td>
<td>393</td>
<td>396</td>
<td>992</td>
</tr>
</tbody>
</table>
\[ \frac{R_n}{\Omega} = 3.394 \times 10^3 \text{ lbf} \]

Allowable shear strength of 1/2 in bolt (Calculated in Section 8.1.3)

\[ F_{nt} = 90 \text{ ksi} \]

Nominal tensile stress [Design Input 12]

\[ F_{nv} = 54 \text{ ksi} \]

Nominal shear stress [Design Input 12]

\[ A_b := 0.1257 \text{ in}^2 \]

Nominal unthreaded bode area of 1/2 inch bolt (conservatively, the root area is used) [Ref B6, Table 6]

\[ \begin{bmatrix} 543 \\ 945 \\ 461 \\ 823 \\ 107 \\ 525 \\ 69 \\ 396 \end{bmatrix} \text{ lbf} \]

Shear load on the bolts

\[ f_v := \begin{bmatrix} 0.16 \\ 0.278 \\ 0.136 \\ 0.242 \\ 0.032 \\ 0.155 \\ 0.02 \\ 0.117 \end{bmatrix} \]

DCRs for bolts in shear

\[ \text{max}(DCR_v) = 0.28 \]

Maximum DCR in shear
\[
\begin{align*}
\sigma_{\text{rv}} &:= \frac{\sigma_v}{A_b} \quad \text{ksi} \\
\text{Required shear stress} &:= \begin{pmatrix} 4.32 \\ 7.518 \\ 3.667 \\ 6.547 \\ 0.851 \\ 4.177 \\ 0.549 \\ 3.15 \end{pmatrix} \\
F'_{nt} &:= \begin{cases} 
\text{for } i \in 1\ldots \text{rows} (\sigma_v) \\
A_i &\leftarrow \min \left( 1.3 \cdot F_{nt} - \frac{\Omega \cdot F_{nt}}{F_{nv} \cdot f_{rv} \cdot F_{nt}} \right) \\
A &\leftarrow \frac{90}{90} 
\end{cases} \quad \text{ksi} \\
\text{Nominal tensile stress modified to include the effects of shear stress} &:= \begin{pmatrix} 90 \\ 90 \\ 90 \\ 90 \\ 90 \end{pmatrix} \\
R_n &:= F'_{nt} A_b \quad \text{lbf} \\
\text{Available tensile strength of the bolt} &:= \begin{pmatrix} 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \end{pmatrix}
\end{align*}
\]
\[
\frac{R_n}{\Omega} = \begin{pmatrix}
5.657 \times 10^3 \\
5.657 \times 10^3 \\
5.657 \times 10^3 \\
5.657 \times 10^3 \\
5.657 \times 10^3 \\
5.657 \times 10^3 \\
5.657 \times 10^3 \\
5.657 \times 10^3 \\
5.657 \times 10^3 \\
\end{pmatrix}
\text{lb}_f
\]

Allowable tensile strength of 1/2 in bolt [Ref B3, pg. 16.1-125]

\[
f_t := \begin{pmatrix}
241 \\
1633 \\
526 \\
347 \\
1983 \\
1897 \\
992 \\
\end{pmatrix}
\text{lb}_f
\]

Tensile load on the bolts

\[
\text{DCR}_t := \frac{f_t}{R_n} = \begin{pmatrix}
0.043 \\
0.289 \\
0.093 \\
0.02 \\
0.061 \\
0.351 \\
0.335 \\
0.175 \\
\end{pmatrix}
\]

DCRs for bolts in tension (with account for shear)

\[
\max(\text{DCR}_t) = 0.35
\]

Maximum DCR in tension (with account for shear)
Bearing Stress at Bolt Holes

\[ \frac{R_n}{\Omega} = 1.495 \times 10^4 \text{lbf} \]

Available bearing strength at a bolt hole (Calculated in Section 8.1.3)

\[ f_v = \begin{pmatrix} 543 \\ 945 \\ 461 \\ 823 \\ 107 \\ 525 \\ 69 \\ 396 \end{pmatrix} \text{lbf} \]

Shear load on the bolts

\[ \text{DCR}_v := \frac{f_v}{\frac{R_n}{\Omega}} = \begin{pmatrix} 0.036 \\ 0.063 \\ 0.031 \\ 0.055 \\ 0.007 \\ 0.035 \\ 0.005 \\ 0.026 \end{pmatrix} \]

DCRs for bolt holes in bearing

\[ \max(\text{DCR}_v) = 0.06 \]

Maximum DCR for bolt holes in bearing
8.3 Lifting Evaluation of the Work Platform

8.3.1 Complete Work Platform Geometry

The work platform geometry is the same as described in Section 8.2.1.

8.3.2 Complete Work Platform Model Contacts

The work platform contacts are the same as described in Section 8.2.2.

8.3.3 Lifting Complete Work Platform Model Restraints

The work platform is supported by slings at the minimum specified 45° angle. To simulate this for the lifting case, 4 stiff springs are attached to the lifting points as shown below in Figure 8-18. The entire platform is considered for lifting as a bounding case to bringing in or removing the spray ring and rolling plates separately.

Figure 8-18. Sling Attachment to Complete Work Platform
To stabilize the model for analysis, the centerlines of the base are restrained for translation as shown below in Figure 8-19 with the rolling platforms hidden for clarity.

**Figure 8-19. Base Centerline Restraints**
8.3.4 Complete Lifting Model Loads

For loading on the operational model, the mass of the handrails (which aren’t modeled) [Design Input 11] are attached to surfaces as shown below in Figure 8-20.

![Handrail Diagram]

**Figure 8-20. Applied Masses to the Lifting Model**
The model is loaded with an acceleration applied to the shell element masses and the added distributed load discussed above. Lifting methodology as discussed in section 2.1.1, 5% is added to the gravitational acceleration loading to account for miscellaneous weight and a 25% dynamic factor is applied. The applied acceleration is shown below in Figure 8-21.

Figure 8-21. Applied Acceleration to the Operational Model
### 8.3.5 Complete Platform Lift Model FEA Results

Results from the finite element analysis are shown below in this section. The allowable stress was calculated in Section 8.1.2. As can be seen in the image, most of the work platform is well below the allowable stress.

![FEA Results](image)

**Figure 8-22. Complete Lift Stress Results**

The allowable stress is 21,543 psi as calculated in Section 8.1.2. The DCR for the stress is 0.74.

The sling / lift ring loads are shown below in Table 8-3.

<table>
<thead>
<tr>
<th>Sling 1 Force</th>
<th>Sling 2 Force</th>
<th>Sling 3 Force</th>
<th>Sling 4 Force</th>
<th>Max Design Force</th>
<th>Ring Allowable</th>
<th>DCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,779</td>
<td>10,808</td>
<td>10,118</td>
<td>10,120</td>
<td>14,411</td>
<td>15,000</td>
<td>0.96</td>
</tr>
</tbody>
</table>

The platform is acceptable to be lifted with a sling angle of 45°. To add an additional factor of safety, the sling angle is specified to be 60° minimum on Drawing H-14-110683 [Ref A1]. This will ensure a DCR well below 0.9.
The loads on the bolts holding the spray ring halves are listed below in Table 8-4.

### Table 8-4. Operational Loads on the Spray Ring Bolts (lbf)

<table>
<thead>
<tr>
<th></th>
<th>Force X</th>
<th>Force Y</th>
<th>Shear Force</th>
<th>Force Z / Tensile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolt 1</td>
<td>37</td>
<td>308</td>
<td>310</td>
<td>123</td>
</tr>
<tr>
<td>Bolt 2</td>
<td>14</td>
<td>557</td>
<td>557</td>
<td>1,128</td>
</tr>
<tr>
<td>Bolt 3</td>
<td>107</td>
<td>350</td>
<td>366</td>
<td>304</td>
</tr>
<tr>
<td>Bolt 4</td>
<td>88</td>
<td>639</td>
<td>645</td>
<td>69</td>
</tr>
<tr>
<td>Bolt 5</td>
<td>49</td>
<td>69</td>
<td>84</td>
<td>188</td>
</tr>
<tr>
<td>Bolt 6</td>
<td>34</td>
<td>372</td>
<td>374</td>
<td>1,187</td>
</tr>
<tr>
<td>Bolt 7</td>
<td>72</td>
<td>76</td>
<td>105</td>
<td>1,368</td>
</tr>
<tr>
<td>Bolt 8</td>
<td>1</td>
<td>449</td>
<td>449</td>
<td>736</td>
</tr>
</tbody>
</table>
Allowable shear strength of 1/2 in bolt (Calculated in Section 8.1.3)

Nominal tensile stress [Design Input 12]

Nominal shear stress [Design Input 12]

Nominal unthreaded bode area of 1/2 inch bolt (conservatively, the root area is used) [Ref B6, Table 6]

Shear load on the bolts

DCRs for bolts in shear

Maximum DCR in shear
\[
f_{rv} := \frac{f_v}{A_b} = \begin{pmatrix} 2.466 \\ 4.431 \\ 2.912 \\ 5.131 \\ 0.668 \\ 2.975 \\ 0.835 \\ 3.572 \end{pmatrix} \text{ksi}
\]

\[
f_{rv} := \frac{f_v}{A_b} = \begin{pmatrix} 90 \\ 90 \\ 90 \\ 90 \end{pmatrix} \text{ksi}
\]

\[
F'_{nt} := \begin{cases} f_v & \text{for } i \ in \ 1 \ to \ \text{rows} \ (f_v) \\ \text{for } i \ in \ 1 \ to \ \text{rows} \ (f_v) \end{cases} 
\]

\[
A_i \leftarrow \min \left( 1.3 \cdot F_{nt} - \frac{\Omega \cdot F_{nt}}{F_{nv} \cdot f_{rv} \cdot F_{nt}} \right) 
\]

\[
R_n := F'_{nt} A_b = \begin{pmatrix} 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \end{pmatrix} \text{lbf}
\]

\[
\text{Nominal tensile stress modified to include the effects of shear stress [Ref B3, pg. 16.1-125]}
\]

\[
\text{Available tensile strength of the bolt [Ref B3, pg. 16.1-125]}
\]
\[
\frac{R_n}{\Omega} = \begin{pmatrix}
5.657 \times 10^3 \\
5.657 \times 10^3 \\
5.657 \times 10^3 \\
5.657 \times 10^3 \\
5.657 \times 10^3 \\
5.657 \times 10^3 \\
5.657 \times 10^3 \\
5.657 \times 10^3 \\
\end{pmatrix} \text{ lbf}
\]

Allowable tensile strength of 1/2 in bolt [Ref B3, pg. 16.1-125]

\[
f_t := \begin{pmatrix}
123 \\
1128 \\
304 \\
69 \\
188 \\
1187 \\
1368 \\
736 \\
\end{pmatrix} \text{ lbf}
\]

Tensile load on the bolts

\[
\text{DCR}_t := \frac{f_t - R_n}{\Omega} = \begin{pmatrix}
0.022 \\
0.199 \\
0.054 \\
0.012 \\
0.033 \\
0.21 \\
0.242 \\
0.13 \\
\end{pmatrix}
\]

DCRs for bolts in tension (with account for shear)

\[
\text{max(DCR}_t) = 0.24
\]

Maximum DCR in tension (with account for shear)
Bearing Stress at Bolt Holes

\[
\frac{R_n}{\Omega} = 1.495 \times 10^4 \text{lbf}
\]

Available bearing strength at a bolt hole (Calculated in Section 8.1.3)

\[
f_v = \begin{pmatrix}
310 \\
557 \\
366 \\
645 \\
84 \\
374 \\
105 \\
449 \\
\end{pmatrix} \text{lbf}
\]

Shear load on the bolts

\[
\text{DCR}_v := \frac{f_v}{\frac{R_n}{\Omega}} = \begin{pmatrix}
0.021 \\
0.037 \\
0.024 \\
0.043 \\
5.618 \times 10^{-3} \\
0.025 \\
7.022 \times 10^{-3} \\
0.03 \\
\end{pmatrix}
\]

DCRs for bolt holes in bearing

\[
\max(\text{DCR}_v) = 0.04
\]

Maximum DCR for bolt holes in bearing
8.4 Vertical Lifting of the Complete Spray Ring

8.4.1 Complete Spray Ring Geometry

The work platform geometry is the same as described in Section 8.2.1 except all parts except the spray ring are suppressed. The geometry used in the analysis is shown below in Figure 8-23. The mesh can be seen in Figure 8-24.

![Complete Spray Ring Shell Thickness](image)

**Figure 8-23. Complete Spray Ring Shell Thickness**
Figure 8-24. Spray Ring Mesh Isometric View
### 8.4.2 Complete Work Platform Model Contacts

The work platform contacts are the same as described in Section 8.2.2 for the bodies shown. This includes the two spray ring halves as multibody parts and the bolts connecting the spray ring halves.

### 8.4.3 Complete Spray Ring Lifting Restraints

The work platform is supported by slings at the minimum specified 45° angle. To simulate this for the lifting case, 4 stiff springs are attached to the lifting points as shown below in Figure 8-25. When compared to lifting half of a spray ring, the slings are out of plane with the 4 lifting points on the complete spray ring. Also, the load is factored to account for support from only 3 lift points. Therefore, analysis of the complete spray ring is bounding of the vertical lift of a spray ring half.

**Figure 8-25. Sling Attachment to Complete Spray Ring**

![Diagram of Sling Attachment to Complete Spray Ring]
To stabilize the model for analysis, the centerlines of the spray ring are restrained for translation as shown below in Figure 8-26.

Figure 8-26. Complete Spray Ring Centerline Restraints
8.4.4 Complete Spray Ring Lifting Loads

The model is loaded with an acceleration applied to the shell element masses. Lifting methodology as discussed in section 2.1.1, 5% is added to the gravitational acceleration loading to account for miscellaneous weight and a 25% dynamic factor is applied. The applied acceleration is shown below in Figure 8-27.

Figure 8-27. Applied Acceleration to the Complete Spray Ring Vertical Lift Model
8.4.5 Complete Spray Ring Lift Model FEA Results

Results from the finite element analysis are shown below in this section. The allowable stress was calculated in Section 8.1.2. As can be seen in Figure 8-22 most of the spray ring has calculated stress well below the allowable stress. The small area of high stress is due to the local discontinuity of the sling attachment. The stress value near the discontinuity is probed to compare to the allowable stress.

![ANSYS R16.0 Diagram]

Figure 8-28. Complete Lift Stress Results

The allowable stress is 21,543 psi as calculated in Section 8.1.2. The DCR for the stress is 0.62.

The sling / lift ring loads are shown below in Table 8-5.

### Table 8-5. Complete Spray Ring Lifting Sling Loads (lbf)

<table>
<thead>
<tr>
<th>Sling 1 Force</th>
<th>Sling 2 Force</th>
<th>Sling 3 Force</th>
<th>Sling 4 Force</th>
<th>Max Design Force</th>
<th>Ring Allowable</th>
<th>DCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,248</td>
<td>1,247</td>
<td>1,248</td>
<td>1,248</td>
<td>1,664</td>
<td>2,500</td>
<td>0.67</td>
</tr>
</tbody>
</table>
The loads on the bolts holding the spray ring halves are listed below in Table 8-6.

Table 8-6. Complete Spray Ring Loads on the Spray Ring Bolts (lb)

<table>
<thead>
<tr>
<th>Bolt</th>
<th>Force X</th>
<th>Force Y</th>
<th>Shear Force</th>
<th>Force Z / Tensile</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>201</td>
<td>612</td>
<td>644</td>
<td>463</td>
</tr>
<tr>
<td>2</td>
<td>342</td>
<td>624</td>
<td>711</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>47</td>
<td>756</td>
<td>758</td>
<td>307</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>467</td>
<td>467</td>
<td>33</td>
</tr>
<tr>
<td>5</td>
<td>206</td>
<td>631</td>
<td>664</td>
<td>453</td>
</tr>
<tr>
<td>6</td>
<td>373</td>
<td>580</td>
<td>689</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>32</td>
<td>752</td>
<td>753</td>
<td>311</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>471</td>
<td>471</td>
<td>37</td>
</tr>
</tbody>
</table>
\[
R_n = 3.394 \times 10^3 \text{lbf}
\]
Allowable shear strength of 1/2 in bolt (Calculated in Section 8.1.3)

\[F_{nt} = 90 \text{ ksi}\]
Nominal tensile stress [Design Input 12]

\[F_{nv} = 54 \text{ ksi}\]
Nominal shear stress [Design Input 12]

\[A_b := 0.1257 \text{in}^2\]
Nominal unthreaded bore area of 1/2 inch bolt (conservatively, the root area is used) [Ref B6, Table 6]

\[
\begin{bmatrix}
644 \\
711 \\
758
\end{bmatrix}
\]
Shear load on the bolts

\[
\begin{bmatrix}
467 \\
664 \\
689 \\
753 \\
471
\end{bmatrix}
\]

\[
\frac{f_v}{\Omega} = DCR_v
\]
DCRs for bolts in shear

\[
\max(DCR_v) = 0.22
\]
Maximum DCR in shear
\[
f_{rv} := \frac{f_v}{A_b} = \begin{pmatrix} 5.123 \\ 5.656 \\ 6.03 \\ 3.715 \\ 5.282 \\ 5.481 \\ 5.99 \\ 3.747 \end{pmatrix} \text{ksi} \quad \text{Required shear stress}
\]

\[
F'_{nt} := \text{for } i = 1 \ldots \text{rows}(f_v) \\
A_i \left\{ \begin{array}{l}
\text{min} \left( 1.3 \cdot F_{nt} - \frac{\Omega \cdot F_{nt}}{F_{nv}} \cdot f_{rv} \cdot F_{nt} \right) \\
\end{array} \right\} \\
A \quad \text{ksi} \quad \text{Nominal tensile stress modified to include the effects of shear stress [Ref B3, pg. 16.1-125]}
\]

\[
R_n := F'_{nt} A_b = \begin{pmatrix} 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \\ 1.131 \times 10^4 \end{pmatrix} \text{lbf} \quad \text{Available tensile strength of the bolt [Ref B3, pg. 16.1-125]}
\]
\[
\frac{R_n}{\Omega} = \begin{bmatrix}
5.65 \times 10^3 \\
5.65 \times 10^3 \\
5.65 \times 10^3 \\
5.65 \times 10^3 \\
5.65 \times 10^3 \\
5.65 \times 10^3 \\
5.65 \times 10^3 \\
5.65 \times 10^3 \\
5.65 \times 10^3 
\end{bmatrix} \text{ lbf}
\]

Allowable tensile strength of 1/2 in bolt [Ref B3, pg. 16.1-125]

\[
f_t := \begin{bmatrix}
463 \\
11 \\
307 \\
33 \\
453 \\
4 \\
311 \\
37
\end{bmatrix} \text{ lbf}
\]

Tensile load on the bolts

\[
\text{DCR}_t := \frac{f_t}{\frac{R_n}{\Omega}} = \begin{bmatrix}
0.082 \\
1.945 \times 10^{-3} \\
0.054 \\
5.834 \times 10^{-3} \\
0.08 \\
7.072 \times 10^{-4} \\
0.055 \\
6.541 \times 10^{-3}
\end{bmatrix}
\]

DCRs for bolts in tension (with account for shear)

\[\max(\text{DCR}_t) = 0.08\]

Maximum DCR in tension (with account for shear)
**Bearing Stress at Bolt Holes**

\[
\frac{R_n}{\Omega} = 1.495 \times 10^4 \text{lbf}
\]

Available bearing strength at a bolt hole (Calculated in Section 8.1.3)

\[
\begin{pmatrix}
644 \\
711 \\
758 \\
646 \\
664 \\
689 \\
753 \\
471
\end{pmatrix}
\]

\[f_v = \begin{pmatrix}
644 \\
711 \\
758 \\
646 \\
664 \\
689 \\
753 \\
471
\end{pmatrix} \text{lbf}
\]

Shear load on the bolts

\[
D\text{CR}_v := \frac{f_v}{\frac{R_n}{\Omega}} = \begin{pmatrix}
0.043 \\
0.048 \\
0.051 \\
0.031 \\
0.044 \\
0.046 \\
0.05 \\
0.031
\end{pmatrix}
\]

DCR for bolt holes in bearing

\[\max(D\text{CR}_v) = 0.05\]

Maximum DCR for bolt holes in bearing
8.5 Horizontal Lifting the Complete Spray Ring

8.5.1 Complete Spray Ring Geometry

The spray ring geometry is the same as described in Section 8.4.1.

8.5.2 Complete Work Platform Model Contacts

The work platform contacts are the same as described in Section 8.4.2.

8.5.3 Complete Spray Ring Lifting Restraints

The work platform is supported by slings at the minimum specified 45° angle. To simulate this for the lifting case, 2 stiff springs are attached to the lifting points and the tip of one fin is restrained vertically (and in the y direction for model stability) as shown below in Figure 8-29. Note that the weight of both spray rings bounds the case of a spray ring half being lifted alone.

![Diagram of spray ring with sling attachment and point support](image)

**Figure 8-29. Sling Attachment and Point Support for Complete Spray Ring Horizontal Lift**
To stabilize the model for analysis, the centerline of the spray ring is restrained for translation as shown below in Figure 8-30.

**Figure 8-30. Complete Spray Ring Centerline Restraint for Horizontal Lift**
8.5.4 Complete Spray Ring Lifting Loads

The model is loaded with an acceleration applied to the shell element masses. Lifting methodology as discussed in section 2.1.1, 5% is added to the gravitational acceleration loading to account for miscellaneous weight and a 25% dynamic factor is applied. The applied acceleration is shown below in Figure 8-31.
8.5.5 Complete Spray Ring Lift Model FEA Results

Results from the finite element analysis are shown below in this section. The allowable stress was calculated in Section 8.1.2. As can be seen in Figure 8-32, the entire spray ring is well below the allowed stress.

![Complete Spray Ring Horizontal Lift](image)

**Figure 8-32. Complete Spray Ring Horizontal Lift Stress Results**

The allowable stress is 21,543 psi as calculated in Section 8.1.2. The DCR for the stress is 0.47.

The sling / lift ring loads are shown below in Table 8-7.

<table>
<thead>
<tr>
<th>Sling 1 Force</th>
<th>Sling 2 Force</th>
<th>Ring Allowable</th>
<th>DCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,197</td>
<td>2,197</td>
<td>2,500</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Table 8-7. Complete Spray Ring Lifting Sling Loads (lbf)
The loads on the bolts holding the spray ring halves are listed below in Table 8-8.

Table 8-8. Complete Spray Ring Loads on the Spray Ring Bolts (lbf)

<table>
<thead>
<tr>
<th>Bolt</th>
<th>Force X</th>
<th>Force Y</th>
<th>Shear Force</th>
<th>Force Z / Tensile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolt 1</td>
<td>161</td>
<td>116</td>
<td>198</td>
<td>554</td>
</tr>
<tr>
<td>Bolt 2</td>
<td>78</td>
<td>66</td>
<td>102</td>
<td>1,091</td>
</tr>
<tr>
<td>Bolt 3</td>
<td>60</td>
<td>191</td>
<td>200</td>
<td>891</td>
</tr>
<tr>
<td>Bolt 4</td>
<td>112</td>
<td>170</td>
<td>204</td>
<td>363</td>
</tr>
<tr>
<td>Bolt 5</td>
<td>176</td>
<td>113</td>
<td>209</td>
<td>564</td>
</tr>
<tr>
<td>Bolt 6</td>
<td>111</td>
<td>46</td>
<td>120</td>
<td>1,095</td>
</tr>
<tr>
<td>Bolt 7</td>
<td>86</td>
<td>174</td>
<td>194</td>
<td>923</td>
</tr>
<tr>
<td>Bolt 8</td>
<td>118</td>
<td>172</td>
<td>209</td>
<td>376</td>
</tr>
</tbody>
</table>
\[ R_n = 3.394 \times 10^3 \text{lbf} \]

Allowable shear strength of 1/2 in bolt (Calculated in Section 8.1.3)

\[ F_{nt} = 90 \text{ ksi} \]

Nominal tensile stress [Design Input 12]

\[ F_{nv} = 54 \text{ ksi} \]

Nominal shear stress [Design Input 12]

\[ A_b = 0.1257\text{in}^2 \]

Nominal unthreaded bode area of 1/2 inch bolt (conservatively, the root area is used) [Ref B6, Table 6]

\[ f_v = \begin{bmatrix} 198 \\ 102 \\ 200 \\ 204 \\ 209 \\ 120 \\ 194 \\ 209 \end{bmatrix} \text{lbf} \]

Shear load on the bolts

\[ DCR_v = \frac{f_v}{R_n/\Omega} = \begin{bmatrix} 0.058 \\ 0.03 \\ 0.059 \\ 0.06 \\ 0.062 \\ 0.035 \\ 0.057 \\ 0.062 \end{bmatrix} \]

DCRs for bolts in shear

\[ \max(DCR_v) = 0.06 \]

Maximum DCR in shear

Mathcad
Fr_v := \frac{f_v}{A_b} \text{ ksi}

\[ \begin{align*}
&\begin{pmatrix}1.575 \\
0.811 \\
1.591 \\
1.623 \\
1.663 \\
0.955 \\
1.543 \\
1.663
\end{pmatrix}
\end{align*} \text{ Required shear stress}

\[ F_{nt} := \text{ for } i \in 1..\text{rows}(f_v) \]

\[ A_i \leftarrow \min \left( 1.3 \cdot F_{nt} - \frac{\Omega \cdot F_{nt} \cdot f_{rv} \cdot F_{nt}}{F_{nv}} \right) \]

\[ \frac{1}{A} \]

\[ \begin{align*}
&\begin{pmatrix}90 \\
90 \\
90 \\
90 \\
90 \\
90 \\
90
\end{pmatrix} \text{ ksi}
\end{align*} \text{ Nominal tensile stress modified to include the effects of shear stress [Ref B3, pg. 16.1-125]}

\[ R_n := F_{nt} A_b = \begin{pmatrix}1.131 \times 10^4 \\
1.131 \times 10^4 \\
1.131 \times 10^4 \\
1.131 \times 10^4 \\
1.131 \times 10^4 \\
1.131 \times 10^4 \\
1.131 \times 10^4
\end{pmatrix} \text{ lbf}
\]

\[ \begin{align*}
&\begin{pmatrix}1.131 \times 10^4 \\
1.131 \times 10^4 \\
1.131 \times 10^4 \\
1.131 \times 10^4 \\
1.131 \times 10^4 \\
1.131 \times 10^4 \\
1.131 \times 10^4
\end{pmatrix} \text{ Available tensile strength of the bolt [Ref B3, pg. 16.1-125]}
\]
Allowable tensile strength of 1/2 in bolt [Ref B3, pg. 16.1-125]

Tensile load on the bolts

DCRs for bolts in tension (with account for shear)

Maximum DCR in tension (with account for shear)
Bearing Stress at Bolt Holes

\[
\frac{R_n}{\Omega} = 1.495 \times 10^4 \text{ lbf}
\]

Available bearing strength at a bolt hole (Calculated in Section 8.1.3)

\[
f_v = \begin{bmatrix} 198 \\ 102 \\ 200 \\ 204 \\ 209 \\ 120 \\ 194 \\ 209 \end{bmatrix} \text{ lbf}
\]

Shear load on the bolts

\[
\text{DCR}_v := \frac{f_v}{\frac{R_n}{\Omega}} = \begin{bmatrix} 6.821 \times 10^{-3} \\ 0.013 \\ 0.014 \\ 8.025 \times 10^{-3} \\ 0.014 \end{bmatrix}
\]

DCRs for bolt holes in bearing

\[
\text{max}(\text{DCR}_v) = 0.01
\]

Maximum DCR for bolt holes in bearing
8.6 Miscellaneous Equipment Evaluations

8.6.1 Handrail Evaluation

Geometric OSHA requirements listed below can be confirmed as being met by inspecting Drawing H-17-110682 [Ref A2]. The work platform falls under the requirements of 29 CFR 1910 Subpart D "Walking-Working Surfaces".

OSHA Requirements [Ref B7]:

- 29 CFR 1910.29(b)(1) The top edge height of top rails, or equivalent guardrail system members, are 42 inches, plus or minus 3 inches, above the walking working surface.
- 29 CFR 1910.29(b)(2)(i) Midrails are installed at a height midway between the top edge of the guardrail system and the walking working surface.
- 29 CFR 1910.29(b)(3) Guardrail systems are capable of withstanding, without failure, a force of at least 200 pounds applied in a downward or outward direction within 2 inches (5 cm) of the top edge, at any point along the top rail.
- 29 CFR 1910.29(b)(4) When the 200-pound test load is applied in a downward direction, the top rail of the guardrail system must not deflect to a height of less than 39 inches above the walking-working surface.
- 29 CFR 1910.29(b)(9) Top rails and midrails are at least 0.25-inches in diameter or in thickness.
- 29 CFR 1910.29(b)(10) When guardrail systems are used at hoist areas, a removable guardrail section, consisting of a top rail and midrail, are placed across the access opening between guardrail sections when employees are not performing hoisting operations. The employer may use chains or gates instead of a removable guardrail section at hoist areas if the employer demonstrates the chains or gates provide a level of safety equivalent to guardrails.

Kee Clamp has performed tests demonstrating the strength of the handrails and fittings [Attachment 5]. The bolts anchoring the handrails are analyzed for the required 200 lb load acting laterally on the weak axis of a single post. The tensile load in the bolts is calculated considering the base prying at its outer edge. Thread engagement in the base plate is also verified.

The temporary chains are available for operations to install as a deterrent from walking near the opened work platform edge. Supplemental fall protection could be required when the work platform is open.

\[
\frac{R_n}{\Omega} = 3.535 \times 10^3 \text{ lbf} \quad \text{Allowable shear strength of 1/2 in bolt (Calculated in Section 8.1.3)}
\]

\[F_{nt} = 93.75 \text{ ksi} \quad \text{Nominal tensile stress [Design Input 14]}\]

\[F_{nv} = 56.25 \text{ ksi} \quad \text{Nominal shear stress [Design Input 14]}\]

\[A_b := 0.1257 \text{in}^2 \quad \text{Nominal unthreaded body area of 1/2 inch bolt (conservatively, the root area is used) [Ref B6, Table 6]}\]

\[N_b := 2 \quad \text{Number of bolts in the base of a handrail post [Attachment 5]}\]

\[F_{hr} := 200 \text{lbf} \quad \text{Design force applied to the top of the handrail [Ref B7, 29 CFR 1910.23(e)(3)(iv)]}\]

\[h_{hr} := 3 \text{ft} + 6 \text{in} \quad \text{Height of the Handrail [Ref A2, H-14-110682, Detail 1]}\]
The analyzed loading on the handrail base is shown in the figure below.

![Handrail Loading Diagram](image)

F<sub>hr</sub> = 200 lbf

t<sub>hr</sub> = 42 in

**Figure 8-33. Handrail Loading**

\[ M_{hr} := h_{hr} \cdot F_{hr} = 8.4 \times 10^3 \text{ in} \cdot \text{lbf} \]

Resultant moment at the base of the handrail post

Considering the handrail prying at the edge, the distance to the 2 bolts resisting the moment is half the "D" dimension shown in Attachment 5.

\[ f_t := \frac{M_{hr}}{N_b \cdot \frac{1}{2} \cdot 3.35 \text{in}} = 2.507 \times 10^3 \text{ lbf} \]

Tensile force on the bolts at the base of the handrail

\[ f_v := \frac{F_{hr}}{N_b} = 100 \text{ lbf} \]

Shear load on the bolts
Shear and Tension on Bolts

\[ DCR_v := \frac{f_v}{R_n} = 0.03 \]  
DCRs for bolts in shear

\[ f_{rv} := \frac{f_v}{A_b} = 0.796 \text{ ksi} \]  
Required shear stress

\[ F'_{nt} := \text{min} \left( 1.3 - 3.16 \frac{\Omega F_{nt}}{F_{nv}}, f_{rv} F_{nt} \right) = 93.75 \text{ ksi} \]  
Nominal tensile stress modified to include the effects of shear stress [Ref B3, pg. 16.1-125]

\[ R_n := F'_{nt} A_b = 1.178 \times 10^4 \text{ lbf} \]  
Available tensile strength of the bolt [Ref B3, pg. 16.1-125]

\[ \Omega = 2 \]  
Safety factor for bolting [Ref B3, pg. 16.1-125]

\[ R_n \frac{\Omega}{\Omega} = 5.892 \times 10^3 \text{ lbf} \]  
Allowable tensile strength of 1/2 in bolt [Ref B3, pg. 16.1-125]

\[ DCR_t := \frac{f_t}{R_n} = 0.43 \]  
DCRs for bolts in tension (with account for shear)

Thread Engagement on Bolts

The thread strength of the bottom plate is evaluated below to confirm it is acceptable.

\[ d_{min} := 0.4876 \text{ in} \]  
Minimum major diameter of 1/2" external thread [Ref B6, Table 2]

\[ D_{2max} := 0.4565 \text{ in} \]  
Maximum pitch diameter of internal 1/2" thread [Ref B6, Table 2]

\[ n := 13 \cdot \text{in}^{-1} \]  
Number of thread per inch for a 1/2" screw diameter [Ref B6, Table 2]

\[ D := \frac{1}{2} \text{ in} \]  
Nominal screw diameter

\[ S_{screw} := 125 \text{ ksi} \]  
Minimum screw material tensile strength [Design Input 14]

\[ S_{base} := 58 \text{ ksi} \]  
Minimum tensile strength of ASTM A36 base material [Design Input 3]

\[ L_{blt} := \frac{1}{2} \text{ in} \]  
Length of bolts [Ref A2, Drawing H-17-110682, BOM Item 13]

\[ t_{wsh} := 0.177 \text{ in} \]  
Maximum 1/2" washer thickness [Ref B8, Table 2]

\[ L_{en} := L_{blt} - 0.39 \text{ in} - t_{wsh} = 0.933 \text{ in} \]  
Length of thread engagement by subtracting base thickness shown in Attachment 5 (dimension "H") and maximum washer thickness
Calculate the allowable screw load using the given screw tensile strength and the nominal screw diameter:

\[
A_s := \frac{\pi}{4} \left[ D - \frac{0.9743}{n} \right]^2 = 0.142 \text{ in}^2
\]

Tensile stress area equation from Section B-1 [ASME B1.1, Appendix B, Ref. B6].

\[
P_{\text{screw}} := S_{\text{screw}} \cdot A_s = 17.737 \text{ kip}
\]

Tensile strength of screw from Section B-3 [ASME B1.1, Appendix B, Ref. B6].

\[
A_{S_n} = \frac{V_{\text{threads}}}{0.5 \cdot S_{\text{base}}}
\]

Internal thread shear strength from Section B-3 [ASME B1.1, Appendix B, Ref. B6].

Using the two equations above and the first equation in Section B-2 [ASME B1.1, Appendix B, Ref. B6] calculate the required thread engagement for the internal thread when its shear strength \(V_{\text{threads}}\) is equal to the screw strength \(P_{\text{screw}}\):

\[
LE := \frac{P_{\text{screw}}}{0.5 \cdot S_{\text{base}}} \cdot \frac{n \cdot \pi \cdot d_{\text{min}}}{2 \cdot n + 0.57735 \cdot (d_{\text{min}} - D_{\text{max}})} = 0.544 \text{ in}
\]

Check if the required thread engagement is less than or equal to the available thread engagement:

\[
\text{Check}_{LE} := \text{if}(LE \leq L_{\text{en}}, \text{"Okay"}, \text{"Not Okay"}) = \text{"Okay"}
\]
8.6.2 Seismic Stop Block Evaluation

All seismic stop block geometry is extracted from the design drawing (H-14-110680, [Ref A4]) unless noted otherwise.

The bottom plate has four seismic stop blocks on its underside to prevent the work platform from sliding into the pit during a seismic event. Conservatively, the entire tool operating weight is placed on one seismic stop block.

The lateral seismic acceleration is conservatively taken as 1.0g.

\[ \text{Lat}_{\text{accel}} := 1.0 \cdot g \]

Lateral Seismic Acceleration [Section 2.2.2].

The FEA model properties are taken from ANSYS which included the worker weight and equipment weight.

<table>
<thead>
<tr>
<th>Object Name</th>
<th>Geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>Fully Defined</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Bounding Box</th>
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<tbody>
<tr>
<td>Length X</td>
<td>201. in</td>
</tr>
<tr>
<td>Length Y</td>
<td>149.25 in</td>
</tr>
<tr>
<td>Length Z</td>
<td>132. in</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Properties</th>
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</thead>
<tbody>
<tr>
<td>Volume</td>
<td>68010 in³</td>
</tr>
<tr>
<td>Mass</td>
<td>25475 lbm</td>
</tr>
<tr>
<td>Surface Area(approx.)</td>
<td>66319 in²</td>
</tr>
</tbody>
</table>

\[ W_{wp,\text{all}} := 25475 \text{ lbm} \]

Approximate weight of the fully loaded work platform for seismic analysis.

\[ F_{SC} := \text{Lat}_{\text{accel}} \cdot W_{wp,\text{all}} = 25475 \text{ lbf} \]

Applied seismic stop block load.
Moment arm length (depth of each seismic stop block).

\[ M_{SC} = F_{SC} \cdot L_{arm} = 5.095 \times 10^4 \text{-in-lbf} \]

Applied moment.

Determine Adequacy of the Rectangular Fillet Weld

The evaluated weld is a rectangle fillet weld connecting the seismic stop blocks to the underside of the tool proper.

**Weld Geometry:**

- **b := 4-in**  
  The width of the weld [DWG H-14-110680 Item 8, Ref A4]
- **d := 4-in**  
  The length of the weld [DWG H-14-110680 Item 8, Ref A4]
- **w_{act} := \frac{5}{16} \text{-in}**  
  The actual weld size [DWG H-14-110680 SHT 1, Ref A4]
- **F_{E0XX} := 70000-\text{psi}**  
  Ultimate stress of the weld metal.

**Connection forces and moments:**

\[ F_x := F_{SC} = 25475 \text{lbf} \]

\[ M_y := M_{SC} = 50950 \text{-in-lbf} \]
Weld Properties Per Blodgett 1991, Table 5, Page 7.4-7 [Ref C1]:

\[
C_x := \frac{b}{2} \quad \text{The distance to the outer fiber in the x-direction.}
\]

\[
C_y := \frac{d}{2} \quad \text{The distance to the outer fiber in the y-direction.}
\]

\[
A_w := 2 \cdot (b + d) \quad A_w = 16 \cdot \text{in} \quad \text{The linear area of the weld.}
\]

\[
S_{wy} := \left( b \cdot d + \frac{b^2}{3} \right) \quad S_{wy} = 21.333 \cdot \text{in}^2 \quad \text{The linear section modulus about the y-axis.}
\]

\[
A_{lin} := \frac{M_y}{S_{wy}} + \frac{F_x}{A_w} = 2.87 \times 10^3 \cdot \frac{\text{lbf}}{\text{in}} \quad \text{Linear weld stress.}
\]

\[
R_u := \frac{A_{lin}}{0.707 \cdot w_{act}} \quad R_u = 13 \cdot \text{ksi} \quad \text{Actual stress in the weld.}
\]

\[
\Omega := 2.00 \quad \text{The safety factor for fillet welds [AISC 14th Ed., ASD, Table J2.5, Ref. B2].}
\]

\[
R_n := 0.6 \cdot F_{E0XX} = 42 \cdot \text{ksi} \quad \text{The design strength of the weld [AISC 14th Ed., Table J2.5, Ref B2].}
\]

\[
\text{DCR}_{SSB,\text{weld}} := \frac{R_u}{R_n} \cdot \frac{1}{\Omega} = 0.62 \quad \text{The DCR is < 1; therefore, \textbf{OK}.}
\]
8.6.3 Cover Plate Evaluation

\[ D_{cp} := 46\text{in} \]

Diameter of the Cover Plate [Ref A1]

\[ t_{cp} := \frac{1}{4}\text{in} \]

Thickness of the Cover Plate [Ref A1]

\[ W := 3000\text{lb} \]

Worker nominal load [Design Input 8]

\[ q := \frac{W}{\pi D_{cp}^2} = 1.805\text{psi} \]

Worker and equipment load on the cover plate

\[ \nu := 0.3 \]

Poisson's ratio (typical)

\[ a := \frac{D_{cp}}{2} = 23\text{in} \]

Radial dimension of the plate

\[ M := \frac{qa(3 + \nu)}{16} = 196.954\text{in-lb} \]

Unit moment on the plate Case 10a for simply supported plate with distributed load [Ref C2, p488]

\[ \sigma := \frac{6M}{t_{cp}^2} = 18.908\text{ksi} \]

Bending stress in the cover plate [Ref C2, p457]

\[ \Omega_b = 1.67 \]

Safety factor for bending (Calculated in Section 8.1.3)

\[ M_n = 36\text{ksi} \]

Nominal bending strength of solid cross sections (Calculated in Section 8.1.3)

\[ \frac{M_n}{\Omega_b} = 21.557\text{ksi} \]

Allowable bending stress (Calculated in Section 8.1.3)

\[ \frac{\sigma}{M_n} \Omega_b = 0.88 \]

The DCR is < 1; therefore, OK.
ATTACHMENT 1

1) HOIST RING RATING WHEN USED WITH ASTM A36 MATERIAL

2) EMAIL: HOIST RING DERATING QUESTIONS
TELECON
No. 17289.004 - PDV-001

Date: April 21, 2003
Time: 10:45 AM

To: Fred Pearl
From: [Signature]

SUBJECT: Actek Hoist Ring Rating When Used with ASTM A36 Material

Actek hoist rings are typically used in material that has a tensile strength of 80,000 psi. However, previous memos from Scott Sorell (formerly of Actek) have authorized the use of Actek hoist rings in ASTM A36 steel with a tensile strength of roughly 70,000 psi. This authorization allowed the hoist rings to be used without derating the load capacity of the rings.

I have an application where the material complies with ASTM A36 but a specific tensile strength, 70,000 psi, is not specified. Per the standard, the steel must have a tensile strength of 58,000 to 80,000 psi to meet the ASTM A36 requirements. Per our conversation this morning, Actek hoist rings can be used in ASTM A36 steel without derating provided the following:

- The tensile strength of the ASTM A36 material must be within the range allowed by the standard,
- The hoist rings are torqued to manufacturer recommended values,
- The screw is going through material that has a thickness of at least 1.5 times the diameter of the screw,
- The hoist ring is within the manufacturer load capacity, and
- The hoist ring is allowed to swivel and pivot freely and the bail of the hoist ring does not come into contact with anything.

Concur:

[Signature]

Fred Pearl
Actek Manufacturing & Engineering, Inc.
<table>
<thead>
<tr>
<th>From:</th>
<th>Roger Ma <a href="mailto:roger@actekmfg.com">roger@actekmfg.com</a></th>
<th>To:</th>
<th>Jacob Williams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cc:</td>
<td></td>
<td>Subject:</td>
<td>RE: Hoist Ring Derating Questions</td>
</tr>
</tbody>
</table>

Jacob,

We would agree with your statement below.

*Therefore, we believe the interpretation of the statement should be as follows: “The thickness of the material and the screw protrusion length must be at least 1.5 times the diameter of the screw.”*

Roger Ma
General Manager
http://www.actekmfg.com

Follow us on Facebook:
https://www.facebook.com/actekmfg

<table>
<thead>
<tr>
<th>From: Ana Rasmussen [<a href="mailto:ana@actekmfg.com">mailto:ana@actekmfg.com</a>]</th>
<th>Sent: Wednesday, November 05, 2014 11:39 AM</th>
<th>To: Roger Ma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject: FW: Hoist Ring Derating Questions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hi Roger,

This customer has old paper work from Fred Pearl

Thank you
Ana

<table>
<thead>
<tr>
<th>From: Jacob Williams [<a href="mailto:jwilliams@arescorporation.com">mailto:jwilliams@arescorporation.com</a>]</th>
<th>Sent: Wednesday, November 05, 2014 10:57 AM</th>
<th>To: Ana Rasmussen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject: RE: Hoist Ring Derating Questions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ana,

To clarify my email below, please see the following:

“The screw is going through material that has a thickness of at least 1.5 times the diameter of the screw”

This statement is unclear in that some of the hoist rings have a thread protrusion length that is less than 1.5 times the screw diameter. Since any of the hoist rings are fully rated in 80 ksi material, logic would lead one to believe that if the material used is less than 80 ksi, e.g., 58 ksi, then the number of engaged threads would need to increase to keep the full load rating of the hoist ring. Therefore, we believe the interpretation of the statement should be as follows: “The thickness of the material and the screw protrusion length must be at least 1.5 times the diameter of the screw.”

Would this be a correct interpretation, and if not, can you please clarify how we can still use the A36 material without any derating (as stated in the email below)?

Thanks again,

Jacob Williams, P.E.
ARES Corporation
509.946.3300 w
www.arescorporation.com
**ATTACHMENT 2**

**ACTEK LIFTING RING DATA SHEETS**
**Title:** AX Farm Spray Ring Type 1 Lifting and Operational Evaluation

**Prepared By:** T. F. Schmitt  
**Date:** 10/10/17

**Checked By:** G. D. Lawrence  
**Date:** 10/10/17

---

**Specifications - Features**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-Bar (D)</td>
<td>1.14</td>
</tr>
<tr>
<td>Rated Load</td>
<td>15000 lbs</td>
</tr>
<tr>
<td>Thread Size</td>
<td>1.14&quot; -7</td>
</tr>
<tr>
<td>Thread Projection (E)</td>
<td>1.89 in</td>
</tr>
<tr>
<td>Bushing Head Diameter</td>
<td>3.20 in</td>
</tr>
<tr>
<td>B</td>
<td>4.12 in</td>
</tr>
<tr>
<td>A</td>
<td>1.75 in</td>
</tr>
<tr>
<td>C</td>
<td>2.11 in</td>
</tr>
<tr>
<td>F</td>
<td>6.73 in</td>
</tr>
<tr>
<td>G</td>
<td>6.5 in</td>
</tr>
<tr>
<td>H</td>
<td>3.76 in</td>
</tr>
<tr>
<td>Torque</td>
<td>470 lbf</td>
</tr>
<tr>
<td>Type</td>
<td>Standard U-Bar</td>
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<tr>
<td>Material</td>
<td>Aircraft Quality Alloy</td>
</tr>
<tr>
<td>Weight</td>
<td>14 lbs</td>
</tr>
<tr>
<td>Applicable Screw P/N</td>
<td>46842</td>
</tr>
<tr>
<td>Actek Manufacturer Number</td>
<td>AK46842</td>
</tr>
<tr>
<td>Product</td>
<td>Safety Swivel Hoist Ring</td>
</tr>
</tbody>
</table>

---

**Features**

- Swivels 360° - Pivot 180°
- Material: Aircraft Quality Alloy
- Finish: Black Oxide per MIL Specification (Cadmium Plated)
- Safety Factor: 5:1
- Magnetic particle inspected
- Certified Heat Treatment

---

(Used on Bottom Plate Assembly)
Title: AX Farm Spray Ring Type 1 Lifting and Operational Evaluation

Prepared By: T. F. Schmitt
Date: 10/10/17
Checked By: G. D. Lawrence
Date: 10/10/17

Specifications - Features

Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-Bar (D)</td>
<td>3/4 - Long</td>
</tr>
<tr>
<td>Rated Load</td>
<td>2500 lbs</td>
</tr>
<tr>
<td>Thread Size</td>
<td>1/2 - 13</td>
</tr>
<tr>
<td>Thread Protrusion (E)</td>
<td>0.78 in</td>
</tr>
<tr>
<td>Bushing Head Diameter</td>
<td>1.45 in</td>
</tr>
<tr>
<td>B</td>
<td>4.25 in</td>
</tr>
<tr>
<td>A</td>
<td>0.88 in</td>
</tr>
<tr>
<td>C</td>
<td>1.22 in</td>
</tr>
<tr>
<td>F</td>
<td>6.72 in</td>
</tr>
<tr>
<td>G</td>
<td>3.52 in</td>
</tr>
<tr>
<td>H</td>
<td>1.99 in</td>
</tr>
<tr>
<td>Torque</td>
<td>28 Mlb</td>
</tr>
<tr>
<td>Type</td>
<td>Long U-Bar</td>
</tr>
<tr>
<td>Material</td>
<td>Aircraft Quality Alloy</td>
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<tr>
<td>Weight</td>
<td>2.6 lbs</td>
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<tr>
<td>Applicable Screw Pin</td>
<td>46548</td>
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<tr>
<td>Actek Manufacturer Number</td>
<td>AK46544</td>
</tr>
<tr>
<td>Product</td>
<td>Safety Swivel Hoist Ring</td>
</tr>
</tbody>
</table>

Features

- Swivels 360° - Pivots 180°
- Material: Aircraft Quality Alloy
- Finish: Black Oxide per MIL Specification (Cadmium Plated)
- Safety Factor: 5:1
- Magnetic particle inspected
- Certified Heat Treatment

(Used on Sliding Plate Assemblies and Spray Ring Halves)
RPP-CALC-60841, Rev. 1

CALCULATION SHEET

<table>
<thead>
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<tr>
<td>054409.15.065</td>
<td>054409.15.013-S-003</td>
<td>3</td>
<td>99 of 113</td>
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</table>

Title: AX Farm Spray Ring Type 1 Lifting and Operational Evaluation

Prepared By: T. F. Schmitt  Date: 10/10/17  Checked By: G. D. Lawrence  Date: 10/10/17

ATTACHMENT 3

ACTEK SAFETY NOTE 5
SAFETY ENGINEERED SWIVEL HOIST RING

SAFETY PRECAUTIONS

**WARNING:** PRIOR TO USING ANY HOIST RING, PLEASE READ THE FOLLOWING FOR PROPER INSTALLATION AND USAGE.

As with all mechanical devices, regular inspection for wear and strict adherence to use instruction is necessary to prevent misuse failure.

- Despite the 5:1 safety factor, **NEVER EXCEED THE RATED LOAD CAPACITY.** This safety margin is needed in case of misuse, which could drastically lower load capacity.

- Tighten mounting screws to torque recommended. Periodically check torque because screws could loosen in extended service.

- Tensile strength of parent material should be above 80,000 PSI to achieve full load rating. For weaker material, consider through-hole mounting with a nut and washer on the other side.

- **DO NOT APPLY SHOCK LOADS.** Always lift gradually. Repeat magnaflux testing if shock loading ever occurs.

- **Make sure the hoist ring pivots and rotates in all directions freely.**

**Important:** The load on each hoist ring is not simply total weight divided by the number of hoist rings. The resultant force can be significantly greater at shallow lift angles and with unevenly distributed loads. See the example below.

\[ L = \frac{W}{N \sin A} \]

If \( A = 60^\circ \):

\[ L = \frac{2000}{4 \sin 60^\circ} = 577 \text{ Lbs.} \]

If \( A = 20^\circ \):

\[ L = \frac{2000}{4 \sin 20^\circ} = 1,462 \text{ Lbs.} \]
ATTACHMENT 4

LOAD RUNNER ROLLER CUT SHEETS
CUSTOMER DESIGNED

Track Requirements

Track Alignment

Whether using our rail or yours, the track and roller should be aligned so that the roller tread lies flat on the track surface.

Track Capacity

For steel track of 180,000 PSI tensile strength (Rc=40), refer to the track capacity chart to find the track load capacity for the style and size of roller to be used. For steel track other than 180,000 PSI tensile strength, first refer to the track capacity factor chart for the type of steel to be used. Then multiply the track capacity for the roller being used by the track capacity factor for the steel to be used.

<table>
<thead>
<tr>
<th>Roller Size</th>
<th>Capacity</th>
<th>Roller Size</th>
<th>Capacity</th>
<th>Track Capacity</th>
<th>Track Capacity Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>14,700</td>
<td>3</td>
<td>10,500</td>
<td>8,330</td>
<td>0.369</td>
</tr>
<tr>
<td>3 1/4</td>
<td>16,000</td>
<td>3 1/4</td>
<td>10,500</td>
<td>12,000</td>
<td>0.552</td>
</tr>
<tr>
<td>3 1/2</td>
<td>17,250</td>
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<td>14,200</td>
<td>0.755</td>
</tr>
<tr>
<td>4</td>
<td>23,250</td>
<td>4</td>
<td>19,000</td>
<td>16,100</td>
<td>1.000</td>
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<td>5</td>
<td>36,600</td>
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<td>26,400</td>
<td>20,200</td>
<td>1.235</td>
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<td>6</td>
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<td>47,250</td>
<td>23,800</td>
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<td>7</td>
<td>70,900</td>
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<td>10</td>
<td>137,800</td>
<td>37,700</td>
<td>2.305</td>
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</tbody>
</table>

* Radial load only for tracks made of 180,000 PSI steel (Hardness Rc = 40)
Title: AX Farm Spray Ring Type 1 Lifting and Operational Evaluation

Prepared By: T. F. Schmitt
Date: 10/10/17
Checked By: G. D. Lawrence
Date: 10/10/17

Load Runners
Plain - Eccentric Stud Style, Inch Sizes

For metric sizes, please turn to page 64

<table>
<thead>
<tr>
<th></th>
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<td>0.000</td>
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<td>0.000</td>
</tr>
</tbody>
</table>

Other sizes available on request.
**Flat washer, lock washer and jam nut available at additional cost. For size, see "N" dimension.
*For stud hex socket size, see page 65.

Quality Assurance Procedure 3.1

Calculation Sheet (05-10)
**Title:** AX Farm Spray Ring Type 1 Lifting and Operational Evaluation

**Prepared By:** T. F. Schmitt  
**Date:** 10/10/17  
**Checked By:** G. D. Lawrence  
**Date:** 10/10/17

---

### Load Runners

#### Load at Mounting (Mtg.) Rail

- Concentrated Load at B/2
- Concentrated Load at B

#### Retaining Ring Allowable Load

---

### Load Capacities

<table>
<thead>
<tr>
<th>Mounting Member Thickness</th>
<th>Ball on Single Roller Bearings</th>
<th>Bearing Capacity Radial Load (lbs)</th>
<th>Bearing Capacity Static Threat (lbs)</th>
<th>Stud Capacity (lbs)</th>
<th>Retaining Ring Capacity (lbs)</th>
<th>Approx Weight (lbs)</th>
<th>Part No.</th>
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<tbody>
<tr>
<td>0.625 - 0.500</td>
<td>BB</td>
<td>240</td>
<td>630</td>
<td>230</td>
<td>160</td>
<td>480</td>
<td>210</td>
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<td>0.750 - 0.625</td>
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<td>620</td>
<td>1350</td>
<td>660</td>
<td>310</td>
<td>880</td>
<td>390</td>
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<tr>
<td>0.750 - 0.625</td>
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<td>520</td>
<td>1350</td>
<td>660</td>
<td>310</td>
<td>880</td>
<td>390</td>
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<td>0.875 - 0.750</td>
<td>BB</td>
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<td>2950</td>
<td>680</td>
<td>610</td>
<td>650</td>
<td>5780</td>
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<tr>
<td>1.000 - 0.875</td>
<td>BB</td>
<td>1050</td>
<td>2950</td>
<td>680</td>
<td>610</td>
<td>650</td>
<td>5780</td>
</tr>
<tr>
<td>1.250 - 1.000</td>
<td>BB</td>
<td>1460</td>
<td>3100</td>
<td>1620</td>
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<td>3100</td>
<td>1620</td>
<td>1060</td>
<td>1600</td>
<td>1610</td>
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<tr>
<td>1.250 - 1.000</td>
<td>THB</td>
<td>1930</td>
<td>2950</td>
<td>2270</td>
<td>1460</td>
<td>2750</td>
<td>1710</td>
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<tr>
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<td>2950</td>
<td>2270</td>
<td>1460</td>
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<td>1710</td>
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<tr>
<td>1.375 - 1.250</td>
<td>THB</td>
<td>6800</td>
<td>14210</td>
<td>20000</td>
<td>12000</td>
<td>13430</td>
<td>6370</td>
</tr>
<tr>
<td>1.375 - 1.250</td>
<td>THB</td>
<td>6800</td>
<td>14210</td>
<td>20000</td>
<td>12000</td>
<td>13430</td>
<td>6370</td>
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<tr>
<td>1.500 - 1.375</td>
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<td>6800</td>
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<td>12000</td>
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<td>14210</td>
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<td>12000</td>
<td>13430</td>
<td>6370</td>
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<tr>
<td>2.500 - 2.250</td>
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<td>13960</td>
<td>32200</td>
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<td>32500</td>
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<td>32200</td>
<td>5900</td>
<td>32500</td>
<td>34120</td>
<td>17590</td>
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</table>

**LOAD CAPACITIES ARE BASED ON UNIFORM AND STEADY LOADING.**

**www.LOADRUNNERS.com** • **F 216 361 1606** • **P 800 720 5248**

---

**Quality Assurance Procedure 3.1**  
**Calculation Sheet (05-10)**
Load Runners
V-Grooved - Concentric Stud Style, Inch Sizes

For metric sizes, please turn to page 70

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Item No.</th>
<th>A</th>
<th>B</th>
<th>F</th>
<th>G</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>N</th>
<th>R</th>
<th>S</th>
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<tbody>
<tr>
<td>WR-1-1/2</td>
<td>92304</td>
<td>1500</td>
<td>0.781</td>
<td>1128</td>
<td>0.391</td>
<td>0.427</td>
<td>1000</td>
<td>0.500</td>
<td>7/16-20</td>
<td>0.650</td>
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<td>1.975</td>
<td>0.422</td>
<td>0.500</td>
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<td>0.625</td>
<td>1/2-20</td>
<td>0.625</td>
<td>0.031</td>
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<td>WR-2 1/2</td>
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<td>1.600</td>
<td>0.597</td>
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<td>1.750</td>
<td>0.750</td>
<td>3/16</td>
<td>1.000</td>
<td>0.062</td>
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<td>WR-3-1/2</td>
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<td>1.687</td>
<td>2.250</td>
<td>0.875</td>
<td>0.875</td>
<td>2.000</td>
<td>1.125</td>
<td>7/8-14</td>
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<td>0.062</td>
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<tr>
<td>WR-3 1/2 H-6</td>
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<td>0.875</td>
<td>0.875</td>
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<td>1.125</td>
<td>3/16-12</td>
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<td>0.062</td>
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<td>3.000</td>
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<td>1.250</td>
<td>2.500</td>
<td>1.750</td>
<td>1 1/4-12</td>
<td>1.750</td>
<td>0.062</td>
</tr>
<tr>
<td>WR-6-1/2</td>
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<td>4.000</td>
<td>1.600</td>
<td>1.250</td>
<td>2.750</td>
<td>1.750</td>
<td>1 1/4-12</td>
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<tr>
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<td>5.000</td>
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<td>4.500</td>
<td>2.500</td>
<td>2-1/2</td>
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<td>7.000</td>
<td>1.900</td>
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<td>5.500</td>
<td>3.250</td>
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<td>7.000</td>
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<td>5.500</td>
<td>3.250</td>
<td>2 1/2-12</td>
<td>3.250</td>
<td>0.062</td>
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</table>

Other sizes available on request.
*Lock washer and jam nut available at additional cost. For size, see "H" dimension.
*For stud hex socket size, see page 85.
Title: AX Farm Spray Ring Type 1 Lifting and Operational Evaluation

Prepared By: T. F. Schmitt  Date: 10/10/17  Checked By: G. D. Lawrence  Date: 10/10/17

---

**Load at Mounting (Mtg.) Rail**

**Concentrated Load at Center of V**

**Retaining Ring Allowable Load**

---

### Table: Load Capacities

<table>
<thead>
<tr>
<th>Rec. Mnt Hole Size</th>
<th>Mounting Member Thickness</th>
<th>Ball or Tapered Roller Bearings</th>
<th>Bearing/Capacity Ratio/Load (lbs)</th>
<th>Bearing Capacity Static Thrust (lbs)</th>
<th>Stud Capacity (lbs)</th>
<th>Retaining Ring Capacity (lbs)</th>
<th>Approx Weight (lbs)</th>
<th>Part No.</th>
</tr>
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<tbody>
<tr>
<td>0.0000</td>
<td>0.0000</td>
<td>BB</td>
<td>3000 hrs @ 10,000 RPM</td>
<td>500 hrs @ 35,000 RPM</td>
<td>140</td>
<td>370</td>
<td>1970</td>
<td>180</td>
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<tr>
<td>0.0500</td>
<td>0.025</td>
<td>BB</td>
<td>525</td>
<td>880</td>
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<td>3250</td>
<td>470</td>
</tr>
<tr>
<td>0.7500</td>
<td>1.250</td>
<td>BB</td>
<td>1050</td>
<td>1100</td>
<td>680</td>
<td>1520</td>
<td>5780</td>
<td>470</td>
</tr>
<tr>
<td>0.3750</td>
<td>1.250</td>
<td>BB</td>
<td>1860</td>
<td>2270</td>
<td>140</td>
<td>370</td>
<td>14580</td>
<td>140</td>
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<tr>
<td>0.7500</td>
<td>1.250</td>
<td>TRB</td>
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<td>4350</td>
<td>3150</td>
<td>9580</td>
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<td>1.2500</td>
<td>1.250</td>
<td>TRB</td>
<td>6000</td>
<td>7200</td>
<td>3750</td>
<td>3150</td>
<td>9580</td>
<td>N/A</td>
</tr>
<tr>
<td>1.2500</td>
<td>1.250</td>
<td>TRB</td>
<td>6000</td>
<td>7200</td>
<td>3750</td>
<td>3150</td>
<td>9580</td>
<td>N/A</td>
</tr>
<tr>
<td>0.0000</td>
<td>0.000</td>
<td>TRB</td>
<td>1260</td>
<td>1260</td>
<td>1200</td>
<td>1260</td>
<td>40600</td>
<td>N/A</td>
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<tr>
<td>2.0000</td>
<td>2.000</td>
<td>TRB</td>
<td>3200</td>
<td>3200</td>
<td>3200</td>
<td>3200</td>
<td>10380</td>
<td>N/A</td>
</tr>
<tr>
<td>2.5000</td>
<td>2.250</td>
<td>TRB</td>
<td>3560</td>
<td>3560</td>
<td>3560</td>
<td>3560</td>
<td>10180</td>
<td>N/A</td>
</tr>
<tr>
<td>2.5000</td>
<td>2.250</td>
<td>TRB</td>
<td>3560</td>
<td>3560</td>
<td>3560</td>
<td>3560</td>
<td>10180</td>
<td>N/A</td>
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</tbody>
</table>

*Surface strength of roller OD

LOAD CAPACITIES ARE BASED ON UNIFORM AND STEADY LOADING.
### INSTALLATION NOTES

#### Tightening Torque

<table>
<thead>
<tr>
<th>STUD DIAMETER</th>
<th>DRY THREADS</th>
<th>LUBRICATED THREADS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 5/8&quot;</td>
<td>12 lb. / 20 Nm</td>
<td>6 lb. / 10 Nm</td>
</tr>
<tr>
<td>5/8&quot; to 1&quot;</td>
<td>50 lb. / 68 Nm</td>
<td>25 lb. / 34 Nm</td>
</tr>
<tr>
<td>Over 1&quot;</td>
<td>100 lb. / 136 Nm</td>
<td>50 lb. / 68 Nm</td>
</tr>
</tbody>
</table>

#### Osborn Load Runners Recommended Installation Procedure:

**WARNING:** High voltage and rotating parts may cause serious or fatal injury. Be sure to turn off power to machinery. Read and follow all instructions. Be sure to properly apply pressure when press-fitting your Load Runners. Hammering directly on the bearing could result in bearing damage or personal injury.

While lack of lubrication causes shorter operating life and product damage, Load Runners are designed and lubricated for life. In some instances, there is a convention to re-lubricate your Load Runners. Use the torque chart to install nuts properly. Do NOT over- or under-torque nuts.

#### Stud-Style Installation Considerations

1. Inspect the housing
   - a. Remove all burrs/sharp edges and clean.
   - b. Confirm housing bore diameter, insuring a snug fit with stud.
2. Install stud into housing
   - a. Do NOT hammer Load Runners at any time.
3. Install lock washer and jam nut
   - a. Do not tighten jam nut beyond torque specifications or damage may occur.
   - b. Use hexagonal hole (broach) with hex key to prevent the stud from rotating when the nut is tightened.

#### Blind Hole Mounting

Certain applications require blind hole mounting into tapped threads. Use the hex key to ensure adequate torque is applied.

#### Mounting Considerations

Mounting holes should be machined to the nominal stud size within +.001"/-.000 (+.025 mm/.000 mm) tolerance.

When properly aligned, the roller stud should slip into the mounting member. Do not force the stud into the mounting member as damage to the roller may occur.

When mounting rollers, do not torque the jam nuts beyond what is recommended or damage may occur. Be sure that the mounting member is of sufficient thickness to support the applied loads.

---

**Quality Assurance Procedure 3.1**

**Calculation Sheet (05-10)**
ATTACHMENT 5

KEE SAFETY CUT SHEETS

http://old.keesafety.com/products/kee_klamp
62 - Standard Railing Flange

Ideal when a structural fixing is required. When fixing guardrailing and balustrades, Type 62 should always be used. The holes are of sufficient diameter to insure proper fixing with either a mechanical or chemical anchor. The two set screws in the vertical socket give greater sideload stability to the upright. It is recommended that the fixing holes in the flange should be in line with the applied load. Ø indicates diameter of fixing holes.

<table>
<thead>
<tr>
<th>Part</th>
<th>Weight</th>
<th>A</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>Ø</th>
</tr>
</thead>
<tbody>
<tr>
<td>62-5</td>
<td>1.3 lbs.</td>
<td>5</td>
<td>2.52 in.</td>
<td>4.57 in.</td>
<td>2.99 in.</td>
<td>2.99 in.</td>
<td>0.31 in.</td>
<td>0.43 in.</td>
</tr>
<tr>
<td>62-6</td>
<td>1.61 lbs.</td>
<td>6</td>
<td>2.99 in.</td>
<td>5.04 in.</td>
<td>3.5 in.</td>
<td>3.5 in.</td>
<td>0.31 in.</td>
<td>0.55 in.</td>
</tr>
<tr>
<td>62-7</td>
<td>2.64 lbs.</td>
<td>7</td>
<td>2.95 in.</td>
<td>5.51 in.</td>
<td>3.5 in.</td>
<td>4.02 in.</td>
<td>0.39 in.</td>
<td>0.55 in.</td>
</tr>
<tr>
<td><strong>62-8</strong></td>
<td>2.86 lbs.</td>
<td>6</td>
<td>3.35 in.</td>
<td>6.1 in.</td>
<td>3.5 in.</td>
<td>4.53 in.</td>
<td>0.39 in.</td>
<td>0.55 in.</td>
</tr>
<tr>
<td>62-9</td>
<td>3.87 lbs.</td>
<td>9</td>
<td>4.02 in.</td>
<td>6.5 in.</td>
<td>5 in.</td>
<td>5 in.</td>
<td>0.39 in.</td>
<td>0.71 in.</td>
</tr>
</tbody>
</table>
Metric Beam Load Table

For uneven load distributions or single spans, the required pipe size must be determined by standard bending moment calculations assuming a Kee Klamp joint to give a simply supported beam. The table shown below gives an indication only of the safe load uniformly distributed, in kg, that may be carried per shelf consisting of front and back pipes when used as continuous beams. Recommended set screw torque: 39 Nm.

At loads greater than 900 kg, consideration must be given to grub screw slip.

### BEAM LOAD TABLE (lb)

<table>
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<tr>
<th>KK FITTING</th>
<th>Size 6</th>
<th>Size 6</th>
<th>Size 7</th>
<th>Size 8</th>
<th>Size 9</th>
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</thead>
<tbody>
<tr>
<td>SIZE OF PIPE</td>
<td>½&quot; N.B.</td>
<td>1&quot; N.B.</td>
<td>1¼&quot; N.B.</td>
<td>1½&quot; N.B.</td>
<td>2&quot; N.B.</td>
</tr>
<tr>
<td>GRADE OF MATERIAL</td>
<td>SCH. 40</td>
<td>SCH. 40</td>
<td>SCH. 40</td>
<td>SCH. 40</td>
<td>SCH. 40</td>
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</table>

<table>
<thead>
<tr>
<th>SPAN</th>
<th>1'</th>
<th>2'</th>
<th>3'</th>
<th>3' 6&quot;</th>
<th>4'</th>
<th>4' 6&quot;</th>
<th>5'</th>
<th>5' 6&quot;</th>
<th>6'</th>
<th>6' 6&quot;</th>
<th>7'</th>
<th>7' 6&quot;</th>
<th>8'</th>
<th>9'</th>
<th>10'</th>
</tr>
</thead>
<tbody>
<tr>
<td>1'</td>
<td>1668</td>
<td>1662</td>
<td>1088</td>
<td>813</td>
<td>767</td>
<td>659</td>
<td>599</td>
<td>560</td>
<td>532</td>
<td>499</td>
<td>476</td>
<td>450</td>
<td>323</td>
<td>157</td>
<td>137</td>
</tr>
<tr>
<td>2'</td>
<td>829</td>
<td>1662</td>
<td>813</td>
<td>539</td>
<td>484</td>
<td>439</td>
<td>384</td>
<td>349</td>
<td>300</td>
<td>276</td>
<td>254</td>
<td>230</td>
<td>157</td>
<td>122</td>
<td>110</td>
</tr>
<tr>
<td>3'</td>
<td>553</td>
<td>1662</td>
<td>813</td>
<td>539</td>
<td>484</td>
<td>439</td>
<td>384</td>
<td>349</td>
<td>300</td>
<td>276</td>
<td>254</td>
<td>230</td>
<td>157</td>
<td>122</td>
<td>110</td>
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<td>3' 6&quot;</td>
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<td>66</td>
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<td>6'</td>
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<td>764</td>
<td>664</td>
<td>568</td>
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<td>92</td>
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<td>31</td>
<td>24</td>
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<tr>
<td>6' 6&quot;</td>
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Table reflects a safety factor of 1.67:1
Title: AX Farm Spray Ring Type 1 Lifting and Operational Evaluation

Prepared By: T. F. Schmitt  Date: 10/10/17  Checked By: G. D. Lawrence  Date: 10/10/17

CERTIFICATE
No. B 08 04 18894 038

Holder of Certificate: Kee Safety Ltd.
1 Boulton Road
Reading
RG2 0NH
UNITED KINGDOM

Production Facility(ies): 46030

Certification Mark:

Product: Pipe connector
Model(s): Kee Klamp pipe joint connection

Parameters:
Couplings: 10, 12, 14, 15, 16, 17, 19, 19-85, 20, 21, 25, 26, 27, 28, 29, 30, 35, 40, 45, 46, 55, 56, 58, 66, 67, 68, 89
F50, M50, M51, M52, 114, 121, 145, A10, A10 type B, A12, A21/A26, A35, A40, A45, A45/type B, BC53
Flanges: M50, 60, 61, 62, 662, 63, 64, 65, 67, 68, 69, 70, 75, 115
Sizes: 5 - 8 for outside diameter of tube from 28.9 - 60.3 mm
Range of application: Guard railings, rackings, bracing

Further technical datas see page 2 and 3

Tested according to: PPP 52175:2001

The product was tested on a voluntary basis and complies with the essential requirements. The certification mark shown above can be affixed on the product. The certification mark must not be altered in any way. See also notes overleaf.

Test report no.: 70115009

Date, 2008-04-03
CERTIFICATE
Nr. B 08 04 18894 038

Technical Data

Material:
Pipe joint Connection: Malleable cast iron EN-G-JMB-350-10 acc. EN 1562
SG cast irons EN-GJS-450-10 acc. EN 1563
Binding screw: Caseharding steel, organic zinc

Scope/requirements:
The permissible loads are based on tensile and bending tests
with steel tube, with a minimum wall thickness 3,2 mm.
Starting torque of the set screw: 40 Nm
Safety factor: 2,0

Safety notes:
The permissible working load of the set screws, fixings
and building materials must be considered when
selecting the type of mounting for the flanges of guard
railings.

Due to dynamic load influences screwed connections
may loosen. The tight fit of all screw connections must
be checked at regular intervals and tightened up if
necessary. The interval depends on the respective use
and must be laid down by the operator.

The permissible tensile loads are differentiated between
straight attachment of the tube with one and/or two set screws
and with diagonal attachment of the tube.

The following abbreviations are used in the table:

1 set screw, straight gripping of the tube: 1 ss-str-g-t.
2 set screws, straight gripping of the tube: 2 ss-str-g-t.
Diagonal gripping of the tube: diag.-g-t.
**Title:** AX Farm Spray Ring Type 1 Lifting and Operational Evaluation

**Prepared By:** T. F. Schmitt  
**Date:** 10/10/17  
**Checked By:** G. D. Lawrence  
**Date:** 10/10/17

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TÜV SÜD Product Service GmbH · Zertifizierstelle · Riedlerstrasse 65 · 80339 München · Germany