# HAR-BACH MARKETING, INC.
# PADEYE EVALUATION
# SAFETY WARNINGS/INSTRUCTIONS

## Project 21721

**September 29, 2015**

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September 29, 2015

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**Re: PadEye Evaluation**

## INTRODUCTION

Har-Bach Marketing, Inc. has engaged the services of Becht Engineering Co. Inc. to review various padeye designs and to provide safety warnings/instructions. The documentation initially provided for review included six different types of lugs varying in size from ½ ton to 6 ½ tons. The first review was documented by the Becht Engineering report dated April 14, 2015 and titled *Lug Evaluation*. Padeye geometry and weld size and types were modified based on the initial design review. The current padeye geometry maximizes the load rating capacity while maintaining adequate room in the bow of the shackle for attaching rigging. This report provides the results of the complete evaluation of each padeye and updated cautions and warnings.

The padeye WLL is based on the design requirements of ASME BTH-1 "Below-the-Hook Lifting Device" 2014 considering possible lateral loading. The fillet weld stresses and lug stresses were evaluated considering in-line loading, and lateral load conditions.

## REFERENCES

American Society of Mechanical Engineers ASME BTH-1. *Below-the-Hook Lifting Device*, 2014.
American Institute of Steel Construction AISC, Thirteenth Edition.

## LIST OF REVIEWED DOCUMENTS

- *½ ton padeye,* Page 1, Fabrication drawing
- *1 ton padeye,* Page 1, Fabrication drawing
- *1 ½ ton padeye,* Page 1, Fabrication drawing
- *2 ton padeye,* Pages 1, Fabrication drawing
- *4 ¾ ton padeye,* Page 1, Fabrication drawing
- *6 ton padeye,* Page 1, Fabrication drawing

## RECOMMENDED WARNINGS/INSTRUCTIONS

- Inspect prior to each use for cracks or damage
- Do not exceed the working load limit WLL of padeye (see load limit tables)
- WLL of padeye may be less than WLL of shackle depending on Category and Class
- In-Line load limit is equal to shackle WLL for Category A Class 0
- Shackle must be Crosby G-2130, or equivalent
- Shackle pin must be allowed to rotate in the shackle pin holes
- All welding to AWS D1.1 or D14.1
- Do not cold bend the lug

- Do not hammer on the lug
- Do not use for Fall Protection (see 29CFR1926 (502d))
- Use the appropriate size shackle pin and capacity to match the lug hole diameter and capacity
- Do not use an undersized shackle pin
- Temperature limit +10 degrees F to 200 degrees F
- Weld only onto acceptable base metal
- Weld only onto a flat surface
- Weld must be on the same surface/plane
- Do not allow out of plane weld returns
- Fillet weld sizes are minimum requirements for WLL
- Show welding symbols on instruction/warning tag
- Insure base metal thickness and weld size comply with Table 3-3.4.3-1

**Table 3-3.4.3-1 Minimum Sizes of Fillet Welds**

| Material Thickness of Thicker Part Joined, in. (mm) | Minimum Size of Fillet Weld, in. (mm) |
|---|---|
| To 1/4 (6) | 1/8 (3) |
| Over 1/4 (6) to 1/2 (13) | 3/16 (5) |
| Over 1/2 (13) to 3/4 (19) | 1/4 (6) |
| Over 3/4 (19) | 5/16 (8) |

- The lug and base metal must not exceed the thickness requirements of the thicker part
- Use a qualified welding procedure to weld lug onto equipment
- Welding procedure shall be qualified to meet minimum strengths required per design
- No welding of lugs onto equipment that is stress relieved for environmental reasons or per code, for that alloy, without owner's review and approval

**RECOMMENDED QA/QC**

- For new supplier, sample 2 lugs or 5% (whichever is greater) of every lot produced for destructive testing
- Perform metallography
- The sample should be split down the middle and examined for dendritic structure in middle of material, and excessive flow and cracking at flashing at edge of forging
    - This indicates either lack of forging or excessive material flow, respectively
    - These defects would also likely result in reduced tensile or charpy values
- After metallography, take both tensile and charpy tests to confirm it meets A36 specification
- Charpy samples should be cut to test for both outer and inner material on lifting lug
- Destructive testing should continue for a few orders until new supplier has demonstrated consistent ability to meet quality specs
- 10-20% of each lot should have lugs magnetic particle tested to look for cracking, regardless of new or old supplier
- Visual inspection for cracking on all lugs produced

**EVALUATION**

The various lugs were evaluated for compliance with the ASME BTH-1 "Design of Below-the-Hook Lifting Devices", 2014 edition. In order to determine the load limit for each category and class, each lug was evaluated for all BTH-1 stress limits based on:

1. In-line loading
2. Lateral loading from the shackle at
3. Lateral loading from the shackle at

The new design includes lettering that is stamped into the padeye. Each padeye was evaluated to determine the exact thickness at the base of the padeye due to lettering and the resulting section modulus. The new section modulus is included in the new load/stress tables 1A, 1B, 2A and 2B.

The ASME BTH-1 "Below-the-Hook Lifting Devices" provides two design categories, A and B, and five design classifications, 0 to 4. Design category A lifts have a design factor Nd of 2.0 for limit states of yielding or buckling and 2.4 for limit states of fracture and connection design. Category B lifters have a design factor Nd of 3.0 for limit states of yielding or buckling and 3.6 for limit states of fracture and connection design. In accordance with ASME BTH-1, there are several potential failure modes that must be considered in the evaluation of padeyes. The strength of pin-connected plates in the region of the pin hole shall be taken as the least value of:

a) the tensile strength of the effective area on a plane through the center of the pin hole, perpendicular to the line of the applied load as shown below

b) the fracture strength beyond the pin hole on a single plane parallel to the line of action of the applied load as shown below

c) the double plane shear strength beyond the pin hole parallel to the line of action on the applied load as shown below

Tensile strength, fracture strength and double plane shear are all capable of 100 percent in-line loading. The load capacities, which are greater than the shackle capacities, are shown in the calculations. Therefore, all padeyes are qualified for in-line loading equal to the shackle WLL.

The next evaluation is for the stress on the net section through the pin hole. The class E fracture limits of section 3-3.3.3 must be checked for this failure mode as follows:

> **3-3.3.3 Fatigue Loading.** The average tensile stress on the net area through the pinhole shall not exceed the limits defined in para. 3-4.3 for Stress Category E.
>
> Pinholes in connections designed for Service Classes 1 through 4 shall be drilled, reamed, or otherwise finished to provide a maximum surface roughness of 500 μin. (12.5 μm) around the inside surface of the hole.

The design of lugs must meet the fatigue load requirements for Stress Category E. This is also explained in the commentary section of the BTH-1 code. Stress level for Service Class 1 Stress Category E is 22,000 psi, Service Class 2 is 13,000 psi, etc.

**Table 3-4.3-1 Allowable Stress Ranges, ksi (MPa)**

| Stress Category (From Table 3-4.4-1) | Service Class 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| A | 63 (435) | 37 (255) | 24 (165) | 24 (165) |
| B | 49 (340) | 29 (200) | 18 (125) | 16 (110) |
| B′ | 39 (270) | 23 (160) | 15 (100) | 12 (80) |
| C | 35 (240) | 21 (145) | 13 (90) | 10 (70) [Note (1)] |
| D | 28 (190) | 16 (110) | 10 (70) | 7 (50) |
| E | 22 (150) | 13 (90) | 8 (55) | 5 (34) |
| E′ | 16 (110) | 9 (60) | 6 (40) | 3 (20) |
| F | 15 (100) | 12 (80) | 9 (60) | 8 (55) |
| G | 16 (110) | 9 (60) | 7 (48) | 7 (48) |

NOTE:
(1) Flexural stress range of 12 ksi (80 MPa) permitted at the toe of stiffener welds on flanges.

The analysis shows that none of these failure modes govern the WLL. All padeyes are qualified for the **In-line WLL** of the shackle for Category A, Class 0 and Category B, Class 1 through 4.

The evaluation determined the maximum stress levels considering the worst case lateral loading. Based on the highest possible load condition in any orientation of the shackle, the evaluation provides the maximum service classification that can be achieved. The fillet weld stresses, fillet weld with PJP weld, and lug stresses were evaluated considering the and load conditions.

Sketch 1 shows the dimensions of the lug and shackle along with the and load angle. Table 1A and 1B shows the moment due to the horizontal load condition. Table 2A and 2B shows the resulting bending stress in the lug due to the lateral load. All tables are excel files with embedded formulas which calculate the stresses and allowable loads. Generally, the bending stress at the base of the padeye governs the Class 1 through 3, while the weld stress governs the Class 4 padeye loads. Overall the designs are robust and provide excellent load capacities vs. the load condition.

The following summary table provides all the WLL for in-line loading, lateral load and lateral loading for three failure locations; bending in the padeye, weld stress and fracture at the head of the padeye. The governing stress between padeye bending vs. padeye weld stress vs. fracture at the head of the padeye, are included in this table. Refer to Table 1A, 1B, 2A, and 2B for padeye bending, padeye weld stress and fracture at the head to find the associated stress levels presented in this table.

## SUMMARY

| | | | WLL | SUMMARY | | TABLE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Category A | Class 0 | Category B | Class 1 | Category B | Class 2 | Category B | Class 3 | Category B | Class 4 |
| Rating | | | | | | | | | | | |
| | | WLL | % | WLL | % | WLL | % | WLL | % | WLL | % |
| 1/2 TON | In Line | 1,000 | 100 | 1,000 | 100 | 1,000 | 100 | 1,000 | 100 | 1,000 | 100 |
| 1,000 | 45 Degree | 673 | 67 | 459 | 46 | 459 | 46 | 459 | 46 | 289 F | 29 |
| | 90 Degree | 577 | 58 | 385 | 38 | 385 | 38 | 361 F | 36 | 226 F | 23 |
| 1 TON | In Line | 2,000 | 100 | 2,000 | 100 | 2,000 | 100 | 2,000 | 100 | 2,000 | 100 |
| 2,000 | 45 Degree | 1,736 | 87 | 1,184 | 59 | 1,184 | 59 | 1,184 | 59 | 1,027 F | 51 |
| | 90 Degree | 1,474 | 74 | 983 | 49 | 983 | 49 | 983 | 49 | 648 F | 32 |
| 1 1/2 TON | In Line | 3,000 | 100 | 3,000 | 1000 | 3,000 | 100 | 3,000 | 100 | 3,000 | 100 |
| 3,000 | 45 Degree | 2,129 | 71 | 1,452 | 48 | 1,452 | 48 | 1,452 | 48 | 907 W | 30 |
| | 90 Degree | 1,845 | 62 | 1,230 | 41 | 1,230 | 41 | 1,068 F | 36 | 668 F | 22 |
| 2 TON | In Line | 4,000 | 100 | 4,000 | 100 | 4,000 | 100 | 4,000 | 100 | 4,000 | 100 |
| 4,000 | 45 Degree | 2,646 | 66 | 1,804 | 45 | 1,804 | 45 | 1,804 | 45 | 1,349 W | 34 |
| | 90 Degree | 2,281 | 57 | 1,520 | 38 | 1,520 | 38 | 1,520 | 38 | 1,245 W | 31 |
| 4 3/4 TON | In Line | 9,500 | 100 | 9,500 | 100 | 9,500 | 100 | 9,500 | 100 | 9,500 | 100 |
| 9,500 | 45 Degree | 6,929 | 73 | 4,724 | 50 | 4,724 | 59 | 4,242 W | 45 | 2,615 W | 28 |
| | 90 Degree | 6,056 | 64 | 4,037 | 42 | 4,037 | 42 | 4,037 | 42 | 2,447 W | 26 |
| 6 1/2 TON | In Line | 13,000 | 100 | 13,000 | 100 | 13,000 | 100 | 13,000 | 100 | 13,000 | 100 |
| 13,000 | 45 Degree | 9,759 | 75 | 6,654 | 51 | 6,474 | 48 | 6,474 | 48 | 4,599 W | 35 |
| | 90 Degree | 8,519 | 66 | 5,679 | 44 | 5,679 | 44 | 5,679 | 44 | 4,104 W | 32 |
| | | | Note: | F = Fracture at Head | | W= Weld | | | | | |

## COMMENTS

The fabrication tolerances should be very tight. If the lug is too thick then the shackle will not fit over the lug. If the lug is thinner than design requirements then the BTH-1 code will not be met.

The six attached sketches show the working load limits for all load cases. The padeye with the shackle shows the load limits for in-line, $45^0$ and $90^0$.

We sincerely appreciate this opportunity to be of service to Har-Bach Marketing, Inc. Please feel welcome to contact me at any time if additional discussion would be helpful.

Regards,

T. C. Mackey

Tom Mackey
Senior Engineering Advisor

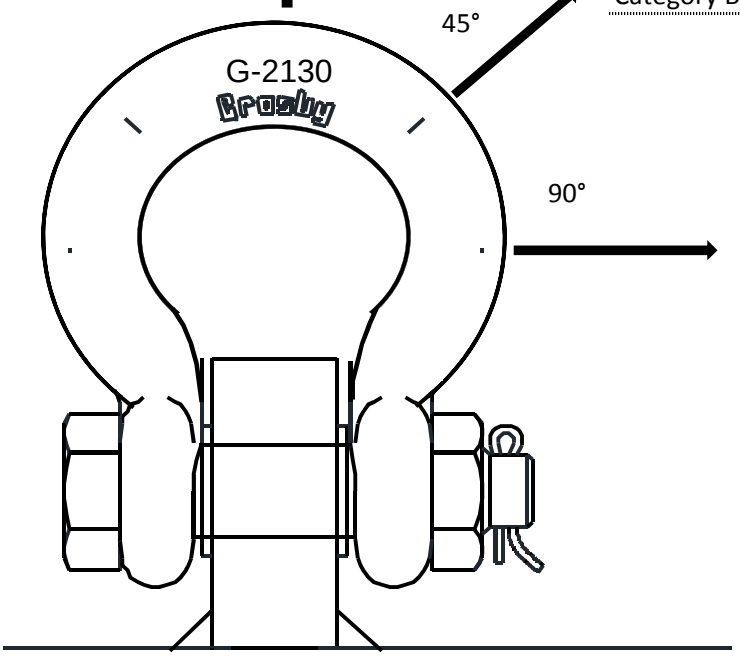
# 1/2 Ton Padeye

| | | |
|---|---|---|
| Category A | Class 0 | 1,000 |
| Category B | Class 1 | 1,000 |
| Category B | Class 2 | 1,000 |
| Category B | Class 3 | 1,000 |
| Category B | Class 4 | 1,000 |

In Line

| | | |
|---|---|---|
| Category A | Class 0 | 673 |
| Category B | Class 1 | 459 |
| Category B | Class 2 | 459 |
| Category B | Class 3 | 459 |
| Category B | Class 4 | 289 |

45°




90°

| | | |
|---|---|---|
| Category A | Class 0 | 577 |
| Category B | Class 1 | 385 |
| Category B | Class 2 | 385 |
| Category B | Class 3 | 361 |
| Category B | Class 4 | 226 |

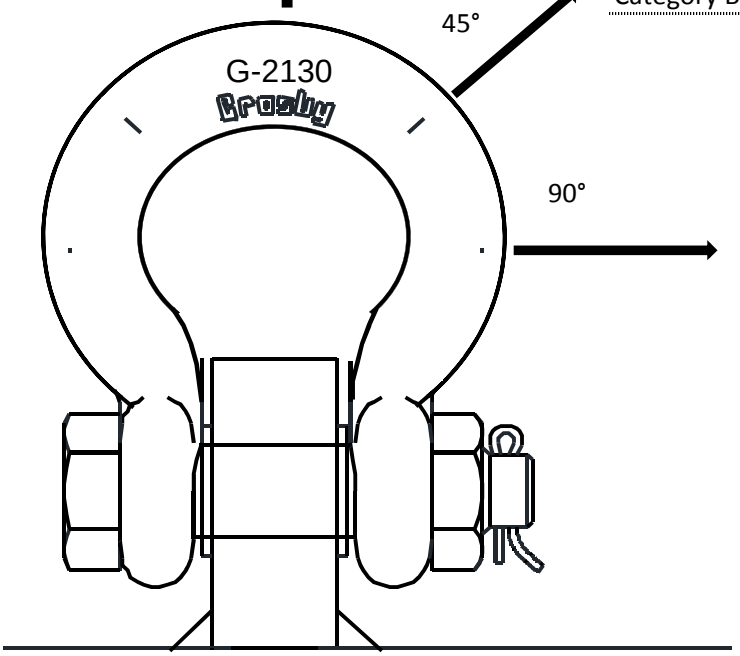
# 1 Ton Padeye

| | | |
|---|---|---|
| Category A | Class 0 | 2,000 |
| Category B | Class 1 | 2,000 |
| Category B | Class 2 | 2,000 |
| Category B | Class 3 | 2,000 |
| Category B | Class 4 | 2,000 |

In Line

| | | |
|---|---|---|
| Category A | Class 0 | 1,736 |
| Category B | Class 1 | 1,184 |
| Category B | Class 2 | 1,184 |
| Category B | Class 3 | 1,184 |
| Category B | Class 4 | 1,027 |

45°




90°

| | | |
|---|---|---|
| Category A | Class 0 | 1,474 |
| Category B | Class 1 | 983 |
| Category B | Class 2 | 983 |
| Category B | Class 3 | 983 |
| Category B | Class 4 | 648 |

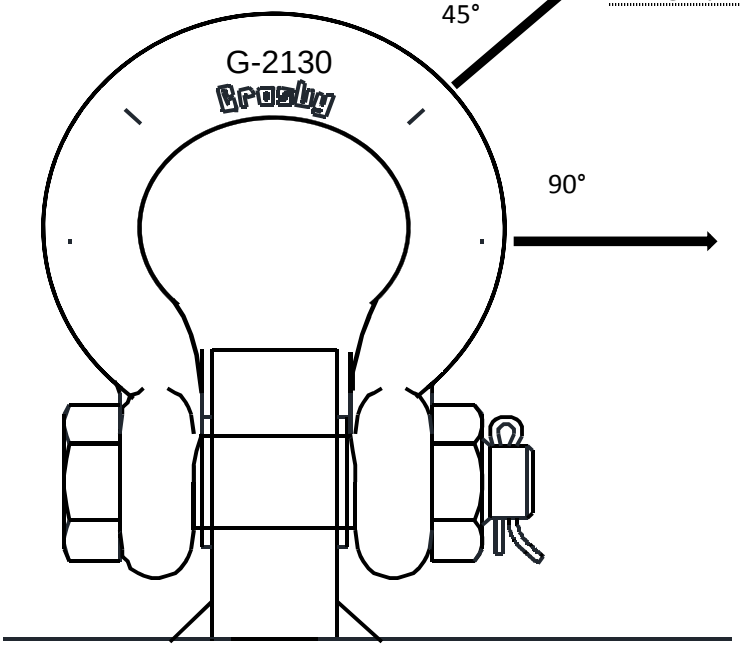
# 1 1/2 Ton Padeye

| | | |
|---|---|---|
| Category A | Class 0 | 3,000 |
| Category B | Class 1 | 3,000 |
| Category B | Class 2 | 3,000 |
| Category B | Class 3 | 3,000 |
| Category B | Class 4 | 3,000 |

In Line

45°

| | | |
|---|---|---|
| Category A | Class 0 | 2,129 |
| Category B | Class 1 | 1,452 |
| Category B | Class 2 | 1,452 |
| Category B | Class 3 | 1,452 |
| Category B | Class 4 | 907 |




90°

| | | |
|---|---|---|
| Category A | Class 0 | 1,845 |
| Category B | Class 1 | 1,230 |
| Category B | Class 2 | 1,230 |
| Category B | Class 3 | 1,068 |
| Category B | Class 4 | 668 |

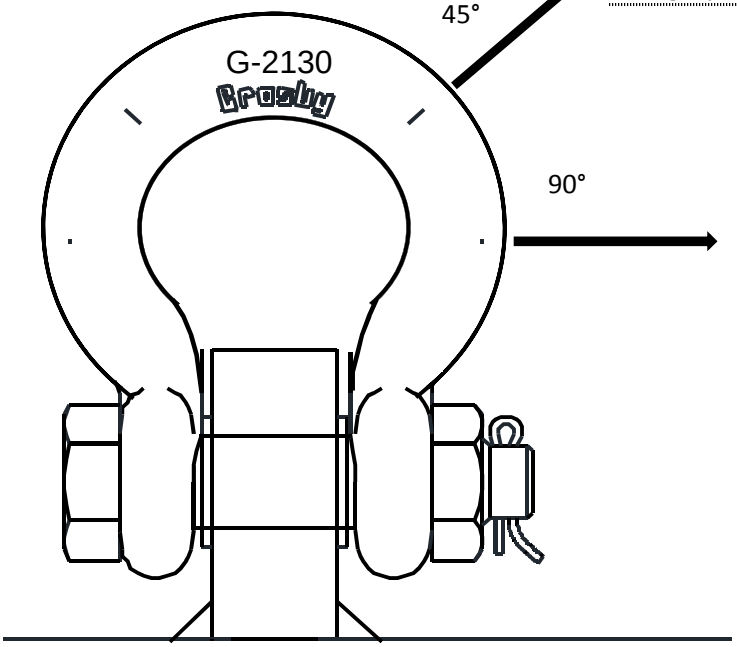
# 2 Ton Padeye

| | | |
|---|---|---|
| Category A | Class 0 | 4,000 |
| Category B | Class 1 | 4,000 |
| Category B | Class 2 | 4,000 |
| Category B | Class 3 | 4,000 |
| Category B | Class 4 | 4,000 |

In Line

45°

| | | |
|---|---|---|
| Category A | Class 0 | 2,646 |
| Category B | Class 1 | 1,804 |
| Category B | Class 2 | 1,804 |
| Category B | Class 3 | 1,804 |
| Category B | Class 4 | 1,349 |




90°

| | | |
|---|---|---|
| Category A | Class 0 | 2,281 |
| Category B | Class 1 | 1,520 |
| Category B | Class 2 | 1,520 |
| Category B | Class 3 | 1,520 |
| Category B | Class 4 | 1,245 |

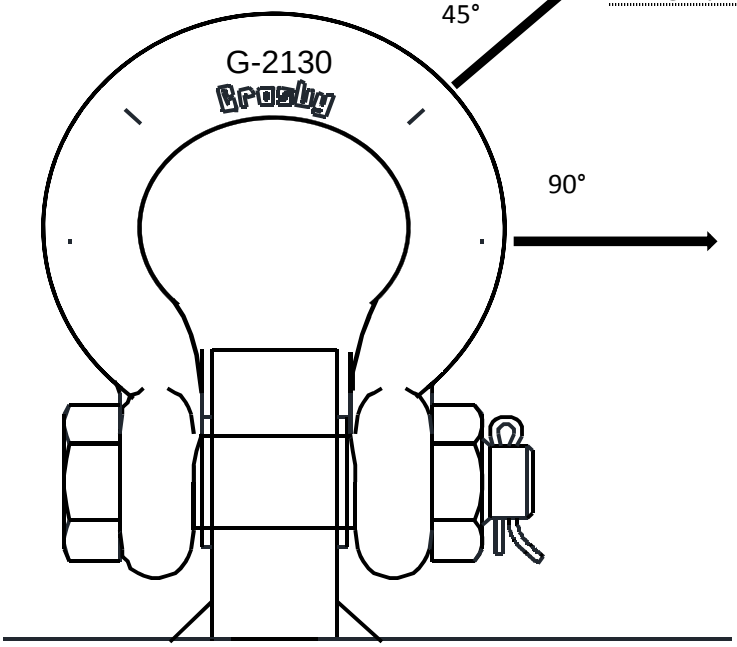
# 4 3/4 Ton Padeye

| | | |
|---|---|---|
| Category A | Class 0 | 9,500 |
| Category B | Class 1 | 9,500 |
| Category B | Class 2 | 9,500 |
| Category B | Class 3 | 9,500 |
| Category B | Class 4 | 9,500 |

In Line

45°

| | | |
|---|---|---|
| Category A | Class 0 | 6,929 |
| Category B | Class 1 | 4,724 |
| Category B | Class 2 | 4,724 |
| Category B | Class 3 | 4,242 |
| Category B | Class 4 | 2,615 |




90°

| | | |
|---|---|---|
| Category A | Class 0 | 6,056 |
| Category B | Class 1 | 4,037 |
| Category B | Class 2 | 4,037 |
| Category B | Class 3 | 4,037 |
| Category B | Class 4 | 2,447 |

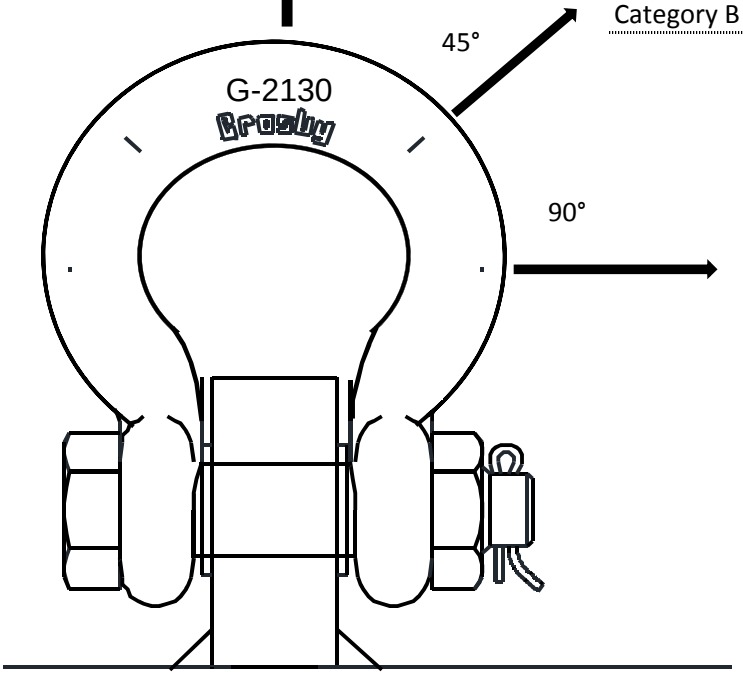
# 6 1/2 Ton Padeye

| | | |
|---|---|---|
| Category A | Class 0 | 13,000 |
| Category B | Class 1 | 13,000 |
| Category B | Class 2 | 13,000 |
| Category B | Class 3 | 13,000 |
| Category B | Class 4 | 13,000 |

In Line

| | | |
|---|---|---|
| Category A | Class 0 | 9,759 |
| Category B | Class 1 | 6,654 |
| Category B | Class 2 | 6,474 |
| Category B | Class 3 | 6,474 |
| Category B | Class 4 | 4,599 |

45°




90°

| | | |
|---|---|---|
| Category A | Class 0 | 8,519 |
| Category B | Class 1 | 5,679 |
| Category B | Class 2 | 5,679 |
| Category B | Class 3 | 5,679 |
| Category B | Class 4 | 4,104 |