CLARK REDER
ENGINEERING

6/6/2013

Attn: Hermann Fruhm
Parasol Advanced Systems Inc.
106-552A Clarke Road
Coquitlam,BC
Canada,V3J-0A3

RE: Parasol Star600 Series
CRE Project: 13.301.14

Dear Hermann,

At your request we have reviewed the Parasol Star600 Series light track. The light track has been checked for a maximum allowable design load of 600 pounds. The hanging light load is assumed to be evenly distributed over the system. As part of our review we were also sent a video of the system being tested with an evenly distributed live load of 675 pounds.

Based on our analysis (see appendix B), the system is adequate to support a maximum evenly distributed load of 600 pounds. The system, with this loading, will have a minimum factor of safety of ~~2:1.~~ 4:1

We trust this information is sufficient for your needs at this time. Please do not hesitate to contact our office should you have any questions.

Regards,
Clark-Reder Engineering, Inc.

JEFFREY M.
REDER
E-67450
6/7/13

Jeffrey M. Reder, P.E.

APPENDIX A

PARASOL STAR600 Series INTRODUCTION

SIMILARITIES of the STAR600 Series to the Parasol KLR Series.

- The STAR600 has a track plate and a driven plate like the KLR
- The load bearing wheel assemblies are exactly the same as the KLR

DIFFERENCES of the STAR600 Series to KLR Series

- The diameter of the STAR600 track plate is much smaller. Its OD is only 43" (vs 120" on KLR10)
- STAR600 is built as one piece. (as opposed to separate arc sections in the KLR series)
- There is ***no*** support truss. The track plate is instead, supported and made rigid by a circular, rolled, 1.5" x 3" x .25" C channel that is securely bolted to the Track Plate at 15 degree intervals.

GENERAL Technical/Mechanical Description.

The STAR 600 essentially consists of 3 "**LAYERS**" :

LAYER 2, the "middle" layer, is the TRACK PLATE Assembly. The track plate is stationary
The track plate supports the rotating DRIVEN PLATE. The entire product is ultimately rigged from the TRACK PLATE Assembly

LAYER 1, the "bottom" layer is the DRIVEN PLATE Assembly.
The driven plate is suspended from the track plate by 6 load bearing wheels that travel around the outside edge of the track plate. It is the DRIVEN PLATE that rotates underneath the TRACK PLATE. The lighting fixtures are mounted to the DRIVEN PLATE

LAYER 3, the "top" layer is the SUPER-STRUCTURE LAYER. The super-structure supports the motor and gear head drive mechanism and also contributes to the rigging options of the product.

CLARK REDER
ENGINEERING

APPENDIX B

Parasol Advanced Systems - Star600 Light Ring

Design Codes and Standards

- The Aluminum Association, Aluminum Design Manual 2005: Specifications and Guidelines for Aluminum Structures
- ANSI E1.2 - 2000, Entertainment Technology, Design, Manufacture and Use of Aluminum Trusses and Towers
- ANSI E1.2-2006, Entertainment Technology, Temporary Ground Supported Overhead Structures Used to Cover Stage Areas and Support Equipment in the Production of Outdoor Entertainment Events.
- 2009 International Building Code

Project Description:

The Star600 is a moving light assembly. The main structure of the assembly is a 48" diameter aluminum track plate which supports the lighting loads and hangs from pipes supported from the plate.

Analysis Assumptions

- The track plate will be supported at (4) locations
- The motor and its attachment have not been reviewed as part of this calculation.
- The aluminum used in the construction of the system is 6061-T6 or 6005-T5 and the weld filler is 5556.
- All bolts are Grade 8, $F_u = 150$ ksi
- The assembly will be reviewed for a total load of 600 pounds uniformly distributed.

Design Loads

Track Plate 45.125"x3/8" (Layer 2)

Weight of plate: $wt_{plate} := 51 \cdot lbf$

Drive Plate 64"x3/8" (Layer 1 plate)

Weight of plate: $wt_{plateh} := 64 \cdot lbf$

Channel weight: $wt_{channel} := 20 \cdot lbf = 20\,lbf$

Total assembly weight: $wt_{track} := 1.1 \cdot (wt_{plateh} + wt_{channel}) = 92.4\,lbf$

Weight of lights and equipment

Weight of equipment: $wt_{equip} := 600 \cdot lbf$

Main Radius Support Arm

Design load per radius arm: $P_{design} := 200 \cdot lbf$ There are (6) radial arms

The lighting tube is suspended from the driven plate via bolts. The tube is a 2"x1/4" thick member spanning 30".

Allowable member stress: $F_b := 21 \cdot ksi$

Section properties: $S_{tube} := 0.537 \cdot in^3$

Allowable point load: $P_{tube} := \frac{F_b \cdot S_{tube}}{15 \cdot in} = 751.8 \cdot lbf$ **The 2x2x1/4 is adequate to support the load**

Bolt tension: $T_{bolt} := P_{design} \cdot \left(\frac{15 \cdot in}{15 \cdot in}\right) = 200\ lbf$ **The bolts are 3/8" and are adequate by inspection**

Typical Hanger Bearing Wheel Assembly

The bearing wheel assembly is composed of a 1.5"x1.5"x0.125" aluminum tube and an L5x3.5 aluminum angle. The bearing wheel is housed within the tube member and bolted to the 5" angle leg via a 5/16 grade 8 bolt. The horizontal (3") leg of the angle is bolted to the rotating plate with (3) 3/8" grade 8 bolts.

5/16" Grade 8 Bolt Capacity

This bolt holds the hanger plate wheel in place. It spans 1.5" between the walls of the tube.

Tensile strength: $Fu_{bolt} := 150 \cdot ksi$

Bolt diameter: $d_b := 0.3125 \cdot in$

Bolt area: $A_b := \frac{d_b^{\ 2} \cdot \pi}{4}$

Bolt tensile strength: $Ta_{bolt} := \frac{0.75 \cdot Fu_{bolt} \cdot A_b}{2.0}$ $Ta_{bolt} = 4.314 \cdot kip$

Bolt shear strength: $Va_{bolt} := \frac{0.4 \cdot Fu_{bolt} \cdot A_b}{2.0}$ $Va_{bolt} = 2.301 \cdot kip$

Shear in bolt (max): $V_{bolt} := P_{design} = 200\ lbf$

Percent used: $\text{bolt\_percent} := \frac{V_{bolt}}{2 \cdot Va_{bolt}} = 4.346 \cdot \%$ **The bolts are adequate in shear**

Bolt bending: $M_{bolt} := \frac{P_{design} \cdot 1.5 \cdot in}{4} = 0.075 \cdot in \cdot kip$

Plastic section modulus: $Z_x := \frac{{d_b}^3}{6} = 0.005 \cdot in^3$

Allowable moment: $M_{allow\_bolt} := \frac{\min\left(Z_x \cdot 120 \cdot ksi, 0.00299 \cdot in^3 \cdot 120 \cdot ksi \cdot 1.6\right)}{1.67} = 0.344 \cdot in \cdot kip$

Percent used: $\text{bolt\_percent} := \frac{M_{bolt}}{M_{allow\_bolt}} = 21.818 \cdot \%$ **The bolts are adequate in flexure**

Weld of tube to vertical angle

Moment in vertical leg: $M_{vert} := \frac{P_{design}}{2} \cdot (1.75 \cdot in) + \frac{P_{design}}{2} \cdot 0.25 \cdot in = 0.2 \cdot in \cdot kip$

Section modulus of weld (sides only) $S_{weld} := \frac{(1.5 \cdot in)^2}{3} = 0.75 \cdot in^2$

Area of weld (sides only): $A_{weld} := 2 \cdot 1.5 \cdot in = 3 \cdot in$

Stress in weld due to hanger load: $f_{b\_weld} := \frac{M_{vert}}{S_{weld}} + \frac{P_{design}}{A_{weld}} = 0.333 \cdot \frac{kip}{in}$

Allowable weld stress:

Per 7.3.2.2 stress on a fillet weld shall be considered to be shear for any direction of applied load.

Filler shear ultimate (5556): $F_{suf} := 42ksi$

Base metal shear ultimate welded: $F_{suw} := 15ksi$

Base metal tensile ultimate welded: $F_{tuw} := 24ksi$

Safety factor $n_u := 1.95$

Size of weld $s_{weld} := \frac{3}{16} in$

Effective throat of fillet weld $E_{weld} := S_{weld}\frac{\sqrt{2}}{2}$ $E_{weld} = 0.1326\cdot in$

Weld shear stress $F_{sw} := \frac{\min(F_{suf}\cdot E_{weld}, F_{suw}\cdot S_{weld}, F_{tuw}\cdot S_{weld})}{n_u}$ $F_{sw} = 1.442\cdot\frac{kip}{in}$

Percent used: $weld\_percent := \frac{f_{b\_weld}}{F_{sw}} = 23.111\cdot\%$ **The weld is adequate**

Vertical Angle Leg Flexure and Axial Load

The vertical leg is a 1/2" by 5" tall by 3" wide.

Thickness of angle: $t_{angle} := 0.5\cdot in$

Width of angle: $w_{angle} := 3\cdot in$

Height of angle: $h_{angle} := 5\cdot in$

Area of plate: $A_{pl} := t_{angle}\cdot w_{angle} = 1.5\cdot in^2$

Moment of inertia: $Ix_{pl} := \frac{1}{12}\cdot t_{angle}\cdot w_{angle}^3 = 1.125\cdot in^4$ $Iy_{pl} := \frac{1}{12}\cdot t_{angle}^3\cdot w_{angle} = 0.031\cdot in^4$

Moment of inertia: $rx_{pl} := \sqrt{\frac{Ix_{pl}}{A_{pl}}} = 0.866\cdot in$ $ry_{pl} := \sqrt{\frac{Iy_{pl}}{A_{pl}}} = 0.144\cdot in$

Section modulus: $Sx_{pl} := \frac{1}{6}\cdot t_{angle}\cdot w_{angle}^2 = 0.75\cdot in^3$ $Sy_{pl} := \frac{1}{6}\cdot t_{angle}^2\cdot w_{angle} = 0.125\cdot in^3$

Axial Capacity

Axial tension - 3.4.1

Allowable stress: $F_{t\_3.4.1} := 19\cdot ksi$

Compression - 3.4.7

Slenderness: $S_{7\_c} := \frac{1.0\cdot 5\cdot in}{ry_{pl}}$ $S_{7\_c} = 34.641$

Allowable stress: $F_{c\_3.4.7} := \begin{Vmatrix} (20.2 - 0.126\cdot S_{7\_c})\cdot ksi \ \text{ if } (0 < S_{7\_c}) \wedge (66 > S_{7\_c}) \\ \left(\frac{51100}{S_{7\_c}^2}\right)\cdot ksi \ \text{ if } 66 < S_{7\_c} \end{Vmatrix}$ $F_{c\_3.4.7} = 15.8\cdot ksi$

Flexural Capacity

Axial tension - 3.4.4

Allowable stress: $F_{t\_3.4.4} := 28 \cdot \text{ksi}$

Compression - 3.4.13

Slenderness: $S_{13} := \dfrac{w_{angle}}{t_{angle}} \cdot \sqrt{\dfrac{h_{angle}}{w_{angle}}}$ $\qquad S_{13} = 7.746$

Allowable stress:

$$F_{c\_3.4.13} := \begin{cases} (28 \cdot \text{ksi}) & \text{if } S_{13} \le 14 \\ \left(40.5 - 0.927 \cdot \sqrt{S_{13}}\right) \cdot \text{ksi} & \text{if } (14 < S_{13}) \wedge (167 \ge S_{13}) \\ \left[\dfrac{11400}{\left(\dfrac{w_{angle}}{t_{angle}}\right)^2 \cdot \sqrt{\dfrac{h_{angle}}{w_{angle}}}} \right] \cdot \text{ksi} & \text{if } 390 < S_{13} \end{cases}$$

$F_{c\_3.4.13} = 28 \cdot \text{ksi}$

Vertical leg axial tension capacity: $T_{allow\_vert} := A_{pl} \cdot F_{t\_3.4.1} = 28.5 \cdot \text{kip}$

Vertical leg axial compression capacity: $C_{allow\_vert} := A_{pl} \cdot F_{c\_3.4.7} = 23.753 \cdot \text{kip}$

Vertical leg flexural capacity: $M_{allow\_vert} := \min\left(F_{t\_3.4.4}, F_{c\_3.4.13}\right) \cdot Sy_{pl} = 3.5 \cdot \text{in} \cdot \text{kip}$

By inspeciton of the tension and compression allowable capacities, the plate is adequate for a 250 pound load. Check the flat bending of the plate.

Moment in vertical leg: $M_{vert} := \dfrac{P_{design}}{2} \cdot (1.75 \cdot \text{in}) + \dfrac{P_{design}}{2} \cdot 0.25 \cdot \text{in} = 0.2 \cdot \text{in} \cdot \text{kip}$ OK by inspection of the loads

Combined Stress Checks

Axial compressive stress in vertical: $f_c := \dfrac{P_{design}}{A_{pl}} = 0.133 \cdot \text{ksi}$

Axial tension stress in vertical: $f_t := \dfrac{P_{design}}{A_{pl}} = 0.133 \cdot \text{ksi}$

Stress due to bending: $f_{by} := \dfrac{M_{vert}}{Sy_{pl}} = 1.6 \cdot \text{ksi}$

Combined Axial Load and Bending - 4.1.1:

Coefficient for sway: $C_{mx} := 1.0$ $\qquad E_a := 10100 \cdot ksi$

Coefficient for sway: $C_{my} := 1.0$

Elastic buckling: $F_{ex} := \dfrac{\pi^2 \cdot E_a}{1.95 \cdot (S_{7\_c})} = 1475.693 \cdot ksi$

Elastic buckling: $F_{ey} := \dfrac{\pi^2 \cdot E_a}{1.95 \cdot (S_{7\_c})} = 1475.693 \cdot ksi$

Eqn 4.1.1-1: $ratio_{4.1.1\_1} := \dfrac{f_c}{F_{c\_3.4.7}} + \dfrac{C_{mx} \cdot f_{by}}{F_{c\_3.4.13} \cdot \left(1 - \dfrac{f_c}{F_{ex}}\right)} = 0.066$

Eqn 4.1.1-2: $ratio_{4.1.1\_2} := \dfrac{f_c}{F_{c\_3.4.7}} + \dfrac{f_{by}}{F_{c\_3.4.13}} = 0.066$

Eqn 4.1.1-3: $ratio_{4.1.1\_3} := \dfrac{f_c}{F_{c\_3.4.7}} + \dfrac{f_{by}}{F_{c\_3.4.13}} = 0.066$

Combined check:
$$int_{ct} := \left| \begin{array}{ll} ratio_{4.1.1\_3} & \text{if } \dfrac{f_c}{F_{c\_3.4.7}} < 0.15 \\ \max\left(ratio_{4.1.1\_1}, ratio_{4.1.1\_2}\right) & \text{if } \dfrac{f_c}{F_{c\_3.4.7}} \geq 0.15 \end{array} \right.$$

$int_{ct} = 0.066$

Combined Axial Load and Bending - 4.1.2:

Eqn 4.1.2-1: $ratio_{4.1.2\_1} := \dfrac{f_t}{F_{t\_3.4.1}} + \dfrac{f_{by}}{F_{c\_3.4.13}}$ $\qquad ratio_{4.1.2\_1} = 0.064$

The vertical angle leg is adequate

Horizontal Angle Leg Flexure

The horizontal leg is a 3/8" by 3.5" tall by 3" wide.

Thickness of angle: $t_{angle2} := 0.368 \cdot in$

Width of angle: $w_{angle2} := 3 \cdot in$

Height of angle: $h_{angle2} := 3.5 \cdot in$

Area of plate: $A_{pl2} := t_{angle2} \cdot w_{angle2} = 1.104 \cdot in^2$

Moment of inertia: $Ix_{pl2} := \frac{1}{12} \cdot t_{angle2} \cdot w_{angle2}^{\;3} = 0.828 \cdot in^4$ $\quad Iy_{pl2} := \frac{1}{12} \cdot t_{angle2}^{\;3} \cdot w_{angle2} = 0.012 \cdot in^4$

Moment of inertia: $rx_{pl2} := \sqrt{\frac{Ix_{pl2}}{A_{pl2}}} = 0.866 \cdot in$ $\quad ry_{pl2} := \sqrt{\frac{Iy_{pl2}}{A_{pl2}}} = 0.106 \cdot in$

Section modulus: $Sx_{pl2} := \frac{1}{6} \cdot t_{angle2} \cdot w_{angle2}^{\;2} = 0.552 \cdot in^3$ $\quad Sy_{pl2} := \frac{1}{6} \cdot t_{angle2}^{\;2} \cdot w_{angle2} = 0.068 \cdot in^3$

Flexural Capacity

Axial tension - 3.4.4

Allowable stress: $F_{t\_3.4.4} := 28 \cdot ksi$

Compression - 3.4.13

Slenderness: $S_{13} := \frac{w_{angle2}}{t_{angle2}} \cdot \sqrt{\frac{h_{angle2}}{w_{angle2}}}$ $\quad S_{13} = 8.805$

Allowable stress:
$$F_{c\_3.4.13\_2} := \left| \begin{array}{l} (28 \cdot ksi) \;\text{ if }\; S_{13} \le 14 \\ \left(40.5 - 0.927 \cdot \sqrt{S_{13}}\right) \cdot ksi \;\text{ if }\; (14 < S_{13}) \wedge (167 \ge S_{13}) \\ \left[\dfrac{11400}{\left(\dfrac{w_{angle}}{t_{angle}}\right)^2 \cdot \sqrt{\dfrac{h_{angle}}{w_{angle}}}} \right] \cdot ksi \;\text{ if }\; 390 < S_{13} \end{array} \right.$$

$F_{c\_3.4.13\_2} = 28 \cdot ksi$

Horizontal leg flexural capacity: $M_{allow\_horz} := \min\left(F_{t\_3.4.4}, F_{c\_3.4.13\_2}\right) \cdot Sy_{pl2} = 1895.936 \cdot in \cdot lbf$

Moment in horizontal leg: $M_{horz} := \frac{P_{design}}{2} \cdot (1.75 \cdot in) + \frac{P_{design}}{2} \cdot 0.25 \cdot in + P_{design} \cdot 1.5 \cdot in = 0.5 \cdot in \cdot kip$

Percent used: $horz\_percent := \frac{M_{horz}}{M_{allow\_horz}} = 26.372 \cdot \%$ **The horizontal leg is adequate**

3/8" Grade 8 Bolt Capacity

These bolts connect the horizontal leg to the drive plate.

Tensile strength: $Fu_{bolt} := 150 \cdot ksi$

Bolt diameter: $d_b := 0.375 \cdot in$

Bolt area: $A_b := \frac{d_b^{\,2} \cdot \pi}{4}$

Bolt tensile strength: $Ta_{bolt} := \frac{0.75 \cdot Fu_{bolt} \cdot A_b}{2.0}$ $Ta_{bolt} = 6.213 \cdot kip$

Bolt shear strength: $Va_{bolt} := \frac{0.4 \cdot Fu_{bolt} \cdot A_b}{2.0}$ $Va_{bolt} = 3.313 \cdot kip$

Tension in bolts assuming enitre load is on one side: $T_{bolt} := \frac{M_{horz}}{1 \cdot in} = 500\, lbf$

Percent used: $bolt\_percent := \frac{T_{bolt}}{Ta_{bolt}} = 8.048 \cdot \%$ **The bolts are adequate**

Typical Hanger Bearing Wheel Assembly

The bearing wheel assembly is composed of an L5x3.5 aluminum angle with 1/2" diameter shouldered bolt. The bearing wheel is cantilevered from the bolt which attaches to the angle. The horizontal (3") leg of the angle is bolted to the rotating plate with (3) 3/8" grade 8 bolts.

1/2" Grade 8 Bolt Capacity

This bolt holds the hanger plate wheel in place. It spans 1.5" between the walls of the tube.

Tensile strength: $Fu_{bolt} := 150 \cdot ksi$

Bolt diameter: $d_b := 0.5 \cdot in$

Bolt area: $A_b := \frac{d_b^{\,2} \cdot \pi}{4}$

Bolt tensile strength: $Ta_{bolt} := \frac{0.75 \cdot Fu_{bolt} \cdot A_b}{2.0}$ $\qquad Ta_{bolt} = 11.045 \cdot kip$

Bolt shear strength: $Va_{bolt} := \frac{0.4 \cdot Fu_{bolt} \cdot A_b}{2.0}$ $\qquad Va_{bolt} = 5.89 \cdot kip$

Shear in bolt (max): $V_{bolt} := P_{design} = 200\ lbf$

Percent used: $bolt\_percent := \frac{V_{bolt}}{Va_{bolt}} = 3.395 \cdot \%$ **The bolts are adequate in shear**

Bolt bending: $M_{bolt} := 500 \cdot lbf \cdot 0.875 \cdot in = 0.438 \cdot in \cdot kip$

Plastic section modulus: $Z_x := \frac{d_b^{\,3}}{6} = 0.021 \cdot in^3$

Elastic section modulus: $S_x := \frac{\pi \cdot d_b^{\,3}}{32} = 0.012 \cdot in^3$

Allowable moment: $M_{allow\_bolt} := \frac{\min\left(Z_x \cdot 120 \cdot ksi, S_x \cdot 120 \cdot ksi \cdot 1.6\right)}{1.67} = 1.411 \cdot in \cdot kip$

Percent used: $bolt\_percent := \frac{M_{bolt}}{M_{allow\_bolt}} = 31.009 \cdot \%$ **The bolts are adequate in flexure**

Bearing of Bolt on Vertical Angle

The reaction on the front face: $R_{front} := \dfrac{P_{design} \cdot (0.875 \cdot in + 0.5 \cdot in)}{0.5 \cdot in} = 550\ lbf$

The reaction on the front face: $R_{back} := \dfrac{P_{design} \cdot (0.875 \cdot in)}{0.5 \cdot in} = 350\ lbf$

Maximum bearing stress in angle: $stress\_brg := \dfrac{R_{front}}{0.5 \cdot in \cdot 0.1 \cdot in} = 11 \cdot ksi$ allowable stress is 39 ksi - OK

Driven Plate

The driven plate will have load applied directly adjacent to the hanger plate. Check the plate for the bending between the application of load and the hanger.

Driven Plate

The driven plateis 3/8" thick x 19" wide aluminum (6061-T6 plates). This plate hangs from the hanger plates and supports the hang plates. Assume the plate spans between hanger plates for vertical loads. The OD of the entire driven plate assembly is 126 inches.

Drive Plate Weak Axis Flexure.

Thickness of plate: $t_{plate} := 0.375 \cdot in$

Width of plate: $w_{plate} := 6 \cdot in$ effective width of plate

Area of plate: $A_{pl} := t_{plate} \cdot w_{plate} = 2.25 \cdot in^2$

Moment of inertia: $Ix_{pl} := \dfrac{1}{12} \cdot t_{plate} \cdot w_{plate}^3 = 6.75 \cdot in^4$ $Iy_{pl} := \dfrac{1}{12} \cdot t_{plate}^3 \cdot w_{plate} = 0.026 \cdot in^4$

Moment of inertia: $rx_{pl} := \sqrt{\dfrac{Ix_{pl}}{A_{pl}}} = 1.732 \cdot in$ $ry_{pl} := \sqrt{\dfrac{Iy_{pl}}{A_{pl}}} = 0.108 \cdot in$

Section modulus: $Sx_{pl} := \dfrac{1}{6} \cdot t_{plate} \cdot w_{plate}^2 = 2.25 \cdot in^3$ $Sy_{pl} := \dfrac{1}{6} \cdot t_{plate}^2 \cdot w_{plate} = 0.141 \cdot in^3$

Flexural Capacity

Axial tension - 3.4.4

Allowable stress: $F_{t\_3.4.4} := 28 \cdot \mathrm{ksi}$

Compression - 3.4.13

Slenderness: $S_{13} := \frac{t_{plate}}{w_{plate}} \cdot \sqrt{\frac{w_{plate}}{t_{plate}}}$ $\qquad S_{13} = 0.25$

Allowable stress: $$F_{c\_3.4.13\_2} := \left| \begin{array}{l} (28 \cdot \mathrm{ksi}) \ \text{ if } S_{13} \le 14 \\ \left(40.5 - 0.927 \cdot \sqrt{S_{13}}\right) \cdot \mathrm{ksi} \ \text{ if } \left(14 < S_{13}\right) \wedge \left(167 \ge S_{13}\right) \\ \left[\dfrac{11400}{\left(\dfrac{t_{plate}}{w_{plate}}\right)^2 \cdot \dfrac{33 \cdot \mathrm{in}}{t_{plate}}} \right] \cdot \mathrm{ksi} \ \text{ if } 390 < S_{13} \end{array} \right. \qquad F_{c\_3.4.13\_2} = 28 \cdot \mathrm{ksi}$$

Flat plate flexural capacity: $M_{allow\_horz} := \min\left(F_{t\_3.4.4}, F_{c\_3.4.13\_2}\right) \cdot Sy_{pl} = 3937.5 \cdot \mathrm{in} \cdot \mathrm{lbf}$

Flexure in plate assuming midspan point load of single hang plate: $M_{vert} := P_{design} \cdot 6 \cdot \mathrm{in} = 1200 \cdot \mathrm{in} \cdot \mathrm{lbf}$

Percent used: $\mathrm{percent\_flex} := \frac{M_{vert}}{M_{allow\_horz}} = 30.476 \cdot \%$ Driven Plate - OK for flexure

Track Plate

The track plateis 3/8" thick and will support the wheel hangers. The plate will act as beam strips which span between support angles.

Track Plate Weak Axis Flexure.

Thickness of plate: $t_{plate} := 0.375 \cdot in$

Width of plate: $w_{plate} := 6 \cdot in$ effective width of plate

Area of plate: $A_{pl} := t_{plate} \cdot w_{plate} = 2.25 \cdot in^2$

Moment of inertia: $Ix_{pl} := \frac{1}{12} \cdot t_{plate} \cdot w_{plate}^3 = 6.75 \cdot in^4$ $Iy_{pl} := \frac{1}{12} \cdot t_{plate}^3 \cdot w_{plate} = 0.026 \cdot in^4$

Moment of inertia: $rx_{pl} := \sqrt{\frac{Ix_{pl}}{A_{pl}}} = 1.732 \cdot in$ $ry_{pl} := \sqrt{\frac{Iy_{pl}}{A_{pl}}} = 0.108 \cdot in$

Section modulus: $Sx_{pl} := \frac{1}{6} \cdot t_{plate} \cdot w_{plate}^2 = 2.25 \cdot in^3$ $Sy_{pl} := \frac{1}{6} \cdot t_{plate}^2 \cdot w_{plate} = 0.141 \cdot in^3$

Flexural Capacity

Axial tension - 3.4.4

Allowable stress: $F_{t\_3.4.4} := 28 \cdot ksi$

Compression - 3.4.13

Slenderness: $S_{13} := \frac{t_{plate}}{w_{plate}} \cdot \sqrt{\frac{9 \cdot in}{t_{plate}}}$ $S_{13} = 0.306$

Allowable stress: $F_{c\_3.4.13\_2} := \begin{cases} (28 \cdot ksi) & \text{if } S_{13} \le 14 \\ \left(40.5 - 0.927 \cdot \sqrt{S_{13}}\right) \cdot ksi & \text{if } \left(14 < S_{13}\right) \wedge \left(167 \ge S_{13}\right) \\ \left[\dfrac{11400}{\left(\dfrac{t_{plate}}{w_{plate}}\right)^2 \cdot \dfrac{33 \cdot in}{t_{plate}}}\right] \cdot ksi & \text{if } 390 < S_{13} \end{cases}$ $F_{c\_3.4.13\_2} = 28 \cdot ksi$

Track plate flexural capacity: $M_{allow\_horz} := \min\left(F_{t\_3.4.4}, F_{c\_3.4.13\_2}\right) \cdot Sy_{pl} = 3937.5 \cdot in \cdot lbf$

Flexure in plate assuming midspan point load of single hang plate: $M_{vert} := P_{design} \cdot 2 \cdot 9 \cdot in = 3600 \cdot in \cdot lbf$

Percent used: $percent\_flex := \dfrac{M_{vert}}{M_{allow\_horz}} = 91.429 \cdot \%$ Say OK as load is doubled, assumes load at one corner is 400 pounds, OK

Aluminum Track Channel

The track channel is bolted to the track plate at the perimeter to act as a stiffener. The channel is 3"x1.5"x0.313".

Section modulus: $S_x := 1.368 \cdot in^3$

Assume the channel will span approximately 24" between vertical supports.

Moment in beam: $M_{channel} := 600 \cdot lbf \cdot \dfrac{24 \cdot in}{4} = 300\ ft \cdot lbf$

Stress in beam: $f_b := \dfrac{M_{channel}}{S_x} = 2.632\,ksi$ The stress is low, the channel is adequate.

Hanger Plate

The hanger assembly is composed of a channel that is 4x4x1/2 bolted to the track plate. The hanger plate that bolts to the angle is 4"x1/2".

4"x1/2" plate

Plate width: $b_{w1} := 4 \cdot in$

Plate thickness: $t_{w1} := 0.5 \cdot in$

Plate allowable tension: $F_t := 21 \cdot ksi \cdot b_{w1} \cdot t_{w1} = 42\,kip$

Plate allowable net tension: $F_{tu} := 19 \cdot ksi \cdot \left[b_{w1} \cdot t_{w1} - \left[(1 \cdot in + 0.4 \cdot in + 0.4 \cdot in) \cdot t_{w1} \right] \right] = 20900\,lbf$

The plate is adequate for a maximum load of 600 pounds.
The angle is adequate as well by inspection.

Gear Head Mounting Assembly

The mounting assembly will be have various tubes. The smaller tubes are located directly below the Swivel hoists and will not see significant bending. There is a 4x2x1/4" aluminum tube which will be required to cantilever from the hanger plate.

Cantilever length: $\mathrm{arm} := 12 \cdot \mathrm{in}$

Moment in tube: $M_{tube} := \mathrm{arm} \cdot 600 \cdot \mathrm{lbf} = 7200\,\mathrm{in} \cdot \mathrm{lbf}$

Section modulus: $S_{tube} := 2.65 \cdot \mathrm{in}^3$

Stress in tube: $f_{tube} := \frac{M_{tube}}{S_{tube}} = 2.717\,\mathrm{ksi}$