The Design and Construction of a Rear Bumper with Incorporated Spare Tire Rack

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ABSTRACT

This senior project outlines the design and construction of a rear bumper with incorporated spare tire and equipment rack for a 1946 Willys CJ2A Jeep. The spare tire rack is capable of swinging out away from the vehicle to allow for the use of the vehicle's tailgate. The bumper was designed for strength, functionality and aesthetic qualities alike. Additionally, the bumper design considered all vehicle codes and regulations.

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TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

INTRODUCTION

Prior to the engagement of the United States in World War II, the nation was tasked with the production of war supplies including weapons and vehicles. In 1940, the Willys Overland Company began production of a light duty general purpose vehicle known as the “Jeep.” The jeep was the first four-wheeled vehicle of its kind and was designed to transport troops and supplies over rugged terrain. The vehicle became a pivotal and trustworthy tool to many soldiers on the war fronts. As the war came to an end, Willys realized their war time vehicle could be introduced to the consumer vehicle market. The vehicle was an immediate success when the CJ2A model made its market debut in 1945. Figure 1 exhibits a Willy’s CJ2A. Over the years Willys evolved into Jeep, AMC and eventually Chrysler all producing a number of different vehicle models. Today, there are Jeep owners around the world who take pride in their four-wheel drive “grocery-getters.”

Figure 1. Alan Isaacson’s 1946 Willys CJ2A.

Alan Isaacson has been the proud owner of a 1946 CJ2A Willys jeep since 2010 and has spent countless hours rebuilding and maintaining the vehicle. The vehicle sits in a stock configuration including a side mounted tire and tailgate in rear which can be viewed in Figure 2 and Figure 3. When this vehicle is used, it is often loaded with people and supplies including fuel cans, a “Hi-Lift” jack and tool box; but space is limited. The limited space is often uncomfortable and at times unsafe for occupants. Additionally, the side mounted spare tire protrudes 12 inches beyond the side panel of the body making the vehicle a total of 72 inches wide. Often when in operation, the jeep must be negotiated through tight areas and therefore the operator must be mindful of the spare tire’s proximity to objects along a trail as the tire can easily hit, snag or hang-up on hazards. The spare tire's location can be harmful to the occupants, the vehicle and the environment because it can be easily snagged on trees and other foliage. To improve upon this problem, the spare tire and equipment must be relocated. The only practical option for storage in the current state is in the rear of the vehicle tub. Storage of equipment in this area is not ideal and would limit the use of the removable rear seat.

Numerous aftermarket equipment companies have items available for purchase that address storage and spare tire relocation. These items are marketed for many of the modern vehicle models. Because of the age of this particular vehicle, there are few industry solutions to this problem and therefore other means must be taken to construct a device capable of fulfilling the owner's needs.

Figure 2.Stock placement of the spare tire on a Willys CJ2A.

Figure 3. Rear tailgate on a Willys CJ2A.

The objective of this project is to design and construct, based on similar aftermarket solutions, a custom devise that relocates a 31 inch spare tire weighing 45 pounds and allows for storage of an additional 70 pounds of equipment (including two fuel cans and a “Hi-Lift” jack). See Figure 4 for a current aftermarket solution. The idea is to build a custom rear bumper with an integrated spare tire mount and equipment storage rack for a Willys CJ2A. This device will allow the spare tire and equipment to be relocated to the rear of the vehicle allowing for occupant comfort and safety as well as vehicle clearance and functionality. The tire is to be mounted on a rack with a heavy duty hinge that can swing out of the way for the use of the tailgate. The tailgate hinges along the bottom rear edge of the vehicle. To maintain the use of the tailgate, the rack must be capable of swing out of the path of the tailgate; this requires at least 90 degrees of rotation by the rack hinge. The rack itself must maintain a sufficient clearance (approximately 0.5 inches) from the rear of the vehicle when in its closed position. The rack must have a locking/ latching system to hold its position in both the fully closed and fully opened position. The bumper on which the rack mounts must reach from the driver’s side finder to the passenger’s side fender and not protrude passed. The cost of the bumper is to not greatly exceed $500.

Figure 4. An aftermarket bumper and spare tire rack currently produced by 4x4 Group Buy (2016).

LITERATURE REVIEW

Overview

When someone says off-roading one likely thinks Jeep. Jeep has been mastering rugged terrain around the world since its birth in 1941(Allpar, 2015). Since its birth 75 years ago, the past time of off-roading has greatly grown. From 1982 to 1995, participants in off-roading increased 43.8% equating to a total of about 23 million people (Cordell, et. al. 1999). This number has continued to grow since 1995; with such interest many off road vehicle accessories such as spare tire mount incorporated bumpers have emerged in the market. The majority of these accessories are marketed for new model Jeeps, leaving few options for the early models.

Testing

The U.S. Government and the National Highway Traffic Safety Administration (NHSTA) requires that all highway vehicles be fitted with a bumper that meets the 5 mph Federal Motor Vehicle Safety Standards (FMVSS) impact Standard 581 (Evans and Haddad, 1983). A bumper is tested via two pendulum tests. These tests require that a dynamic pendulum of identical curb weight strike a vehicle at the bumper's foremost surface and at the corners, and the vehicle must absorb the impact with no damage to the vehicle and minimal to the bumper system (McCormick, 1991). These testing situations will be considered during the design of the bumper and can me simulated in via a SolidWorks analysis.

Materials

Passenger car bumper systems typically consist of a steel, aluminum, or reinforced plastic bumper beam which spans the width of the vehicle (King et. al., 1993) but can also be made of wood or composite materials such as carbon fiber. At times, numerous materials are combined into a single bumper system. Although bumpers are designed to protect a vehicle and its occupants from an impact, many aftermarket bumpers add other utilities like towing hitches, spare tire mounts and equipment storage. Bumpers are constructed of a wide variety of materials and these materials are selected based on the features of the bumper and the characteristics the material provides.

<u>Plastic</u> . A common material of today's bumper systems, plastic and large sections of foam are often utilized in many small to medium cars, trucks and SUVs. These types of bumpers maximize the weight to strength ratio while reducing cost and improving aesthetic appeal. Plastic bumpers are not ideal in load bearing situations including the use of tow packages or spare tire mount and therefore not ideal for larger trucks, off road vehicles, or for the use in aftermarket bumpers with a spare tire mount. A plastic bumper can be viewed in Figure 5.

Figure 5. A stock plastic bumper on a Toyota 4runner (Toyota, 2015).

Carbon Fiber . Carbon fiber, like plastic, maximizes the strength to weight ratio. Carbon fiber utilizes millions of small fibers bonded together with an epoxy resin. These bumpers are often very light weight, strong and non-flammable but can be brittle and quite pricey. These types of bumpers are widely utilized on super cars or other applications where weight is more important than the piece for the bumper itself (doityourself.com). An image of a carbon fiber bumper can be viewed in Figure 6.

Figure 6. Carbon fiber bumper on a 2011 Austin Martin Vantage S (Top Speed, 2011).

Aluminum . Aluminum is becoming increasingly common in the automotive industry for both body panels as well as bumpers. Ford is currently producing its F150 model with fully aluminum body panels saving over 700 pounds from previous models (Ford, 2015). Aluminum is much lighter but has similar strength characteristics when compared with steel. Aluminum is corrosion resistant but requires special equipment and tools to work with and additionally requires specific skills to fabricate, and therefore may be less desirable for a “one-off” design. Aluminum is typically more expensive than steel. An aluminum bumper can be viewed in Figure 7.

Figure 7. Aluminum bumper with spare tire mount on a jeep (Under Cover Fabworks, 2015).

Steel . Steel is a widely used material for both original equipment manufacturing and aftermarket bumpers. Steel has a large weight bearing capacity, performs well with minor to intermediate collisions, and is widely available and is easy to work with. Some downsides of steel include that it has low corrosion resistance and is heavier than aluminum. The majority of large trucks and utility vehicles use steel bumpers because they perform well in collisions on and off-road. They also allow for the use of tow packages and equipment storage and are easy to produce. An example of a steel bumper can be viewed in Figure 8.

Figure 8. A steel bumper with spare tire mount installed on a modern jeep (Rugged Ridge, 2015).

Design . There are many different spare tire mount incorporated bumper designs on the market. The bumpers in Figure 8 and Figure 9 essentially perform the same task, but this task is done with some significant differences. Publications like 4Wheel Drive Hardware (2015) provide many design ideas. Ultimately, a bumper must be designed to meet the characteristics, necessities and restraints of a specific vehicle while being safe and road legal. Most of the current bumper designs utilize a cantilevered beam with a hub assembly to allow for the spare tire to swing out of the way. Methods for the analysis of such conditions can be found in AISC (2011), Budynas and Nisbett (2008) and Ryerson Data Book (1975). These sources provide specific formulas and methods for correctly sizing structural members by calculating the stresses produced under various conditions. Potential conditions that must be analyzed include bending and shear stress in the cantilevered beam, the spindle (pivot) and the bumper to frame mounts; view Figure 9 for the identification of these items.

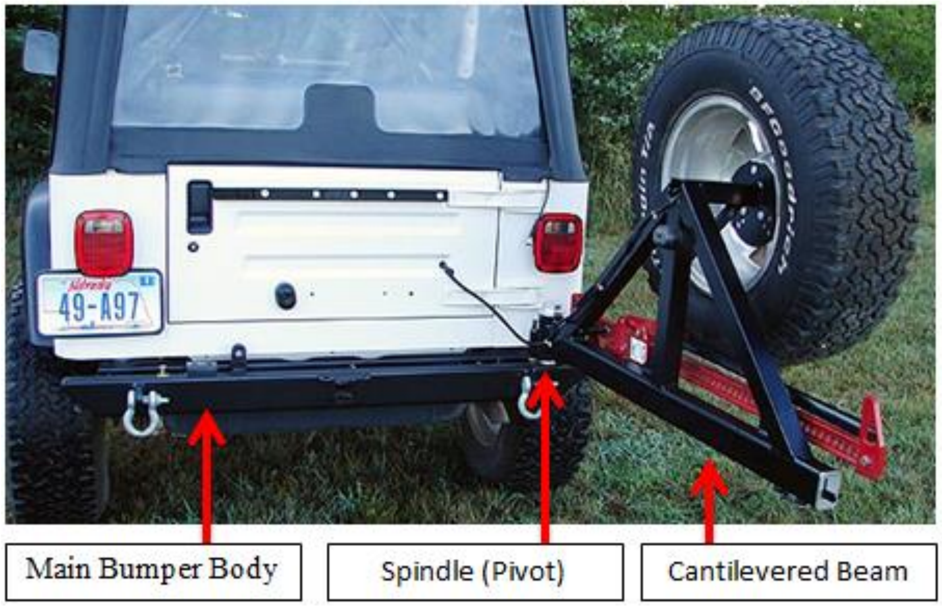

Figure 9. Major bumper components (4x4 Group Buy, 2016)

‘Jeep’ Universal (1965) provides many dimensions and drawings of early jeep vehicles. Figure 7 provides an image of the frame and Table 1 provides frame specifications and dimensions. This will prove useful in the sizing and shape of the bumper as well as how it will attach to the frame. Aftermarket bumpers are often welded and therefore should follow guidelines put for by the American Welding Society (2014). All bumpers must be designed with the guidelines and requirements put for by NHSTA (2015), FMVSS and SAE. Specific lamp standards for passenger vehicle bumpers are listed in Table 2.

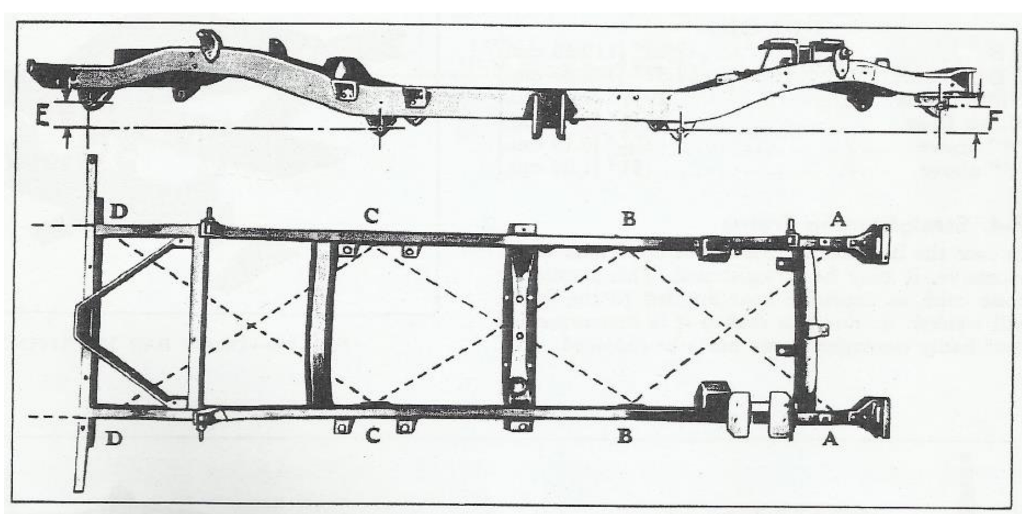

Figure 10. Willys CJ2a frame shape (‘Jeep’ Universal, 1965).

Table 1. Willys CJ2a major frame dimensions (‘Jeep’ Universal, 1965).

R-7. FRAME SPECIFICATIONS

Type — All Models		Ladder with Steel Channel Side Members			
Vehicle	Number of Cross Members	Overall Length	Width Front	Width Rear	Section Modulus
CJ-2A & CJ-3A	4 Intermediate Front Bumper Bar Rear K-member	$122\frac{21}{32}$" [311,54 cm.]	$29\frac{1}{4}$" [74,3 cm.]	$29\frac{1}{4}$" [74,3 cm.]	1.493 in. cu.
CJ-3B	4 Intermediate Front Bumper Bar Rear K-member	$122\frac{21}{32}$" [311,54 cm.]	$29\frac{1}{4}$" [74,3 cm.]	$29\frac{1}{4}$" [74,3 cm.]	1.493 in. cu.
CJ-5	4 Intermediate Front Bumper Bar Rear K-member	$128\frac{7}{16}$" [326,23 cm.]	$29\frac{1}{4}$" [74,3 cm.]	$29\frac{1}{4}$" [74,3 cm.]	1.493 in. cu.
CJ-6	4 Intermediate Front Bumper Bar Rear K-member	$148\frac{7}{16}$" [377,03 cm.]	$29\frac{1}{4}$" [74,3 cm.]	$29\frac{1}{4}$" [74,3 cm.]	1.493 in. cu.
DJ-3A	5	$122\frac{21}{32}$" [311,54 cm.]	$29\frac{1}{4}$" [74,3 cm.]	$29\frac{1}{4}$" [74,3 cm.]	1.493 in. cu.

Table 2. SAE lamp standards for automotive vehicles (U.S. Department of Transportation, 1990).

LAMP ASSEMBLY	SAE STANDARD
Tail	J585e
Stop	J586c
Turn Signal	J588e
Backup	J593c
Side Marker	J592e
Parking	J222

A bumper of similar function and design was constructed by Morgan Defty, a Cal Poly graduate of the BioResource and Agricultural Engineering Department. The bumper was to include a spare tire mount and be fitted for a Chevy Suburban. The designs and methods of Mr. Defty’s project will be referenced and considered in the construction of the bumper at hand. A picture of Morgan Defty’s final product can be viewed in Figure 8.

There are some specific differences to note in the design of Mr. Defty’s bumper as compared to the parameters of the design laid out in this report. First and foremost, Mr. Defty’s bumper was designed for a vehicle much larger than a Willys CJ2A thus making the over bumper design much larger as well. Additionally, the design in Figure 8 only allows for the mounting of a spare tire and no equipment and is hinged on the driver’s side. The design of this project is to incorporate the storage of a spare tire and equipment (including fuel cans and a “Hi-Lift” jack) onto a bumper and have it hinge on the passenger’s side of the vehicle.

Figure 11. The senior project of Morgan Defty (Defty, 2012).

PROCEDURES AND METHODS

Design

All design work for this bumper was conducted via SolidWorks, a 3D computer modeling software. The design was driven by two main factors: 1) the size, shape and location of the vehicle and its components to be equipped and 2) the size of the spare tire to be mounted on the rack. Other factors also contributed to the design of the bumper including: 1) ascetics, 2) location of license plate and tail lights, 3) location and function of a latching system, 4) location of a receiver hitch, 5) incorporation of Jerry (fuel) cans and 6) overall weight. Additionally, force calculations were conducted to ensure the proposed bumper was safely and adequately built. The finished SolidWorks model can be viewed in Figure 12 and Figure 13.

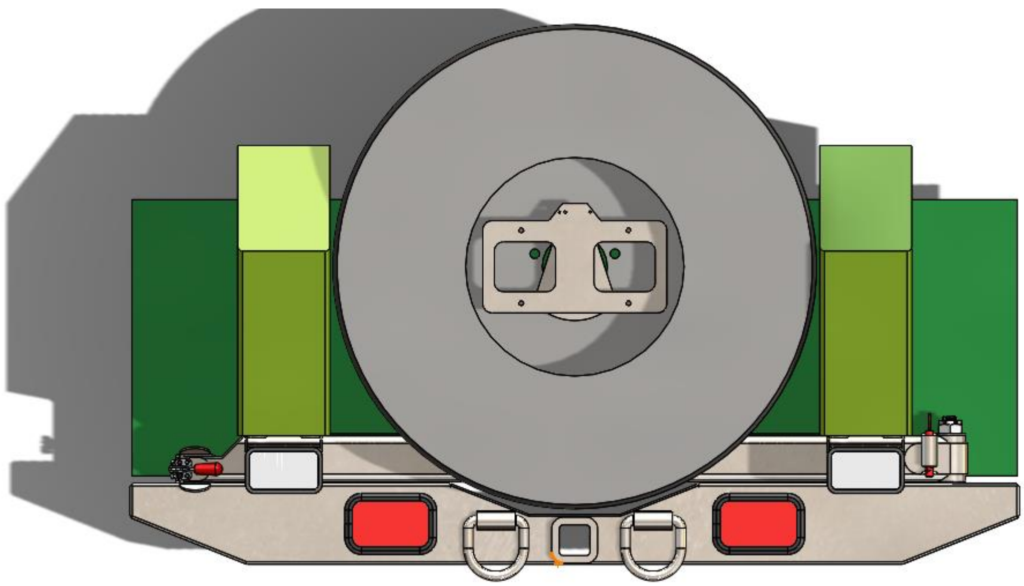

Figure 12. Completed SolidWorks model (transport position).

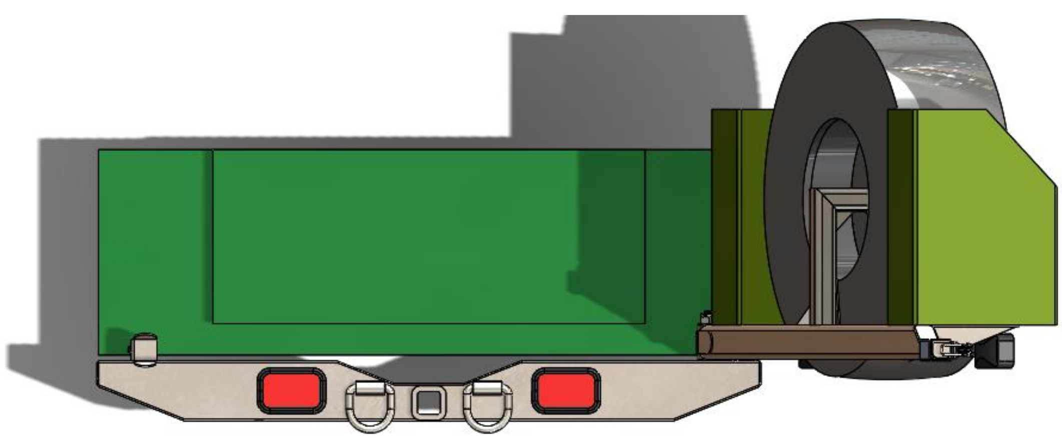

Figure 13. Completed SolidWorks model (tailgate access position).

Bumper . The bumper is the main body that spans the width of the vehicle that not only protects the vehicle from impacts but also supports the spare tire rack. The bumper was designed to mimic some of the characteristics of the stock bumper including tapering outer end, see Figure 14. The bumper also had to incorporate a hitch receiver and be capable of towing a small, single axle trailer. Flush mounted taillights were also desired. To combine all of this into a single design, SolidWorks was utilized. In Figure 15, the SolidWorks rendition exhibits tapering outer edges and cut outs for the taillights and hitch receiver. To incorporate strength, save weight and maximize the number of available metal working tools, 10 gauge (0.135") sheet steel was chosen. The bumper was designed to be cut out of a sheet of hot rolled 10 gauge via plasma cutter and then bent into shape via press brake. The bumper flat pattern can be viewed in Figure 16. The bumper was to be bent into a channel and because of this the constraints of the press brake had to be considered. Because of such constraints, the bumper's main channel was sized to have a top flange of 5 inches, web of 5 inches and a bottom flange of 4 inches. The bumper to frame mounts were designed to be made out of 0.25 inch plate and bolted directly to the frame using two 0.5 inch bolts per mount.

Figure 14. A stock CJ2A rear bumper (G503, 2007).

Figure 15. SolidWorks rendition of bumper design.

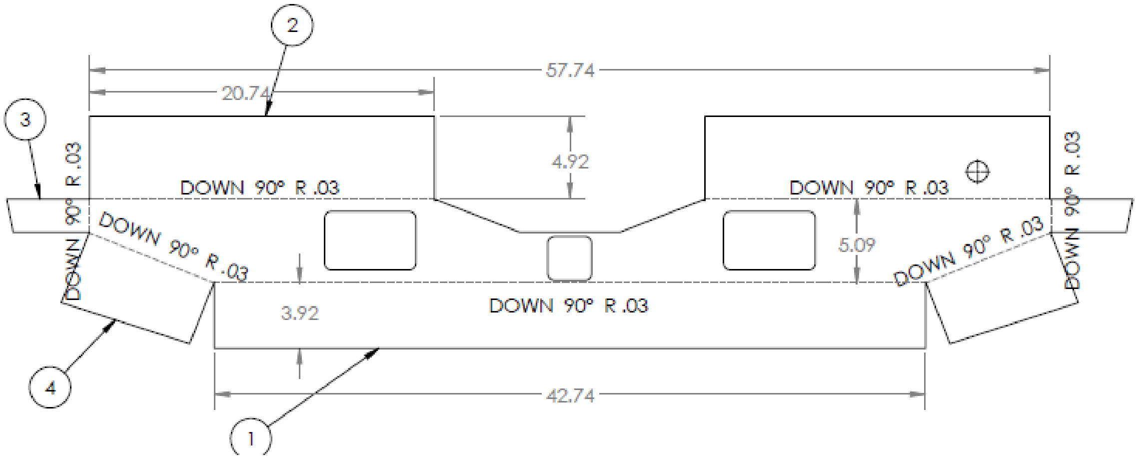

Figure 16. Bumper flat pattern.

Spare Tire Rack . The spare tire rack is the device that allows for the mounting of a full sized spare tire. It had to be designed so that the use of the vehicle's rear tailgate would not be limited. Additionally is had to incorporate mounts for Jerry (fuel) cans, the license plate, and a latching system. The rack was designed to utilize a spindle – hub type assembly that would allow the rack to swing open and out of the way when the use of the vehicle's tailgate was desired. A 2 inch x 3 inch x 0.125 inch tube was utilized as the main body of the rack. A hub was placed on one side and the other side was tapered to fit into a latching shelf. In the center of the tube, a riser and mounting flange was placed to allow the spare tire to be bolted onto the rack. See Figure 17 for the rack design.

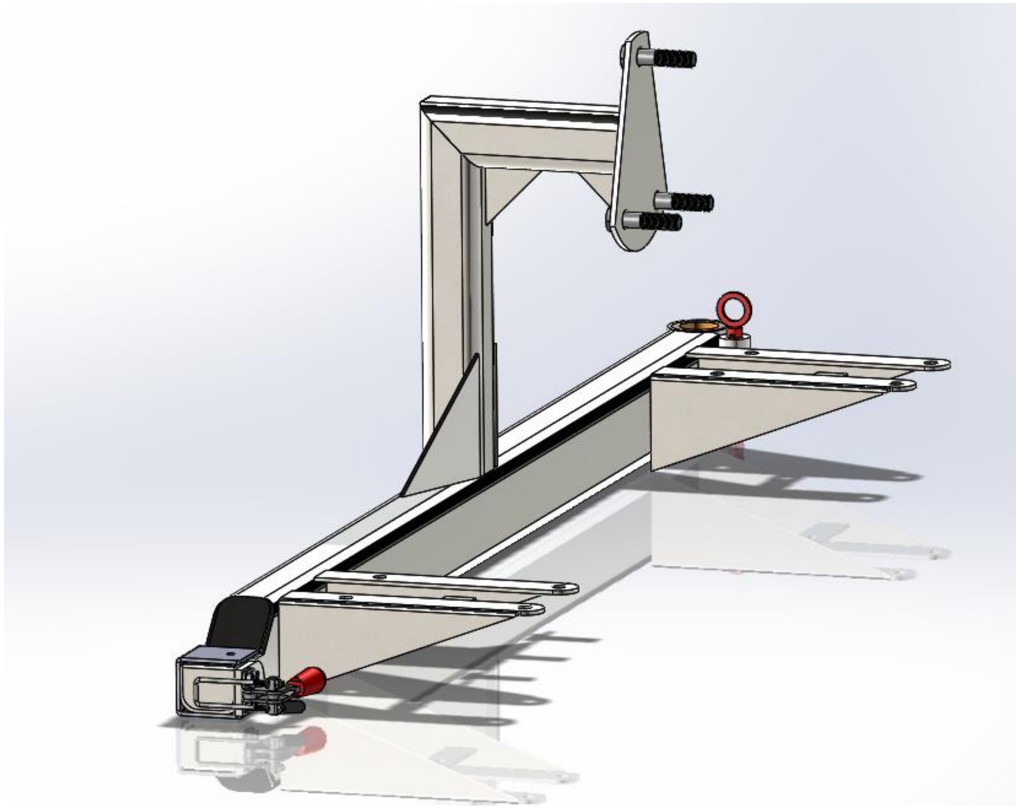

Figure 17. SolidWorks rendition of rack design.

Spindle – Hub Assembly . The spindle – hub assembly is designed to allow for the swinging action of the rack enabling it to be moved out of the way when the use of the vehicle's tailgate is desired. The spindle was designed from a 1.25 inch diameter hot rolled stock with 1 inch – NF – 14 threads cut to allow for a retaining nut. The hub was produced from a piece of 2 inch DOM tubing with a 0.25 inch wall pressed fit oil-impregnated brass bushing. Grease passages were added in the spindle to allow for lubrication between the spindle and the bushing. The spindle had to be correctly size to be capable of withstanding the bending and shear forces produced by the weight and movement of the rack including the spare tire and Jerry (fuel) cans. See Figure 21 through Figure 20 to view the spindle-hub assembly.

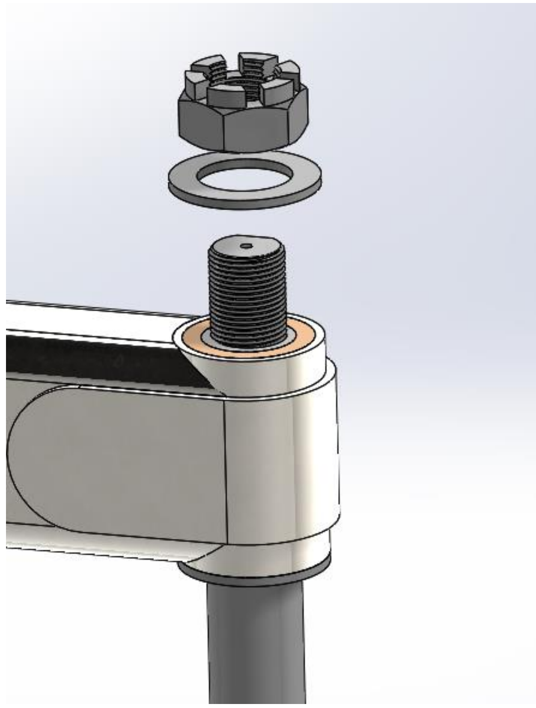

Figure 18. SolidWorks rendition of the spindle-hub assembly.

Figure 19. Exploded view of the spindle-hub assembly.

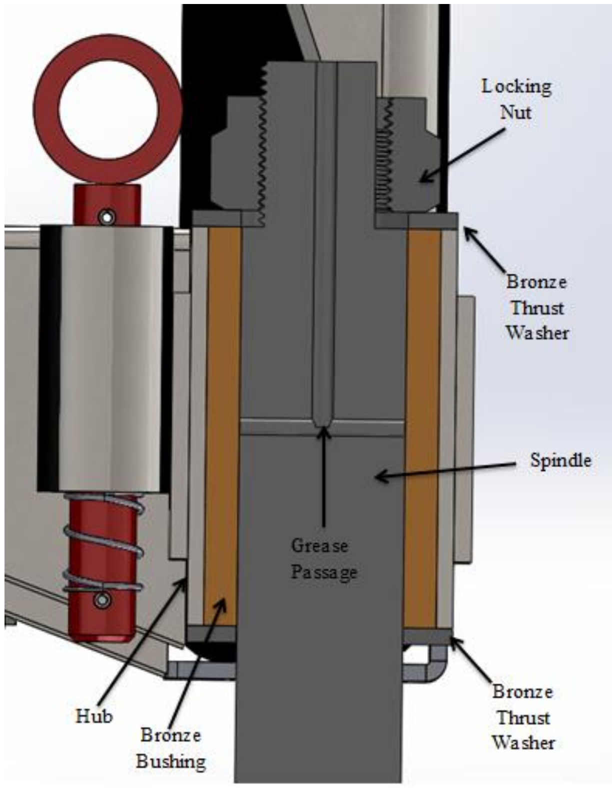

Figure 20. Cross-section view of the spindle-hub assembly.

Latching . Two different latching systems were designed for the rack. One system keeps the rack in a “closed” position keeping it locked in a position parallel with the bumper. The tapered end of the rack is designed to be lock within a shelf unit. This self prevents any vertical or horizontal movement of the rack when locked. To lock the rack within the shelf, a toggle clamp was used. See Figure 22. The second system uses a spring-loaded pin that locks into place when the rack swing 122 degrees form the “closed” position to the “open” position. The pin runs up a ramp and then falls into a locking slot. When the rack is to be replaced to the “closed” position, the pin must be manually lifted out of the slot unlocking the rack and allowing it to swing.

The latch “closed” design was designed to keep the rack locked in place when driving down the road. Because failure of this latch could be catastrophic and harmful to motorist or pedestrians, it was designed to handle large loads. The toggle clamp sized for this application is rated for 500 pounds. The latch “open” design was designed to prevent the rack from swinging toward the closed direction when this action was not desired. Because the rack will see minimal loads when in this position, this latch was not designed to handle large loads.

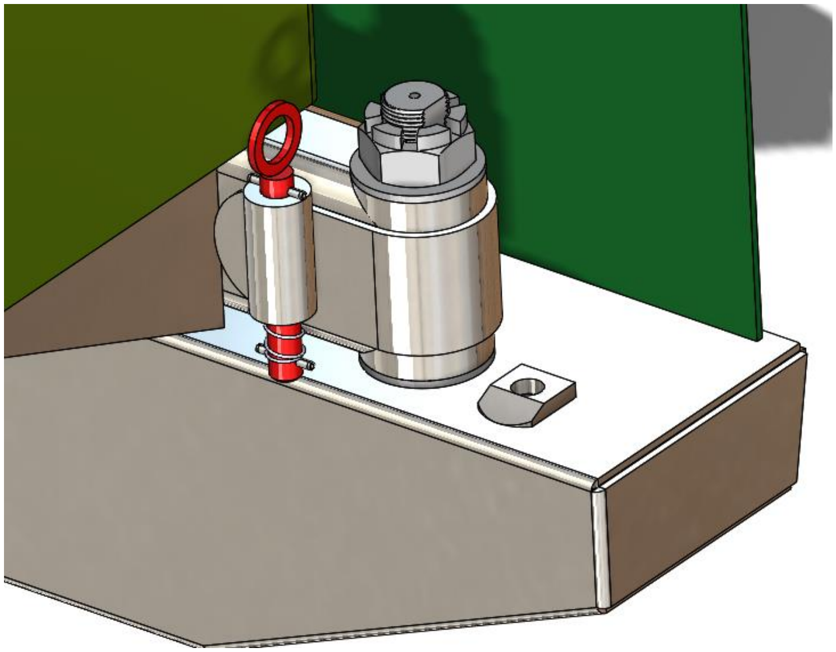

Figure 21. Spindle – Hub assembly with spring loaded latching in the open (tailgate access) position.

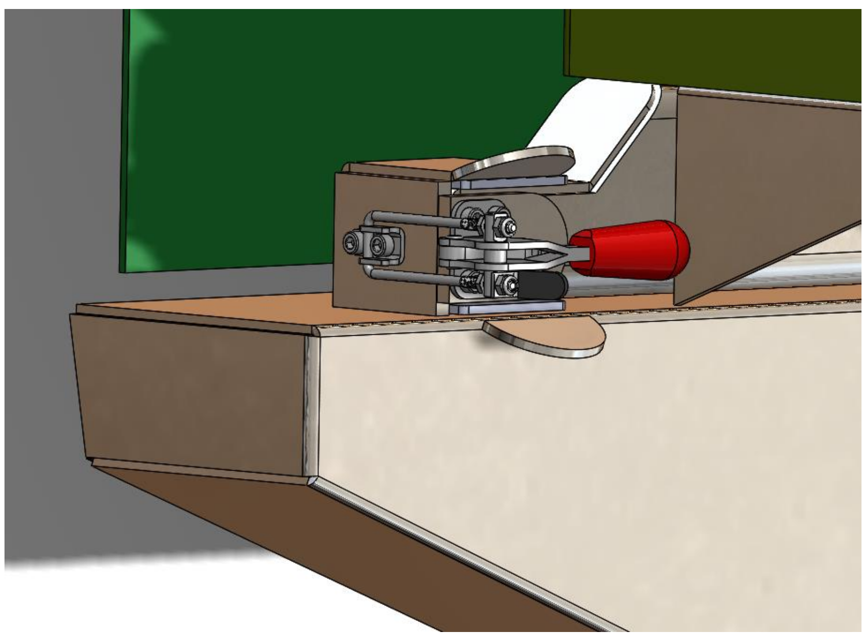

Figure 22. Rack latching system for the closed (road transportation) position.

<u>License Plate Mount</u> . A mount was designed to allow the license plate to be bolted in front of the spare tire using the spare tire studs. This location allows for proper visibility of the license plate, protects the license plate from objects on the trail and doesn't limit

the visibility of other items including the taillights. See Figure 23 for the placement and design of the license plate mount.

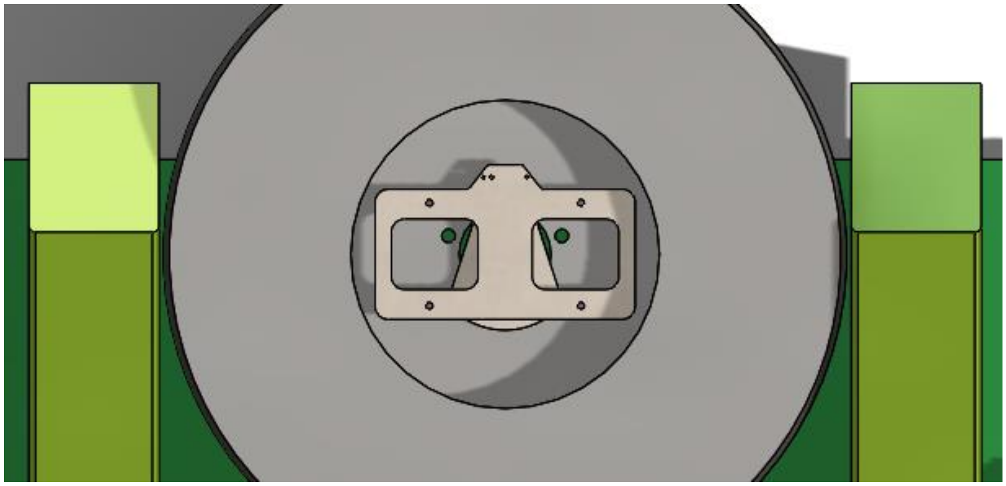

Figure 23. License Plate Mount.

Design Analysis

Hand Calculations . A hand calculation was conducted to analyze the allowable and yield load of the bumper. This test was set up as a simply supported beam analysis. To simplify the analysis and find the "worst-case scenario," the mid span cross-section of the bumper design was taken as the uniform cross-section of the bumper in its entirety. Yield and allowable stress were established as 36,000 psi and 15,000 psi respectively. It was determined that the yield and allowable loads are 2200 pounds and 900 pounds respectively. Additionally the maximum deflection caused by the allowable load was determined to be 0.006 inches. SeeAPPENDIX B – Design Calculations and SolidWorks FEA for the step by step analysis of the above.

SolidWorks FEA . SolidWorks offers a Fundamental Element Analysis simulation that allows the user to apply various loading situations to a part or assembly. FEA was used to analyze the main body of the bumper with a top load (straight down) of 900 pounds. This analysis determined that the 900 pounds induced a 12,000 psi stress and 0.014 inches of deflection at mid-span. These values are not far off from the hand calculations and the discrepancy between the two is likely caused by small variations in the conditions of the analysis including fixtures / supports and loading.

Additionally, FEA simulations were conducted on the bumper in a draft condition, the Bumper to Frame Mounts and the Hub Spindle. See APPENDIX B – Design Calculations and SolidWorks FEA for the SolidWorks FEA report for each simulation.

Construction

Bumper . The flat pattern of the bumper and rear plates was plasma cut from the 10 gauge sheet. Flanges 3 and 4 were cut off of the flat pattern so the channel could be bent in the press brake; see Figure 16. Bends at flanges 3 and 4 were not possible due to the constraints of the press break. Flange 1 was bent before flange 2. See Figure 24 and Figure 25 for a view of the channel made from bending flange 1 and 2. Once the channel was bent, flanges 3 and 4 that were originally cut off of the flat pattern, were welded into place. Additionally, the bumper mounting plates were plasma cut and welded into the bumper channel along with the receiver tube, D-rings and additional channel flanges. These can be viewed in Figure 26 and Figure 27. See

APPENDIX C – for all bumper part and assembly drawings and dimensions.

Figure 24. Bent channel of the bumper (back view).

Figure 25. Bent channel of the bumper (top view).

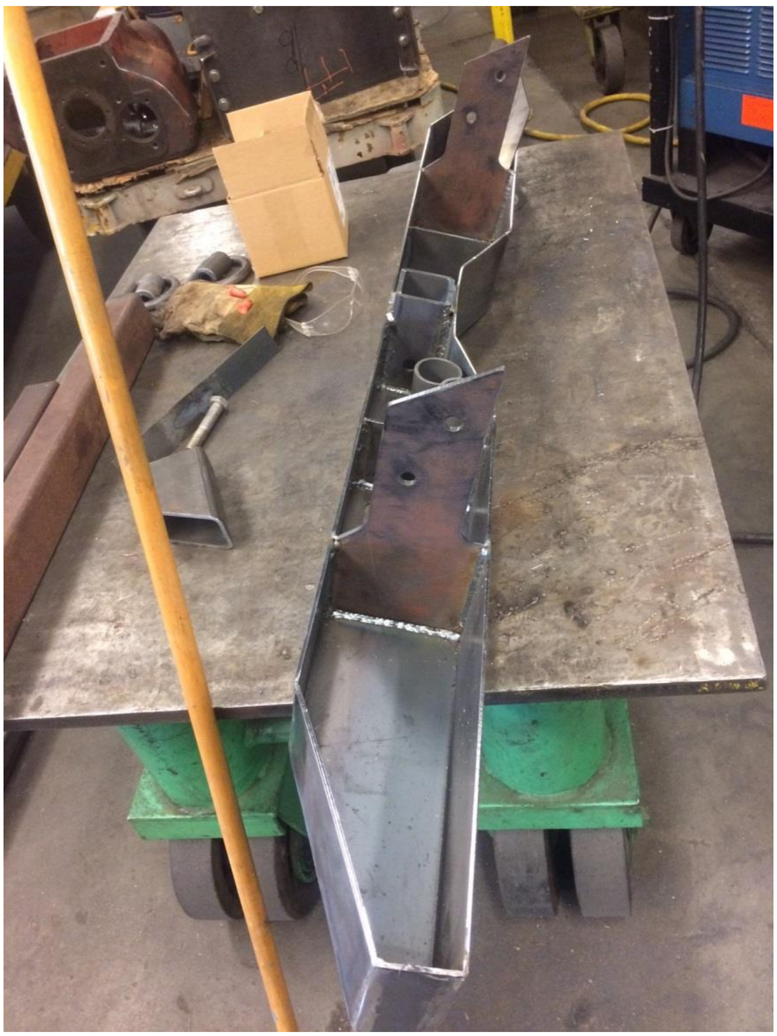

Figure 26. Bumper channel with side flanges, mounting plates and channel flanges welded in place.

Figure 27. Receiver tube welded into bumper channel.

Rack . The main tube of the rack was cut to length and a fish mouth was cut into one side to allow for the hub. A taper was cut on the opposing end of the tube allowing it to fit within the latching structure. The hub was welded in and a cap was placed on the tapered tube end. The riser was welded with gussets to the main tube and a plasma cut spare tire flange was welded to the riser. The completed rack can be seen sitting on top of the bumper in Figure 28. Gussets were added to the spare tire riser to counteract the bending caused from the weight of the spare tire. Brackets were also added to the rear face of the rack to all for the mounting of the Jerry (fuel) cans and can been seen in Figure 29. See APPENDIX D – Rack Part and Assembly Drawings for all rack part and assembly drawings and measurements.

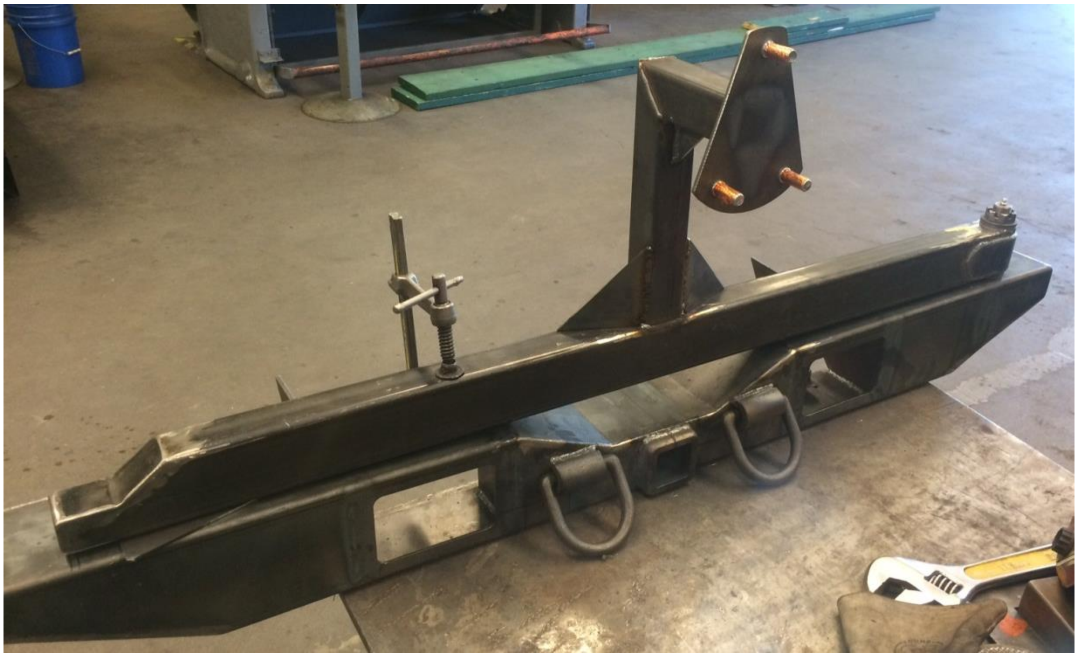

Figure 28. Completed rack placed on top of bumper.

Figure 29. Jerry (fuel) can mounting bracket installed on rack.

<u>Spindle – Hub Assembly</u> . A shaft was machined to act as a spindle in the pivot assembly. Threads were cut at the top of the spindle to allow for a retaining nut. A flat was machined on one side of the threaded portion to allow for a locking “D-washer”. Grease passages were also drilled to aid in the lubrication of the pivot. The hub was constructed out of a piece of DOM tube with a press fit, oil-impregnated brass bushing. The hub was welded to the fish mouthed end of the rack main tube and an additional strap was welded around the hub and across the welded joint to strengthen this connection. The bushing was machined on a lathe and pressed into the hub; see Figure

30. See APPENDIX D – Rack Part and Assembly Drawings for all Spindle - Hub part and assembly drawings and measurements.

Figure 30. Spindle – Hub assembly with bushing installed.

Figure 31. Spindle – hub assembly with spindle welded to bumper and rack installed.

Figure 32. Spindle – Hub assembly with thrust washers, retaining nut and grease zerk visible.

Latching . The “closed” position latch used a stainless steel toggle clamp rated to 500 pounds of force. Stainless steel was chosen for its corrosion resistant properties. 500 pounds was seen as sufficient for this application. A shelf- type retaining structure was constructed and holes had to be drilled and taped in both the rack main tube and shelf to allow for the mounting of the toggle clamp. A Delrin plastic strip was added to the tapered end of the rack tube allowing for a wear surface for when the rack engages with the latching shelf. Close consideration had to be made in reference to the placement of the toggle clamp so that the toggling characteristics of the clamp were maintained. The toggle clamp and locking shelf can be viewed in Figure 34. The “open” position latch used a pin with a weld on collar in which the pin would slide. Holes had to be drilled in the pin to allow for retaining pins to be placed. The retaining pins hold the spring and the locking pin in place within the collar. The locking ramp was welded onto the top flange of the bumper and can be viewed in Figure 35. See APPENDIX D – Rack Part and Assembly Drawings for all latching part and assembly drawings and measurements.

Figure 33. Delrin plastic strip added as a wear surface.

Figure 34. Toggle clamp and latching shelf for the “closed” position.

Figure 35. Spring loaded pin and locking ramp for the “open’ position.

License Plate Mount . The License Plate Mount was constructed out of two plates and a small tube spacer. The rear plate allowed for the mounting to the spare tire studs. The front plate allowed for the mounting of the license plate and a small light to illuminate the license plate at night. The tube was welded between the two plates allowing the mount to fit within the offset of the rim. This mount is not structural and therefore the plates were plasma cut out of 20 gauge sheet steel. See Figure 36 for the finished mount. See APPENDIX D – Rack Part and Assembly Drawings for all license plate part and assembly drawings and measurements.

Figure 36. License plate mount with light.

Paint

All parts excluding any machined surfaces were chipped, sanded and wiped down with acetone prior to being painted. All painted parts were painted with Rustoleum oil-base enamel to prevent rust and add to the aesthetics of the finished product. All painted parts were initially shot with two coats of primer. The overall look of the bumper was not to be bright and flashy but rather to blend in and not reflect when on an off-road trail.

Olive . The two Jerry (fuel) cans were painted a flat olive color to resemble a military issue type can. Black was not desired due to its thermal characteristics thus causing the vaporization and expansion of the fuel inside.

Red . The “closed” and “open” positions latches were both painted red for their visibility to the user. Red allows the user to quickly identify the points of input. The color red not only sticks out against the black bumper but also signifies immediate user attention.

Black . The remainder of the parts, including the overall bumper and rack assemblies were painted black to be consistent with the existing color scheme of the vehicle. Additionally, black is more likely to blend in with a natural atmosphere.

Figure 37. Various parts with a primer coat applied.

Figure 38. Bumper with its final coat of black paint dry.

Installation

The instillation occurred once all parts were painted and the necessary materials were gathered. The instillation included the assembly of the bumper components, the assembly of the rack components, the placement of the rack on the bumper, the bolting on of the bumper assembly to the vehicle frame, instillation of the tail and flood lights and their wiring, the mounting of the spare tire and Jerry (fuel) cans and the mounting of the license plate and light. A trailer light pigtail was also wired in and mounted on the underside of the bumper.

To mount the bumper to the frame, a forklift was used to align the bumper with respect to the bodylines and frame rails of the vehicle. A hand drill was used to place holes in the vehicle's frame for the bumper mounting bolts. The bumper could then be mounted. Four 1/2 in. – NC – 2" bolts were used and tightened with a numeric impact driver.

The original bumper was removed for the purpose of the instillation of this project. The original bumper and spare tire mount was weighed. Additionally the new bumper with incorporated mount was weighed. The spare tire and Jerry (fuel) cans were not included in the weight calculations. The weights were obtained by hanging the items from an electronic load cell. The weight was recorded to ensure that the new bumper would not overload the vehicle.

Figure 39. “Open” position latch installed.

Figure 40. Toggle clamp and Delrin installed.

Figure 41. Bumper and Rack assembly installed.

Figure 42. Bumper mounting plate bolted to frame.

Figure 43. Taillight installed in bumper.

Figure 44. Flood light installed on rack below Jerry (fuel) can.

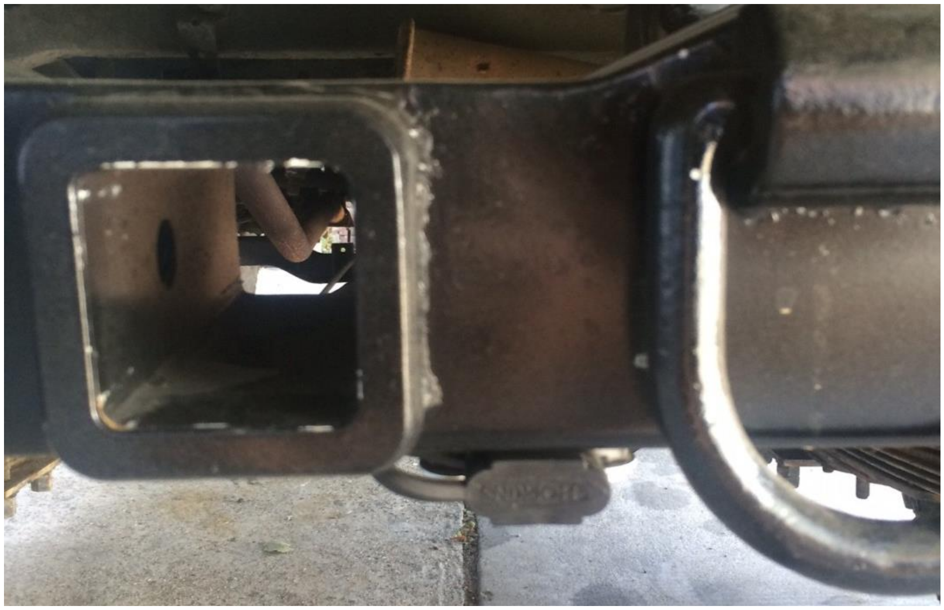

Figure 45. Trailer wiring pigtail installed on bottom side of bumper near receiver tube.

Figure 46. Jerry (fuel) can installed with store-bought tray and strap.

Figure 47. Clearance between rack and tailgate.

Figure 48. Weighing the new bumper and rack assembly.

RESULTS

Appearance

The overall appearance of the finished bumper is aesthetically pleasing. The shape flows well with the body lines. The paint scheme complements the existing scheme of the vehicle. The new location of the tire provides improved the symmetry of the vehicle and the tire is mounted parallel to the body. The license plate and tail lights have increased visibility. See Figure 49 thru Figure 53 for images of the completed design.

Figure 49. Bumper and rack in “closed” (road transportation) position.

Figure 50. Rack open, tailgate closed.

Figure 51. Rack open, tailgate open.

Figure 52. View of the rack and tailgate open.

Figure 53. Rack in “open” (tailgate access) position.

Figure 54. Rack latched in the “opened” position.

Cost

The cost of this project was $383.31 not including the cost of labor. The price of this bumper rivals other simpler type products on the market. Table 3 provides an itemized list of costs associated with the production of this project:

Table 3: Itemized list of costs associated with this project.

Itemized List of Project Costs				
Quantity	Description	Supplier	Part Number	Cost
1	1/2 sheet, 10 Gauge, Hot Rolled	B and B	-	$ 60.00
2	Oil-Embedded Thrust Bearing	McMaster	2879T13	$ 8.33
1	932 Bearing Bronze	McMaster	8911K325	$ 24.93
3	1/2" Wheel Bolt / Stud	Napa	641-1555	$ 6.25
1	2"x2"x6" Hitch Tube	American Muffler	-	$ 22.48
2	1/2" D-Rings	American Muffler	-	$ 17.48
1	Toggle Clamp, Right Angle	McMaster	5135A33	$ 45.47
1	1.5"x1/8"x2' Black Delrin Strip	McMaster	8662K12	$ 13.02
2	STT Kit, 3"x"5 Tail Light	Napa	45002R	$ 33.32
1	Trailer Wire End	O'Reilly Auto Parts	HOP 48030	$ 8.39
1	2 Wire Plug Connector	O'Reilly Auto Parts	HOP 47965	$ 3.39
1	License Plate Light	O'Reilly Auto Parts	OPT LP31CS	$ 4.39
1	Paint and Supplies	Home Depot	-	$ 58.03
2	Jerry / Gas Can Straps	Twin City Surplus	15050	$ 67.16
1	2 Pack Can Gaskets	Twin City Surplus	39	$ 11.17
			Total:	$ 383.81

Weight

The weights of the major components of the original and new bumper were taken with an electronic load cell. Table 4 provides an itemized list of the weight of the original and new bumper and spare tire mount:

Table 4. Itemized Bumper Weights

	Itemized Bumper Weights	
	Original (pounds)	New (pounds)
Bumper	35	50
Rack	10	30
Total	45	80

Functionality

The overall vehicle functionality and ability has improved because of the new bumper. The bumper allows for the storage of an additional ten gallons of fuel, allowed the vehicle to sit level due to the placement of the spare tire in the center of the vehicle and makes the overall width twelve inches smaller allowing for increased maneuverability. The spare tire no longer sticks out where it can catch or snag on objects. Additionally, the bumper did not hinder the use of the tailgate. The spare tire rack latches and unlatches from the opened and closed positions easily and firmly. The rack swings well and easily across its entire range of movement.

As a real life proof of concept, an applied force test was conducted on the bumper. While the front of the vehicle was anchored to a heavy object, a come-along was hooked to a hitch placed in the bumper receiver. The opposite end of the come-along was anchored to the ground. A load cell was also added between the bumper and the come-along. The come-along was used to apply a force of 1200 pounds at an angle of 10 degrees from the ground to the hitch resulting in a vertical down load of 208 pounds and a draft load of 1180 pounds. This test was designed to simulate the loading conditions that would occur from towing a small trailer or the removal of a stuck vehicle. The test resulted in the suspension compressing half of an inch with no other measureable deflection of the bumper itself. See Figure 55 thru Figure 57 for images of the applied force test.

Figure 55. Jeep anchored at front to forklift for applied force test.

Figure 56. Jeep anchored at back to dead-man via come-along.

Figure 57. Load cell installed to take force measurements.

With the spare tire rack in the open position, 200 pounds was applied to the end of the rack tube. This force resulted in a compression of the suspension and an increased gap between the body and the bumper. This gap was not caused by a deflection in the bumper but rather from a deflection in the frame rail of the vehicle. It appears the bumper is stronger than the strength of the vehicle frame.

DISCUSSION

A major consideration in the bumper design was strength. The bumper had to be able to support weight cantilevered out on the spare tire rack and a trailer hooked to the receiver. The vehicle manufacture lists that maximum pay load as 800 pounds and the maximum continuous drawbar pull as 1200 pounds. The bumper produced is capable of such loads although a stronger bumper may be desired for more strenuous conditions. Some factors that limit the strength of the current design include the material thickness and the lack of plating on the backside of the bumper channel at mid span. Plating was not added in this area to allow access to the pinning hole of the receiver tube. The tapering of the bumper channel at mid span can also be identified as a limiting factor because this reduces the area moment of inertia.

Initial designs included a mount for a Hi-Lift jack and a rack for the storage of an ice chest or other equipment. Later designs eliminated a Hi-Lift mount and storage rack because space was limited. The jack and rack would have added more weight to the bumper and were not seen as extremely necessary.

When the rack is loaded down with full Jerry (fuel) cans and a spare tire the rack slides into the latching shelf easily. When the Jerry (fuel) cans are empty, the rack does not engage with the latching shelf straight on because the reduced load causes less deflection of the main rack tube and therefore more force must be applied to place the rack fully within the latching shelf.

The ending cost of the bumper was $384 but this did not include labor. Although this is a custom one-off design, in terms of productivity, to make this bumper rival similar designs in the market place, the cost will likely need to be reduced to be competitive.

The overall look of the bumper is very pleasing however the paint does show some imperfections. These imperfections include runs and ruff surface finish. The runs are caused by too thin of paint or too thick off application during painting and the ruff surface is attributed to the fact that the bumper was painted outdoors under a tree where pollen and other plant debris fell upon the wet paint.

RECOMMENDAITONS

To improve upon the overall strength of the bumper design thicker material could be used. Plating the back of the channel at mid span would help as well. A deeper or wider channel could also be produced. The three options listed above would increase the area moment of inertia and decrease the stress and deflection. Although the bumper could withstand larger loads, the overall max loading of the vehicle must be considered as well.

Although the Hi-Lift Jack was not included in this design, it could replace one of the Jerry (fuel) can. An adapter plate could be produced that adapts the Jerry (fuel) can mounting holes to those of the Hi-Lift. This would decrease the amount of fuel storage and overall weight and increase variability. An alternative would be to build a new bumper with a winch that incorporates a Hi-Lift Jack mount as well.

To prevent the variation in the alignment of the rack tube within the latching shelf, a thicker walled tube or taller tube could be used to increase the area moment of inertia and decrease the deflection. Although the rack will engage with the latching shelf under all conditions, it would be nice for the rack to simply glide into place rather than forcedly pushing it so.

To decrease cost and increase productivity if this bumper were to be massed produced, plasma cutting all parts to exact dimensions as well as setting up for mass production runs with equipment designed for such would significantly reduce the amount of labor involved with producing such a product. Fixtures and templates could be made allowing for swift and accurate production.

To improve the finish quality of the paint, it is recommended that more attention to detail be paid to the thinning of the paint. This will decrease the occurrence of paint runs. Additionally, painting in a paint booth out of the elements would allow for a smoother, more professional finish. To improve upon the overall appearance of the bumper, powder coating should be considered. Although the cost increases, the labor time decreases and the finish quality increases.

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APPENDIX A – How this Project Meets Requirements for the BRAE Major

Major Design Experience

The BRAE senior project must incorporate a major design experience. Design is the process of devising a system, component, or process to meet specific needs. The design process typically includes fundamental elements as outlined below. This project addresses these issues as follows.

Establishment of Objectives and Criteria. Project objectives and criteria are established to meet the needs and expectations of the owner as well as meet the regulations and laws put out by the National Highway Traffic Safety Administration (NHTSA) and Department of Transportation (DOT). See *Design Parameters and Constraints* below for specific objectives and criteria for the project.

Synthesis and Analysis. The project incorporates bending stress and displacement calculations of the main bumper member design, and the consideration of alternative materials and designs.

Construction, Testing and Evaluation. The bumper was designed, constructed and evaluated under varying conditions.

Incorporation of Applicable Engineering Standards. The project utilizes AISC standards for allowable bending stresses and National Highway Traffic Safety Administration regulations for license plate and taillight locations and bumper strength.

Capstone Design Experience

The BRAE senior project is an engineering design project based on the knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses). This project incorporated knowledge/ skills from these key courses.

- BRAE 129 Lab Skills/Safety
- BRAE 133 Engineering Graphics/Drafting
- BRAE 151 AutoCAD
- BRAE 152 SolidWorks
- BRAE 234 Mechanical Systems
- BRAE 421/422 Equipment Engineering
- ME 211/212 Engineering Statics/Dynamics
- CE 204/207 Strength of Materials
- ENGL 149 Technical Writing

Design Parameters and Constraints

This project addresses the categories and constraints listed below.

Physical. The bumper was required to mount directly to the vehicle, incorporate a spare tire mount for a 29 inch tire that allowed for the use of the vehicle’s tailgate and allowed for the mounting of "Jerry (fuel) cans," a "Hi-Lift" jack and have a hitch receiver. The completed bumper is bolted directly to the frame of the vehicle, accommodates Jerry cans and a 31 inch tire. The design did not accommodate a Hi-Lift jack mount. The bumper spans the width of the vehicle and does not protrude passed or rub on the body of the vehicle.

Economic. The cost of project was to not greatly exceed $500. The total cost of the project excluding the cost of labor was $384.

Environmental. Moving the spare tire to the rear of the vehicle will reduce the destruction of brush and shrubs when the vehicle is in use by reducing the overall width of the vehicle. The overall width of the vehicle is now 12 inches narrower.

Sustainability. Modifications to this vehicle will make it more suited to the owner and prevent the owner from selling the old vehicle and replacing it with a new one. The owner has found the vehicle more useful and better suited to his needs.

Manufacturability. Although this is a one-off design, the physical constraints of the design and the equipment at hand had to be considered during the design. Through use of a CNC plasma cutter the time required to manufacture this bumper was reduced. The bumper channel was also sized so it could be accommodated in a press break. If this had not been conducted, the channel would have had to be outsourced.

Health and Safety. The bumper had to be designed based on restrictions and regulations put forth by the NHTSA and DOT for public safety both on and off-road. The bumper has been built to sustain a 10 mph collision per NHTSA regulations, has allocated DOT certified tail lights and license plate lights and lights and the license plate have been located for proper visibility.

Ethical. The construction of this bumper was to employ ethical safety factors at the probability of increased expense to ensure that the product is safely designed. The bumper was design with a loading safety factor of 2.4. These calculations were conducted using a simply supported beam analysis and SolidWorks Fundamental Element Analysis.

Social. The construction of this bumper may affect the construction of similar products in the future which could cause a surge in the market in terms of sales and employment. Although the bumper has been recently completed, some jeep enthusiasts have been interested in the design and availability of such a bumper.

Political. The reduced destruction in wildlife by relocating the rear tire was to help ease the controversy between environmentalists and four-wheel drive enthusiasts. The vehicle is now 12 inches narrower and therefore is less destructive to wildlife along off-road trails. This reduction in destruction will likely improve the look of four-wheel drive enthusiasts in the public eye.

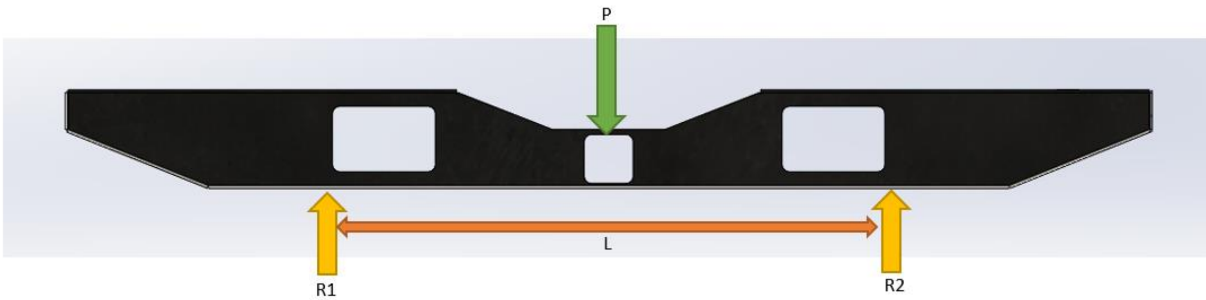
Aesthetics. The finished product was to be painted with a paint gun utilizing high quality black enamel. The bumper was painted with black enamel which produced a pleasing look.

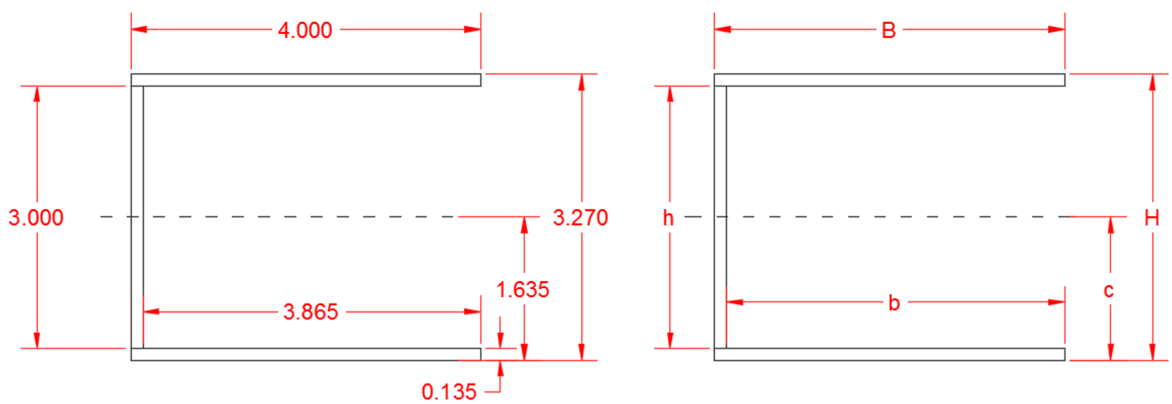
Other – Design. The design must allow for easy access to the rear tailgate by employing a hinge and latching system. The bumper incorporated a rear rack to which the spare tire was mounted. The rack is capable of swinging 122 degrees which allows access to the tailgate.

APPENDIX B – Design Calculations and SolidWorks FEA Reports

GIVEN: The bumper pictured below:

- Distance between frame rails: 30 in.
- Assume small channel dimensions only for analysis
- Hot rolled mild steel
- σ_{Yield} = 36,000 psi
- $\sigma_{Allowable}$ =15,000 psi
- $E = 29{,}000{,}000\ psi$





REQUIRED:

a) Find the maximum and allowable loads, P.
b) Find the maximum deflection, x.

SOLUTION:

a)

$$\sigma = \frac{M * c}{I}$$

$$\sigma = \frac{\left(\frac{P * L}{4}\right)c}{I}$$

$$I = \frac{BH^3}{12} - \frac{bh^3}{12}$$

$$I = \frac{(4.00in.)(3.27in.^3)}{12} - \frac{(3.865in.)(3.00in.)^3}{12}$$

$$I = 2.96in.^4$$

$$\sigma = \frac{\left(\frac{P * L}{4}\right)c}{I}$$

$$P = \frac{4\sigma * I}{c * L}$$

$$P_{Max} = \frac{36{,}000psi * 2.96in.^4}{1.635in. * 30in.}$$

$$\boldsymbol{P_{Max} = 2200\ lb}$$

$$P_{Allow} = \frac{15{,}000psi * 2.96in.^4}{1.635in. * 30in.}$$

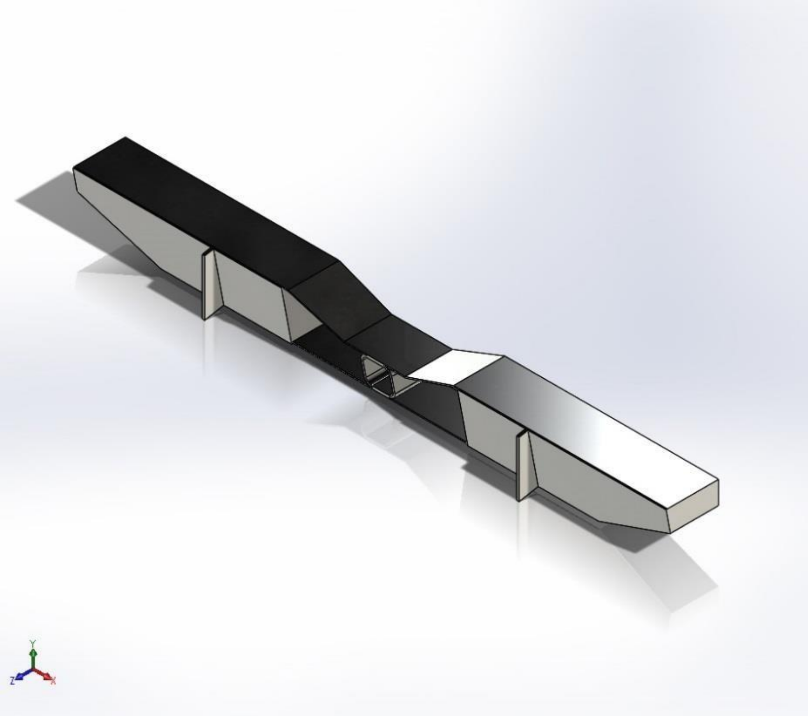
$$\boldsymbol{P_{Allow} = 900\ lb}$$

b)

$$x = \frac{PL^3}{48EI}$$

$$x = \frac{900lb. * 30in.^3}{48 * 29{,}000{,}000psi * 2.96in.^4}$$

$$\boldsymbol{x = 0.006in.}$$



Simulation of Bumper for Simulation

Date: Tuesday, May 10, 2016
Designer: Solidworks
Study name: 900 Lb Load
Analysis type: Static

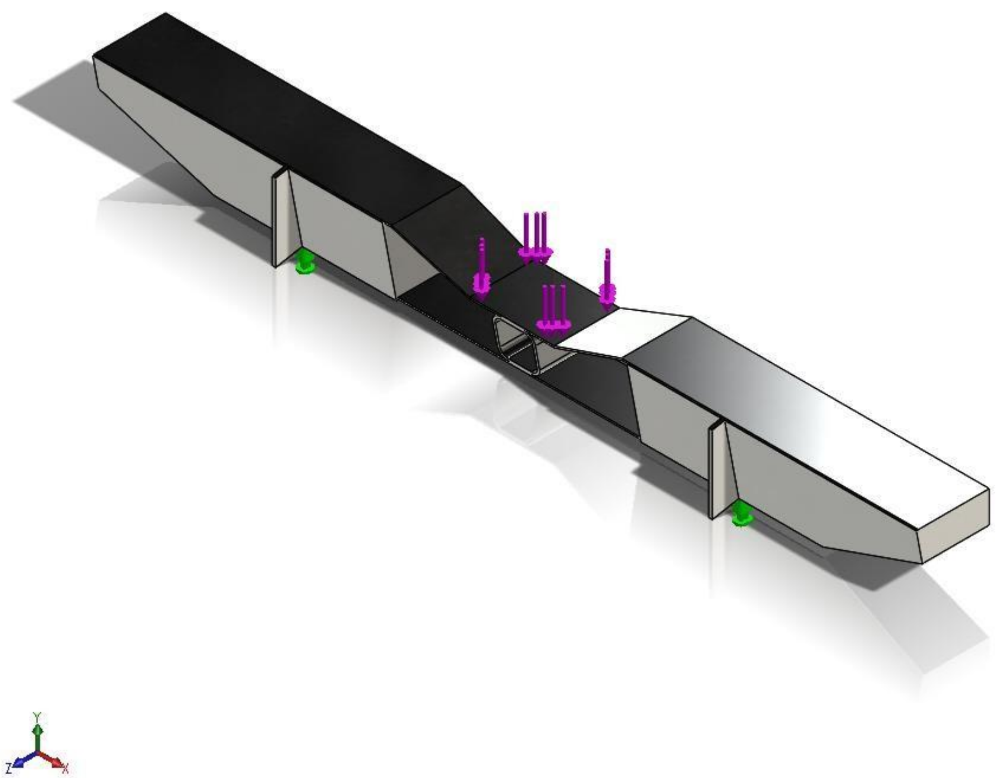
Table of Contents

Description

No Data

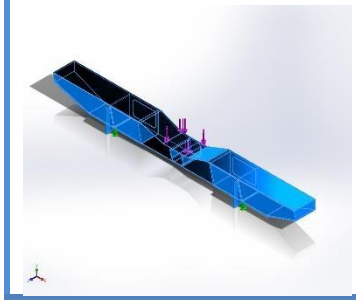
Assumptions

Model Information



Model name: Bumper for Simulation
Current Configuration: Default

Solid Bodies			
Document Name and Reference	**Treated As**	**Volumetric Properties**	**Document Path/Date Modified**

Boss-Extrude7 	Solid Body	**Mass:19.9459 kg Volume:0.00255716 m^3 Density:7800 kg/m^3 Weight:195.47 N**	**E:\Senior Project\SolidWorks\Bumper\Bumper for Simulation.SLDPRT** May 09 12:01:20 2016

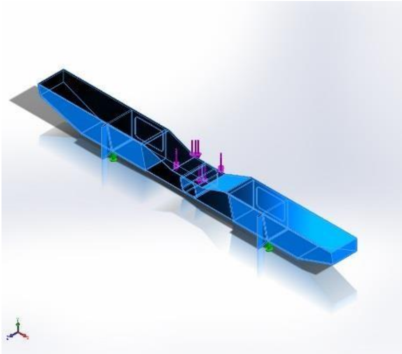
Study Properties

Study name	900 Lb Load
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (E:\Senior Project\SolidWorks\Bumper)

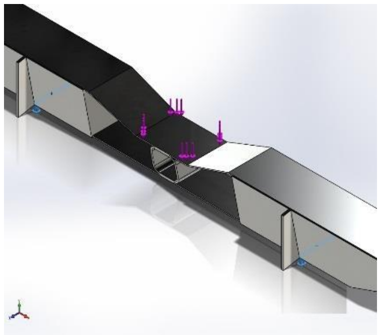
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

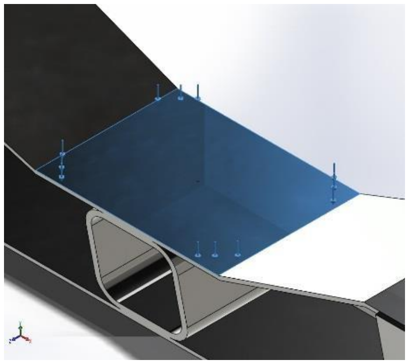
Model Reference	Properties	Components
	**Name:** Plain Carbon Steel **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Yield strength:** 2.20594e+008 N/m^2 **Tensile strength:** 3.99826e+008 N/m^2 **Elastic modulus:** 2.1e+011 N/m^2 **Poisson's ratio:** 0.28 **Mass density:** 7800 kg/m^3 **Shear modulus:** 7.9e+010 N/m^2 **Thermal expansion coefficient:** 1.3e-005 /Kelvin	SolidBody 1(Boss-Extrude7)(Bumper for Simulation)
Curve Data:N/A		

Loads and Fixtures

Fixed-1		**Entities:** 2 face(s) **Type:** Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-1.4224	4006.17	-1.18777	4006.17
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Force-1		**Entities:** 1 face(s) **Type:** Apply normal force **Value:** 900 lbf

Connector Definitions

No Data

Contact Information

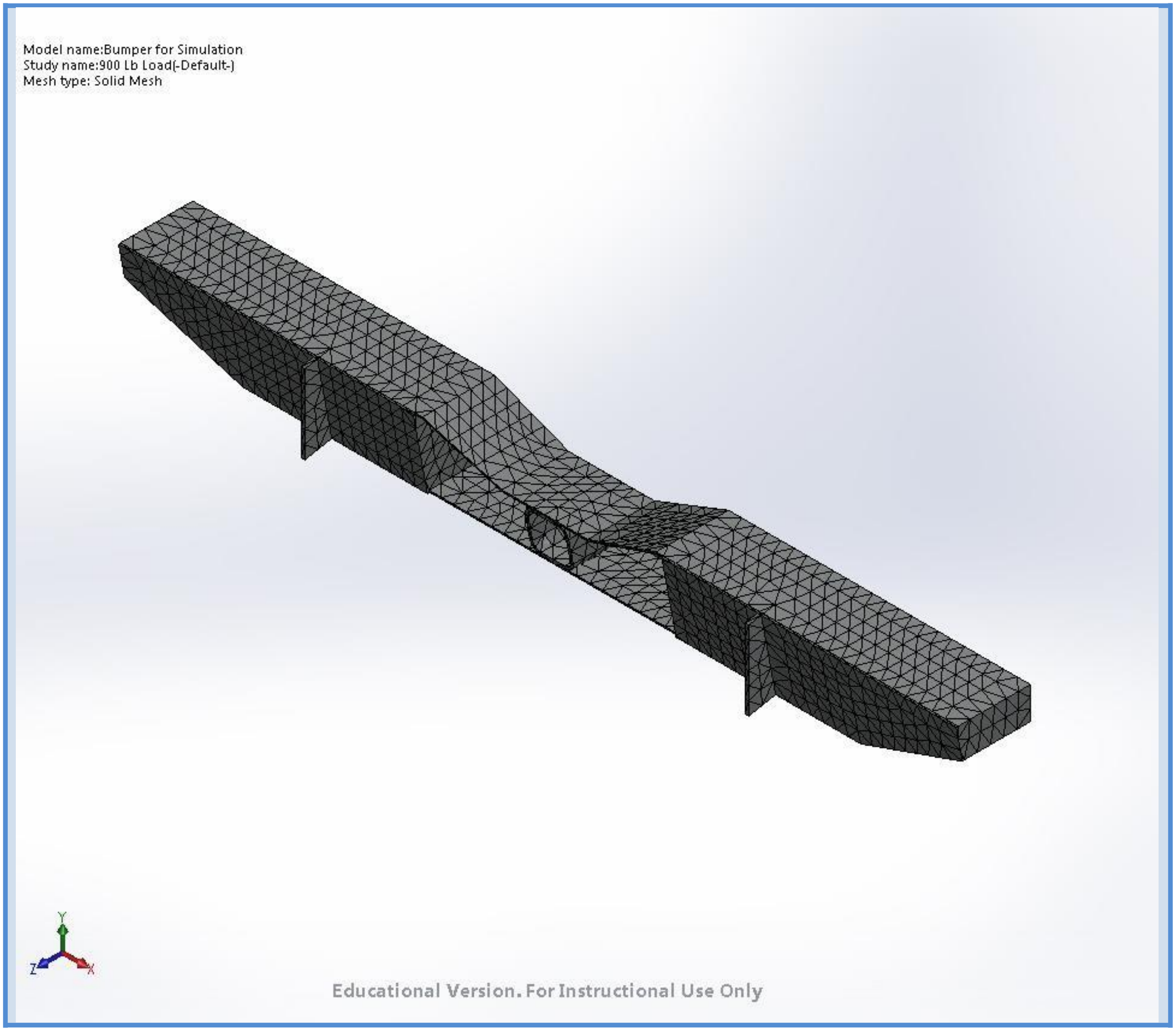
No Data

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	0.927526 in
Tolerance	0.0463763 in
Mesh Quality	High

Mesh information - Details

Total Nodes	16748
Total Elements	8370
Maximum Aspect Ratio	31.096
% of elements with Aspect Ratio < 3	0.765
% of elements with Aspect Ratio > 10	2.19
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:10
Computer name:	CAFES-8A-3C-07



Sensor Details

No Data

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-1.4224	4006.17	-1.18777	4006.17

Reaction Moments

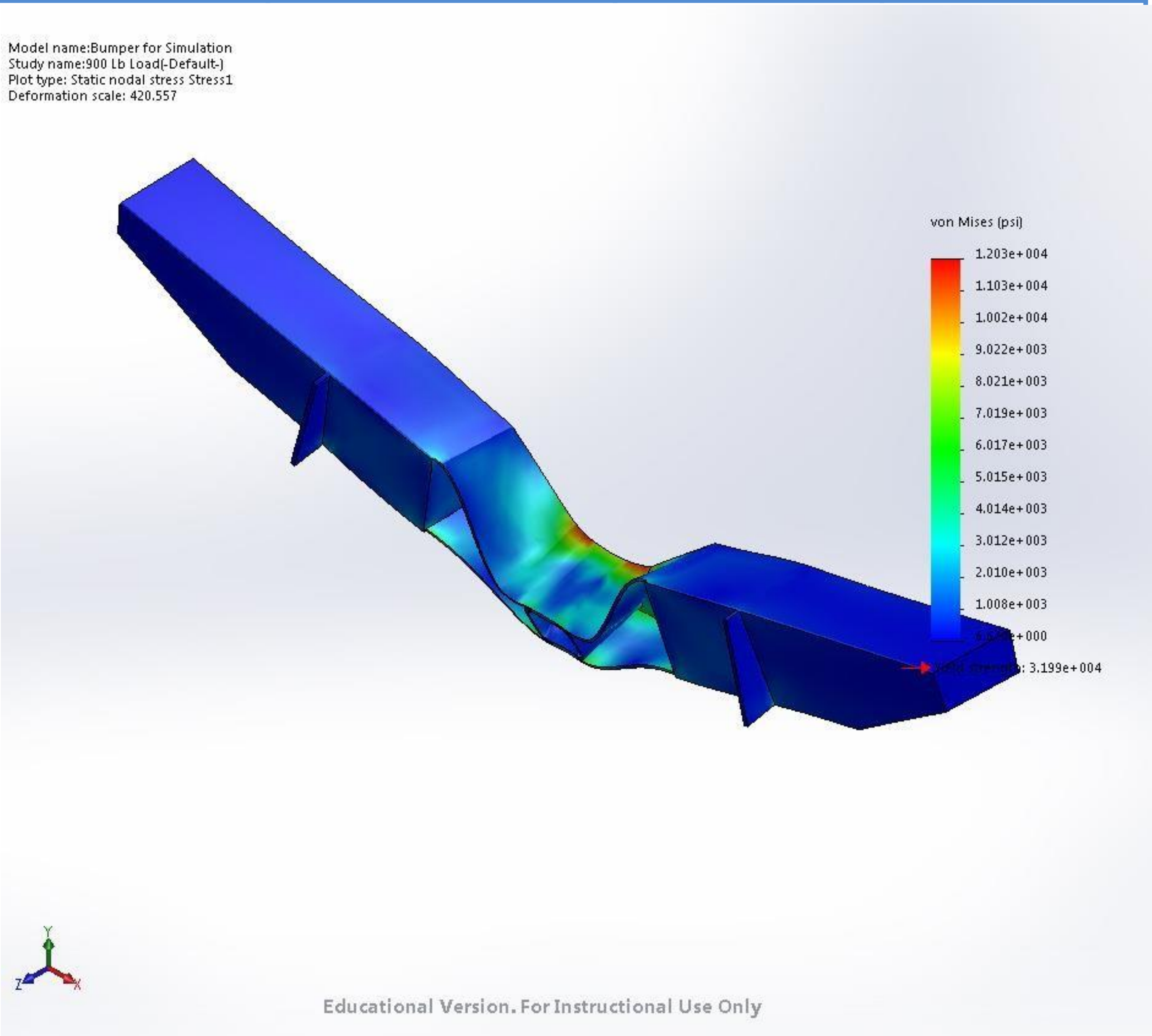
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Beams

No Data

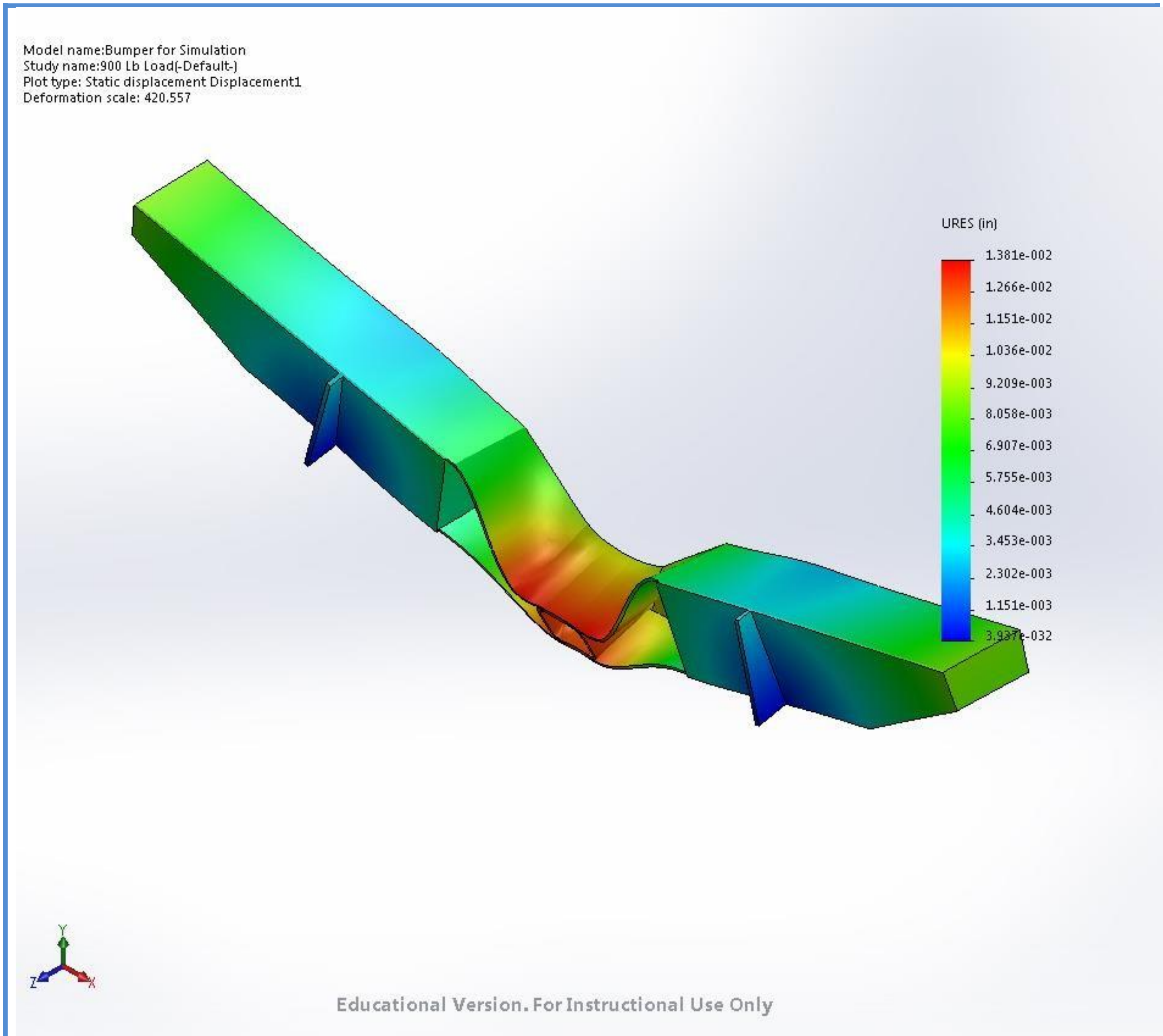
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	6.66967 psi Node: 13127	12027.7 psi Node: 15979



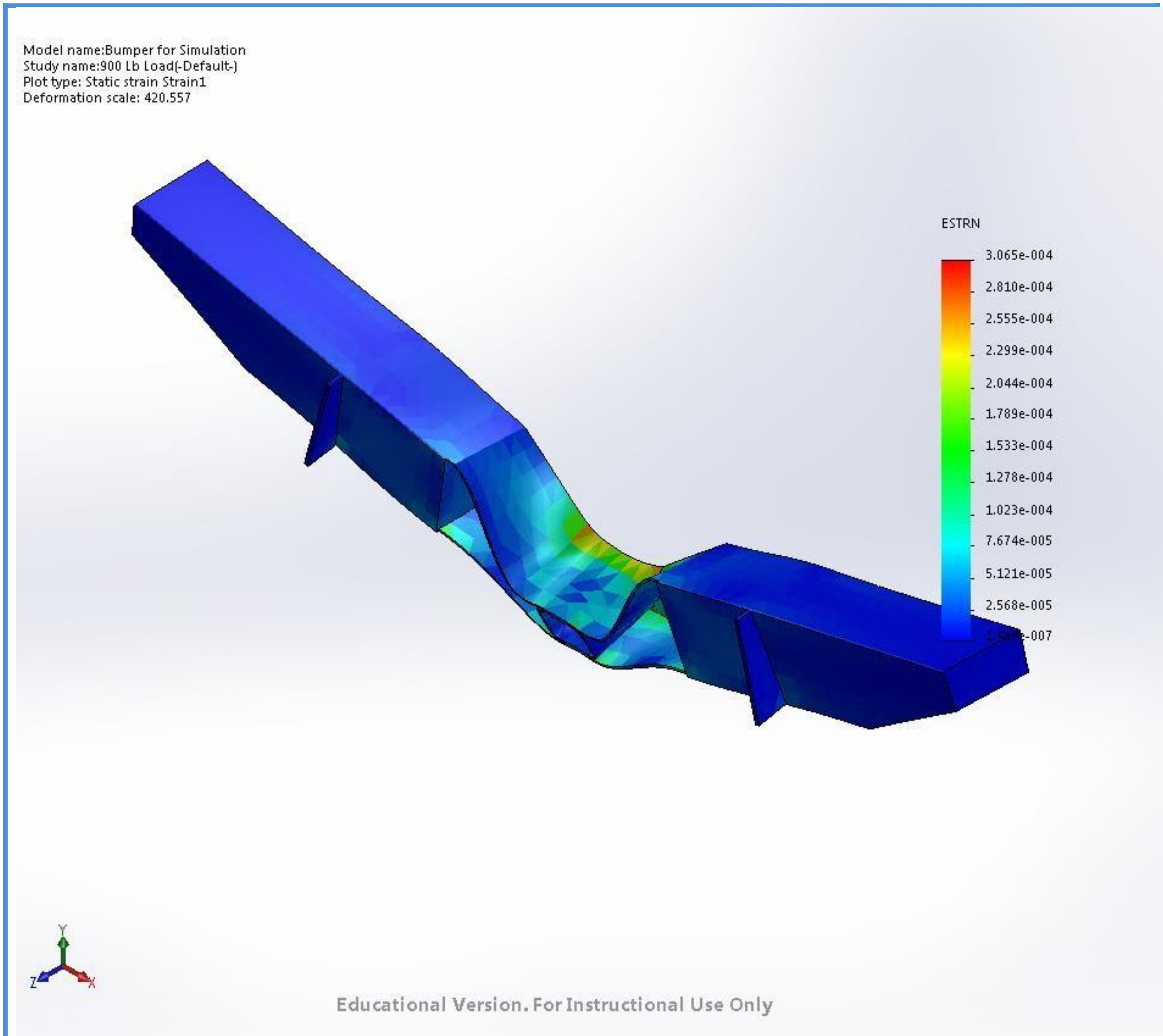
Bumper for Simulation-900 Lb Load-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 in Node: 17	0.013813 in Node: 920



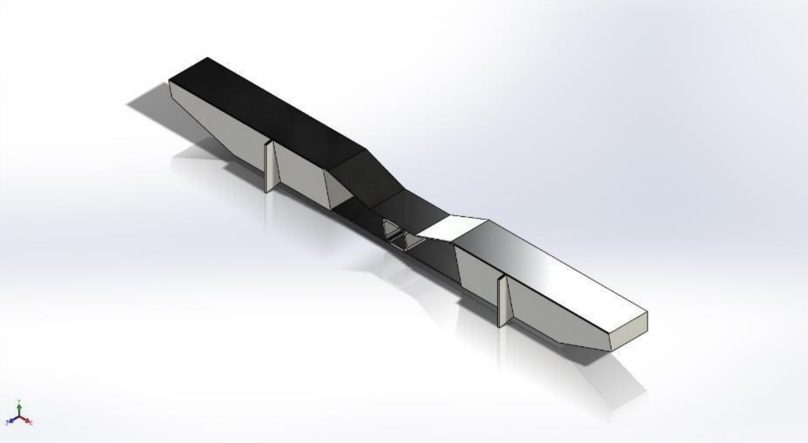
Bumper for Simulation-900 Lb Load-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1.48315e-007 Element: 7224	0.000306519 Element: 6598



Bumper for Simulation-900 Lb Load-Strain-Strain1

Conclusion



Simulation of Bumper for Simulation

Date: Monday, May 09, 2016
Designer: Solidworks
Study name: 1000 Lb Draft
Analysis type: Static

Table of Contents

Description

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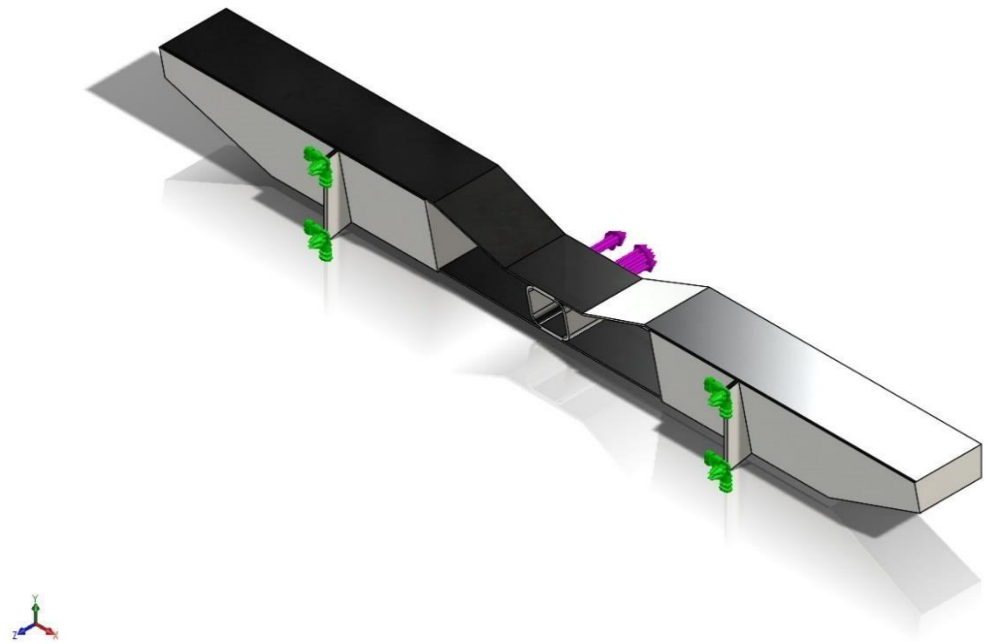
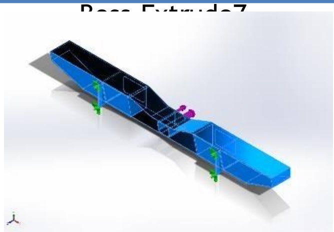
Assumptions

Model Information



Model name: Bumper for Simulation
Current Configuration: Default

Solid Bodies			
Document Name and Reference	**Treated As**	**Volumetric Properties**	**Document Path/Date Modified**
Base-Extrude7 	Solid Body	**Mass:19.9459 kg** **Volume:0.00255716 m^3** **Density:7800 kg/m^3** **Weight:195.47 N**	**E:\Senior Project\SolidWorks\Bumper\Bumper for Simulation.SLDPRT** May 02 16:20:24 2016

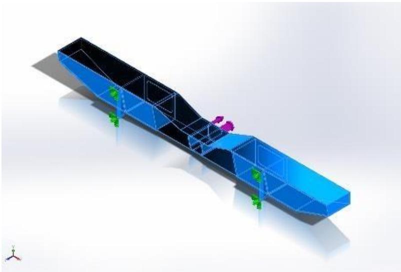
Study Properties

Study name	1000 Lb Draft
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (E:\Senior Project\SolidWorks\Bumper)

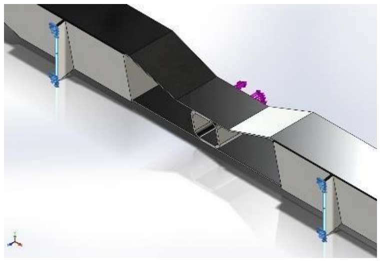
Units

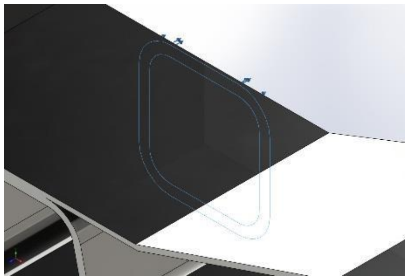
Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

Model Reference	Properties	Components
	**Name:** Plain Carbon Steel **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Yield strength:** 2.20594e+008 N/m^2 **Tensile strength:** 3.99826e+008 N/m^2 **Elastic modulus:** 2.1e+011 N/m^2 **Poisson's ratio:** 0.28 **Mass density:** 7800 kg/m^3 **Shear modulus:** 7.9e+010 N/m^2 **Thermal expansion coefficient:** 1.3e-005 /Kelvin	SolidBody 1(Boss-Extrude7)(Bumper for Simulation)
Curve Data:N/A		

Loads and Fixtures

Fixed-1		**Entities:** 2 face(s) **Type:** Fixed Geometry

Load name	Load Image	Load Details
Force-1		**Entities:** 1 face(s) **Type:** Apply normal force **Value:** -1000 lbf

Connector Definitions

No Data

Contact Information

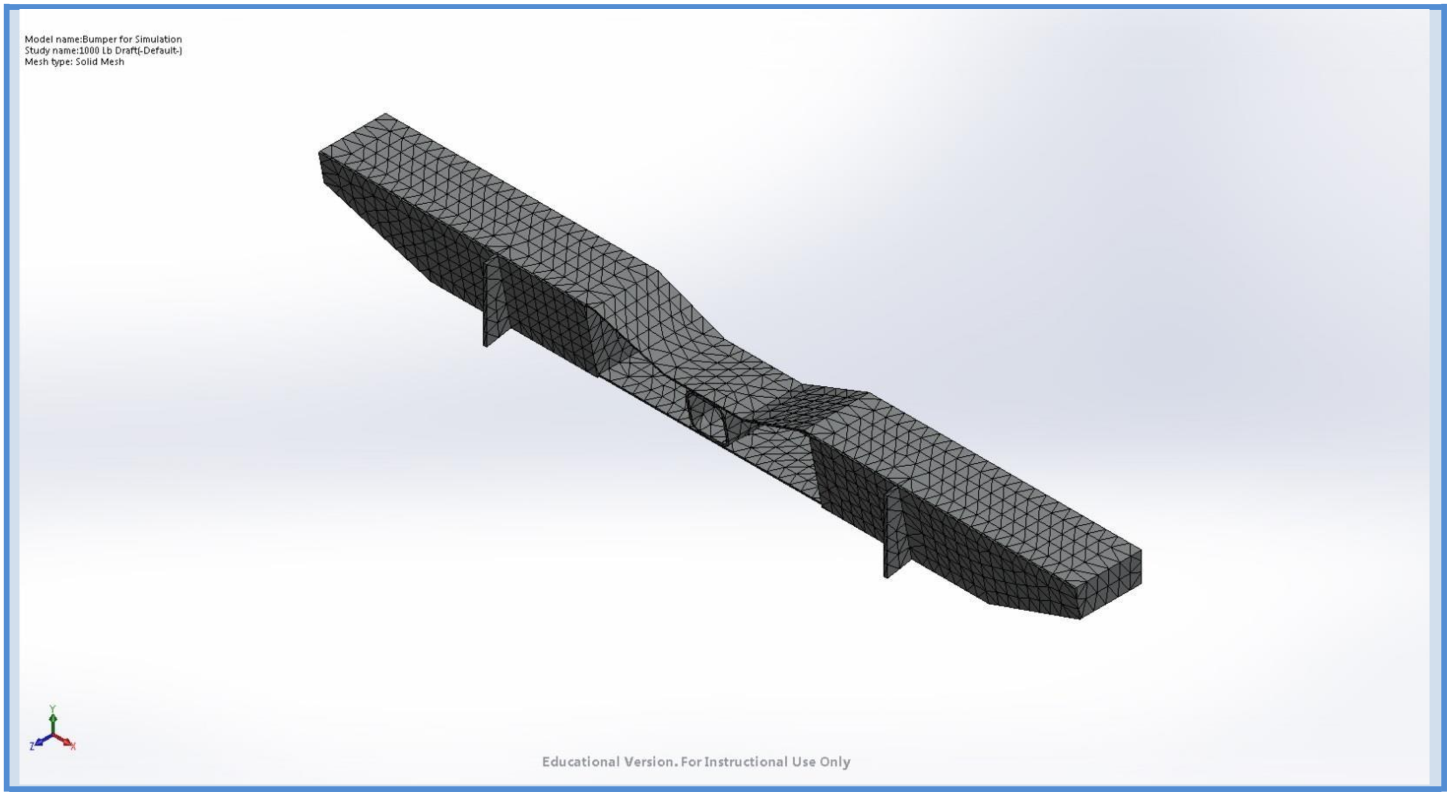
No Data

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	0.927526 in
Tolerance	0.0463763 in
Mesh Quality	High

Mesh information - Details

Total Nodes	16748
Total Elements	8370
Maximum Aspect Ratio	31.096
% of elements with Aspect Ratio < 3	0.765
% of elements with Aspect Ratio > 10	2.19
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:05
Computer name:	CAFES-8A-4C-13



Sensor Details

No Data

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.525146	-0.193918	4394.35	4394.35

Reaction Moments

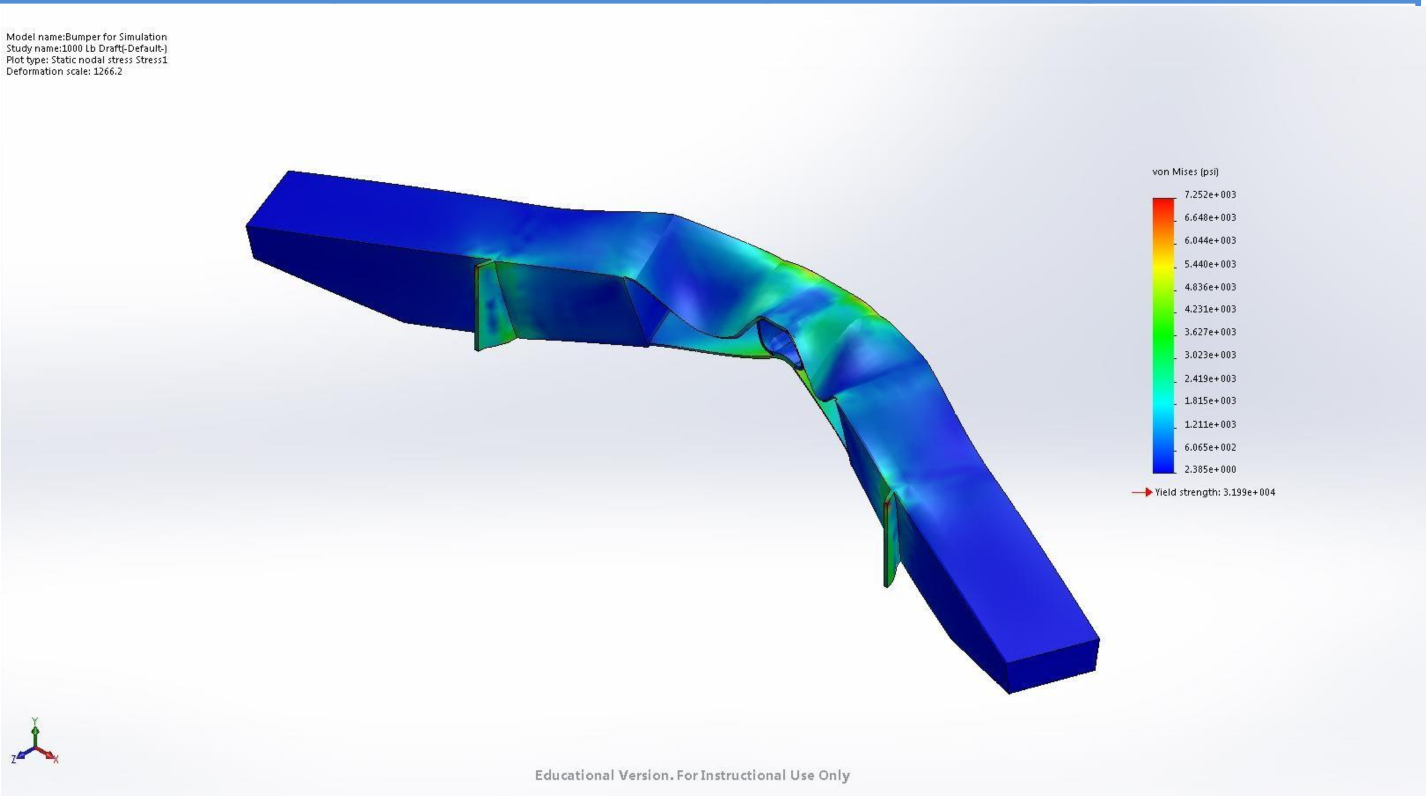
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Beams

No Data

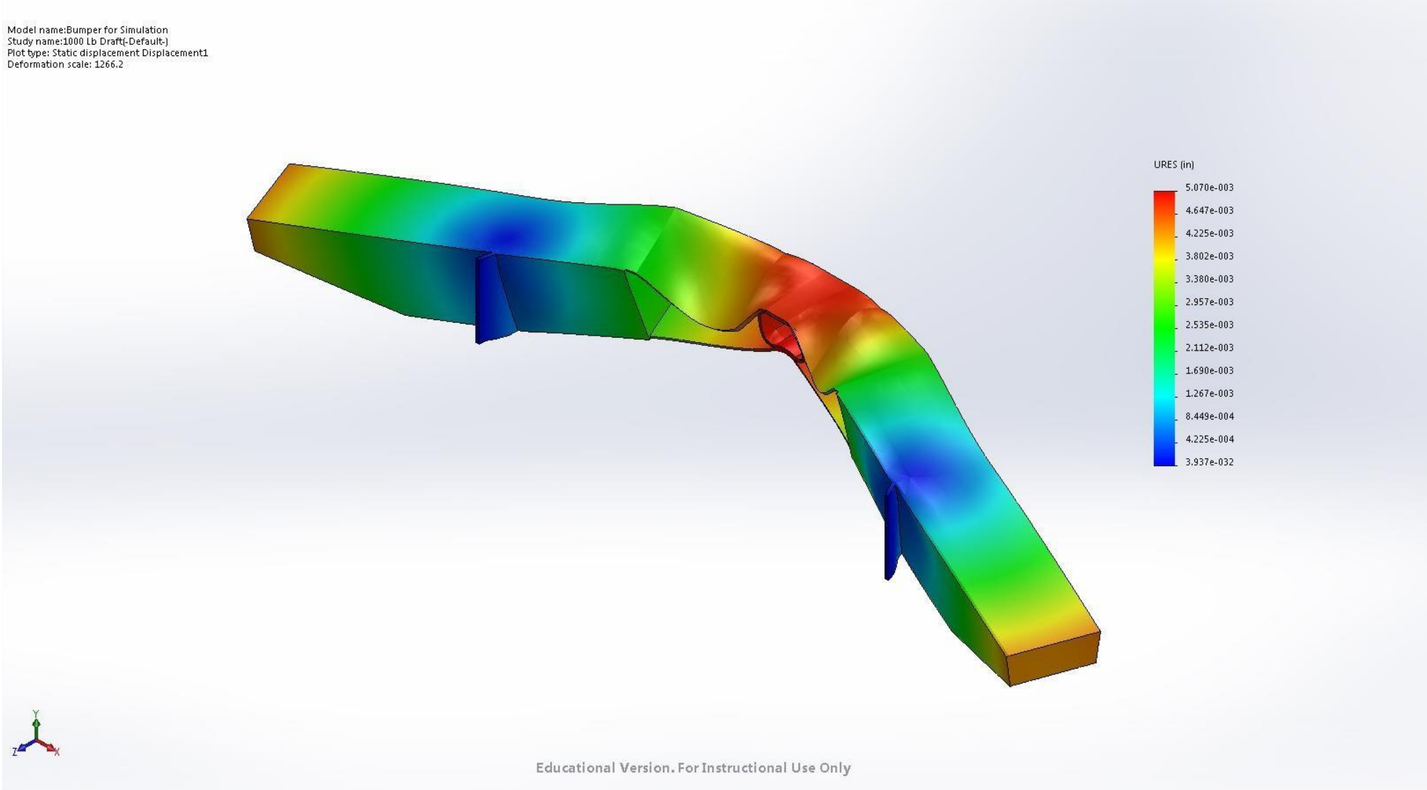
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	2.3853 psi Node: 13127	7252.26 psi Node: 2117



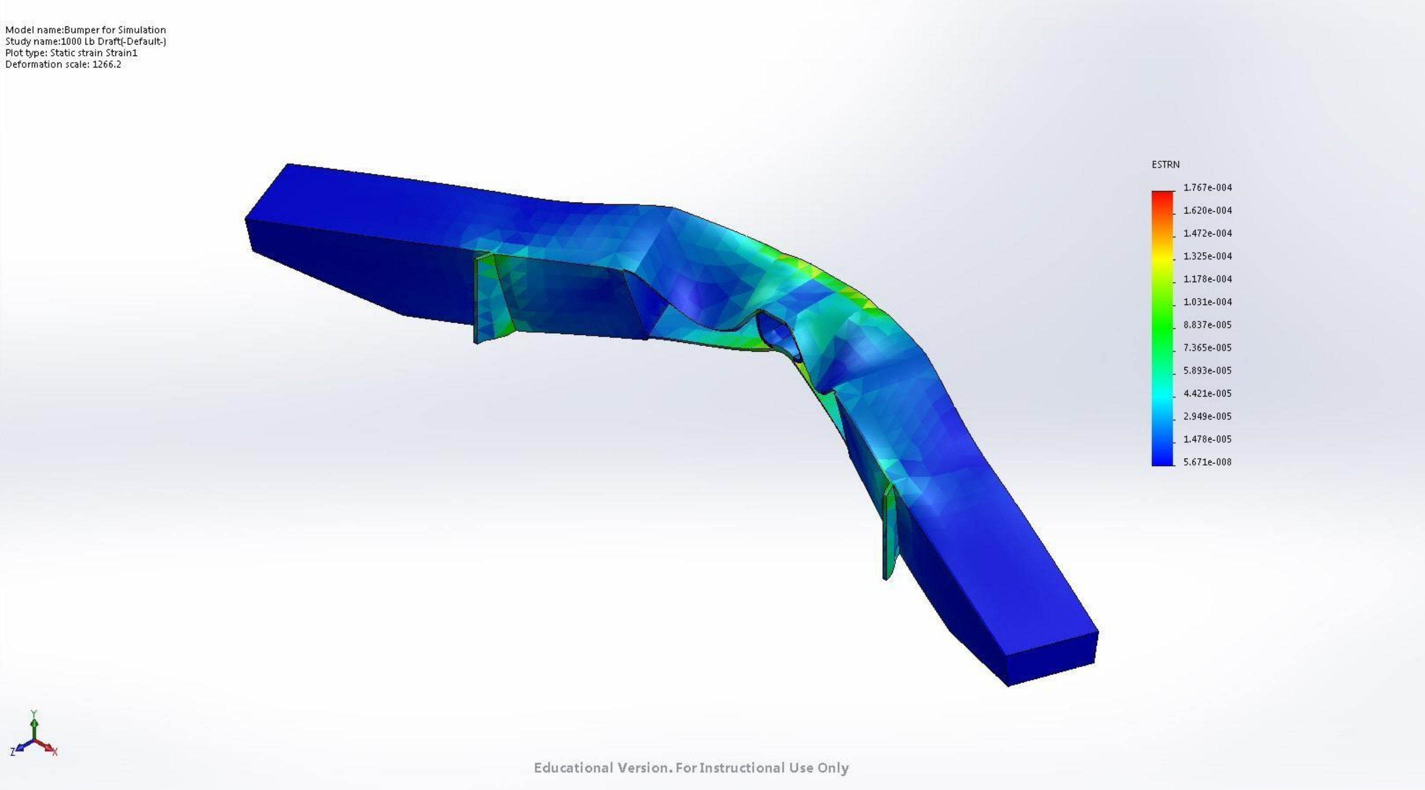
Bumper for Simulation-1000 Lb Draft-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 in Node: 856	0.0050696 in Node: 904



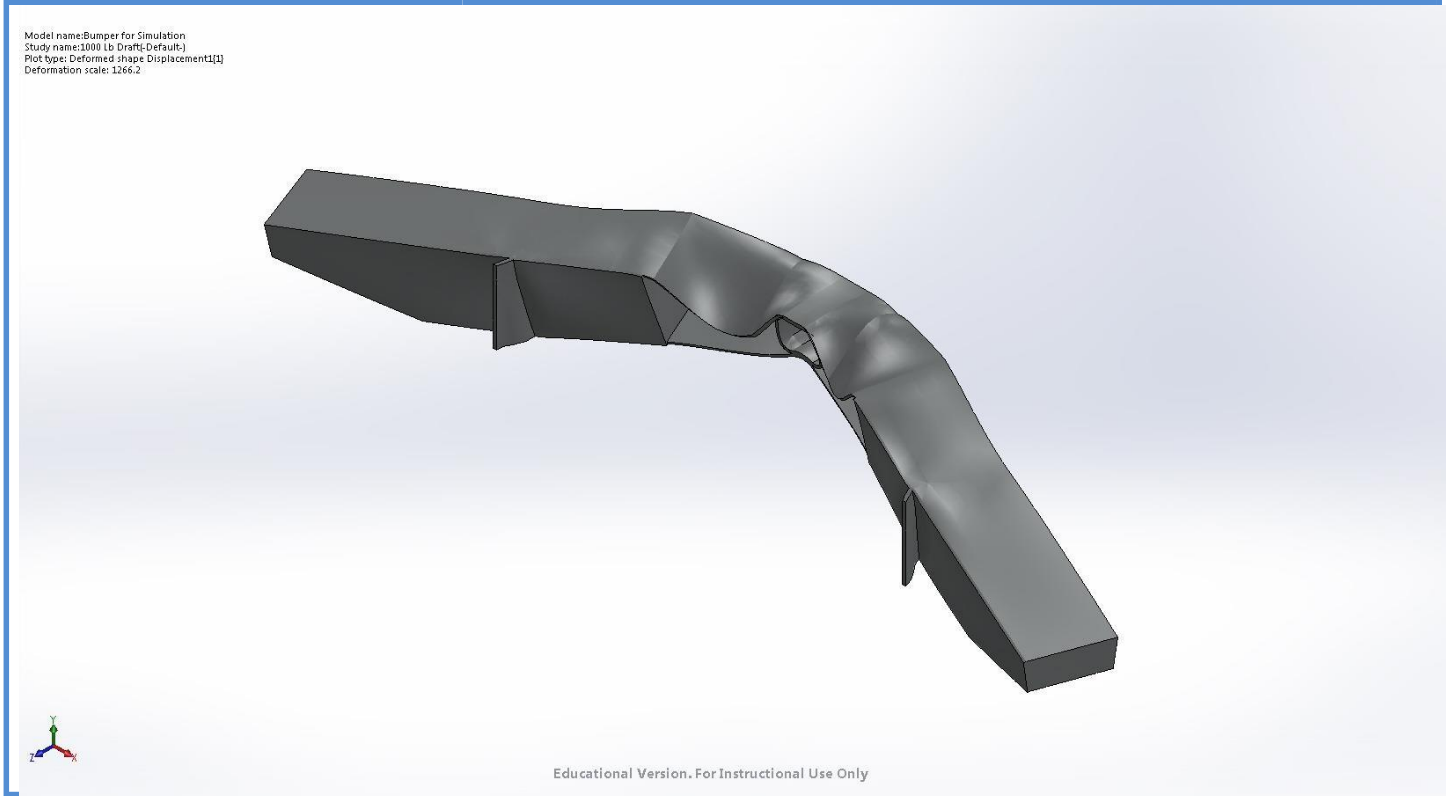
Bumper for Simulation-1000 Lb Draft-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	5.6713e-008 Element: 6113	0.000176684 Element: 6598



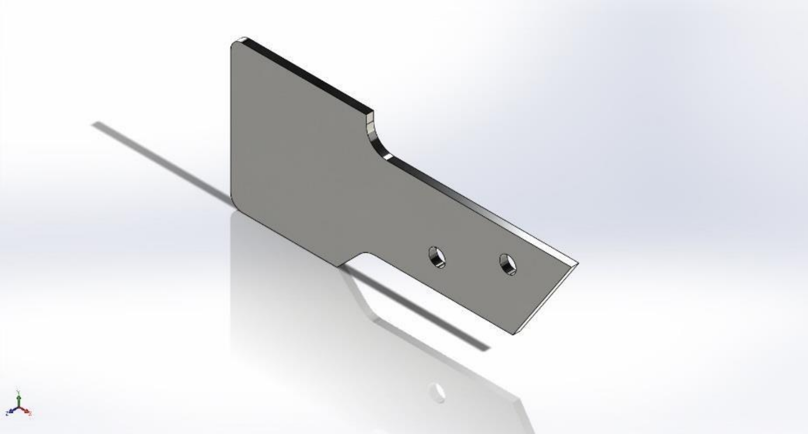
Bumper for Simulation-1000 Lb Draft-Strain-Strain1

Name	Type
Displacement1{1}	Deformed shape



Bumper for Simulation-1000 Lb Draft-Displacement-Displacement1{1}

Conclusion



Simulation of Frame Bracket for Simulation

Date: Monday, May 09, 2016
Designer: Solidworks
Study name: 1000 LB Draft
Analysis type: Static

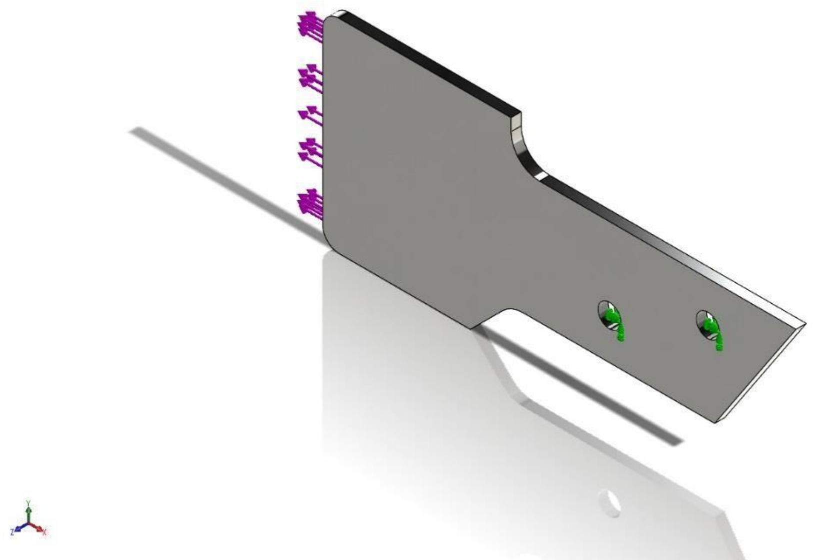
Table of Contents

Description

No Data

Assumptions

Model Information



Model name: Frame Bracket for Simulation
Current Configuration: Default

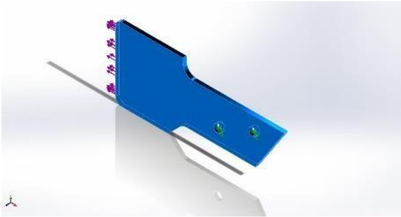
Study Properties

Study name	1000 LB Draft
Analysis type	Static
Mesh type	Shell Mesh Using Mid-surfaces
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (E:\Senior Project\SolidWorks\Bumper)

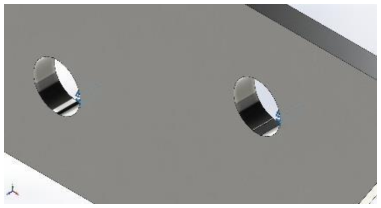
Units

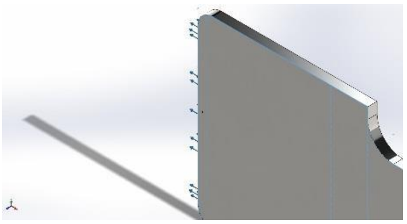
Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

Model Reference	Properties	Components
	**Name:** Plain Carbon Steel **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Yield strength:** 2.20594e+008 N/m^2 **Tensile strength:** 3.99826e+008 N/m^2 **Elastic modulus:** 2.1e+011 N/m^2 **Poisson's ratio:** 0.28 **Mass density:** 7800 kg/m^3 **Shear modulus:** 7.9e+010 N/m^2 **Thermal expansion coefficient:** 1.3e-005 /Kelvin	SolidBody 1(Cut-Extrude1)(Frame Bracket for Simulation)
Curve Data:N/A		

Loads and Fixtures

Fixed-1		**Entities:** 2 face(s) **Type:** Fixed Geometry

Load name	Load Image	Load Details
Force-1		**Entities:** 1 face(s) **Type:** Apply normal force **Value:** -500 lbf

Connector Definitions

No Data

Contact Information

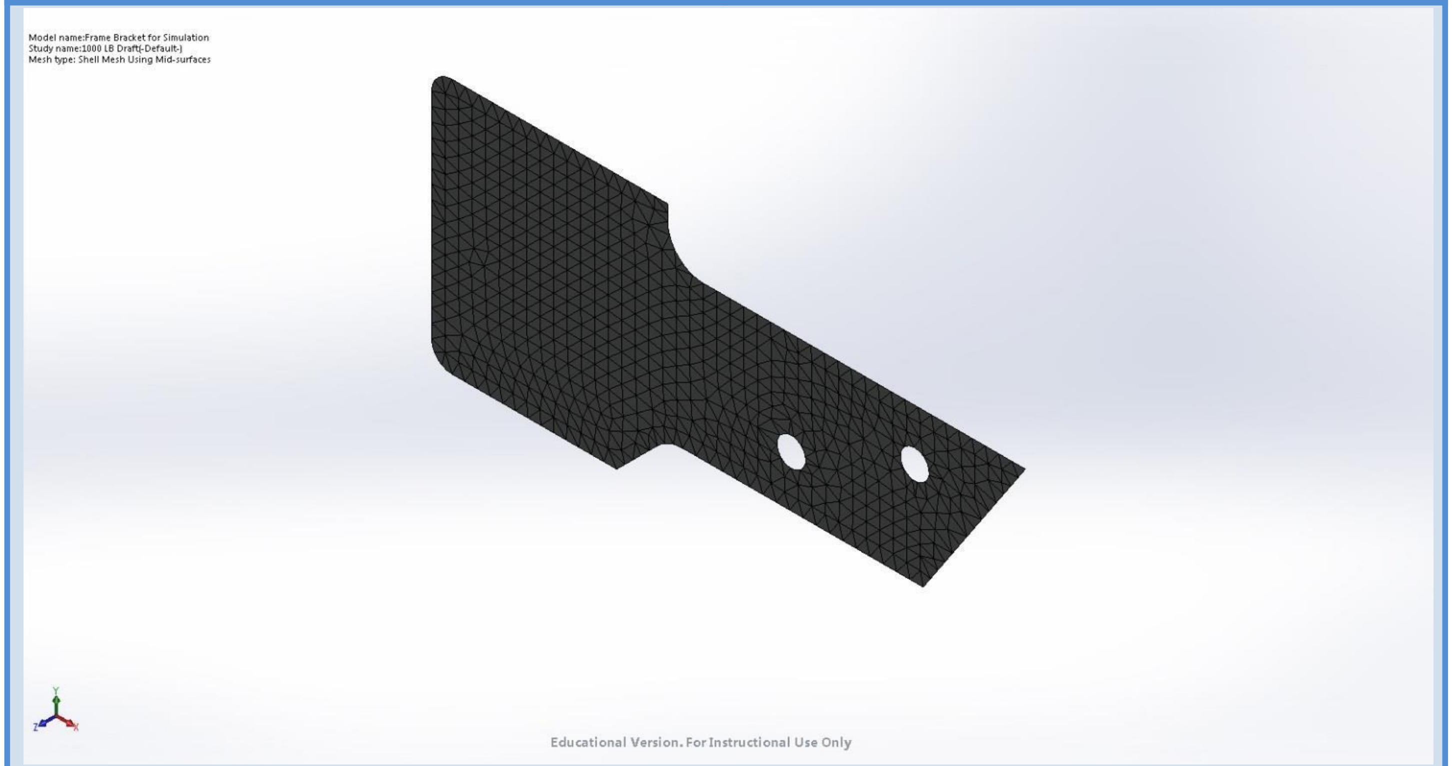
No Data

Mesh information

Mesh type	Shell Mesh Using Mid-surfaces
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	0.266668 in
Tolerance	0.0133334 in
Mesh Quality	High

Mesh information - Details

Total Nodes	2441
Total Elements	1150
Time to complete mesh(hh;mm;ss):	00:00:04
Computer name:	CAFES-8A-4C-13



Sensor Details

No Data

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	2224.12	0.00139618	-5.44928e-030	2224.12

Reaction Moments

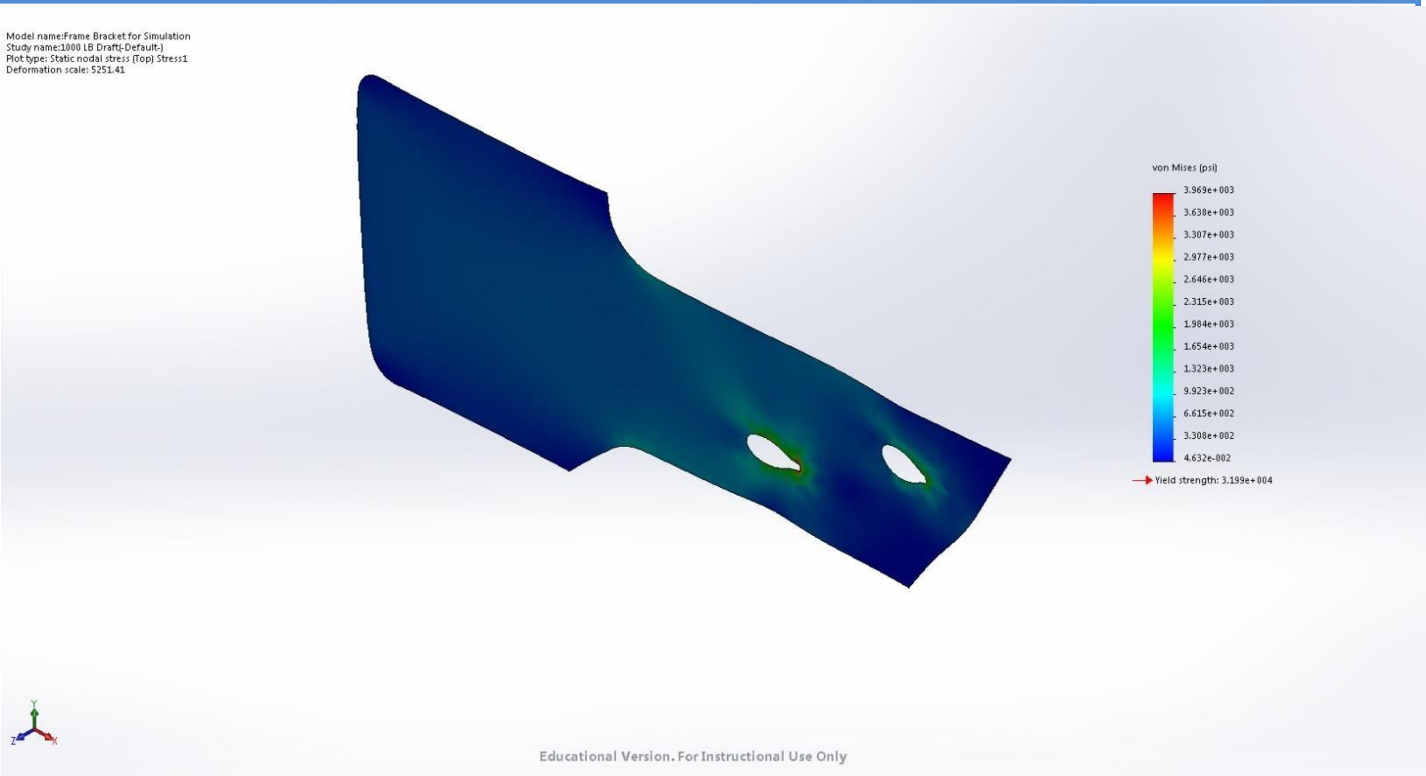
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	4.51765e-033	2.19702e-032	2.2063e-006	2.2063e-006

Beams

No Data

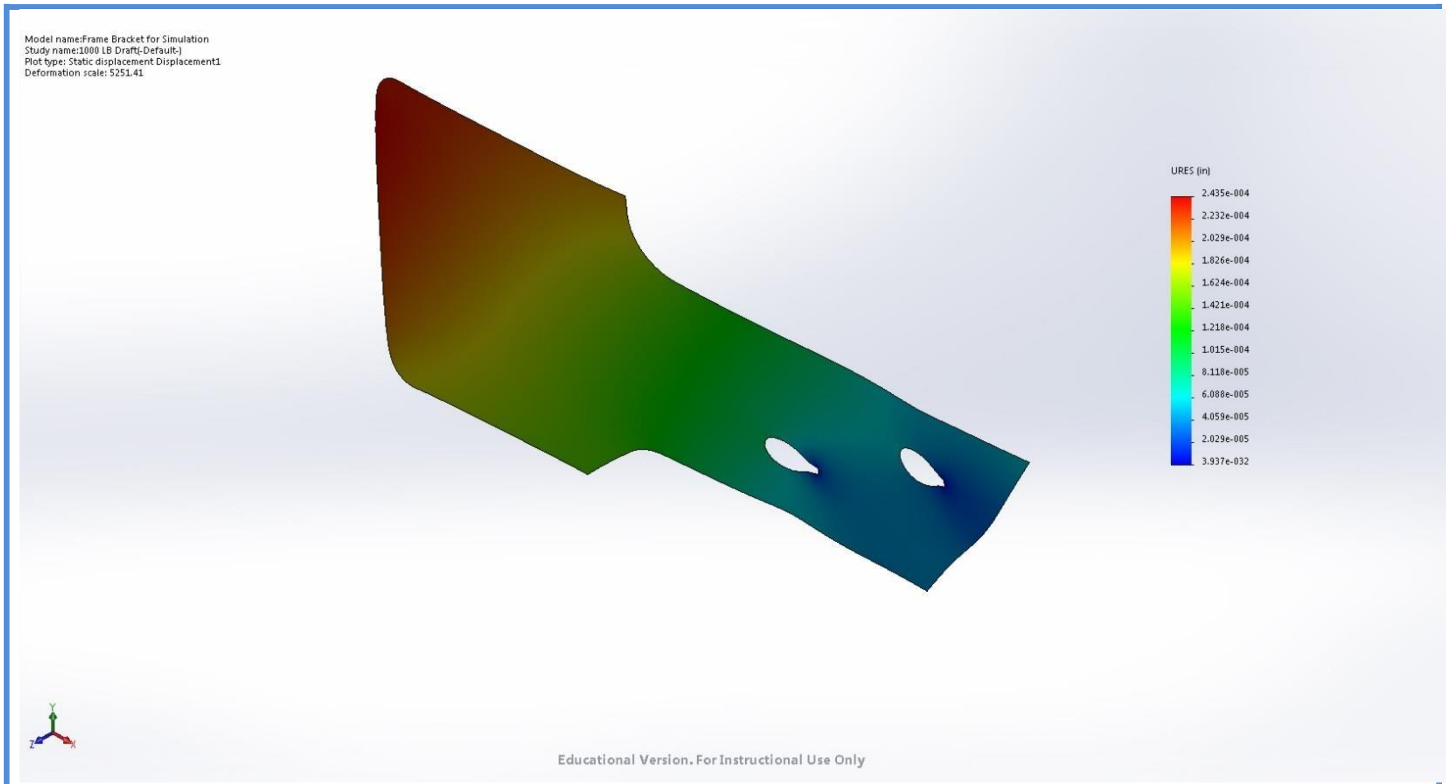
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.046321 psi Node: 119	3968.92 psi Node: 140



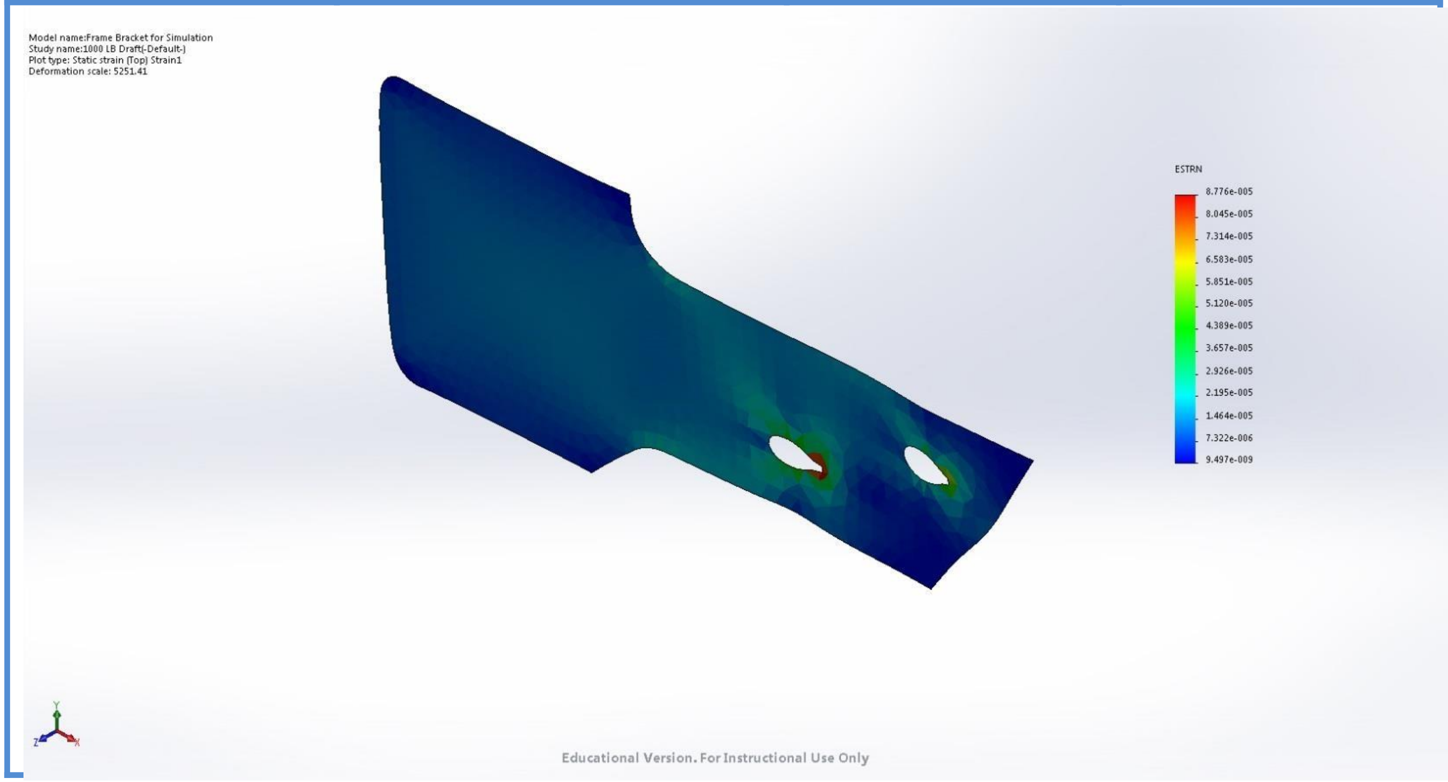
Frame Bracket for Simulation-1000 LB Draft-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 in Node: 1	0.000243532 in Node: 2245



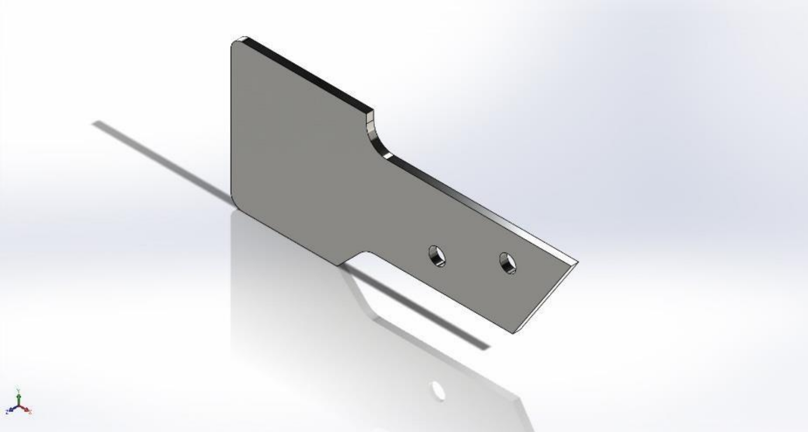
Frame Bracket for Simulation-1000 LB Draft-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	9.49706e-009 Element: 805	8.7765e-005 Element: 59



Frame Bracket for Simulation-1000 LB Draft-Strain-Strain1

Conclusion



Simulation of Frame Bracket for Simulation

Date: Monday, May 09, 2016
Designer: Solidworks
Study name: 1000 LB Load
Analysis type: Static

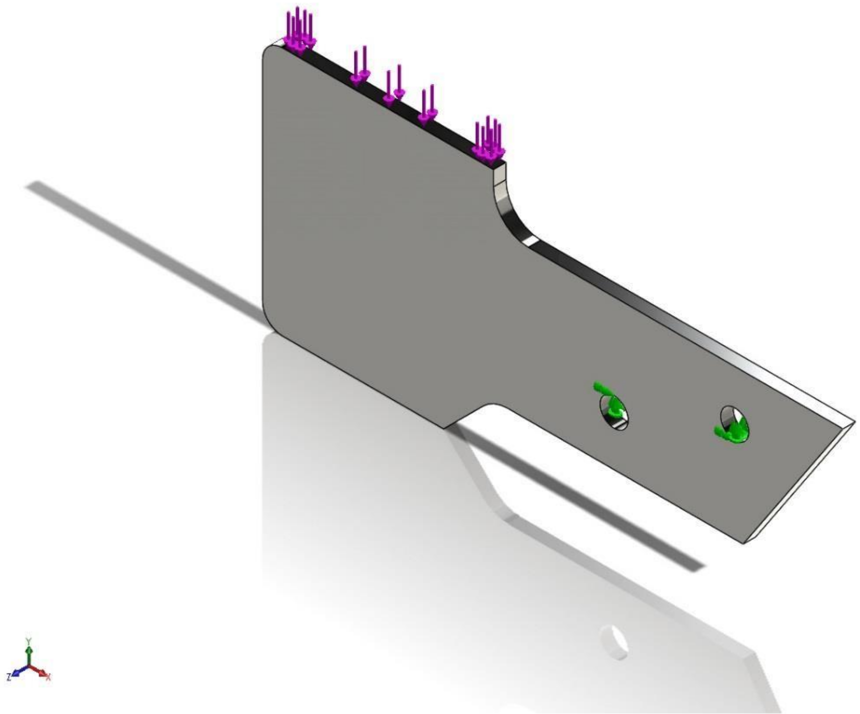
Table of Contents

Description

No Data

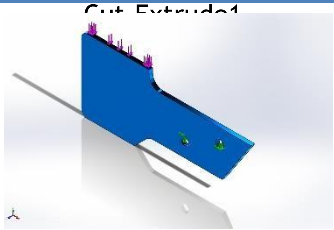
Assumptions

Model Information



Model name: Frame Bracket for Simulation
Current Configuration: Default

Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Cut-Extrude1 	Solid Body	**Mass:1.28376 kg** **Volume:0.000164585 m^3** **Density:7800 kg/m^3** **Weight:12.5809 N**	**E:\Senior Project\SolidWorks\Bumper\Frame Bracket for Simulation.SLDPRT** May 09 10:58:08 2016

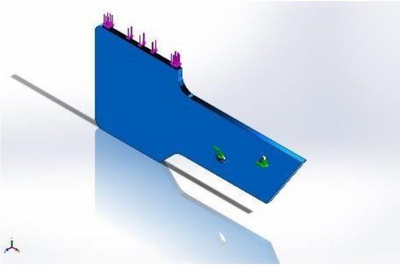
Study Properties

Study name	1000 LB Load
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (E:\Senior Project\SolidWorks\Bumper)

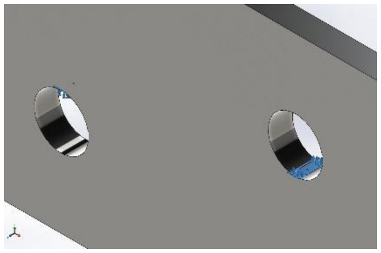
Units

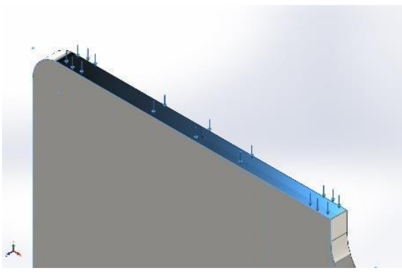
Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

Model Reference	Properties	Components
	**Name:** Plain Carbon Steel **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Yield strength:** 2.20594e+008 N/m^2 **Tensile strength:** 3.99826e+008 N/m^2 **Elastic modulus:** 2.1e+011 N/m^2 **Poisson's ratio:** 0.28 **Mass density:** 7800 kg/m^3 **Shear modulus:** 7.9e+010 N/m^2 **Thermal expansion coefficient:** 1.3e-005 /Kelvin	SolidBody 1(Cut-Extrude1)(Frame Bracket for Simulation)
Curve Data:N/A		

Loads and Fixtures

Fixed-1		**Entities:** 2 face(s) **Type:** Fixed Geometry

Load name	Load Image	Load Details
Force-1		**Entities:** 1 face(s) **Type:** Apply normal force **Value:** 500 lbf

Connector Definitions
No Data

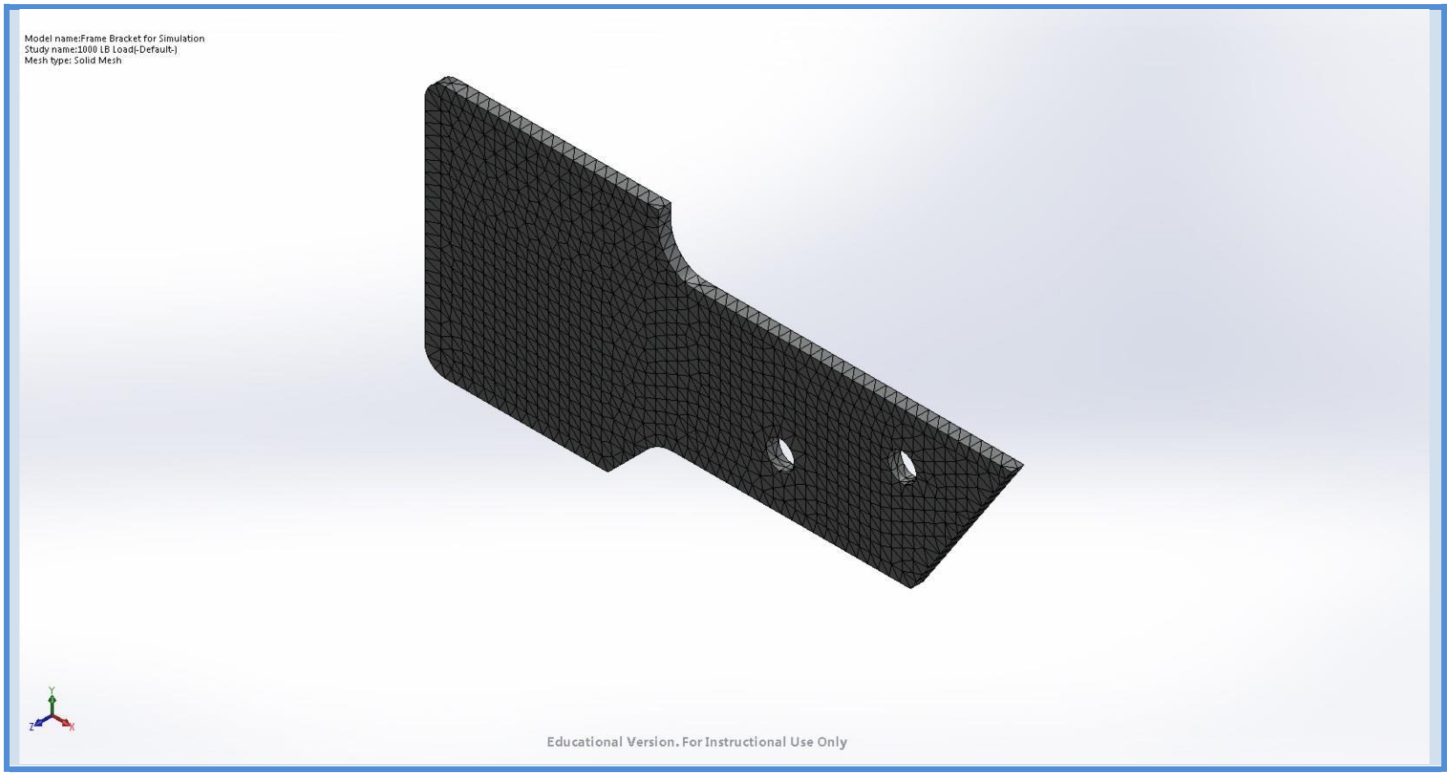
Contact Information
No Data

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	0.215819 in
Tolerance	0.0107909 in
Mesh Quality	High

Mesh information - Details

Total Nodes	16999
Total Elements	9736
Maximum Aspect Ratio	7.094
% of elements with Aspect Ratio < 3	99.8
% of elements with Aspect Ratio > 10	0
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:08
Computer name:	CAFES-8A-4C-13



Sensor Details

No Data

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.125763	2223.88	0.0513856	2223.88

Reaction Moments

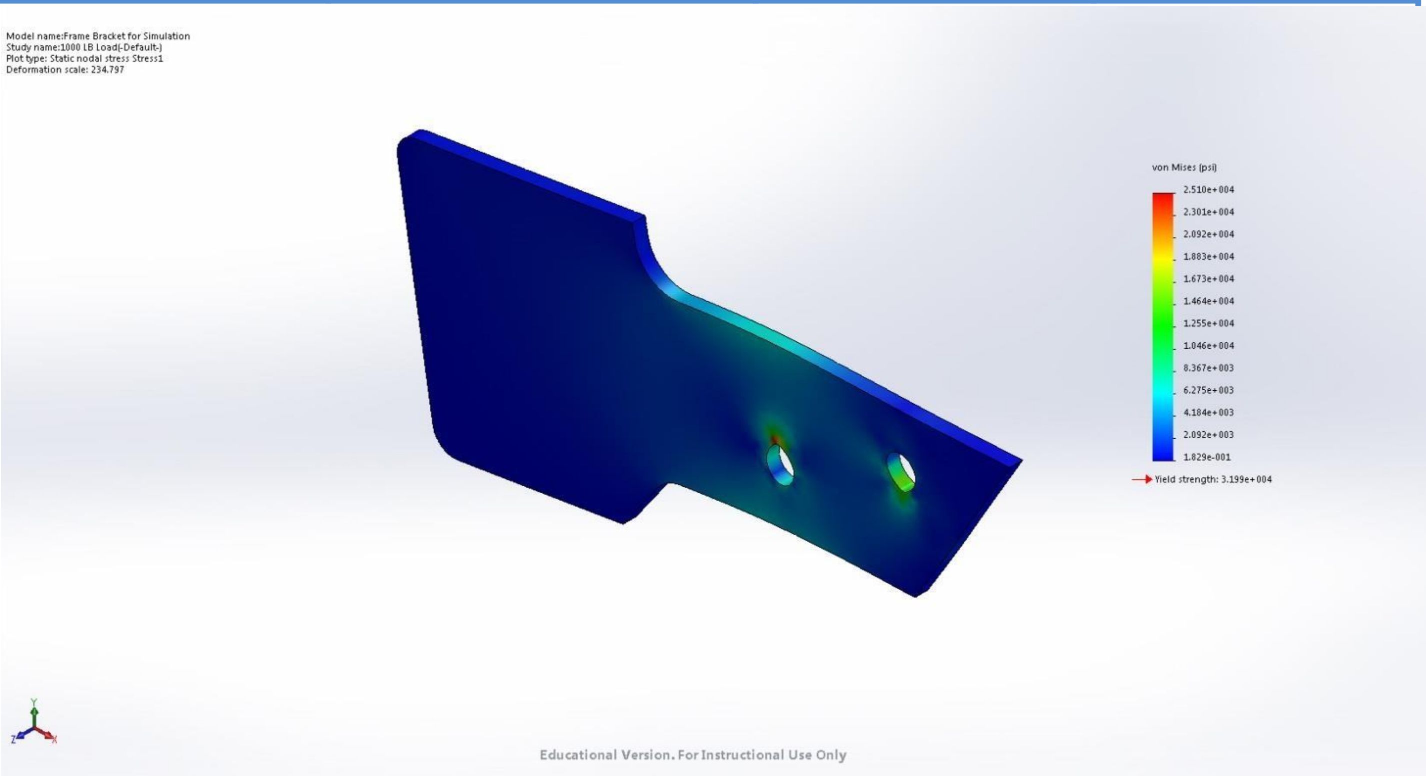
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Beams

No Data

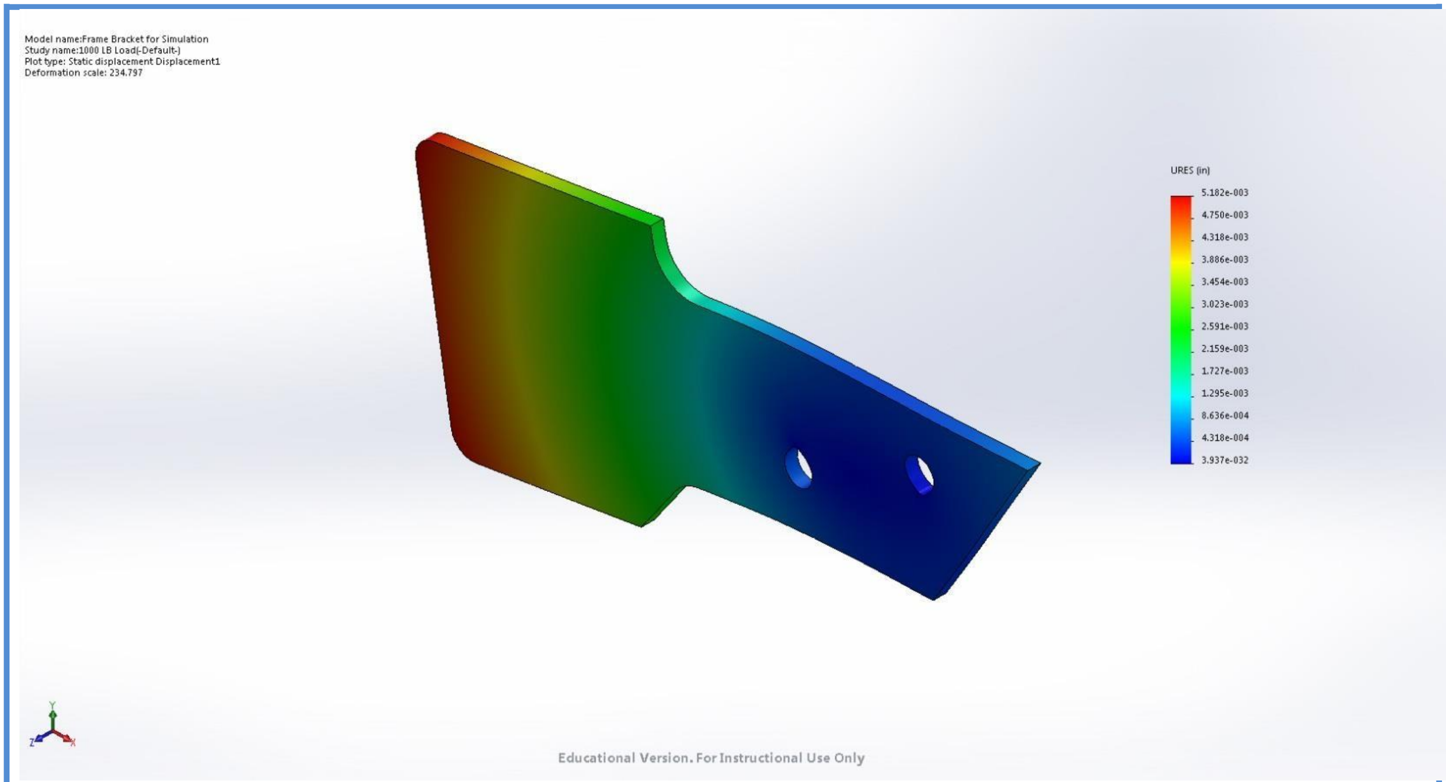
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.182865 psi Node: 3982	25101.3 psi Node: 1122



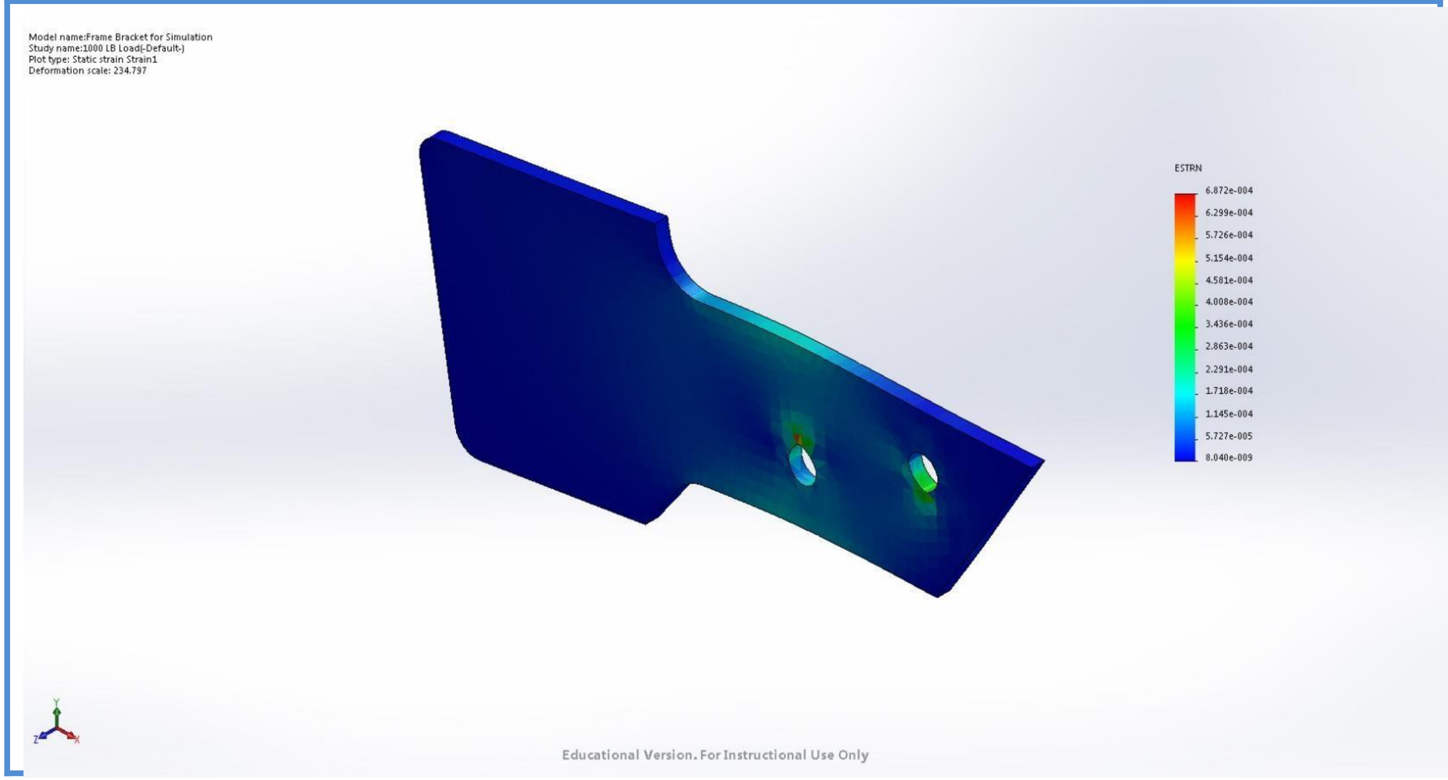
Frame Bracket for Simulation-1000 LB Load-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 in Node: 16	0.00518173 in Node: 9274



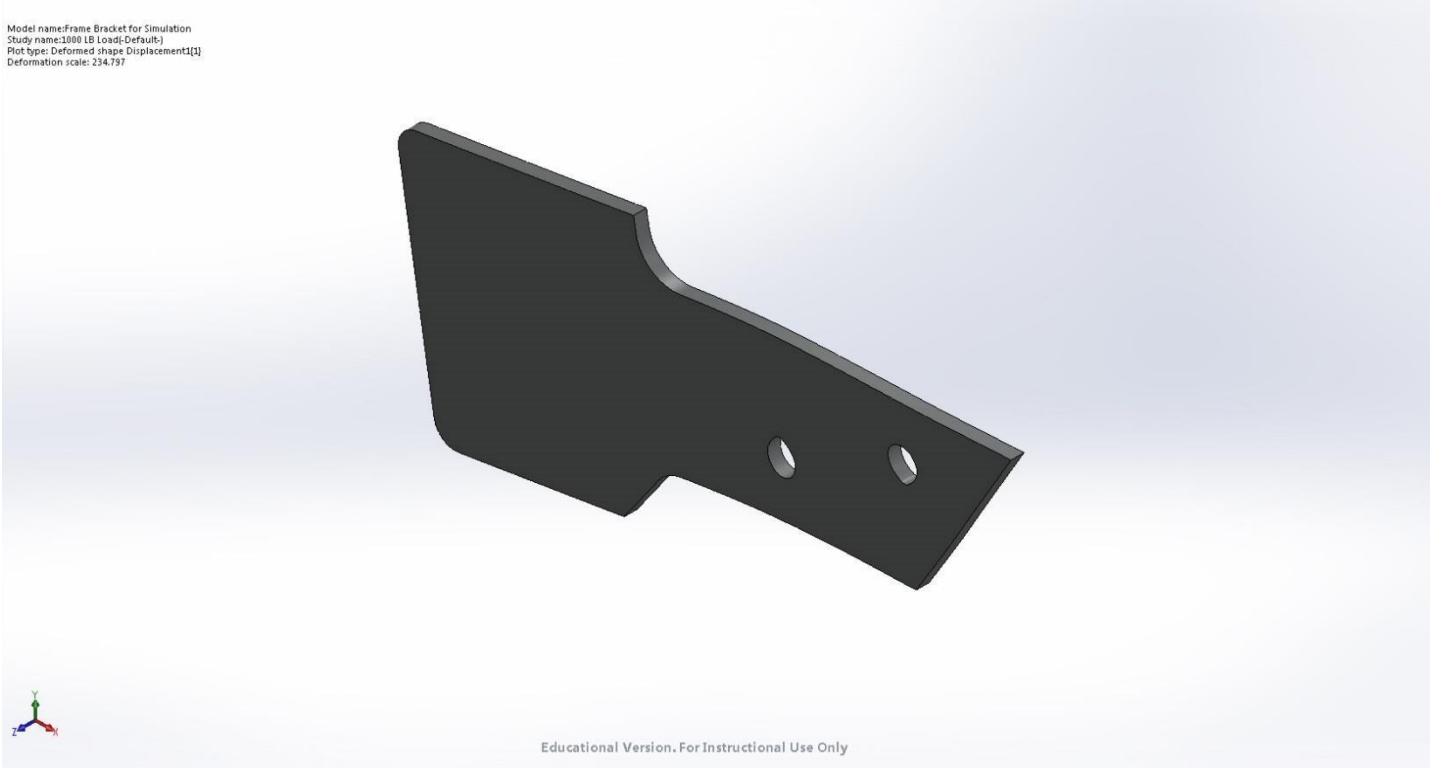
Frame Bracket for Simulation-1000 LB Load-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	8.04025e-009 Element: 4605	0.000687159 Element: 3473



Frame Bracket for Simulation-1000 LB Load-Strain-Strain1

Name	Type
Displacement1{1}	Deformed shape



Frame Bracket for Simulation-1000 LB Load-Displacement-Displacement1{1}

Conclusion

Simulation of Spindle for Simulation

Date: Monday, May 09, 2016
Designer: Solidworks
Study name: 10000 In-Lb
Analysis type: Static

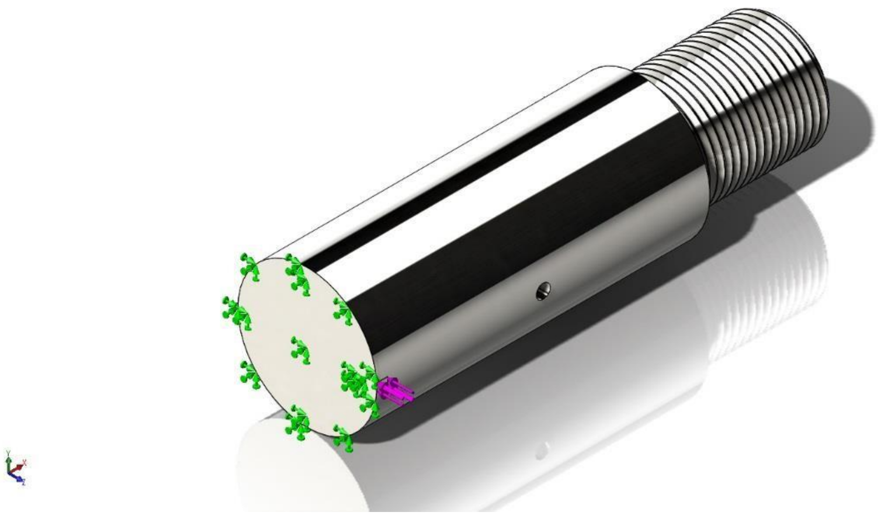
Table of Contents

Description

No Data

Assumptions

Model Information



Model name: Spindle for Simulation
Current Configuration: 91257A998

Solid Bodies			
Document Name and Reference	**Treated As**	**Volumetric Properties**	**Document Path/Date Modified**
Cut-Extrude18 	Solid Body	**Mass:0.569187 kg** **Volume:7.29727e-005 m^3** **Density:7800 kg/m^3** **Weight:5.57803 N**	**E:\Senior Project\SolidWorks\Bumper\Spindle for Simulation.SLDPRT** May 09 11:52:02 2016

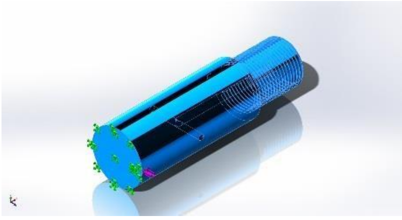
Study Properties

Study name	10000 In-Lb
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (E:\Senior Project\SolidWorks\Bumper)

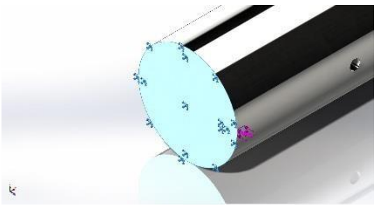
Units

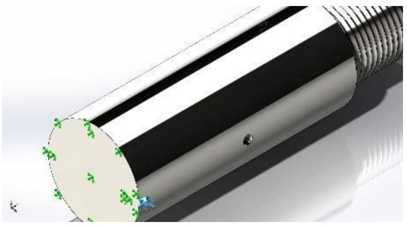
Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

Model Reference	Properties	Components
	**Name:** Plain Carbon Steel **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Yield strength:** 2.20594e+008 N/m^2 **Tensile strength:** 3.99826e+008 N/m^2 **Elastic modulus:** 2.1e+011 N/m^2 **Poisson's ratio:** 0.28 **Mass density:** 7800 kg/m^3 **Shear modulus:** 7.9e+010 N/m^2 **Thermal expansion coefficient:** 1.3e-005 /Kelvin	SolidBody 1(Cut-Extrude18)(Spindle for Simulation)
Curve Data:N/A		

Loads and Fixtures

Fixed-1		**Entities:** 1 face(s) **Type:** Fixed Geometry

Load name	Load Image	Load Details
Force-1		**Entities:** 2 face(s) **Type:** Apply normal force **Value:** 6700 lbf

Connector Definitions

No Data

Contact Information

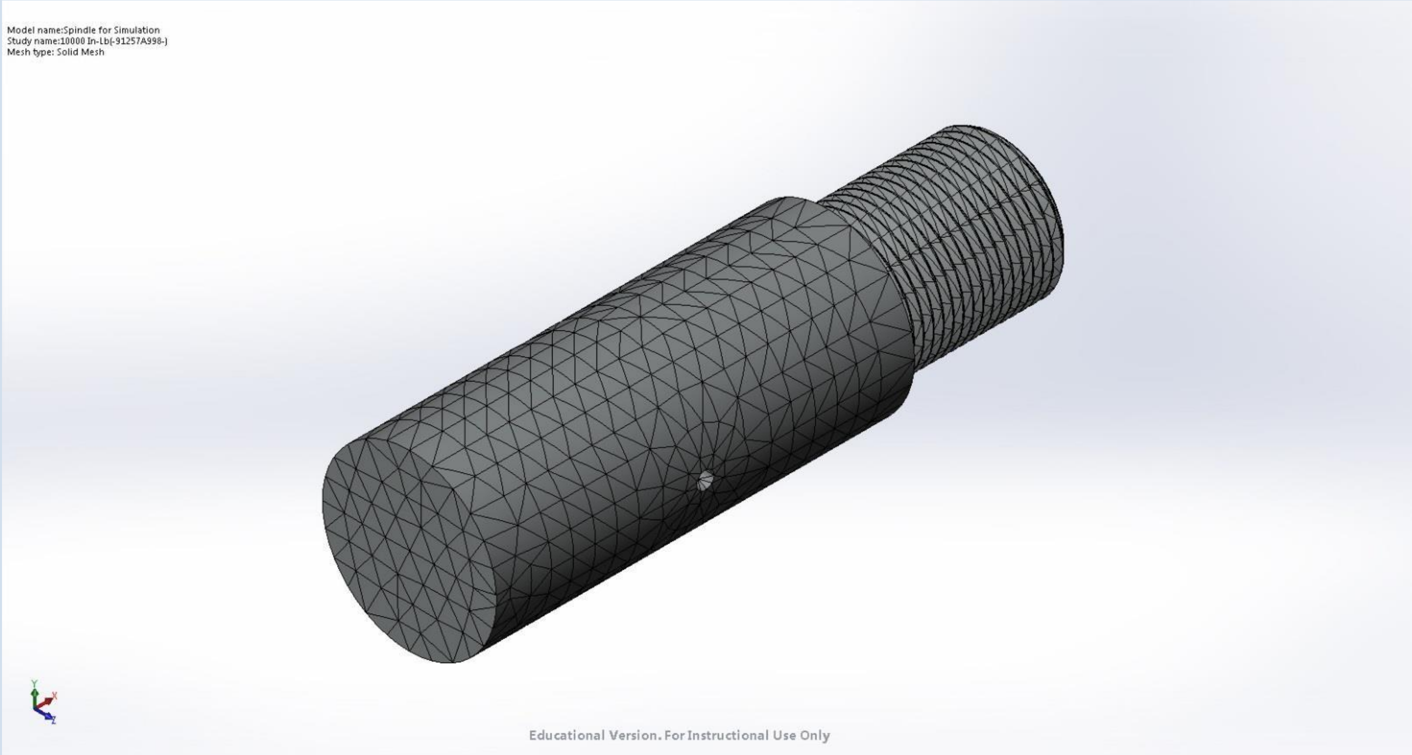
No Data

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Curvature based mesh
Jacobian points	4 Points
Maximum element size	0 in
Minimum element size	0 in
Mesh Quality	High

Mesh information - Details

Total Nodes	26676
Total Elements	16984
Maximum Aspect Ratio	53.648
% of elements with Aspect Ratio < 3	79.9
% of elements with Aspect Ratio > 10	10.4
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:12
Computer name:	CAFES-8A-4C-13



Sensor Details

No Data

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	202.999	-172.291	1.42664	266.261

Reaction Moments

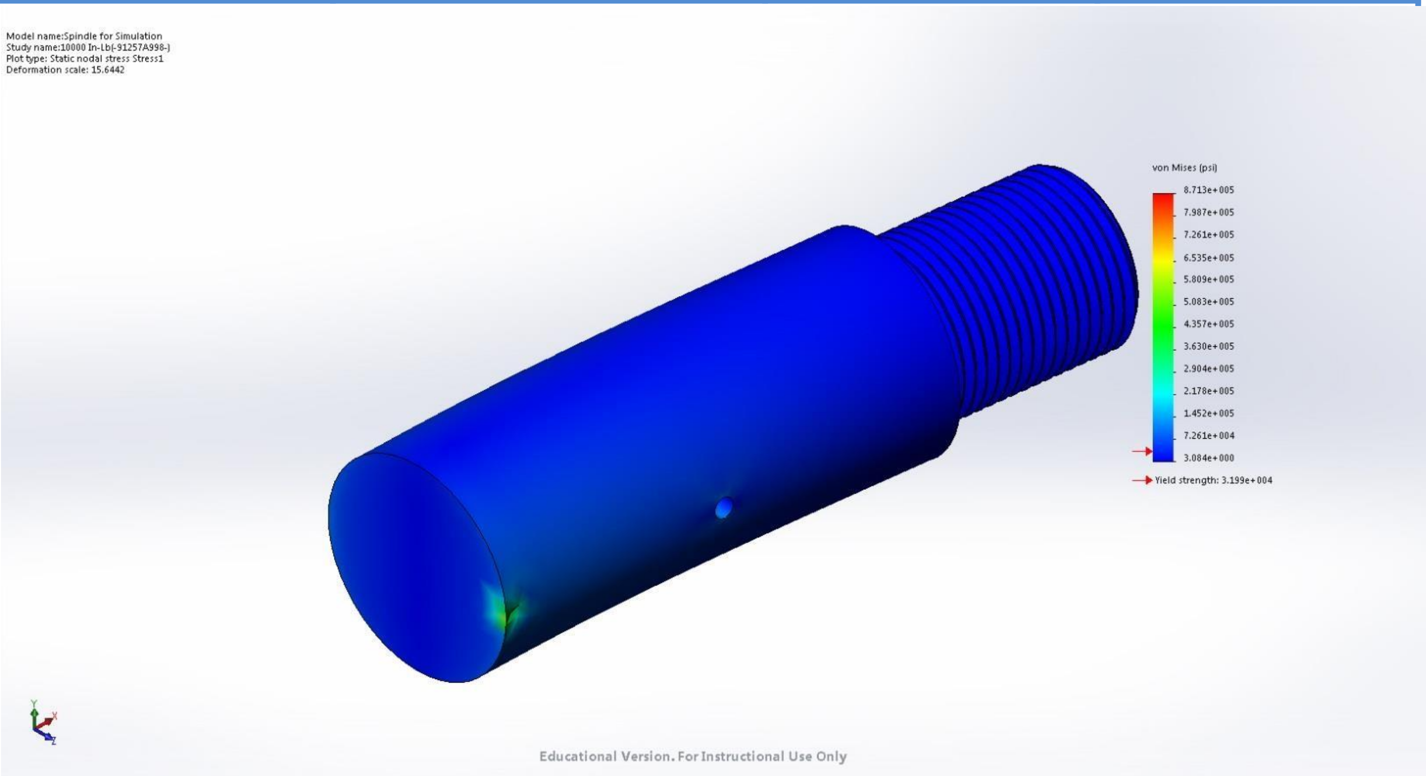
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Beams

No Data

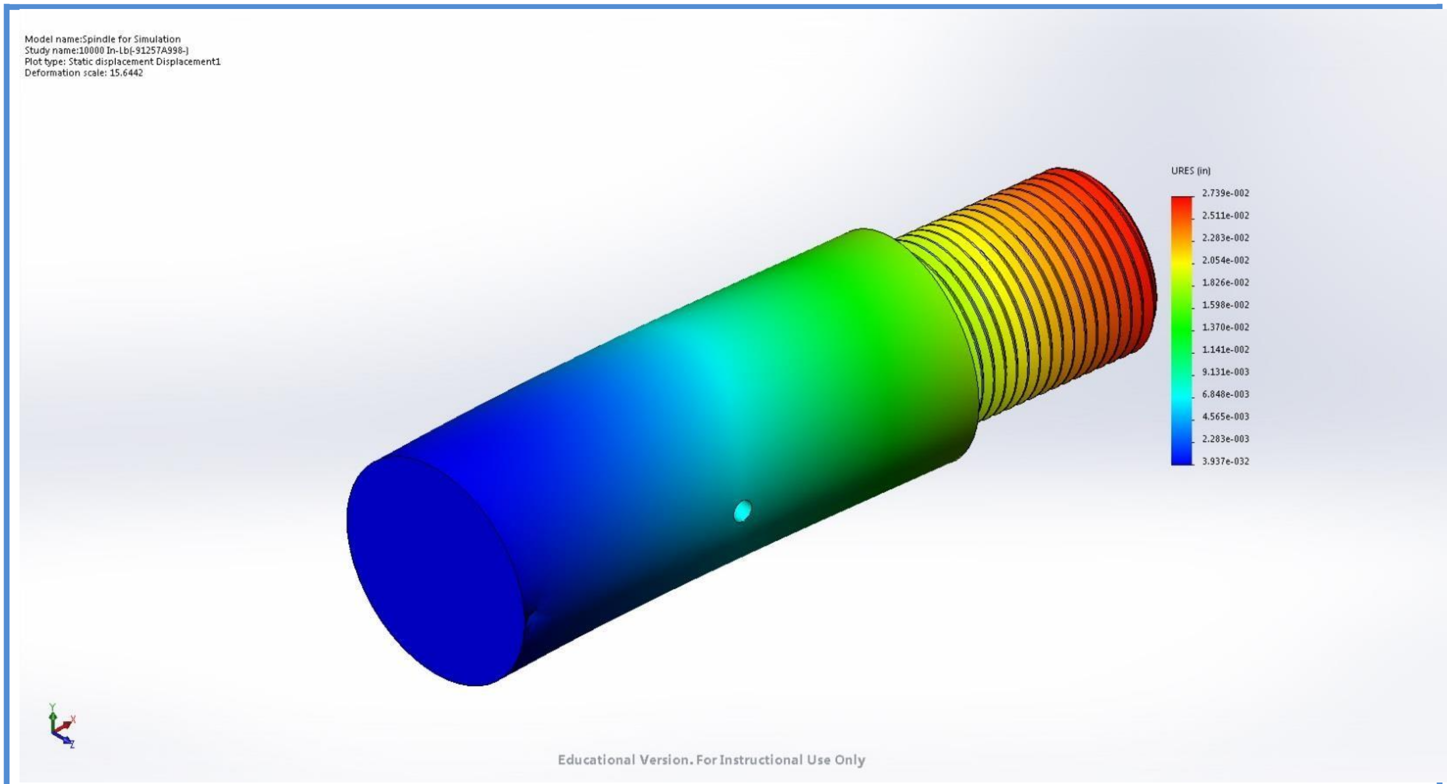
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	3.08359 psi Node: 18027	871307 psi Node: 1154



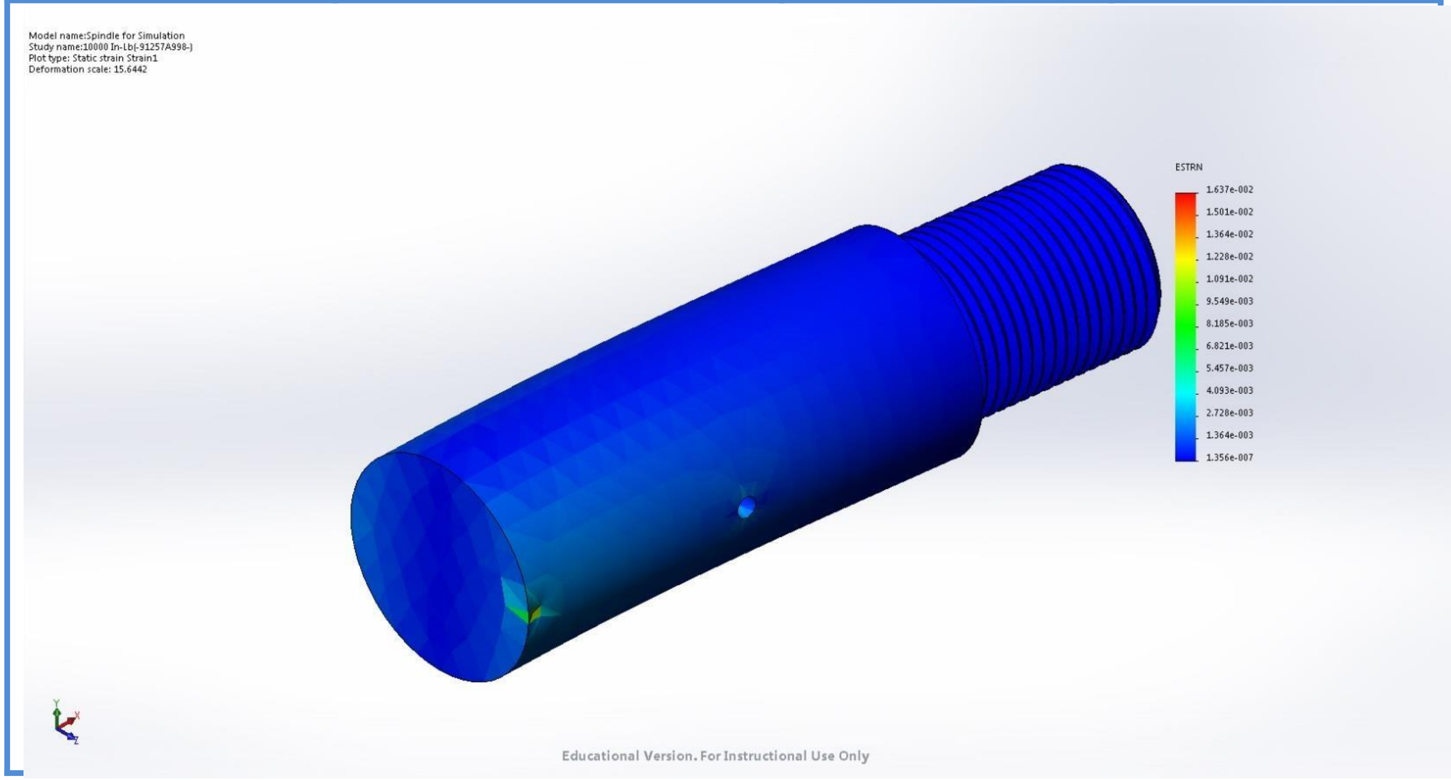
Spindle for Simulation-10000 In-Lb-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 in Node: 956	0.0273917 in Node: 18112



Spindle for Simulation-10000 In-Lb-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1.35617e-007 Element: 3348	0.0163701 Element: 10628



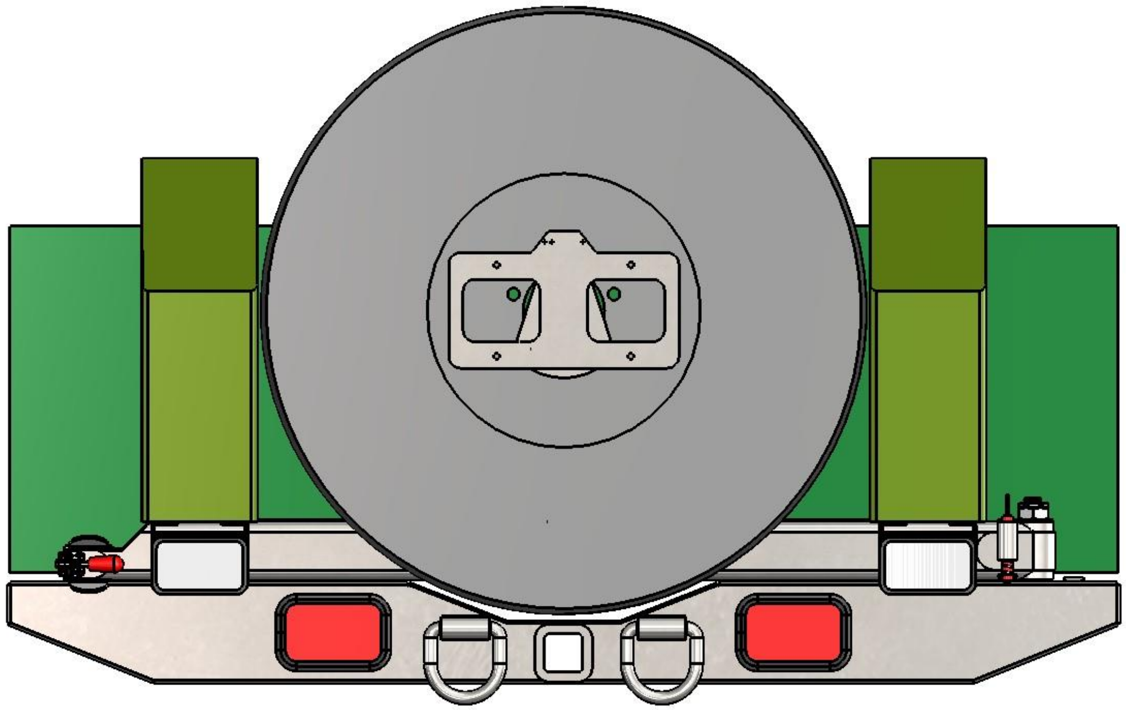
Spindle for Simulation-10000 In-Lb-Strain-Strain1

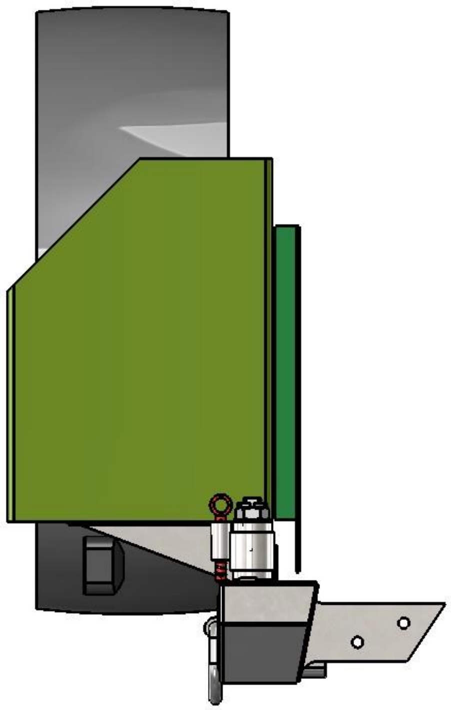
Conclusion

APPENDIX C – Bumper Parts and Assembly Drawings

2 1

B





A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

PROPRIETARY AND CONFIDENTIAL

TITLE:

SIZE	DWG. NO.	REV
	MAain Assembly1	
SCALE: 1:16	WEIGHT:	SHEET 1 OF 1

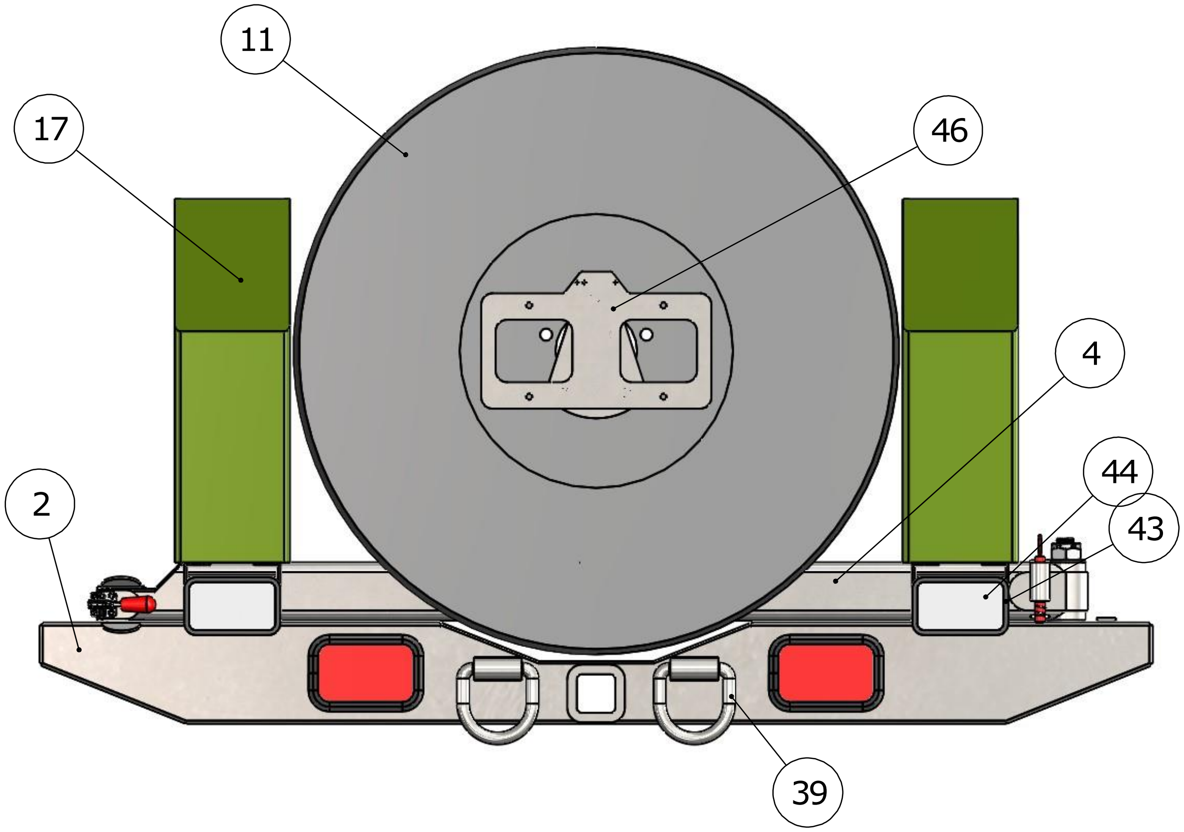
2 1

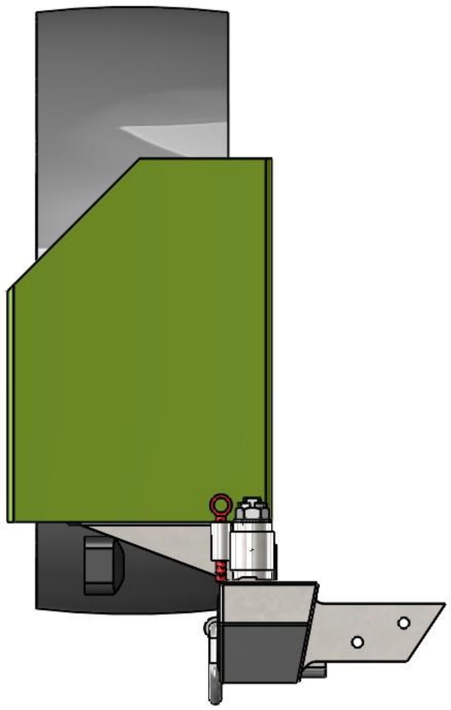
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Tailgate		1
2	Bumper, Main		1
3	Bumper, Step		1
4	Rack, Arm		1
5	Rack, Arm, Cap		1
6	Rack, Hub		1
7	Rack, Hub, Strap		1
8	Rack, Stud Plate		1
9	91257A748		3
10	Rack, Spindle Bushing		1
11	Tire		1
12	Rack, Toggle Clamp, Bracket		1
13	Rack, Toggle Clamp		1
14	91251A337		6
15	Jerry Can mount		2
16	Jerry Can mount - offhand		2
17	Jerry Can		2
18	Rack, Corner Gusset, Large		2
19	Rack, Corner Guesset, Small		2
20	Rack, Flood Light, Bracket		2
21	Rack, Lock Pin, Pin		1
22	Rack, Lock Pin, Collar		1
23	98296A883		2
24	9657K293		1
25	Rack, Wareplate		1
26	91257A998		1
27	2879T13		2
28	95030A320		1
29	6in Reciver Tube		1
30	Rack, Spindle, Gusset		1
31	Back Plate		2
32	Bumper, Main, Light Back		2
33	Rack, Shelf, Plate 2		1

34	Rack, Sheft, Plate 1	1
35	Rack, Toggle Clamp, Clasp	1
36	Rack, Shelf, Plate 3	1
37	Bumper, Main, Gussett	2
38	Frame Bracket	2
39	Bumper, D-ring, Ring	2
40	Bumper, D-ring, Weld Link	2
41	Bumper Tail Light, Light	2
42	Bumper, Tail Light, Gromet	2
43	Rack, Flood Light, Bucket	2
44	Rack, Flood Light, Lense	2
45	Rack, License Plate, Stud Plate	1
46	Rack, License Plate, Back Plate	1
47	Rack, Licens Plate, Standoff	1
48	Rack, Lock Pin, Ramp	1

2 1

B B





A A

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			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

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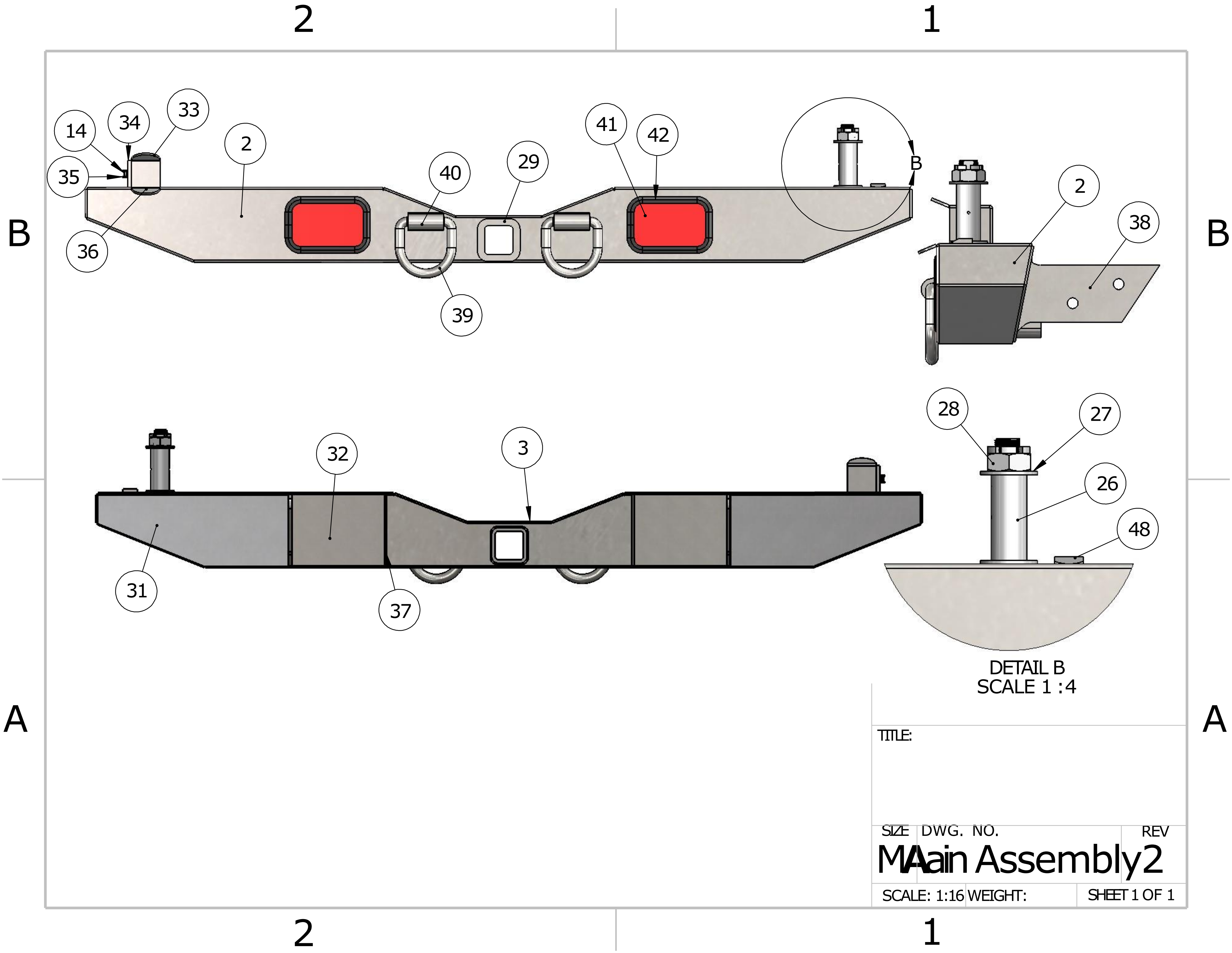
TITLE:

SIZE	DWG. NO.	REV
A	Main Assembly	1.1

SCALE: 1:16 WEIGHT: SHEET 1 OF 1

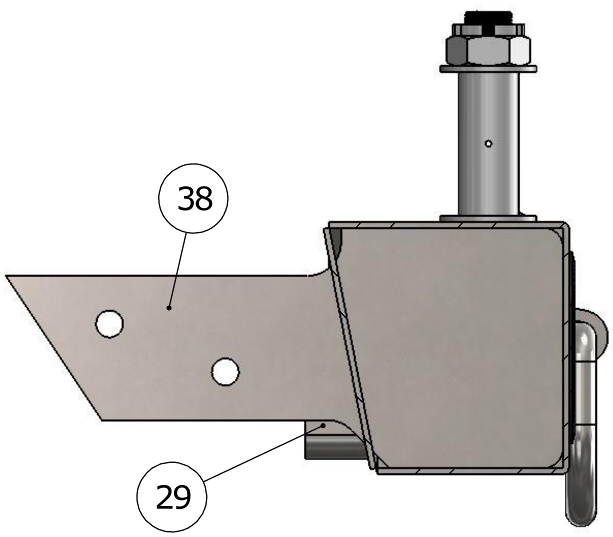
2 1



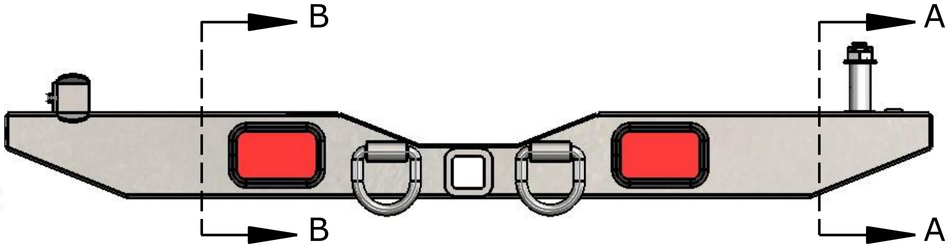
TITLE:		
SIZE	DWG. NO.	REV
M	Main Assembly2	A
SCALE: 1:16	WEIGHT:	SHEET 1 OF 1

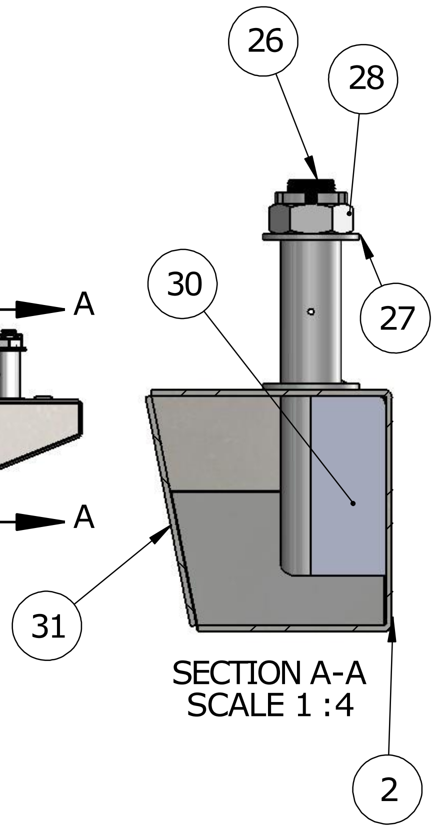
2 1

B B



SECTION B-B
SCALE 1 : 4





SECTION A-A
SCALE 1 : 4

A A

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			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
		DO NOT SCALE DRAWING			

TITLE:

SIZE	DWG. NO.	REV
A	Main Assembly3	

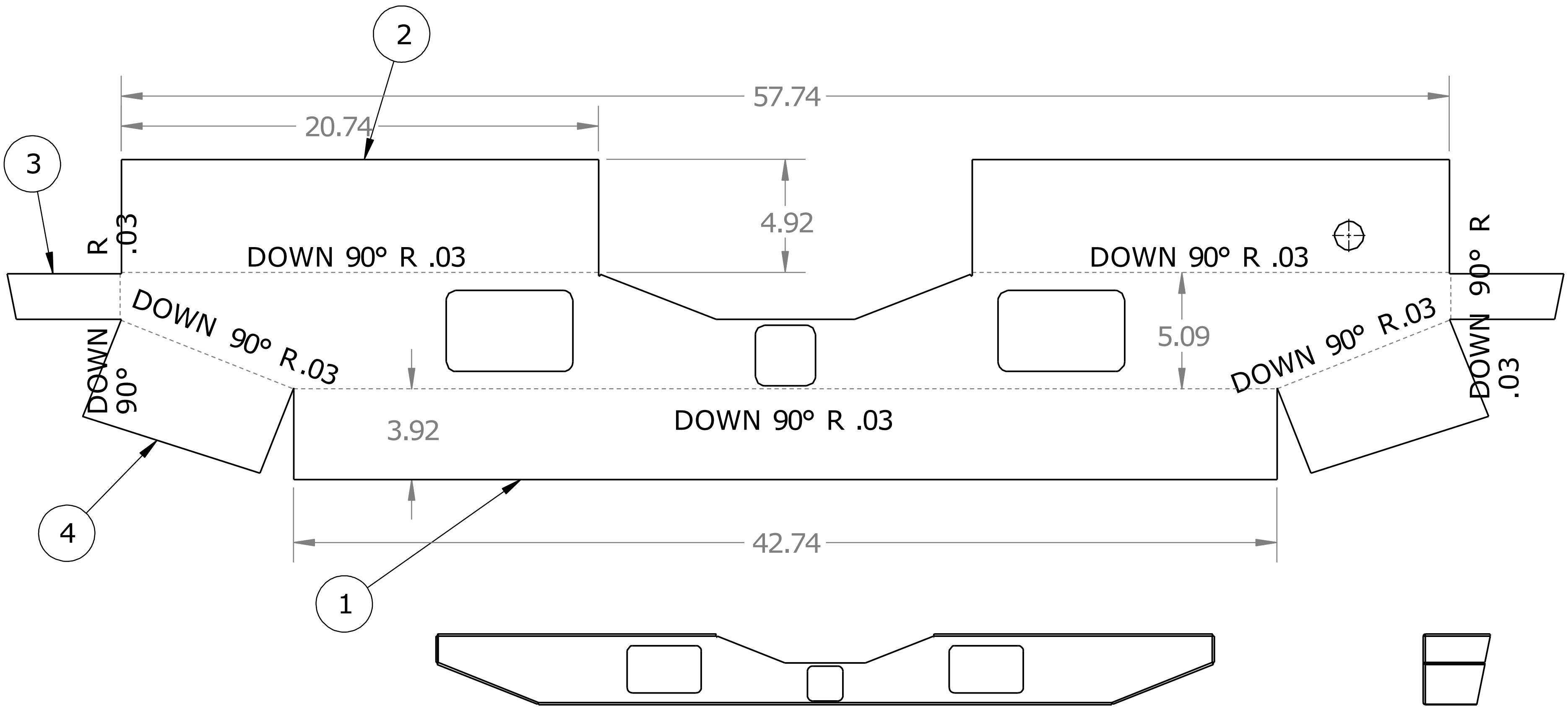
SCALE: 1:12 WEIGHT: SHEET 1 OF 1

1

2 1

B B

NOTE:
10 GAUGE HOTROLLED
CNC PLASMACUT



A A

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			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
		DO NOT SCALE DRAWING			

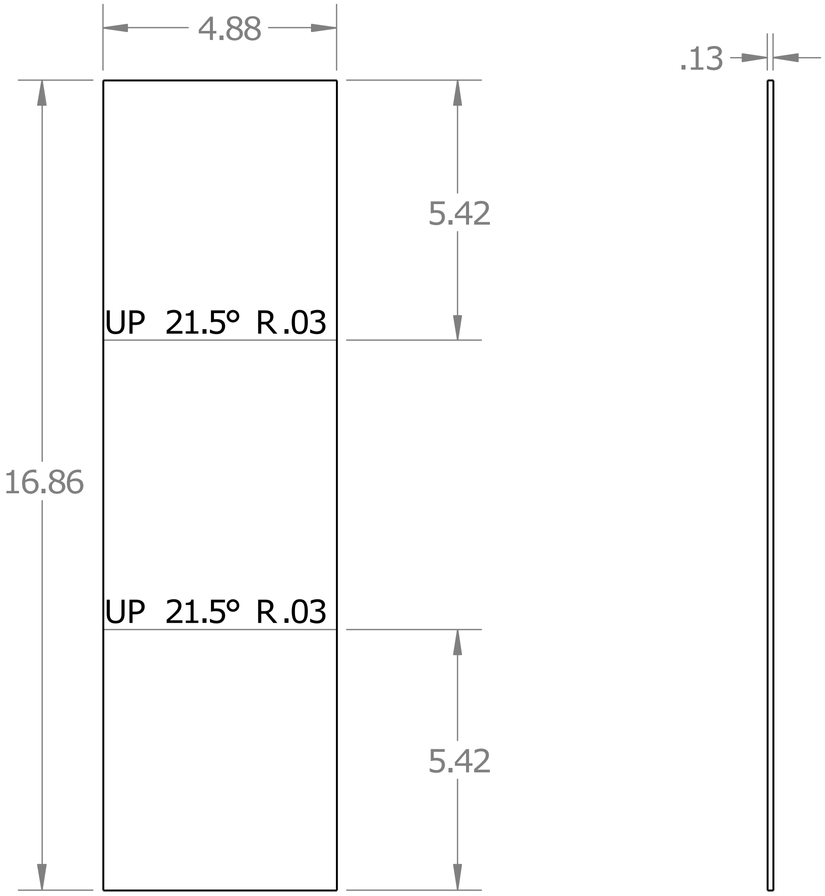
TITLE:

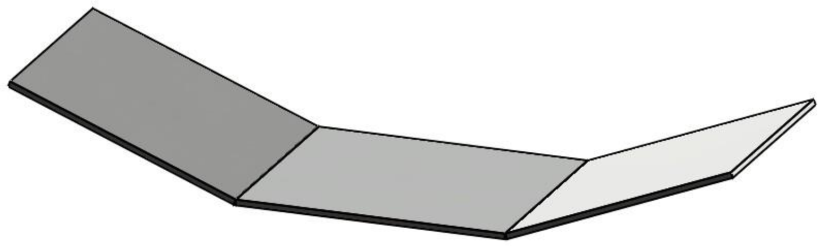
SIZE DWG. NO. REV

A Bumper, Main

SCALE: 1:12 WEIGHT: SHEET 1 OF 1

1





NOTE:
10 GAUGE HOT ROLLED
CNC PLASMA CUT

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UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE DWG. NO. REV

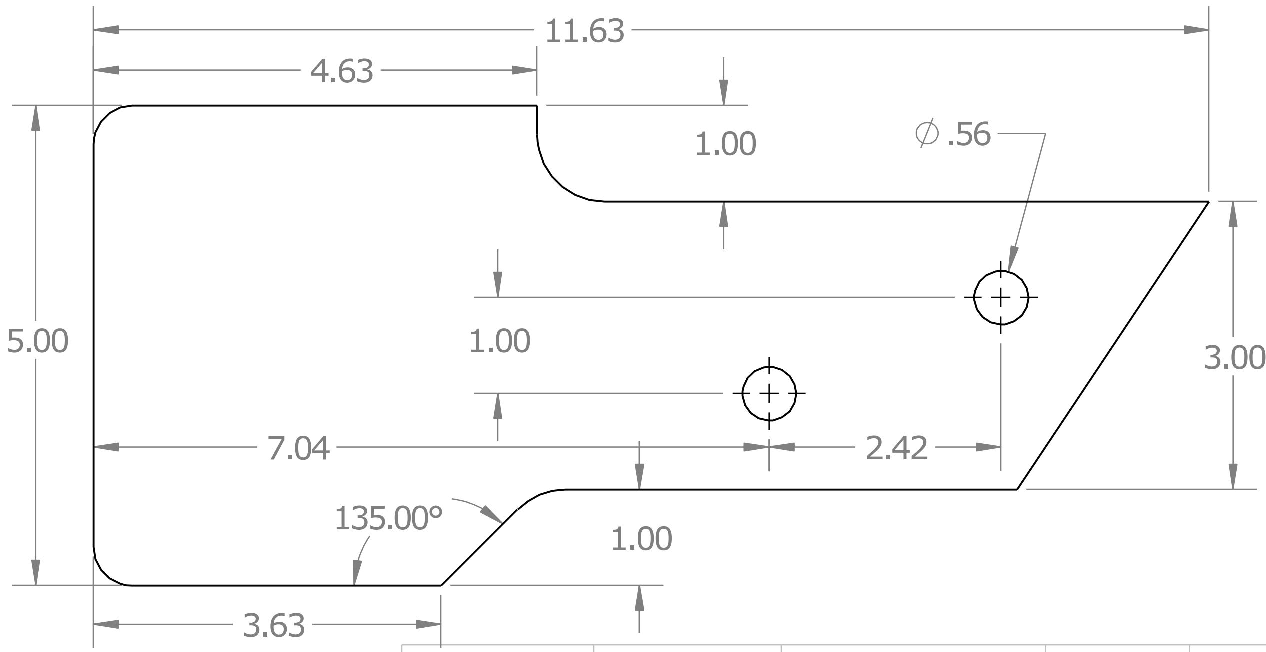
A Bumper, Step

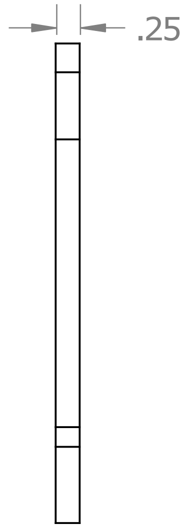
SCALE: 1:4 WEIGHT: SHEET 1 OF 1

2 1

B B

NOTE;
0.25IN. HOT ROLLED PLATE
CNC PLASMA CUT
HOLLED DRILLED VIA MILL





A A

NEXT ASSY	USED ON

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DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE DWG. NO. REV

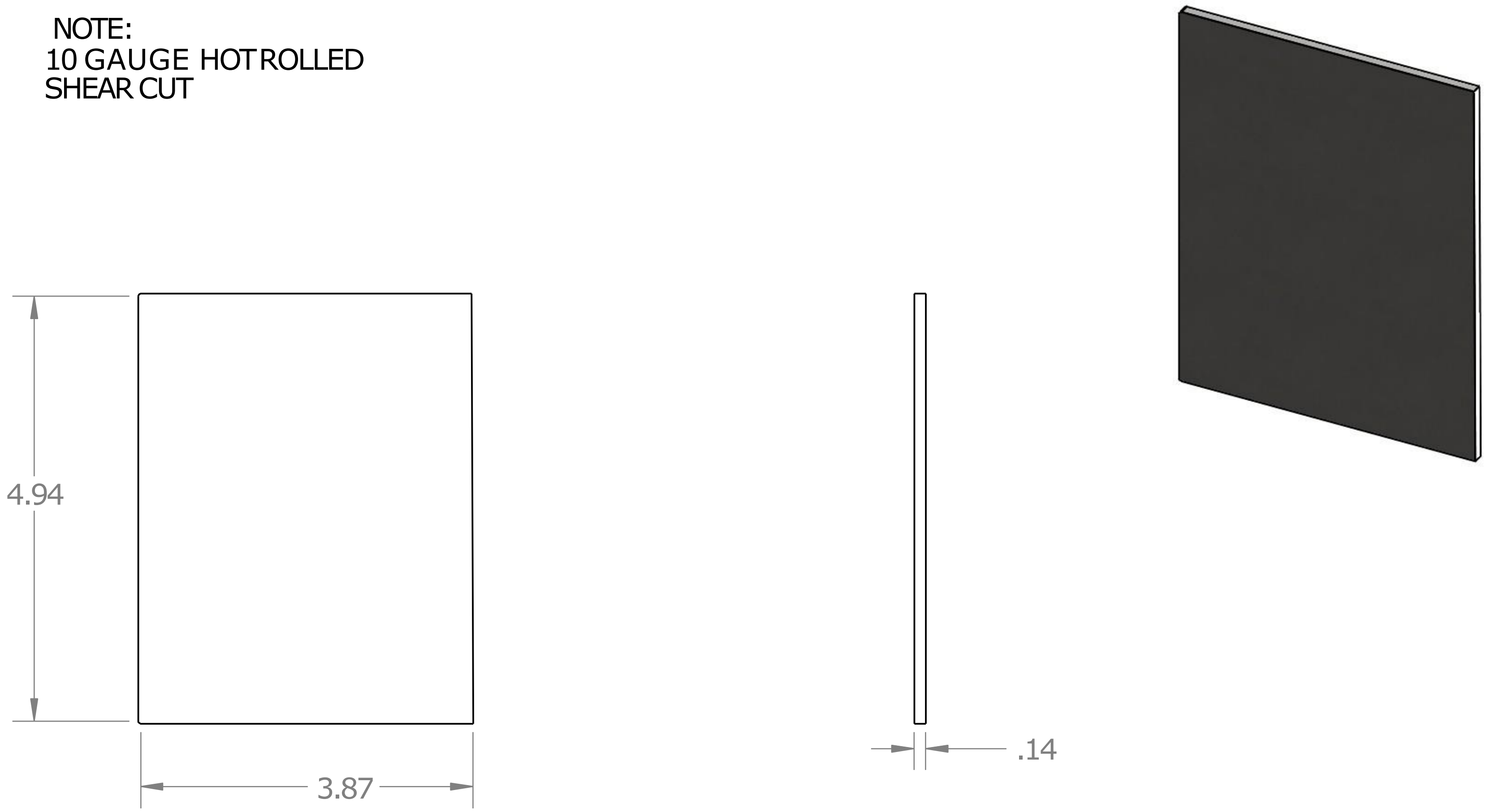
AFrame Bracket

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

1

2 | 1

NOTE:
10 GAUGE HOT ROLLED
SHEAR CUT



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			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
		DO NOT SCALE DRAWING			

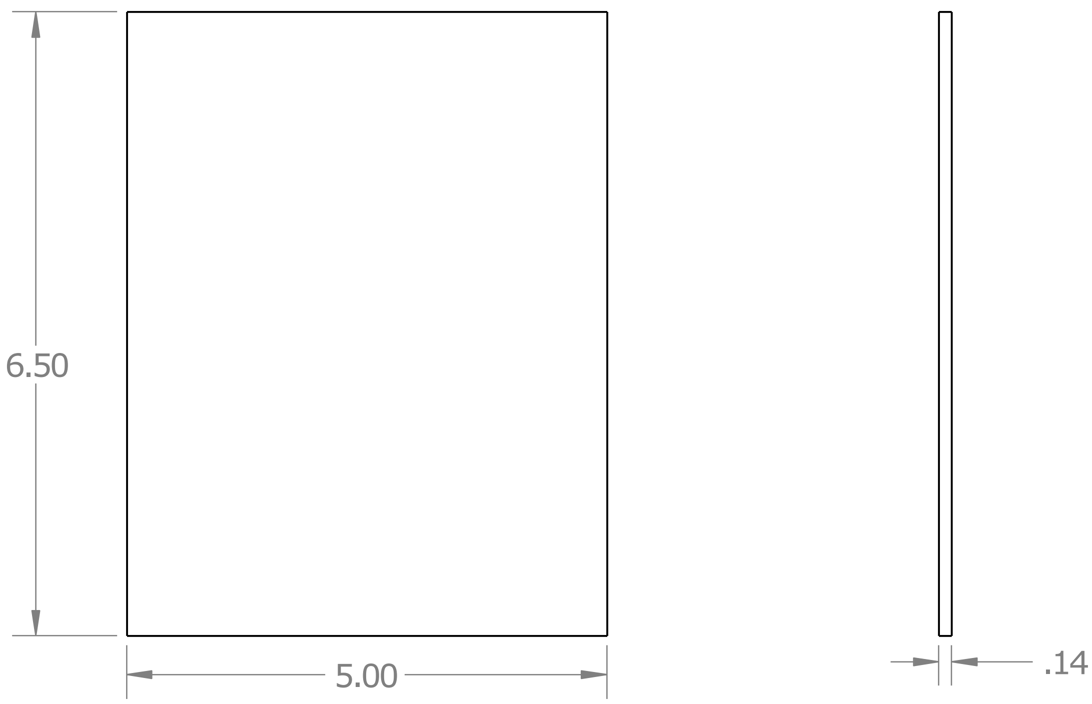
TITLE:

SIZE	DWG. NO.	REV
A	Bumper, Main, Gussett	

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

1

NOTE:
10 GAUGE HOT ROLLED
SHEAR CUT



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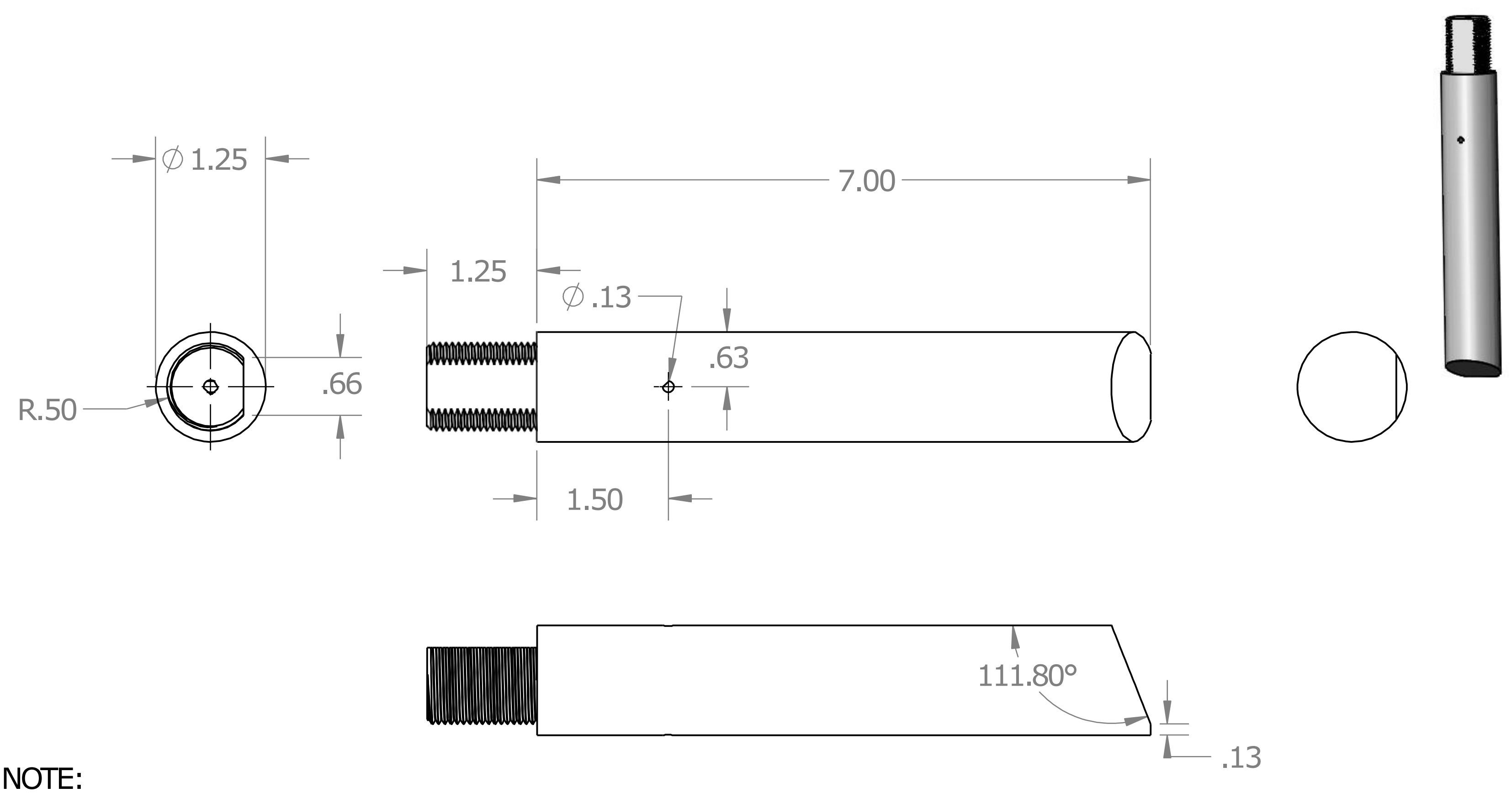
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
		DO NOT SCALE DRAWING			

TITLE:

SIZE A DWG. NO. Bumper, Main, Light Back REV

SCALE: 1:2 WEIGHT: SHEET 1 OF 1



NOTE:
1.25IN. HOT ROLLED ROUND STOCK
THREADS CUT TO 1"-NF-14
MACHINED ON LATHE

NEXT ASSY | USED ON

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

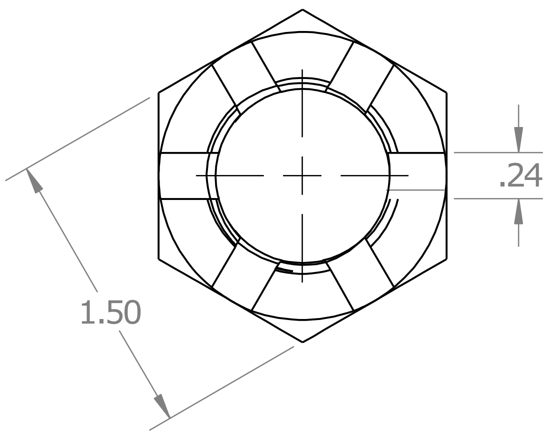
SIZE DWG. NO. REV

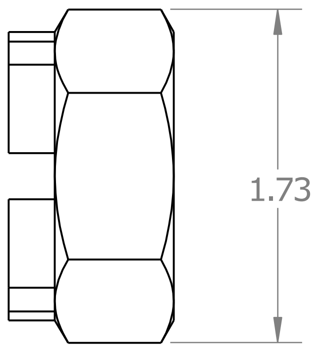
A Rack, Spindle

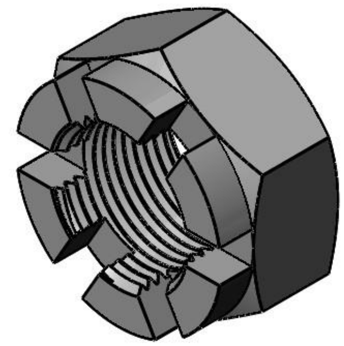
SCALE: 1:4 WEIGHT: SHEET 1 OF 1

2 1

B B







NOTES:
1IN. - NF - 14
STEEL
CASTLE NUT
SEE MCMASTER PART #95030A320

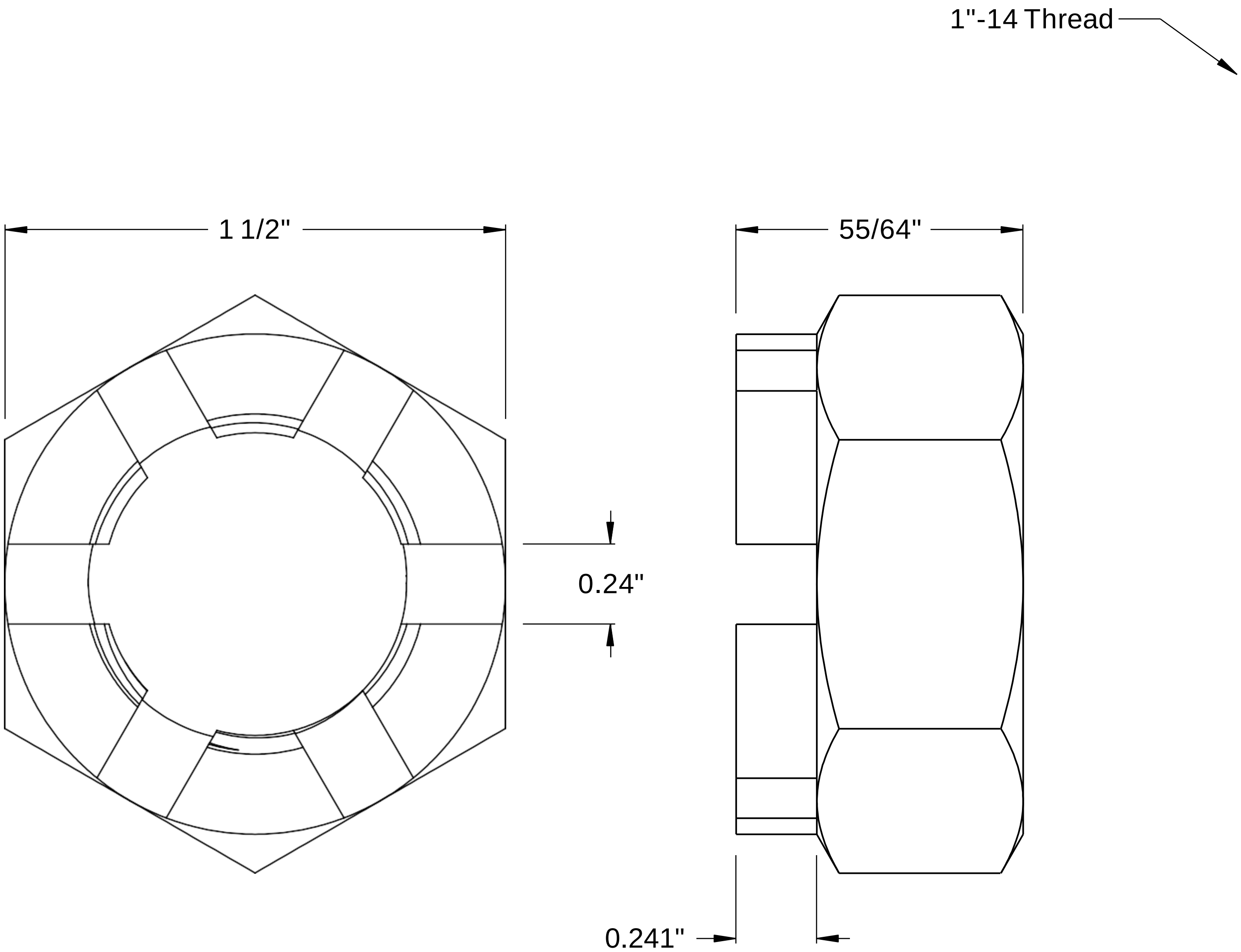
A A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
		DO NOT SCALE DRAWING			

TITLE:

SIZE: A
DWG. NO.: Spindle Nut
REV

SHEET 1 OF 1



For 3/16" Cotter Pin Diameter

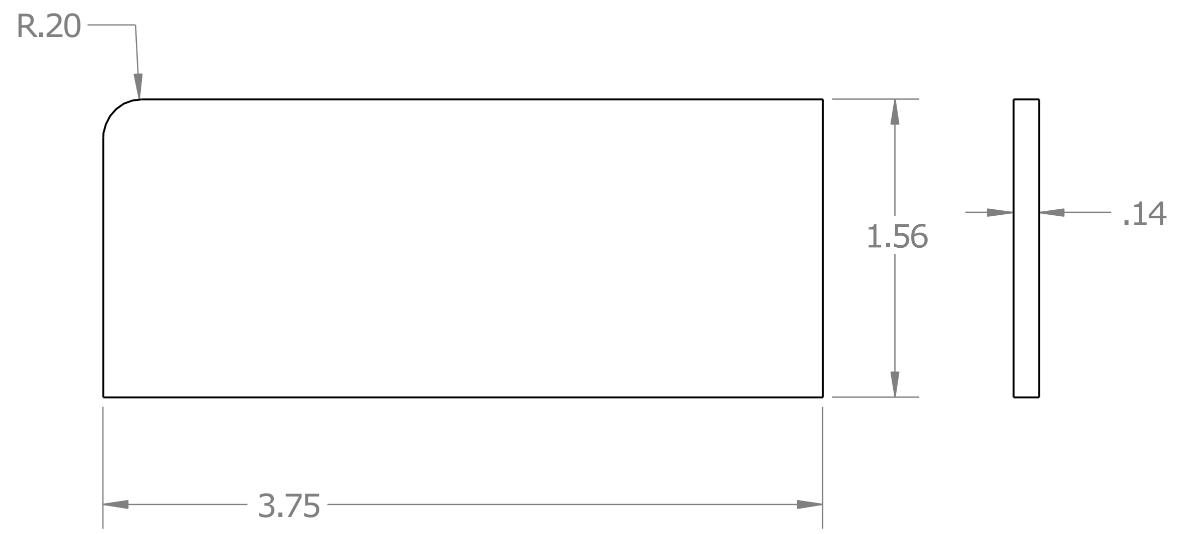
McMASTER-CARR® CAD

PART NUMBER **95030A320**

Slotted Locknut
for use with Cotter Pins

2 1

B B



NOTE:
10 GAUGE HOT ROLLED
SHEAR CUT

A A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
		DO NOT SCALE DRAWING			

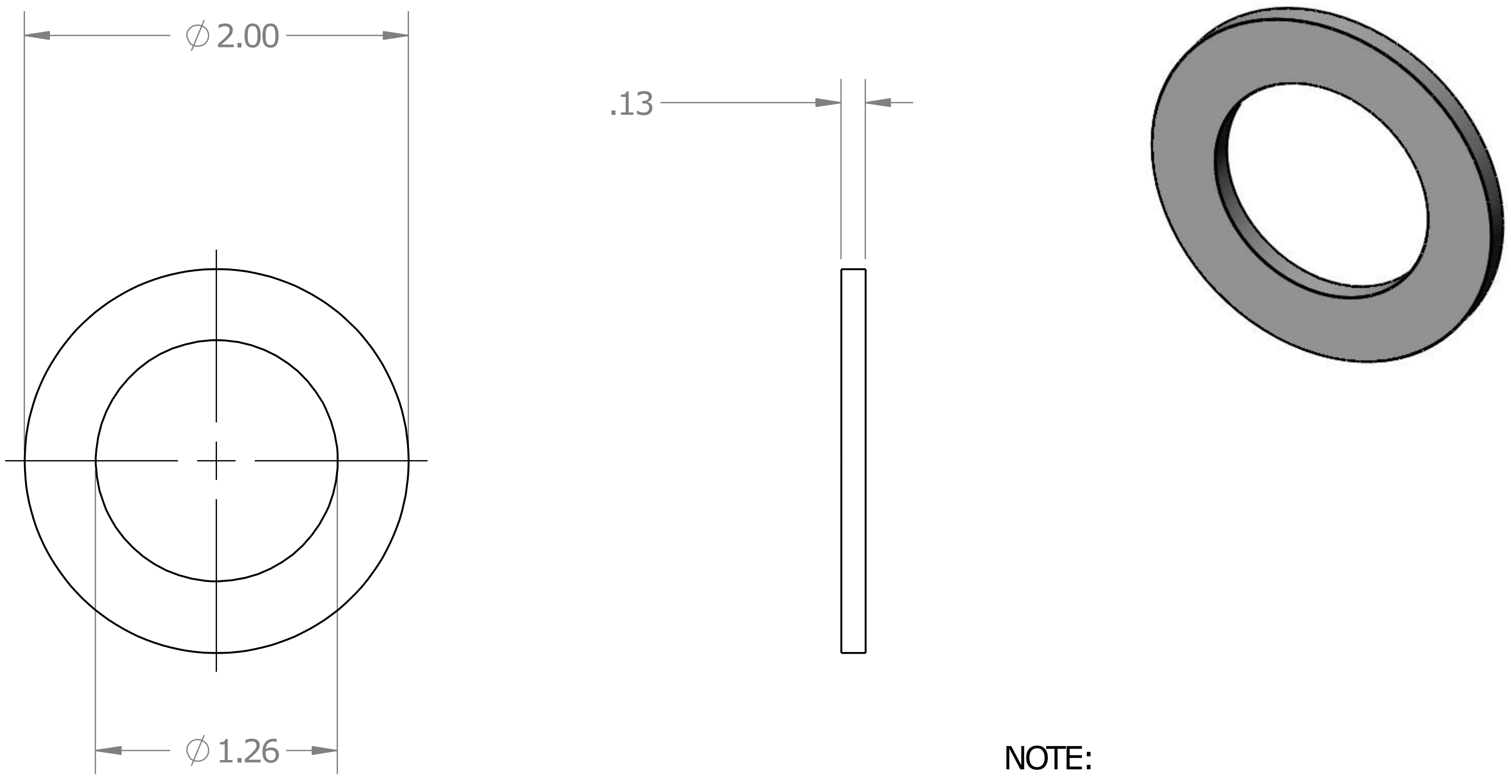
PROPRIETARY AND CONFIDENTIAL

TITLE:

SIZE	DWG. NO.	REV
A	Rack, Spindle, Gusset	

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

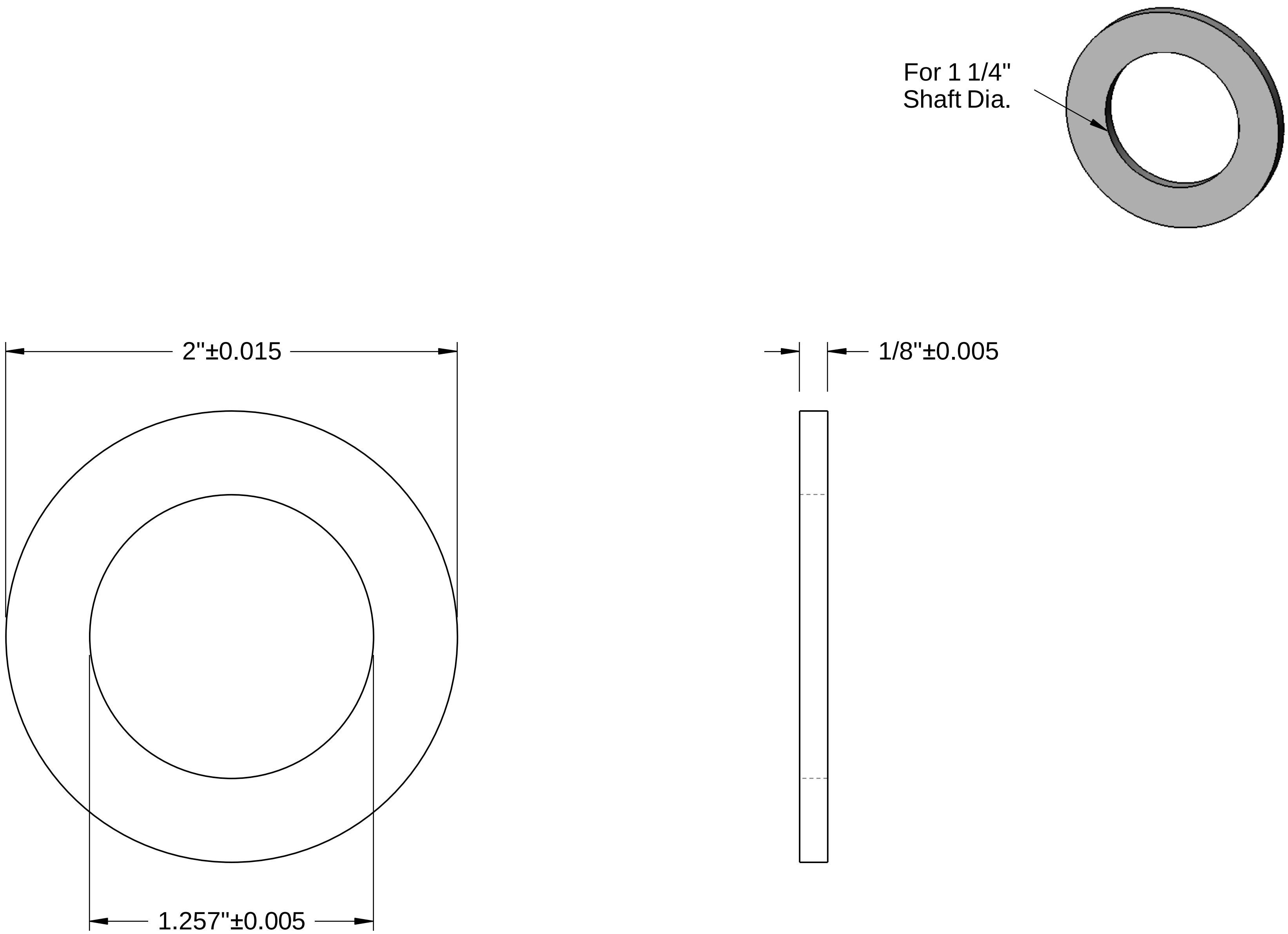
1



NOTE:
OIL INPREGNATED BRONZE THRUST WASHER
SEE MCMASTER PART # 2879T13

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			
	CHECKED			TITLE:
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL	COMMENTS:			SIZE DWG. NO. REV
FINISH				A Thrust Washer
NEXT ASSY / USED ON				
DO NOT SCALE DRAWING				SHEET 1 OF 1

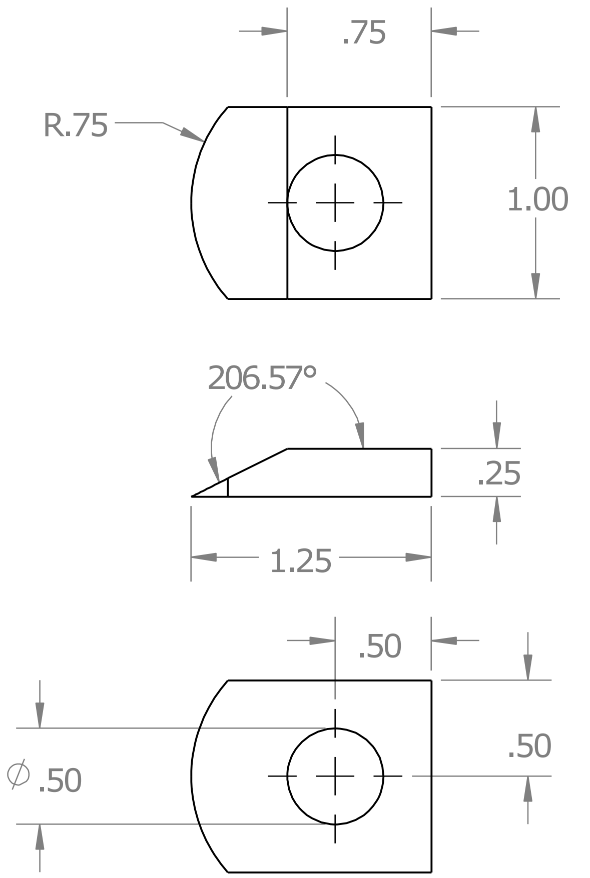
PROPRIETARY AND CONFIDENTIAL

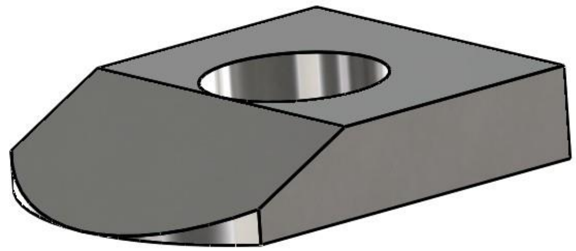


McMASTER-CARR® CAD	PART NUMBER	2879T13
http://www.mcmaster.com © 2015 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	High-Load Oil-Embedded Thrust Bearing	

2 1

B B





NOTE:
0.25IN. HOT ROLLED PLATE
HOLE DRILLED VIA DRILL PRESS
RAMP ANGLE HAND GROUND VIA BENCH GRINDER

A A

		UNLESS OTHERWISE SPECIFIED:	NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN CHECKED ENG APPR. MFG APPR. Q.A.	
		INTERPRET GEOMETRIC TOLERANCING PER:	COMMENTS:	
		MATERIAL		
NEXT ASSY	USED ON	FINISH		
		DO NOT SCALE DRAWING		

TITLE:

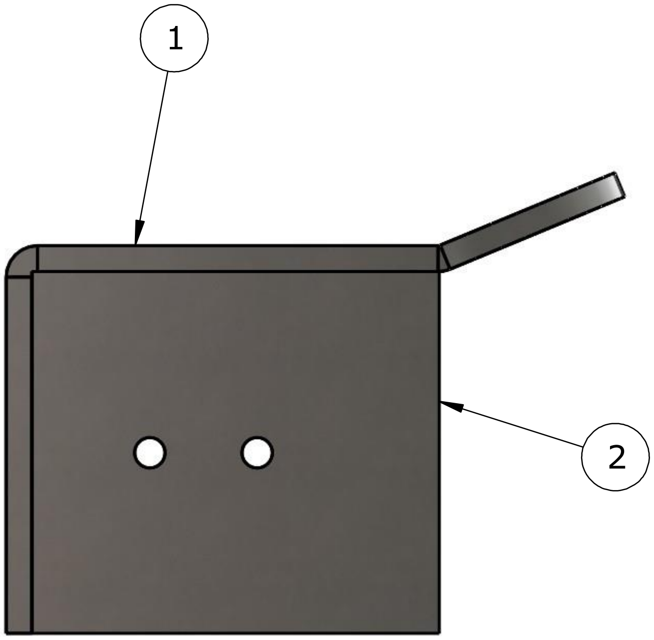
SIZE A DWG. NO. Rack, Lock Pin, Ramp REV

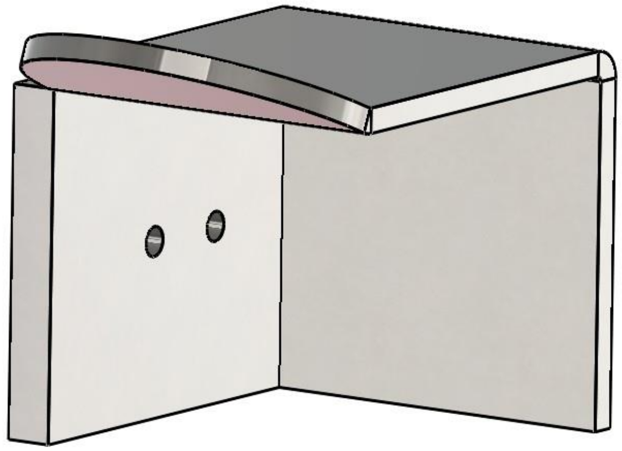
SCALE: 2:1 WEIGHT: SHEET 1 OF 1

1

2 1

B B





ITEM NO.	PART NUMBER	QTY.
1	Rack, Shelf, Plate 2	1
2	Rack, Sheft, Plate 1	1

A A

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

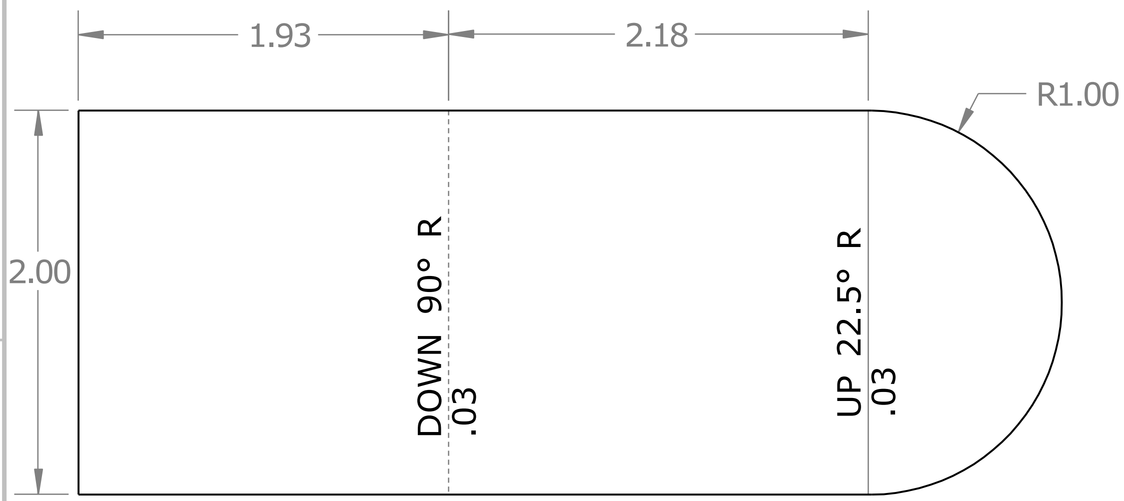
NEXT ASSY | USED ON

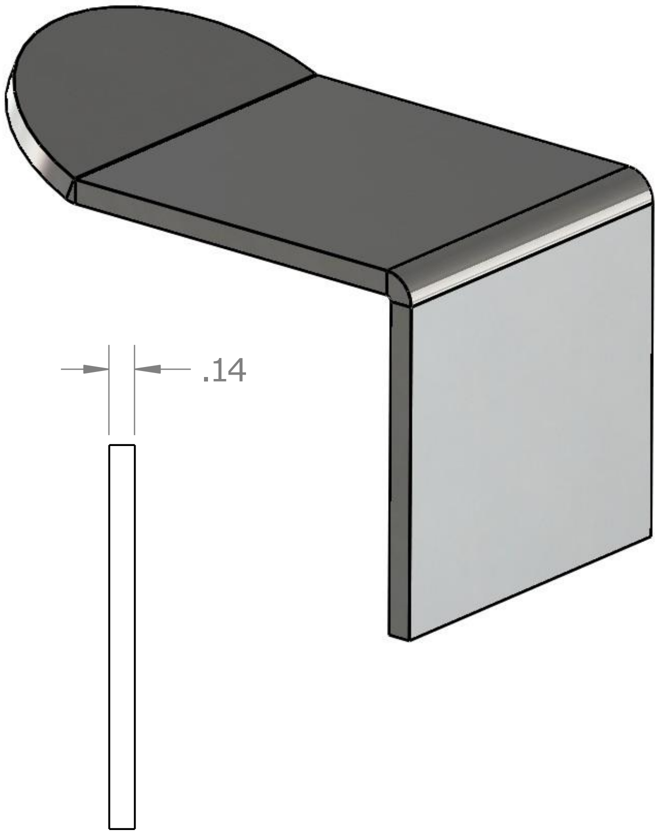
TITLE:

SIZE **A** DWG. NO. **Rack, Shelf** REV

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

1





NOTE:
10 GAUGE HOTROLLED
CNC PLASMA CUT
BENT VIA PRESS BRAKE

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

NEXT ASSY	USED ON

PROPRIETARY AND CONFIDENTIAL

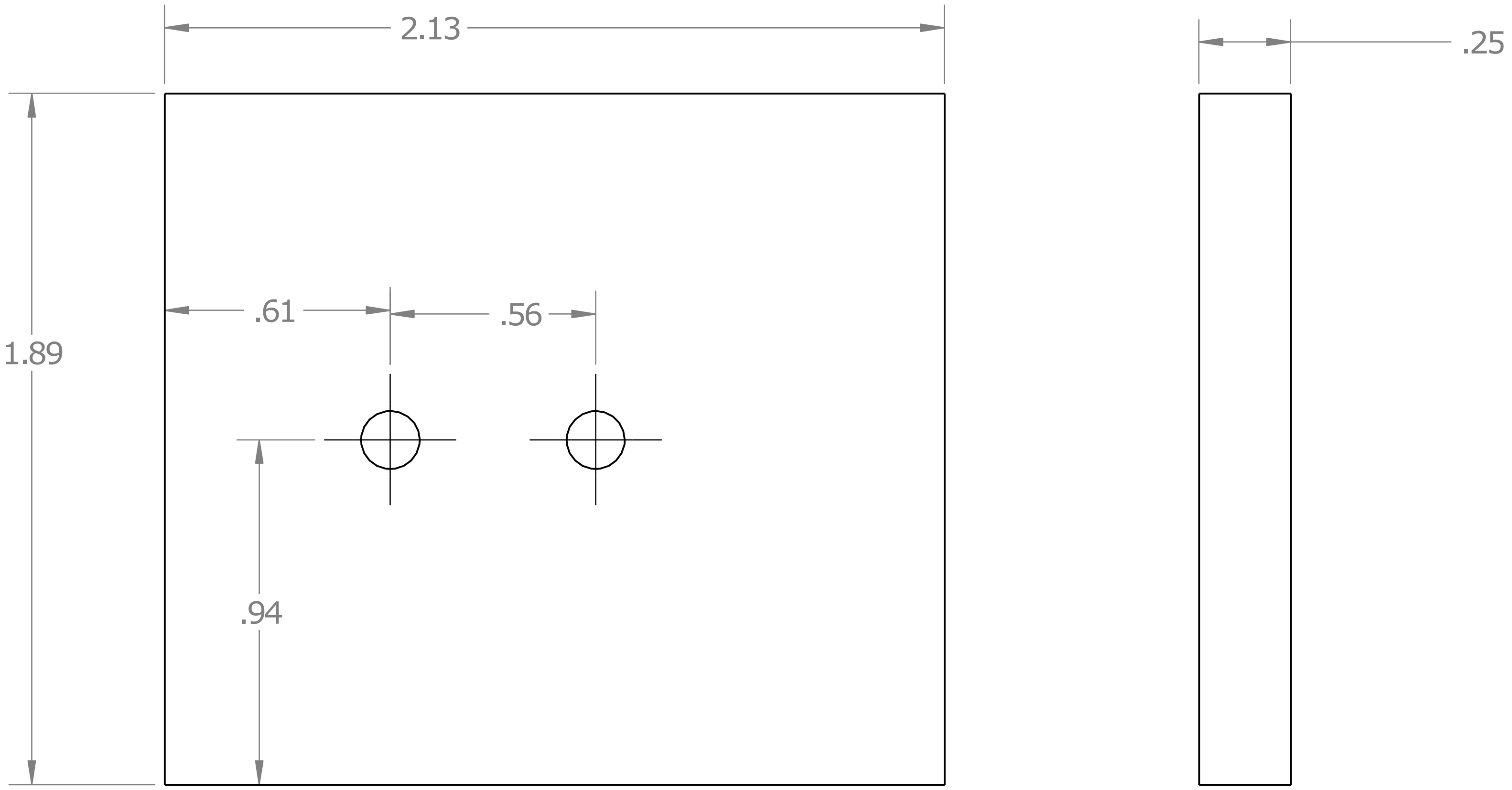
TITLE:

SIZE	DWG. NO.	REV
A	Rack, Shelf, Plate 2	

SHEET 1 OF 1

2 1

B B



NOTE:
0.25IN. HOT ROLLED PLATE
HOLES DRILLED AND TAPPED TO 10-32

A A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE A DWG. NO. Rack, Sheft, Plate 1 REV
NEXT ASSY	USED ON	FINISH				
		DO NOT SCALE DRAWING				SCALE: 2:1 WEIGHT: SHEET 1 OF 1

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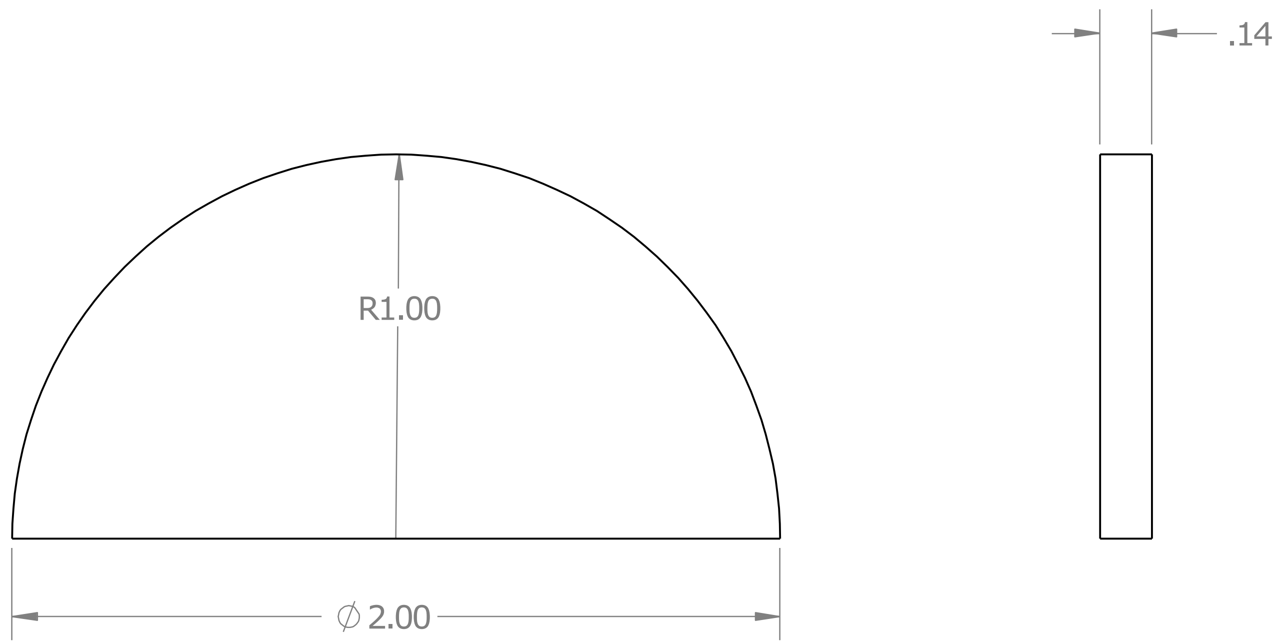
1



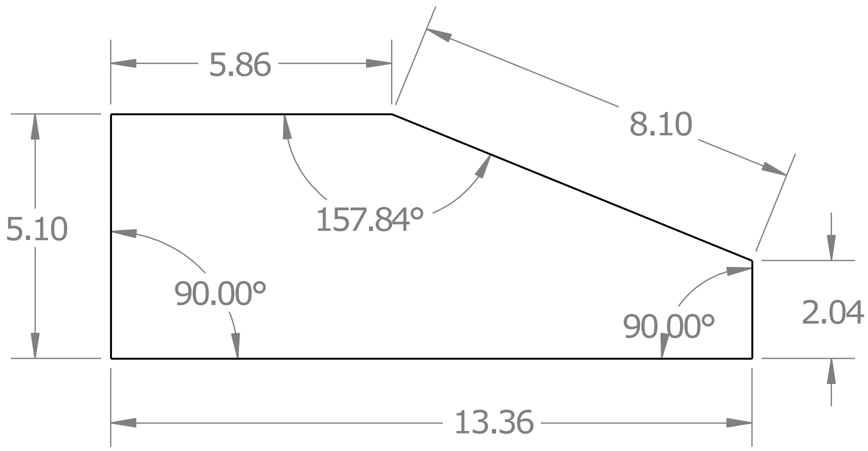
NOTE:
10 GAUGE HOT ROLLED
CNC PLASMA CUT

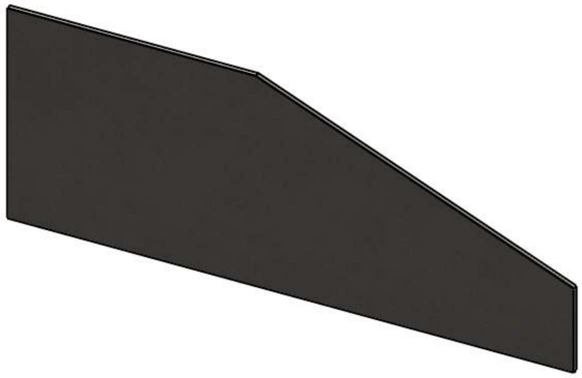
		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE: A DWG. NO.: Rack, Shelf, Plate 3 REV
NEXT ASSY	USED ON	FINISH				
		DO NOT SCALE DRAWING				SHEET 1 OF 1

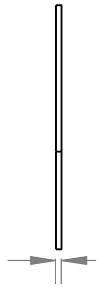
2 | 1

B

NOTE:
CNC PLASMA CUT
10 GAUGE HOT ROLLED







B

A

NEXT ASSY	USED ON

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TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

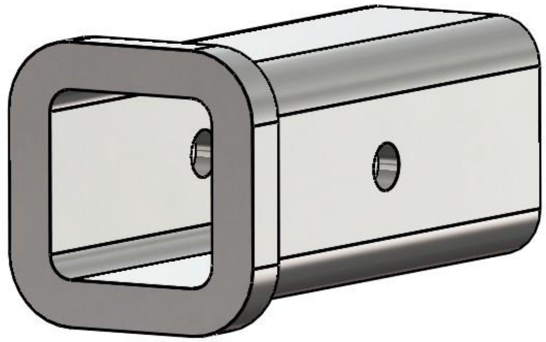
SIZE: A | DWG. NO.: Back Plate | REV

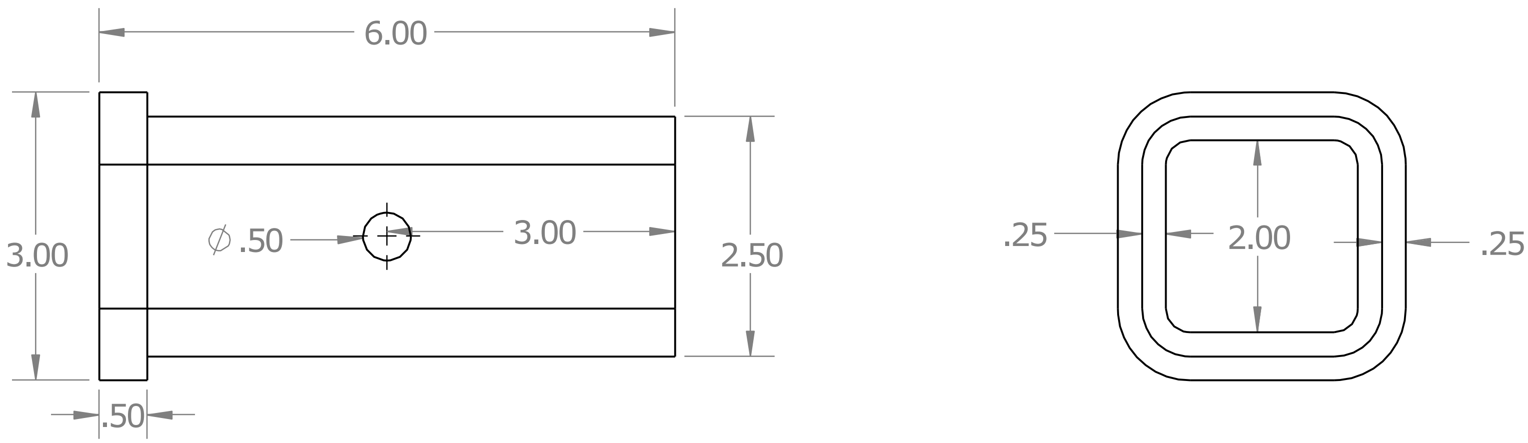
SCALE: 1:4 | WEIGHT: | SHEET 1 OF 1

A

1

NOTE:
PURCHASED FROM AMERICAN MUFFLER.





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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

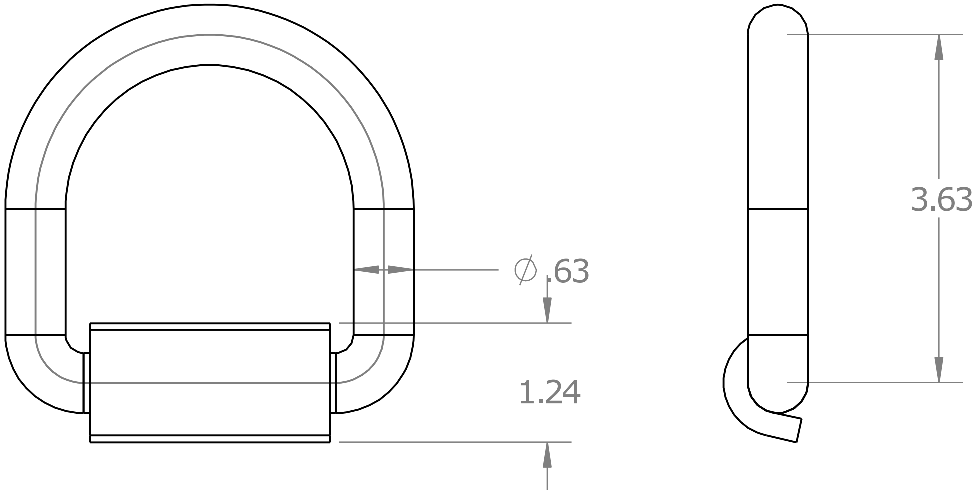
SIZE A DWG. NO. 6 in Reciver Tube REV

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

2 1

B

NOTE:
PURCHASED FROM AMERICAN MUFFLER



B

A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE DWG. NO. REV
NEXT ASSY	USED ON	FINISH				A Bumper, D-ring
		DO NOT SCALE DRAWING				SCALE: 1:2 WEIGHT: SHEET 1 OF 1

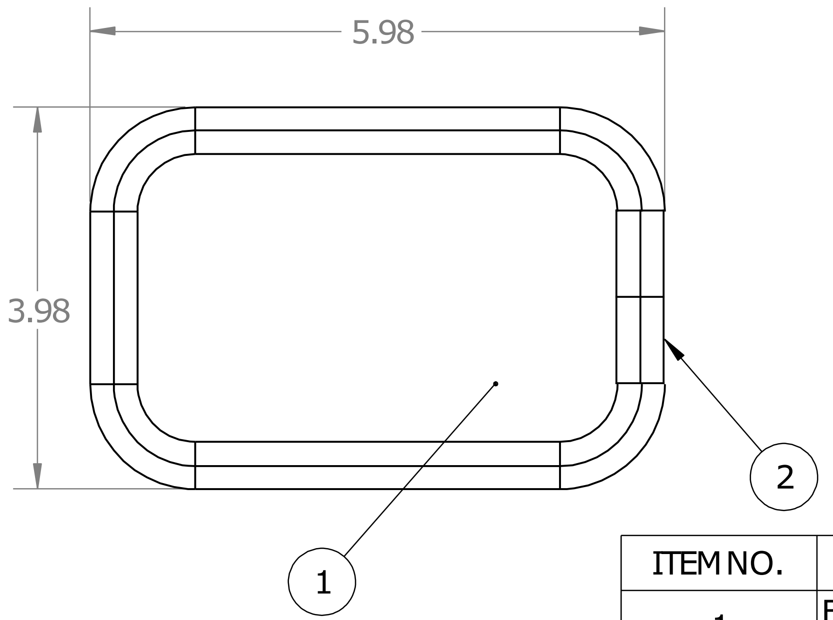
A

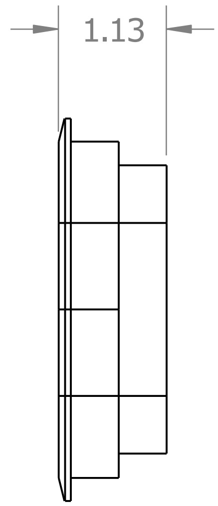
1

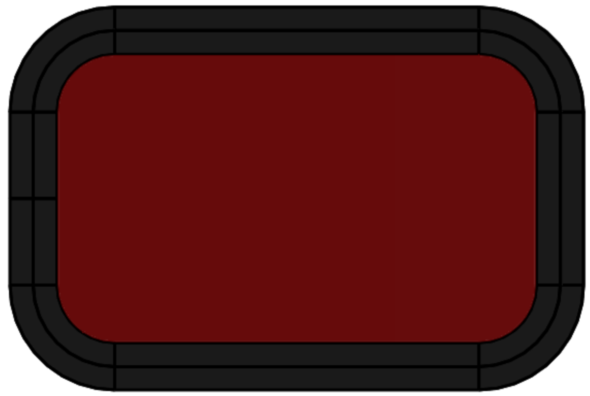
2 1

B

NOTE:
REAR TAIL LIGHT ASSEMBLY
PUCHASED FROM NAPA AUTO PARTS
PART #







B

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Bumper Tail Light, Light	LIGHT BUCKET / LENS	1
2	Bumper, Tail Light, Gromet	RUBBER MOUNTING GROMET	1

A

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NEXT ASSY	USED ON

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE	DWG. NO.	REV
B	Bumper, Tail Light	

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

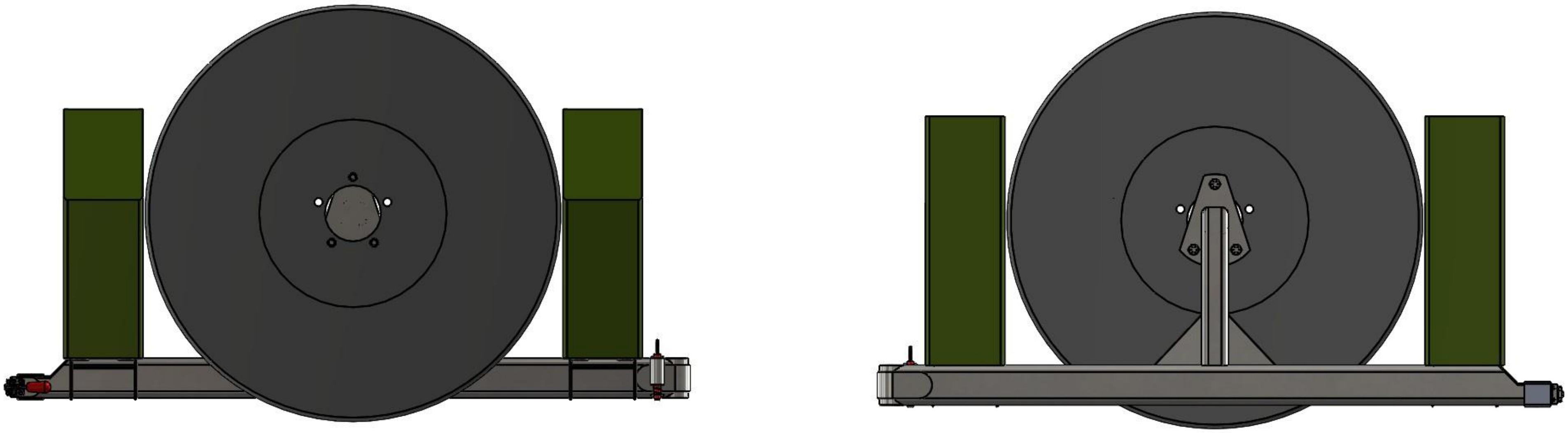
A

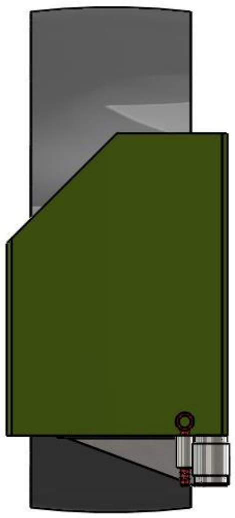
1

APPENDIX D – Rack Part and Assembly Drawings

2 1

B B





A A

TITLE:

SIZE	DWG. NO.	REV
A	Rack Assembly1	

SCALE: 1:12 WEIGHT:

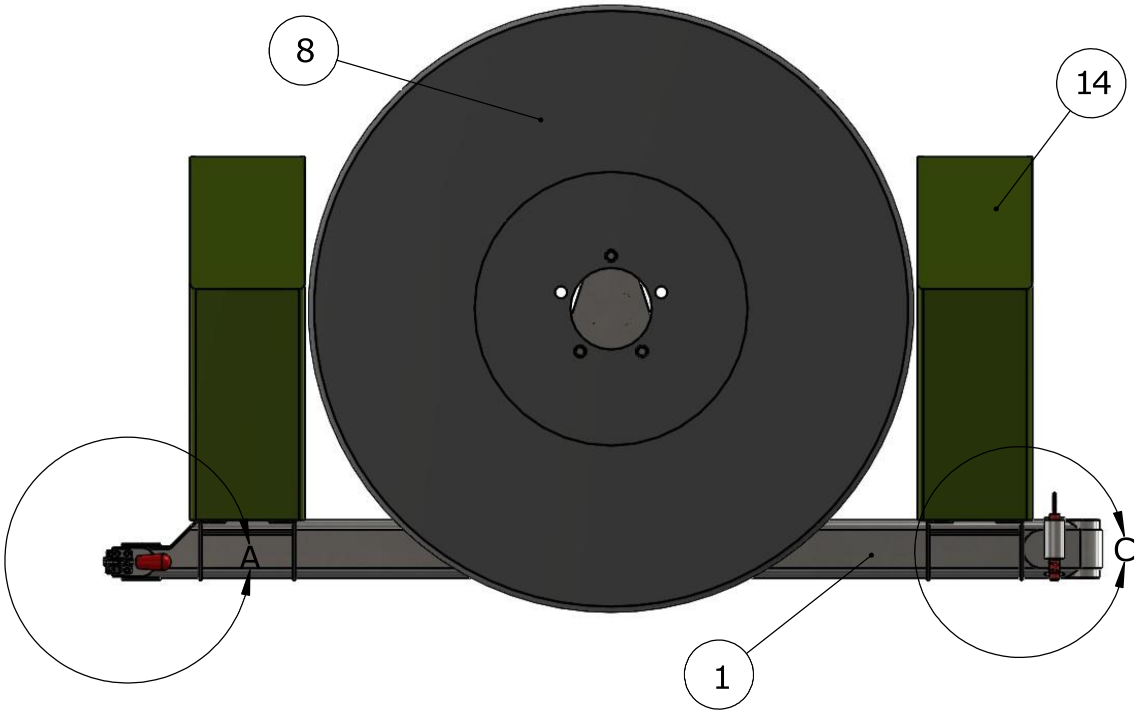
APPLICATION

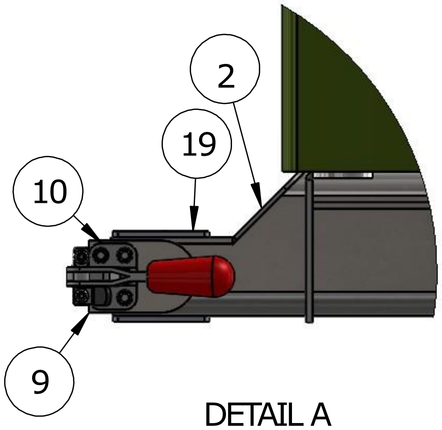
DO NOT SCALE DRAWING

1

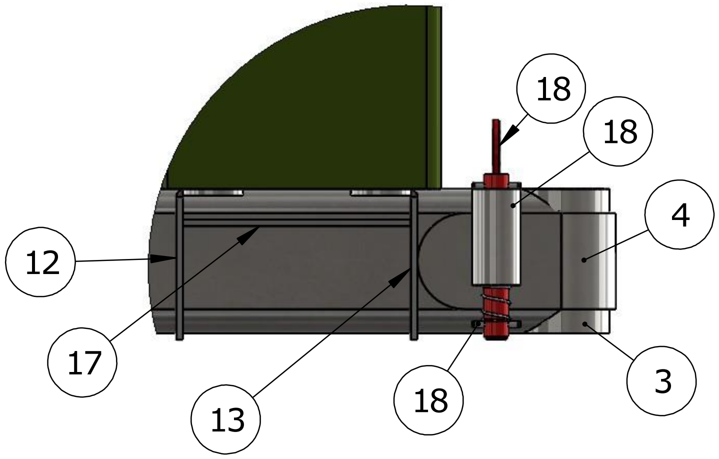
2 1

B





DETAIL A
SCALE 1 :4



DETAIL C
SCALE 1 :4

ITEM NO.	PART NUMBER	QTY.
1	Rack, Arm	1
2	Rack, Arm, Cap	1
3	Rack, Hub	1
4	Rack, Hub, Strap	1
5	Rack, Stud Plate	1
6	91257A748	3
7	Rack, Spindle Bushing	1
8	Tire	1
9	Rack, Toggle Clamp, Bracket	1
10	Rack, Toggle Clamp	1
11	91251A337	4
12	Jerry Can mount	2
13	Jerry Can mount - offhand	2
14	Jerry Can	2
15	Rack, Corner Gusset, Large	2
16	Rack, Corner Guesset, Small	2
17	Rack, Flood Light, Bracket	2
18	Rack, Lock Pin	1
19	Rack, Wareplate	1

A

APPLICATION

DO NOT SCALE DRAWING

SIZE DWG. NO. REV

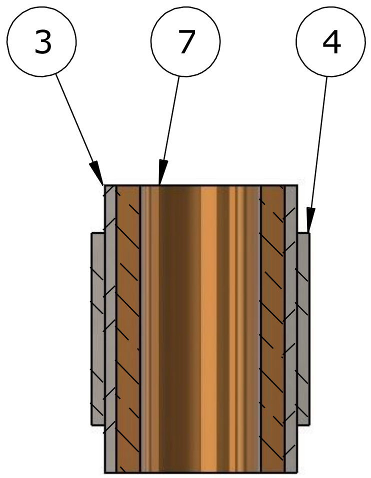
A Rack Assembly2

SCALE: 1:12 WEIGHT:

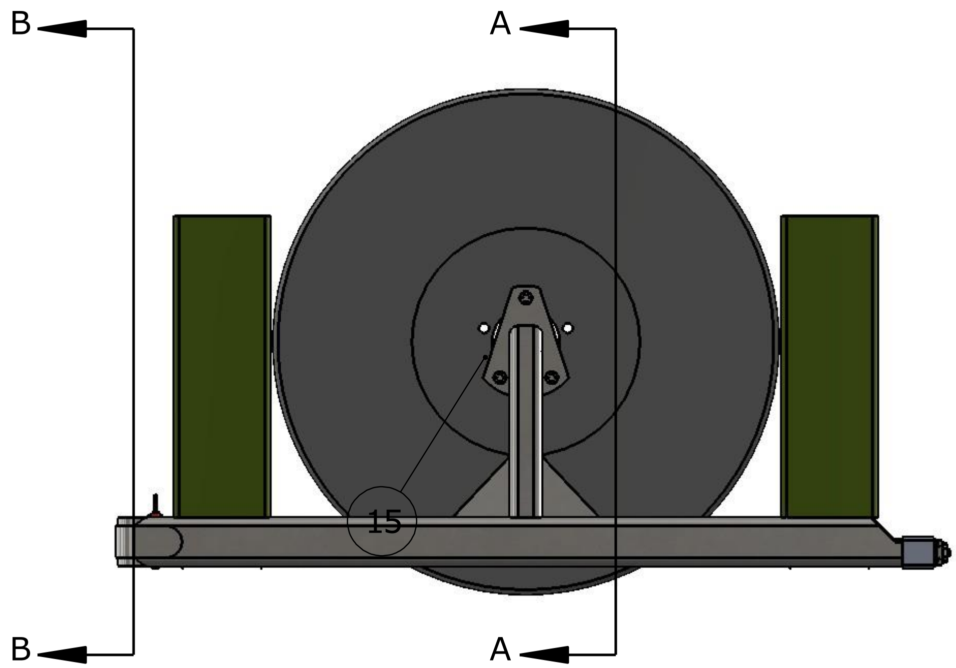
1

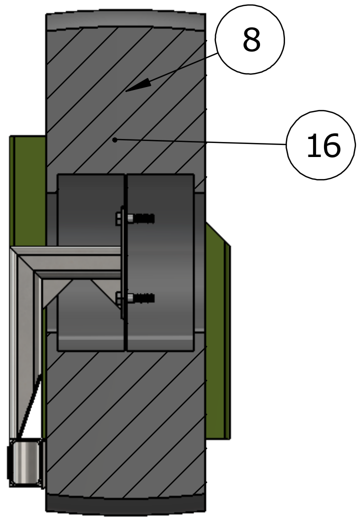
2 1

B B



SECTION B-B
SCALE 1 : 2





SECTION A-A

A A

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APPLICATION	

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TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

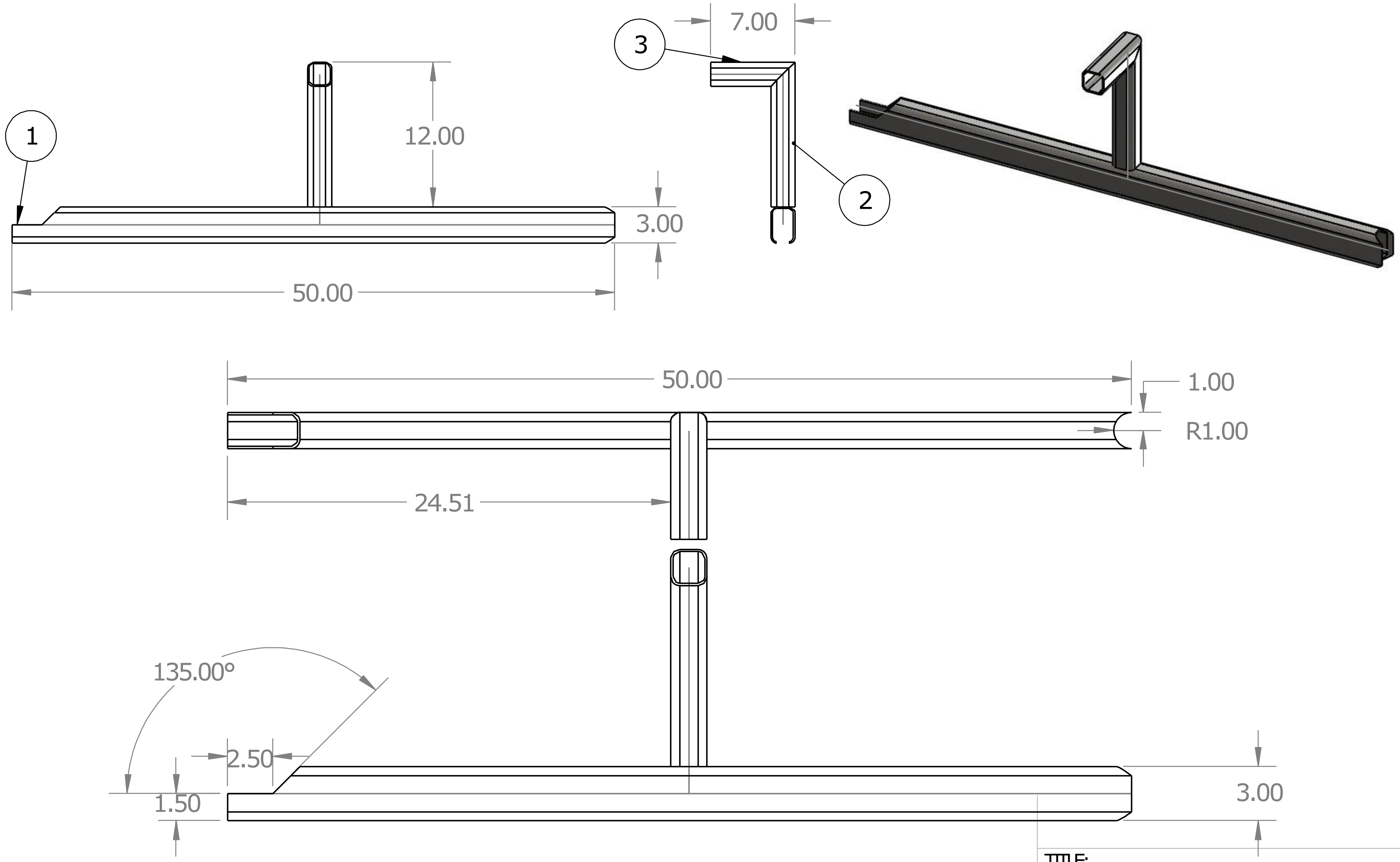
TITLE:

SIZE A DWG. NO. Rack Assembly3 REV

SCALE: 1:12 WEIGHT:

1

2 1



ITEM NO.	QTY.	DESCRIPTION	LENGTH
1	1	TUBE, RECTANGULAR 3.00 X 2.00 X .14	50
2	1	TUBE, SQUARE 2.00 X 2.00 X .13	12
3	1	TUBE, SQUARE 2.00 X 2.00 X .13	7

TITLE:

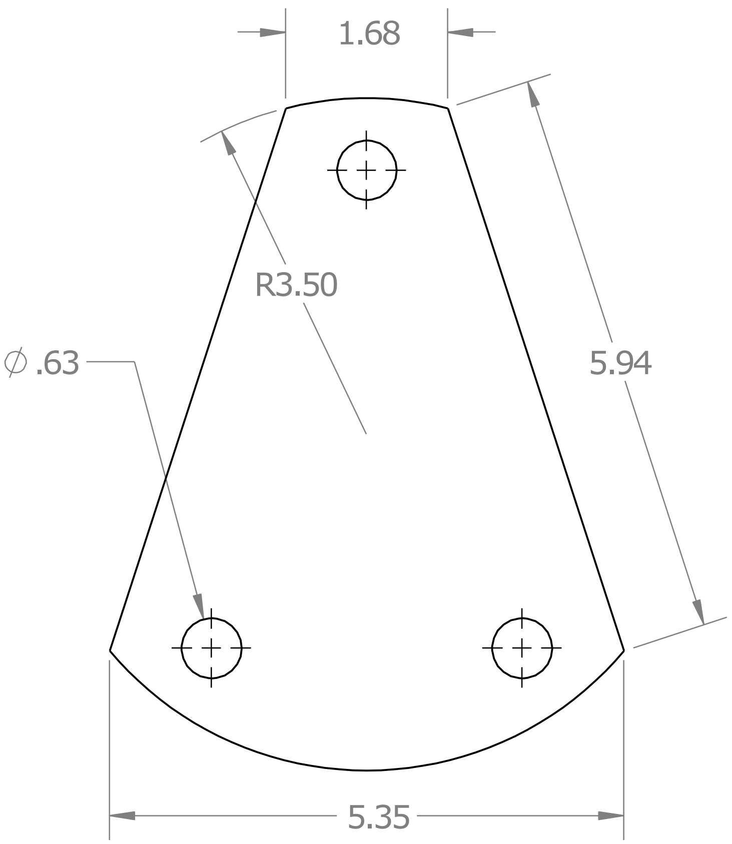
SIZE: A
DWG. NO.: Rack, Arm
REV

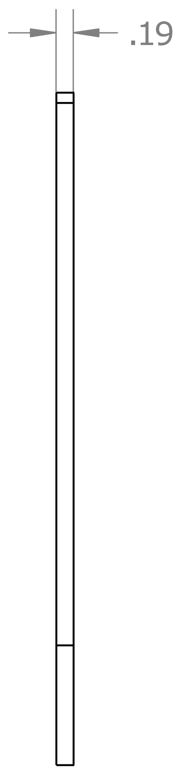
SCALE: 1:12 WEIGHT:

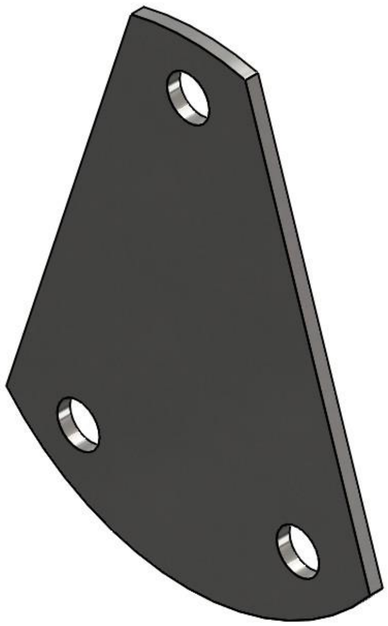
1

2 1

B B







NOTE:
3/16IN. HOT ROLLED PLATE
5 ON 5.5IN. HOLE PATTERN
CNC PLASMA CUT

A A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

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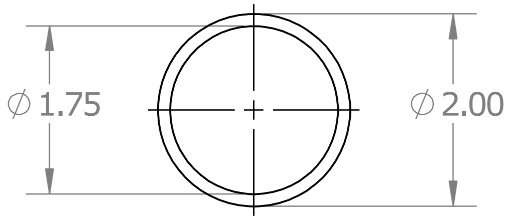
TITLE:

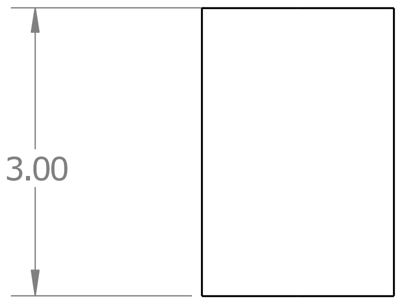
SIZE DWG. NO. REV

A Rack, Stud Plate

SCALE: 1:2 WEIGHT:

1





NOTE:
2IN. DOM TUBE

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APPLICATION	

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ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

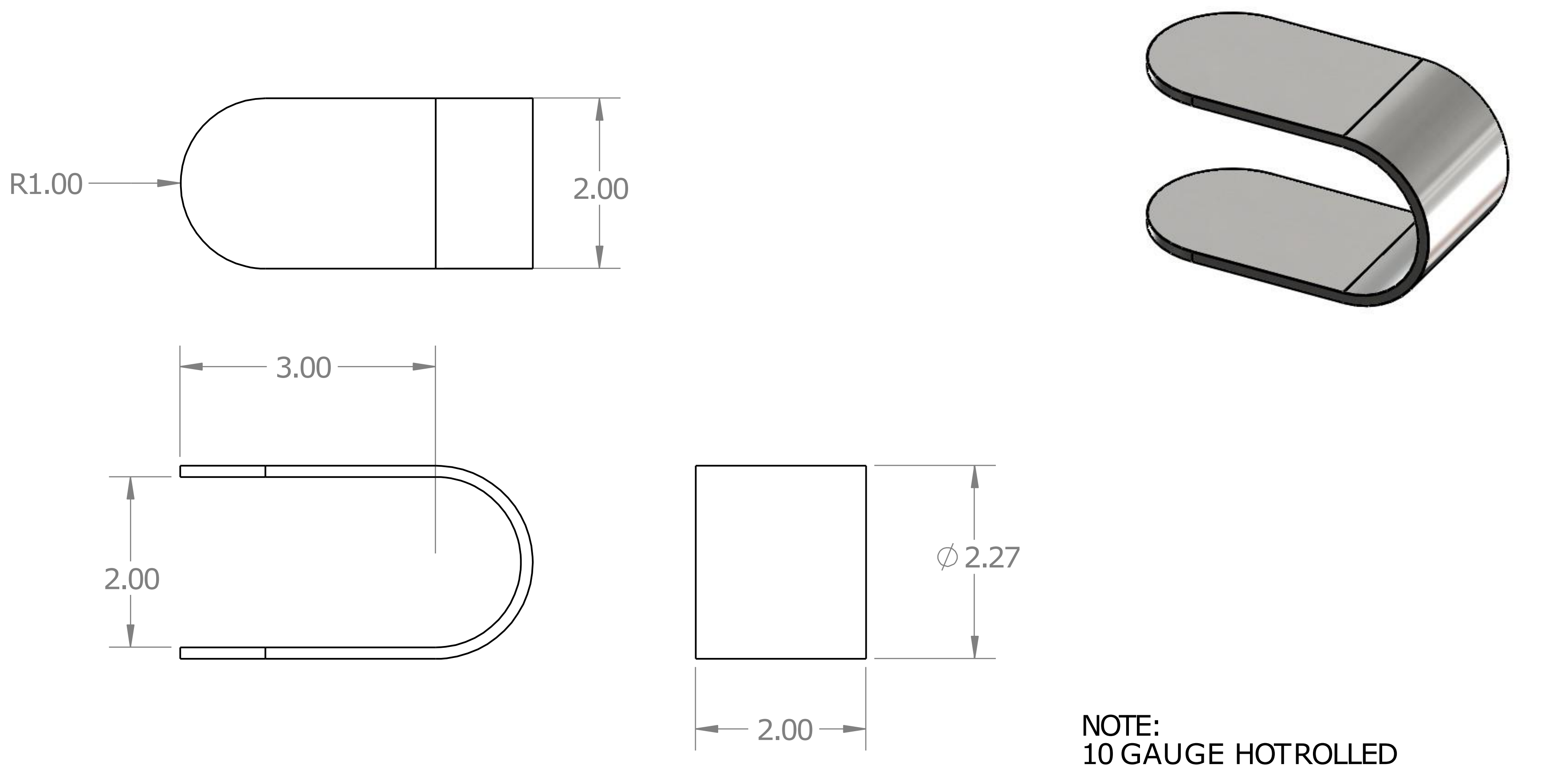
	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE	DWG. NO.	REV
A	Rack, Hub	

SCALE: 1:2 WEIGHT:



NOTE:
10 GAUGE HOT ROLLED
EDGE RADIUSES GROUND TO SHAPE
HAMMER FORMED

UNLESS OTHERWISE SPECIFIED:		
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±		
INTERPRET GEOMETRIC TOLERANCING PER:		
MATERIAL		
FINISH		
DO NOT SCALE DRAWING		

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

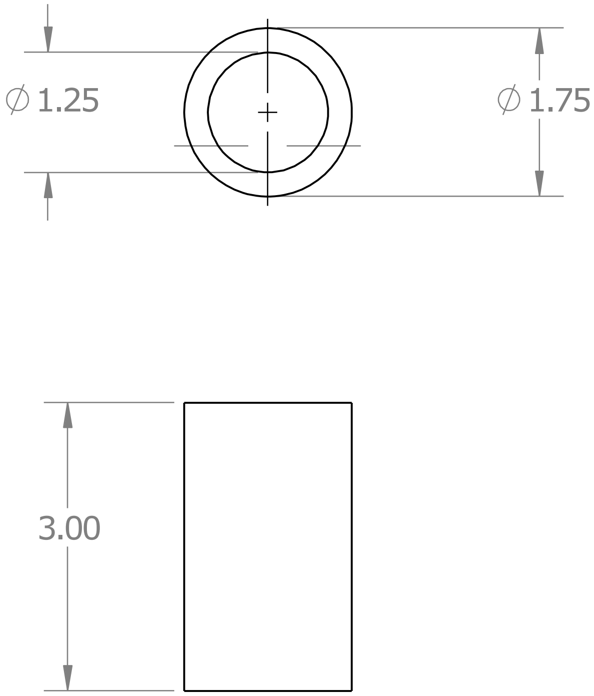
NEXT ASSY	USED ON
APPLICATION	

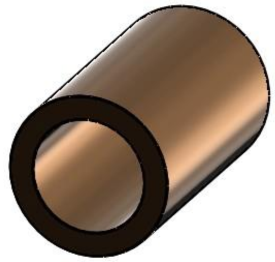
TITLE:

SIZE DWG. NO. REV

RAack, Hub, Strap

SCALE: 1:2 WEIGHT:





NOTE :
OIL IMPREGNATED BRONZE BUSHING
TURNED ON BORED ON LATHE
PURCHASED FROM MCMASTER CARR
PART #

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

TITLE:

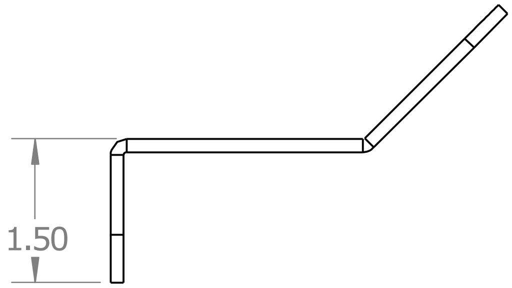
SIZE A DWG. NO. Rack, Spindle Bushing REV

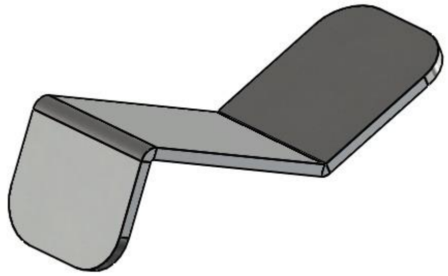
SCALE: 1:2 WEIGHT:

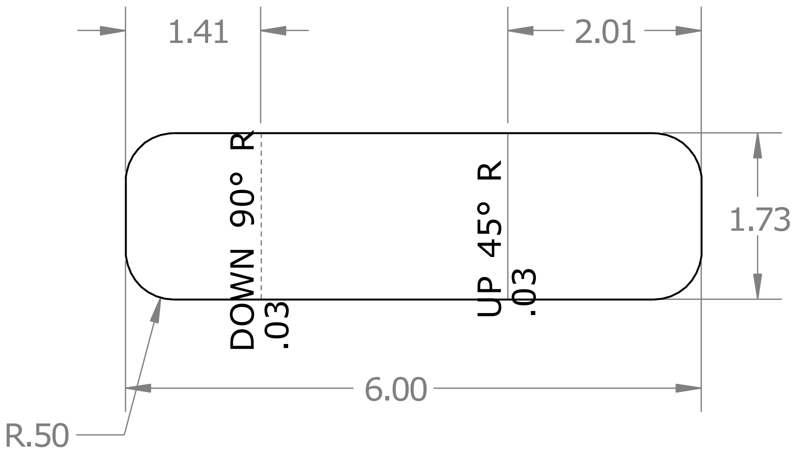
2 | 1

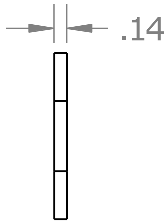
B

NOTE:
10 GAUGE HOTROLLED
CNC PLASMA CUT
BENT VIA PRESS BRAKE









B

A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
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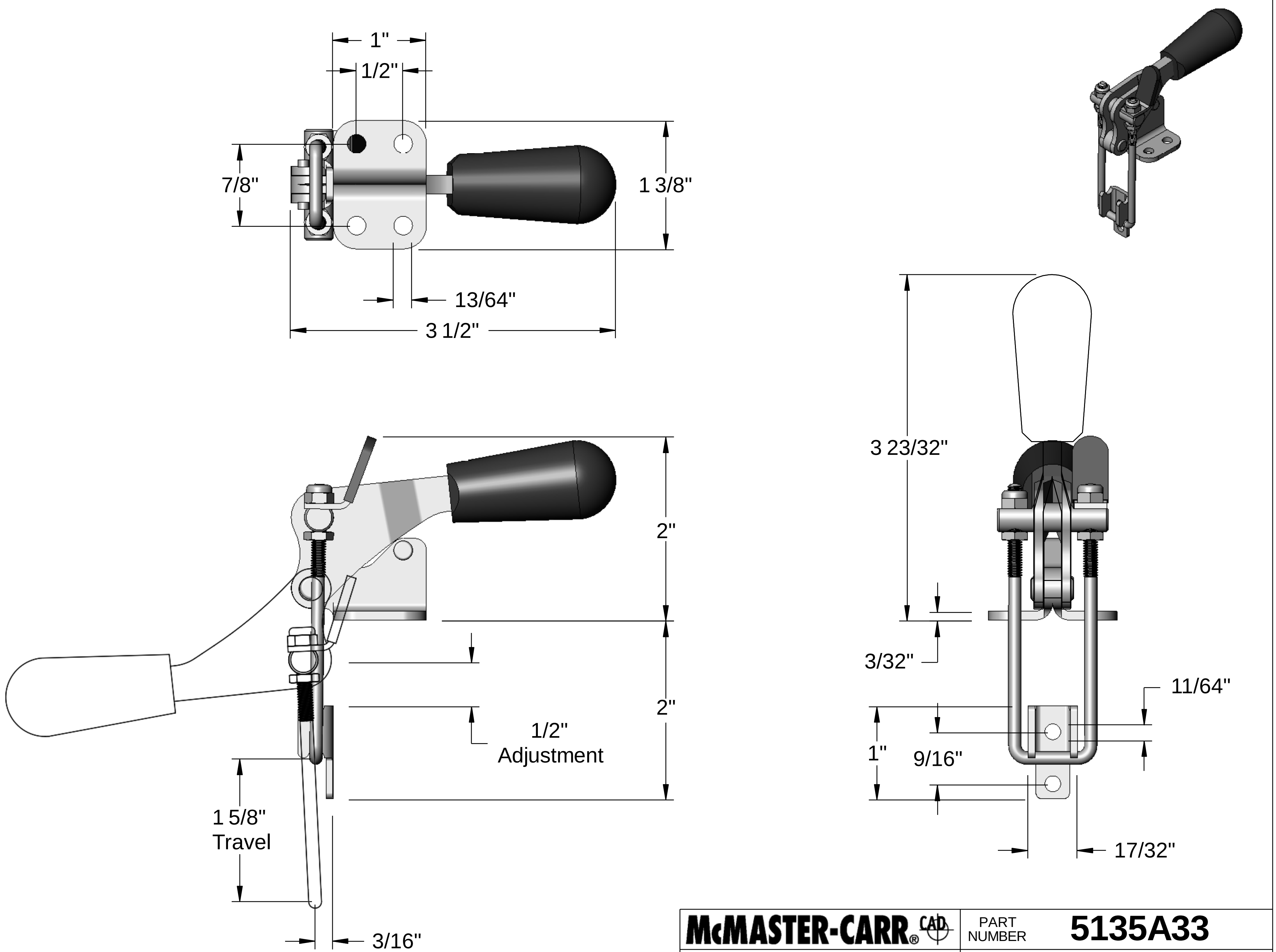
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE DWG. NO. REV
NEXT ASSY	USED ON	FINISH				RAack, Arm, Cap
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:2 WEIGHT:

A

1



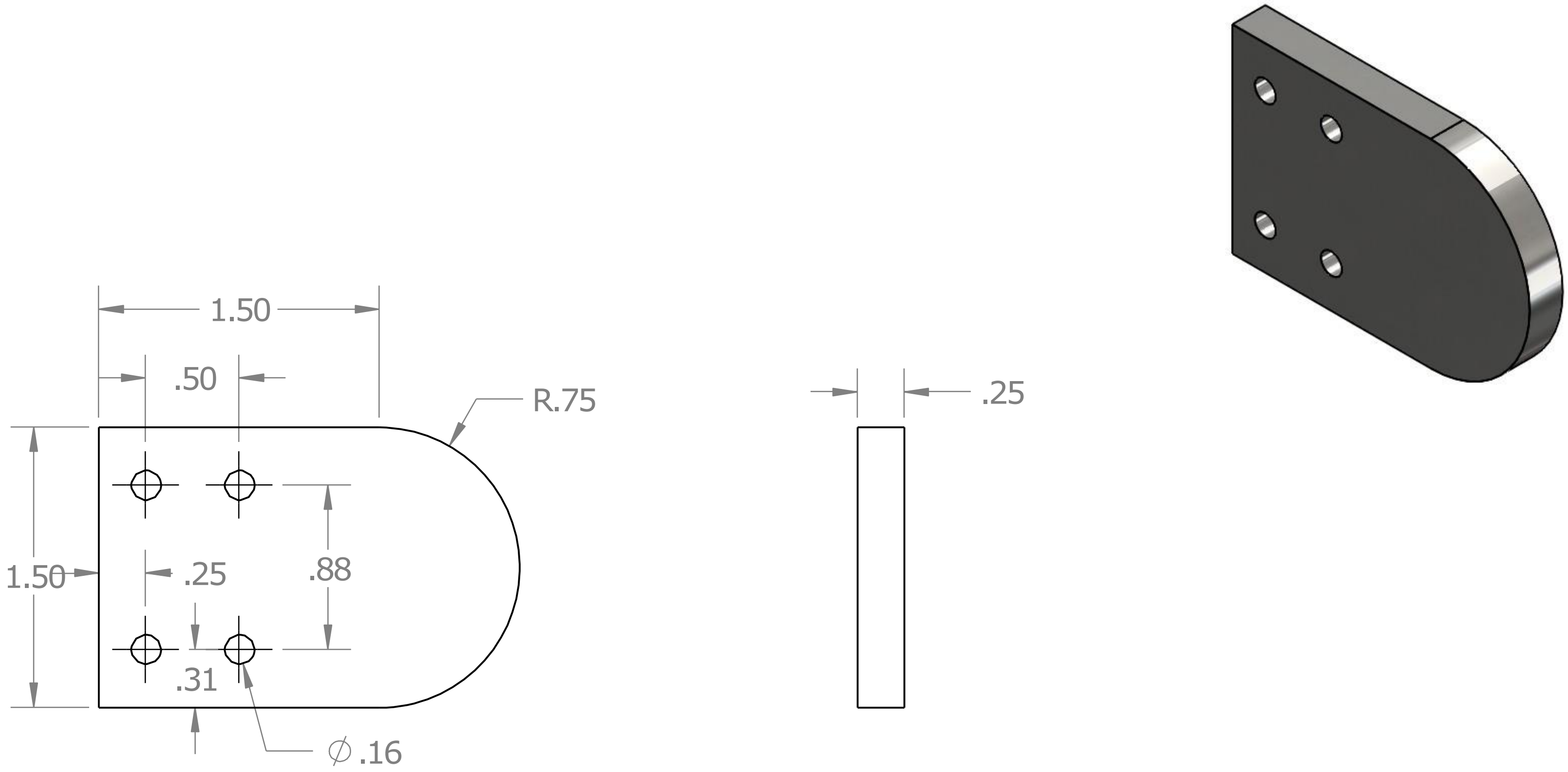
McMASTER-CARR® CAD

PART NUMBER **5135A33**

Pull-Action
Toggle Clamp

2 1

B B



NOTE:
0.25IN. HOT ROLLED PLATE
DRILL AND TAP HOLES TO 10-32

A A

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TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE A DWG. NO. REV

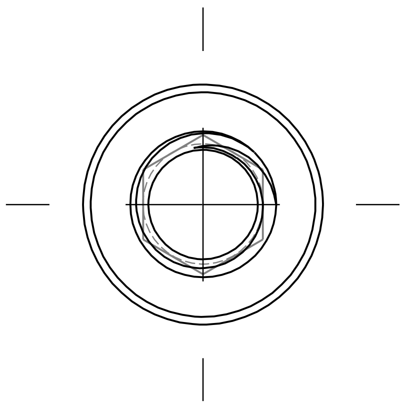
Rack, Toggle Clamp, Brack

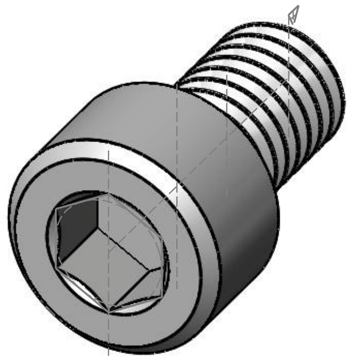
SCALE: 2:1 WEIGHT: SHEET 1 OF 1

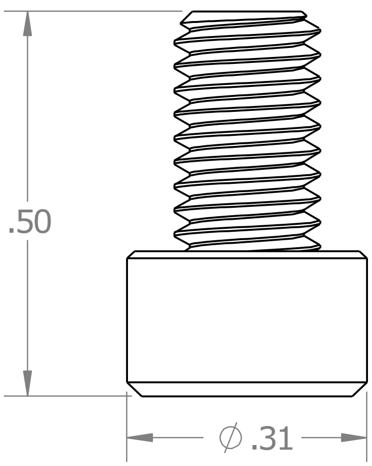
1

2 1

B







NOTE:
10-32 THREADS
STEEL
ALLEN HEAD

A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
		DO NOT SCALE DRAWING			

PROPRIETARY AND CONFIDENTIAL

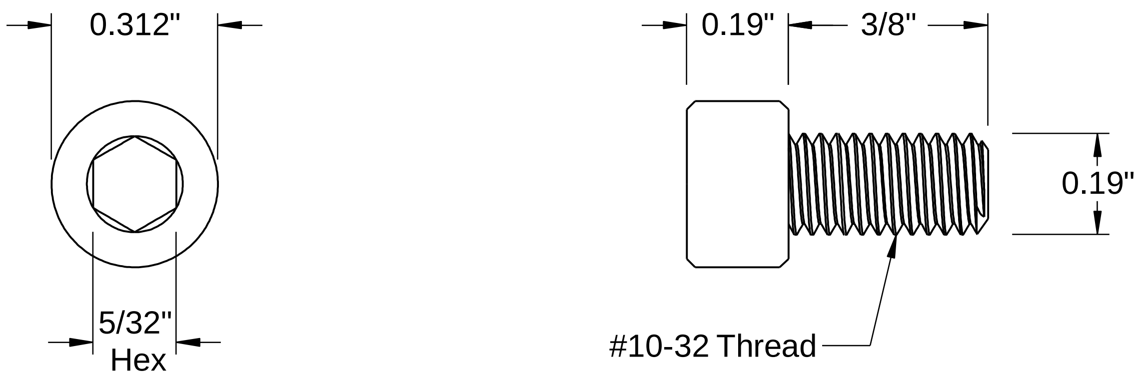
TITLE:

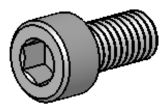
SIZE DWG. NO. REV

A Rack, Toggle Clamp, Scre

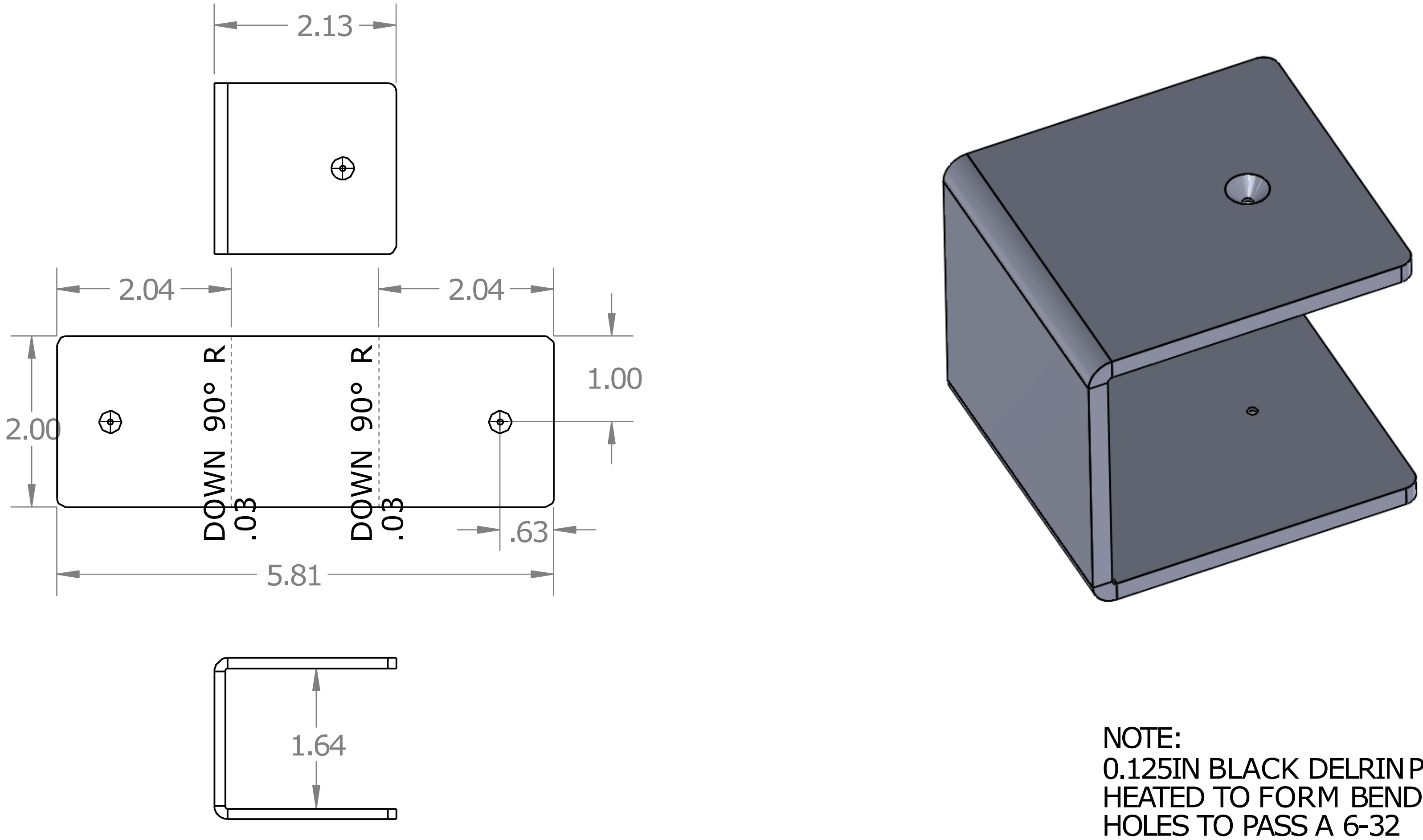
SCALE: 4:1 WEIGHT: SHEET 1 OF 1

1





McMASTER-CARR CAD	PART NUMBER 90128A940
http://www.mcmaster.com © 2014 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	Zinc-Plated Alloy Steel Socket Head Cap Screw



NOTE:
0.125IN BLACK DELRIN PLASTIC
HEATED TO FORM BENDS
HOLES TO PASS A 6-32
SEE PART #91263A506

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
		DO NOT SCALE DRAWING			

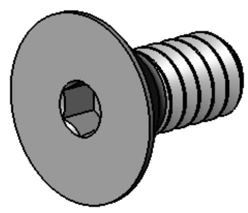
PROPRIETARY AND CONFIDENTIAL

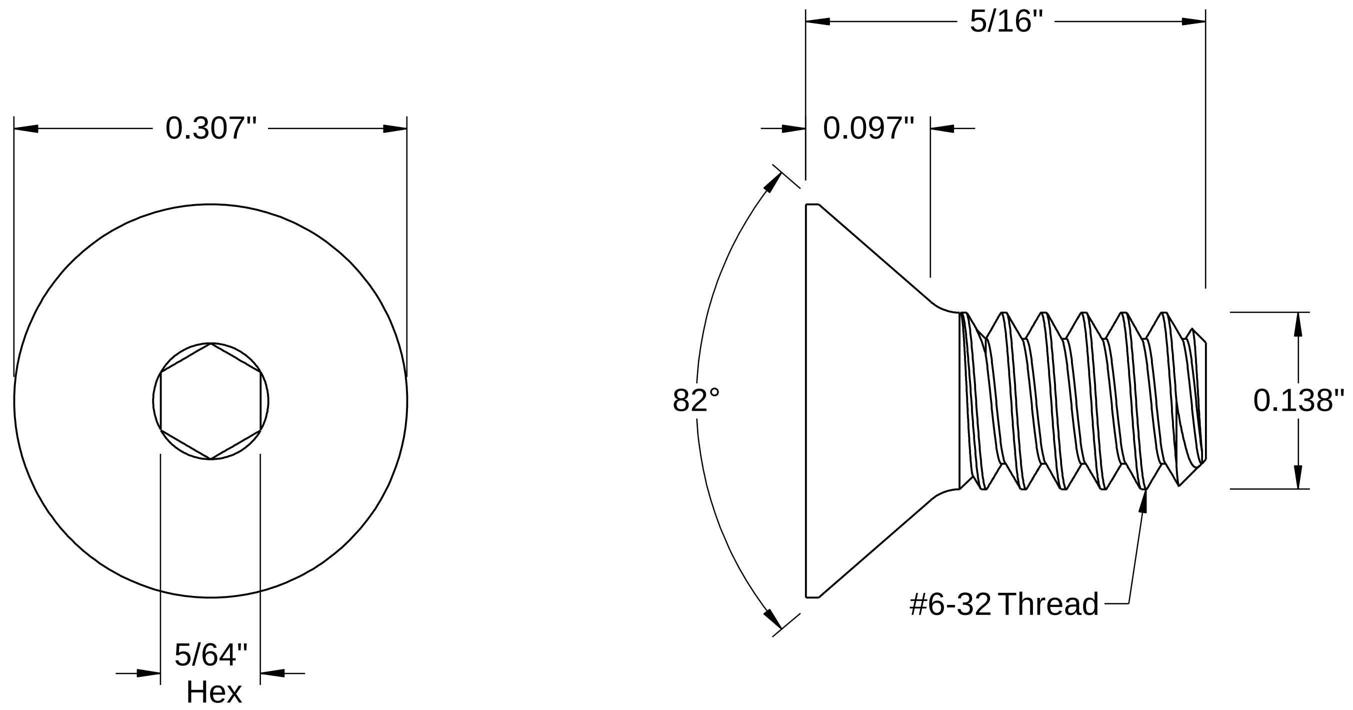
TITLE:

SIZE DWG. NO. REV

RAack, Wareplate

SCALE: 1:1 WEIGHT: SHEET 1 OF 1





McMASTER-CARR® CAD

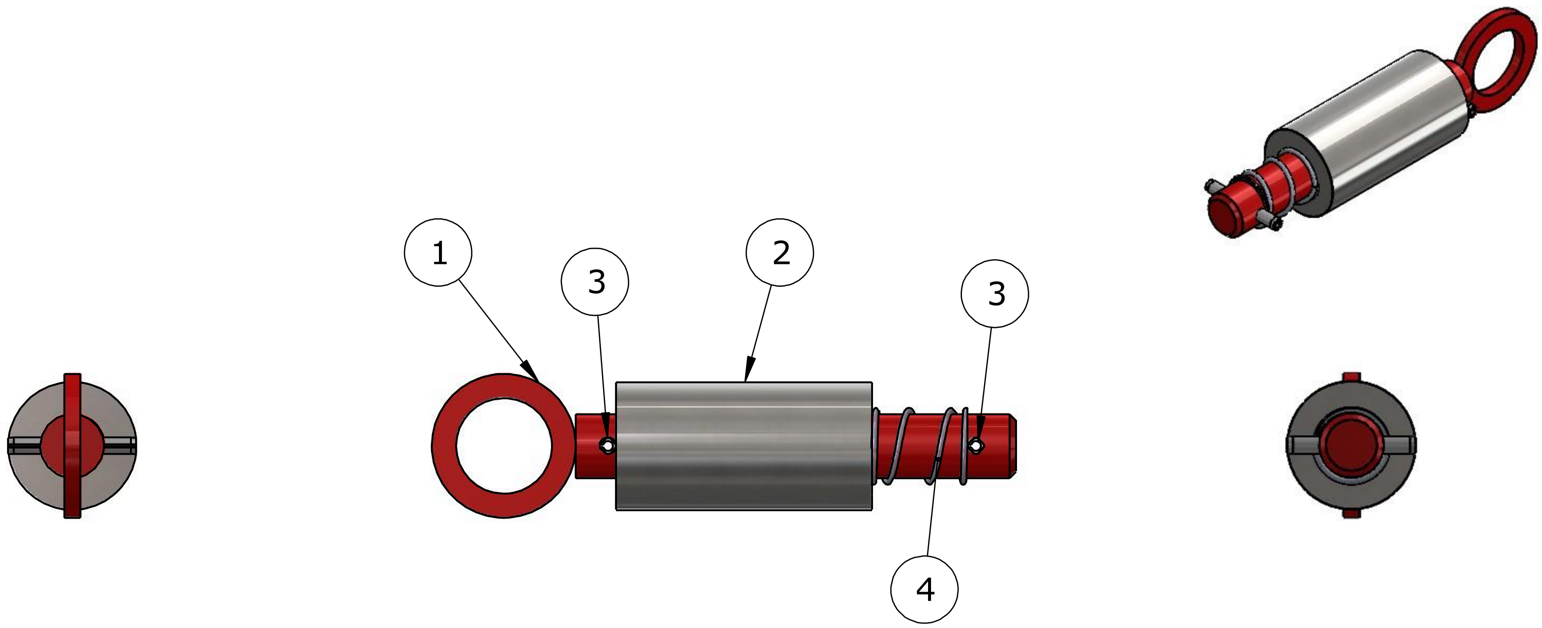
http://www.mcmaster.com

PART NUMBER **91263A506**

Alloy Steel Flat-Head Socket Cap Screw

2 1

B B



ITEM NO.	PART NUMBER	QTY.
1	Rack, Lock Pin, Pin	1
2	Rack, Lock Pin, Collar	1
3	98296A883	2
4	9657K293	1

A A

NEXT ASSY	USED ON

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

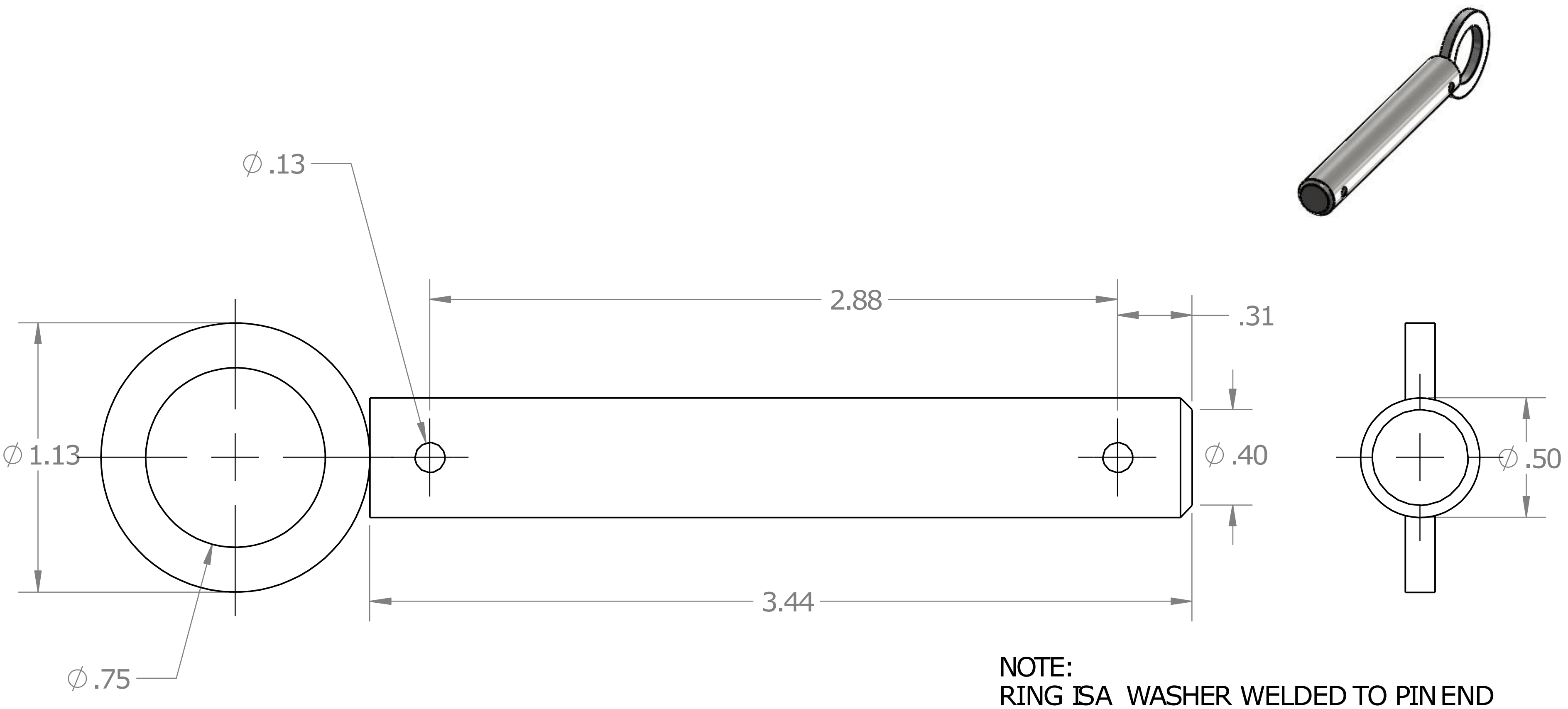
TITLE:

SIZE	DWG. NO.	REV
A	Rack, Lock Pin	

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

1

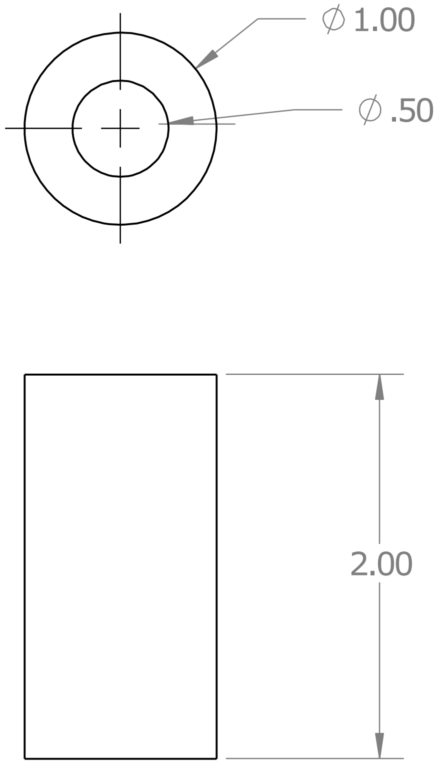
B

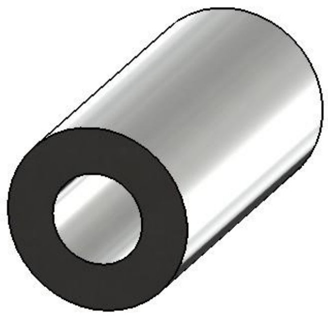


NOTE:
RING IS A WASHER WELDED TO PIN END
0.5IN. HOT ROLLED BAR
HOLES DRILLED VIA MILL

A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			
			CHECKED			TITLE:
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE A DWG. NO. Rack, Lock Pin, Pin REV
NEXT ASSY	USED ON	FINISH				
		DO NOT SCALE DRAWING				SHEET 1 OF 1





NOTE:
HOT ROLLED ROUND SROCK
MILD STEEL
BORED ON LATHE

		UNLESS OTHERWISE SPECIFIED:	NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN CHECKED ENG APPR. MFG APPR. Q.A.	
		INTERPRET GEOMETRIC TOLERANCING PER:	COMMENTS:	
		MATERIAL		
NEXT ASSY	USED ON	FINISH		
		DO NOT SCALE DRAWING		

PROPRIETARY AND CONFIDENTIAL

TITLE:

SIZE A DWG. NO. REV

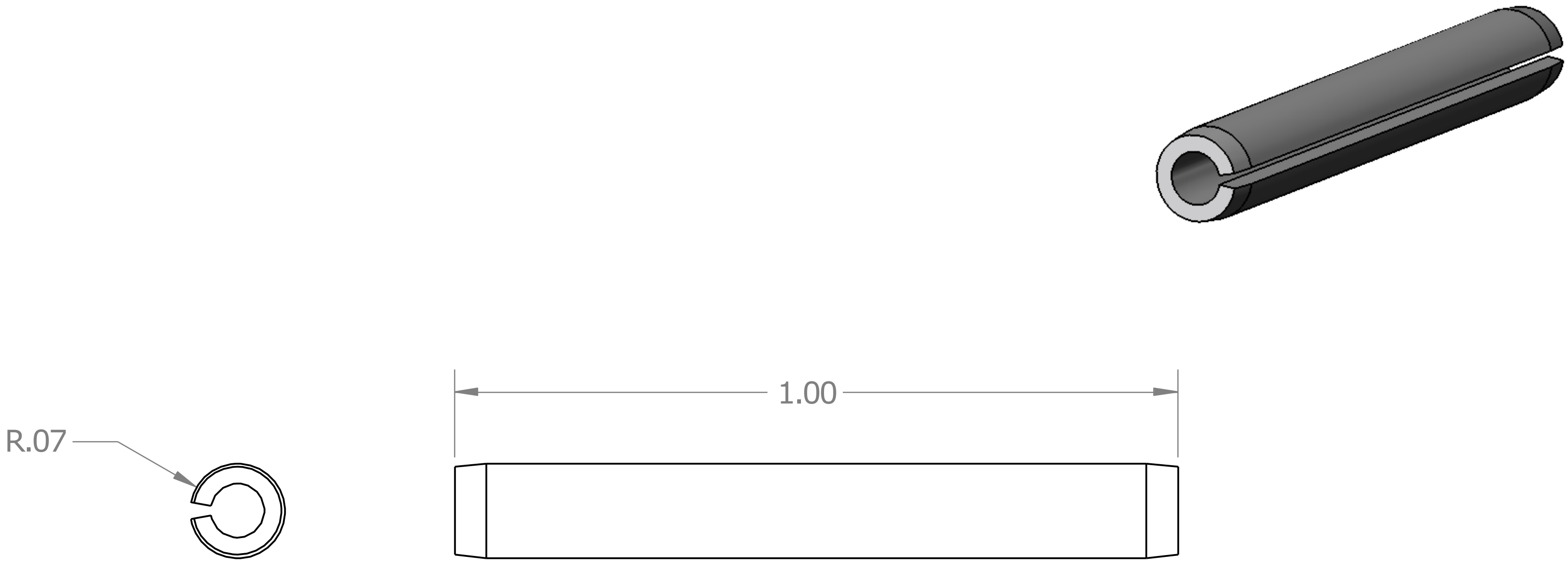
Rack, Lock Pin, Collar

SHEET 1 OF 1

2

1

B



B

NOTE:
STEEL PIN
PURCHASED FROMCMASTER CARR
PART #98296A883

A

A

NEXT ASSY

USED ON

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DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE A

DWG. NO. Rack, Lock Pin, Roll Pin

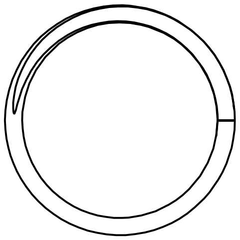
REV

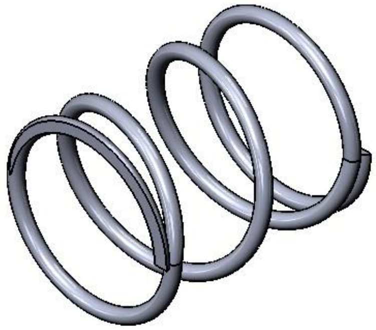
SHEET 1 OF 1

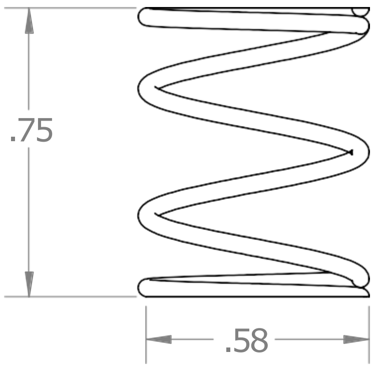
2

1

B







NOTE:
STEEL SPRING
PURCHASED FROM MCMASTER CARR
PART # 9657K293

A

PROPRIETARY AND CONFIDENTIAL

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NEXT ASSY	USED ON

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

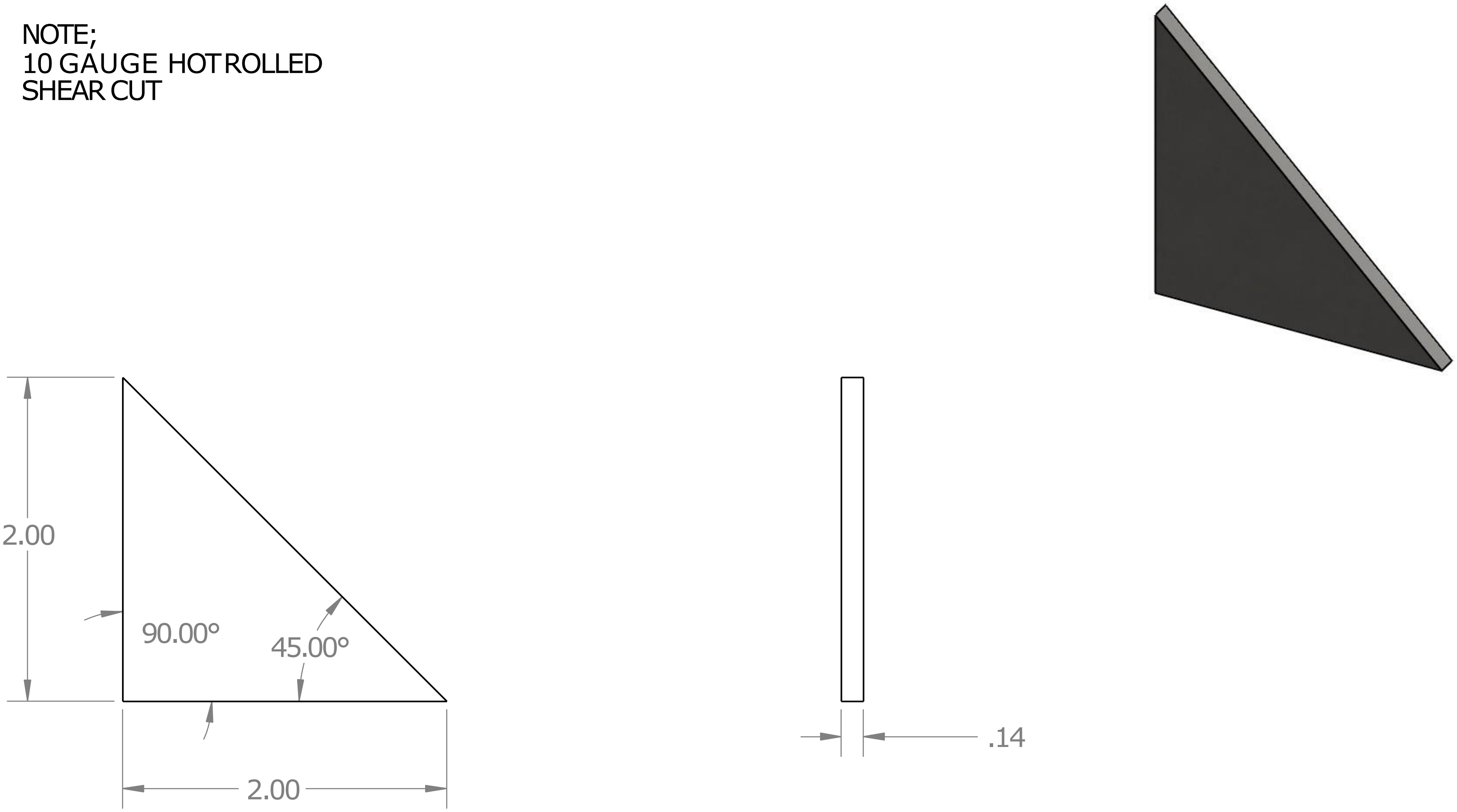
SIZE	DWG. NO.	REV
A	Rack, Lock Pin, Spring 2	

SHEET 1 OF 1

2 1

B B

NOTE;
10 GAUGE HOT ROLLED
SHEAR CUT



A A

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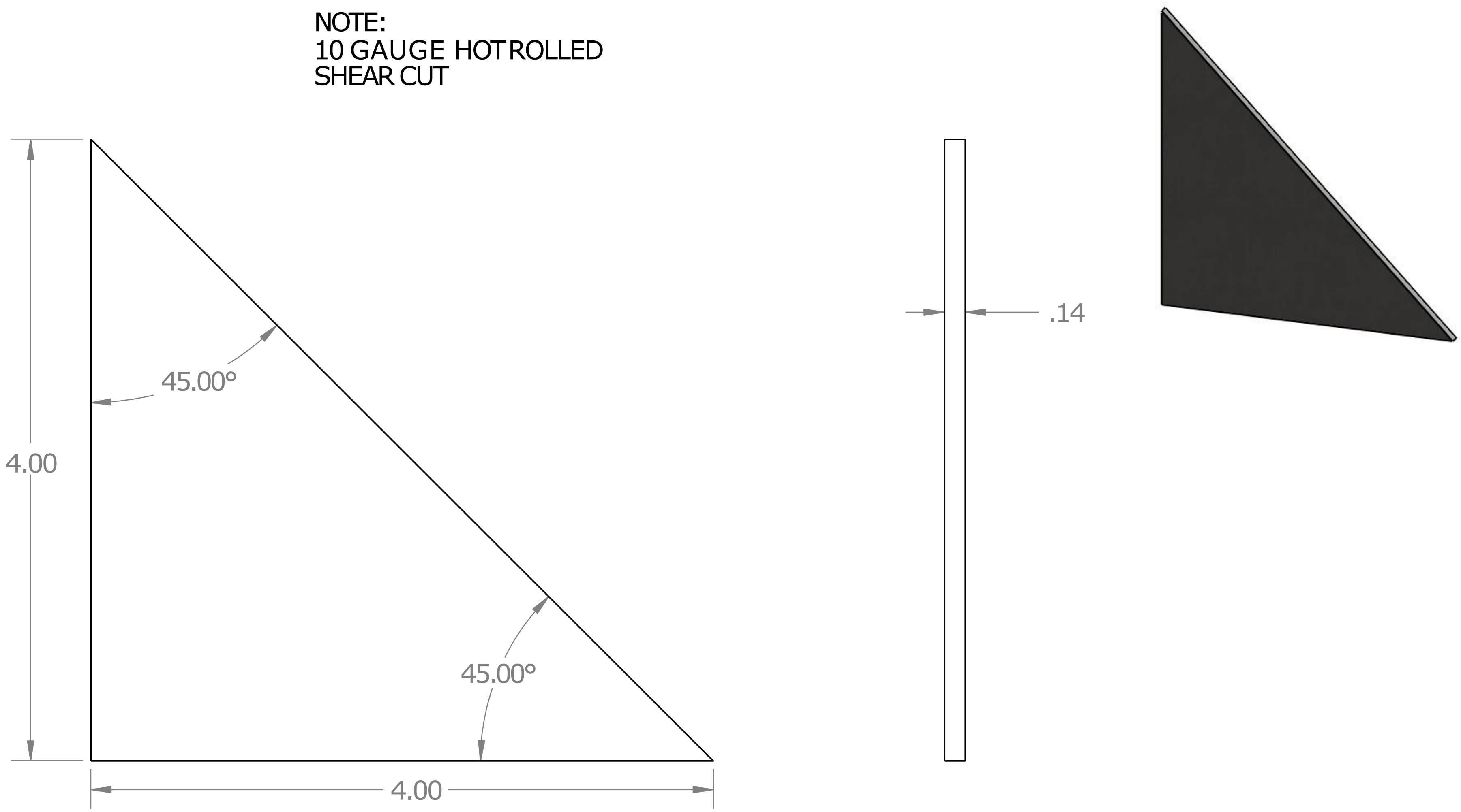
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE A DWG. NO. Rack, Corner Guesset, Sm REV
NEXT ASSY	USED ON	FINISH				
		DO NOT SCALE DRAWING				SCALE: 2:1 WEIGHT: SHEET 1 OF 1

1

2 1

B B

NOTE:
10 GAUGE HOT ROLLED
SHEAR CUT



A A

NEXT ASSY	USED ON

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC
TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

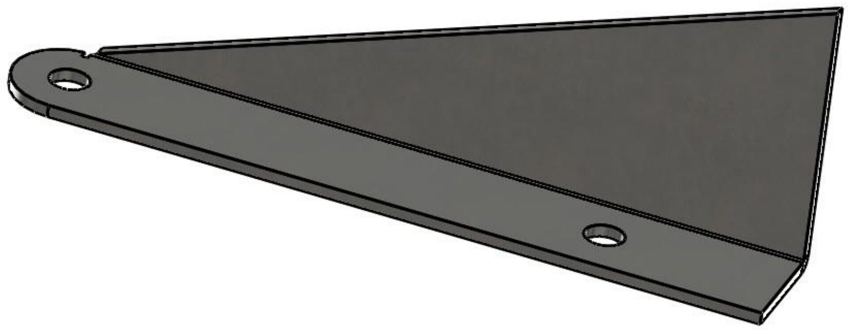
TITLE:

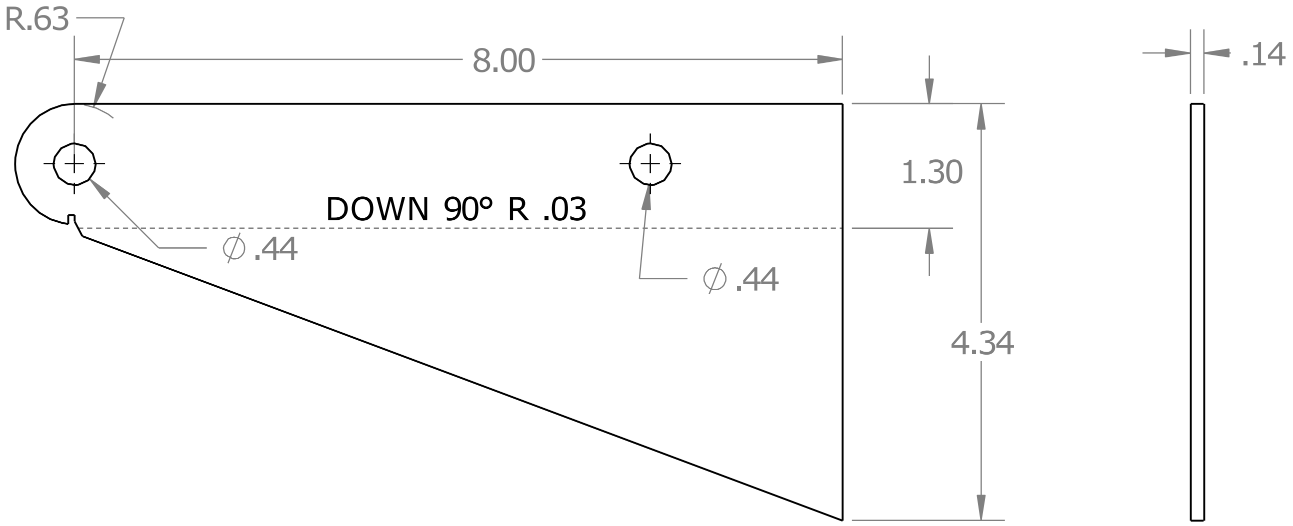
SIZE A DWG. NO. Rack, Corner Gusset, Larg REV

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

1

NOTE:
10 GAUGE HOT ROLLED
CNC PLASMA CUT
BENT VIA PRESS BRAKE





	UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
	DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
		CHECKED			
		ENG APPR.			
		MFG APPR.			
	INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
	MATERIAL	COMMENTS:			SIZE DWG. NO. REV
NEXT ASSY / USED ON	FINISH				A Jerry Can mount - offhan
	DO NOT SCALE DRAWING				SCALE: 1:2 WEIGHT: SHEET 1 OF 1

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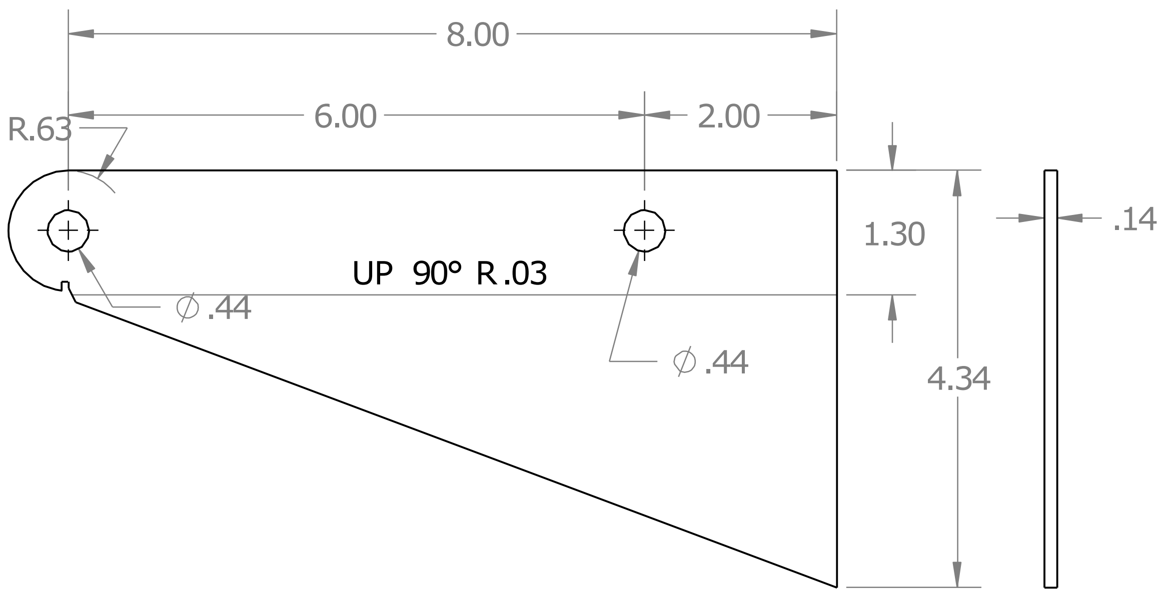
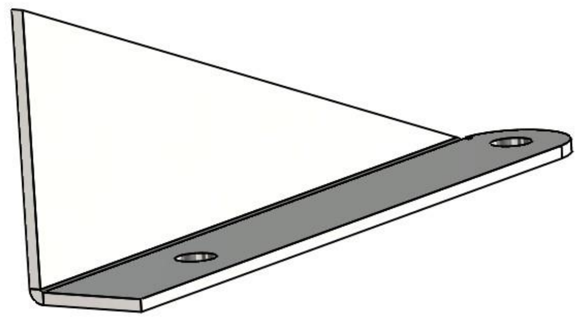
2 1 B A 1

2 | 1

B

NOTE:
10 GAUGE HOTROLLED
CNC PLASMA CUT
BENT VIA PRESS BRAKE





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		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
		DO NOT SCALE DRAWING			

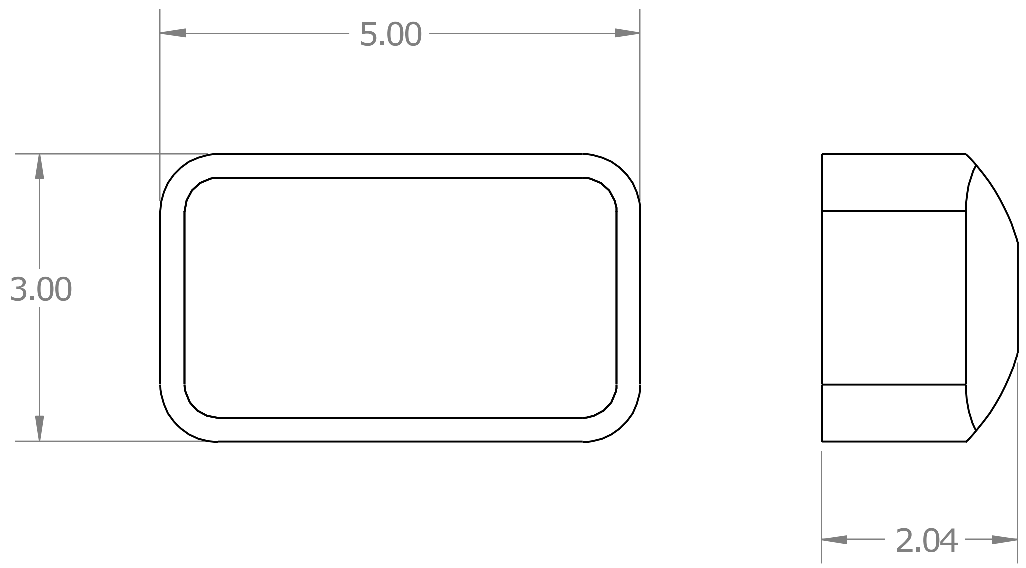
TITLE:

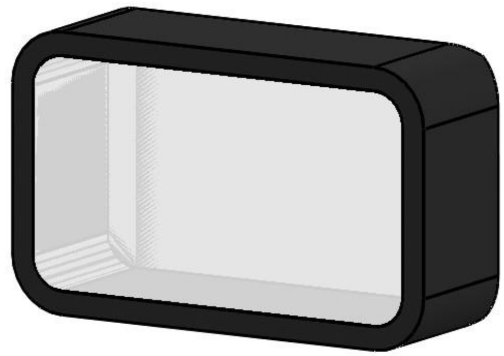
SIZE: A | DWG. NO.: JerryCan mount | REV

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

1

NOTE:
PURCHASED FROM ONLINE RETAILER
MOUNTING BRACKET NOT SHOWN





		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
		DO NOT SCALE DRAWING			

PROPRIETARY AND CONFIDENTIAL

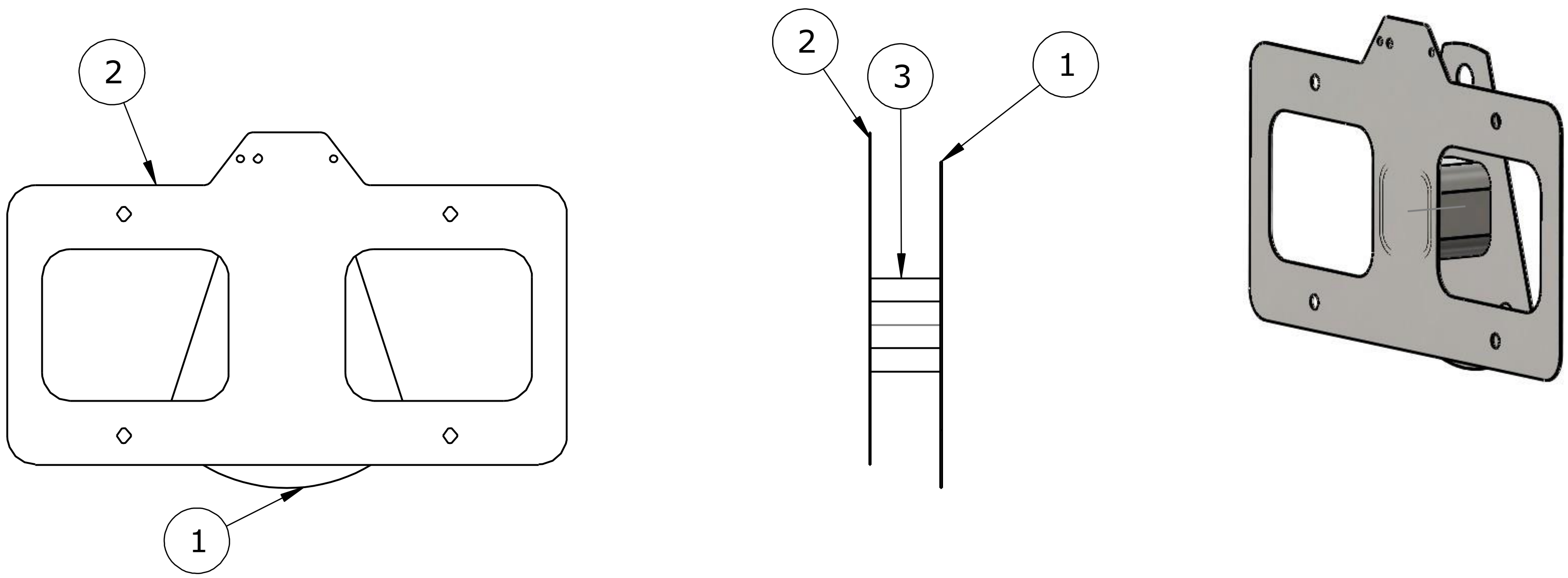
TITLE:

SIZE	DWG. NO.	REV
A	Rack, Flood Light	

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

2 | 1

B



B

ITEM NO.	PART NUMBER	QTY.
1	Rack, License Plate, Stud Plate	1
2	Rack, License Plate, Back Plate	1
3	Rack, Licens Plate, Standoff	1

A

A

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

NEXT ASSY | USED ON

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

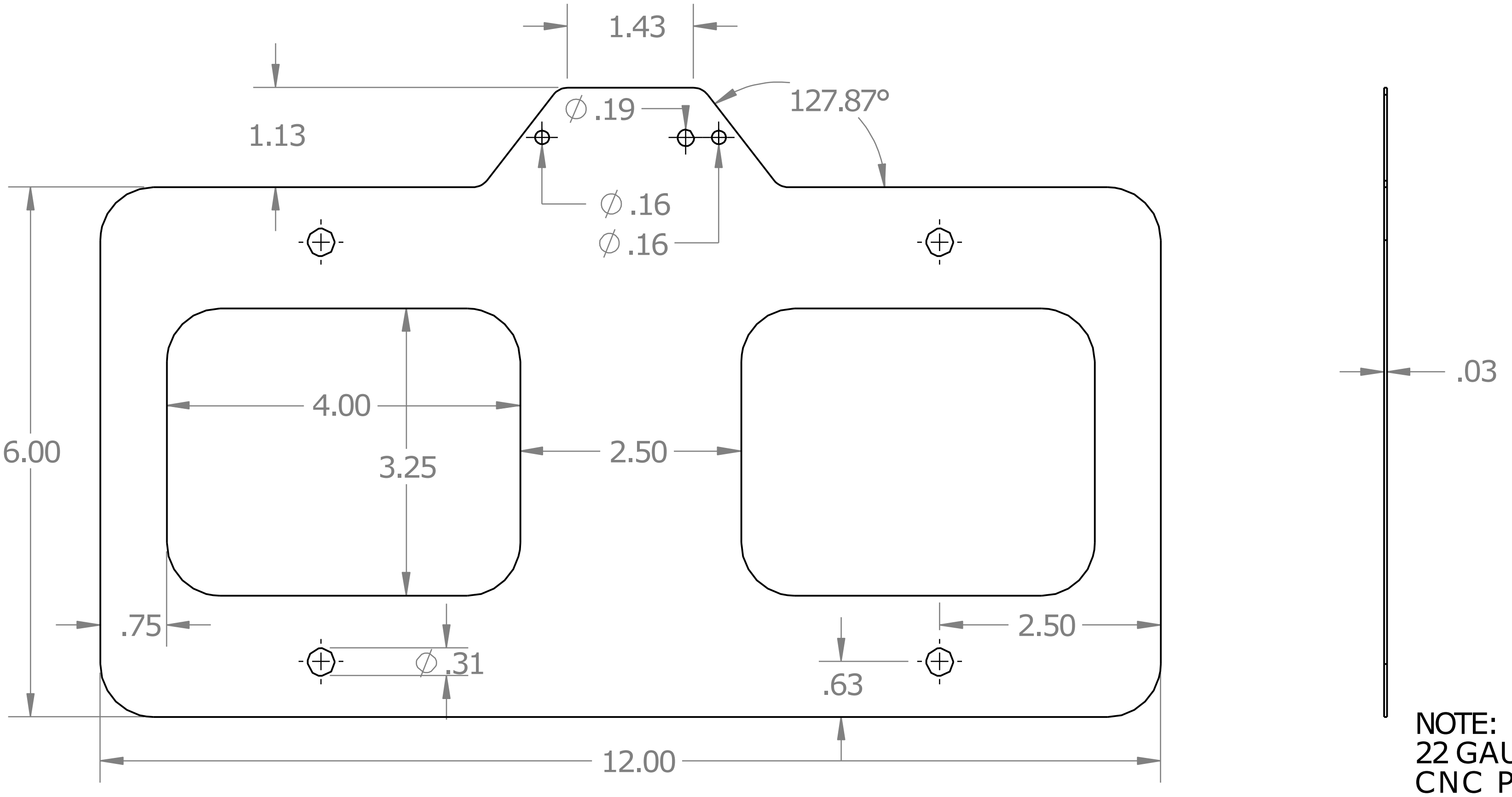
COMMENTS:

TITLE:

SIZE A | DWG. NO. Rack, License Plate | REV

SCALE: 1:4 | WEIGHT: | SHEET 1 OF 1

1



NOTE:
22 GAUGE HOT ROLLED
CNC PLASMA CUT

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
		DO NOT SCALE DRAWING			

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TITLE:

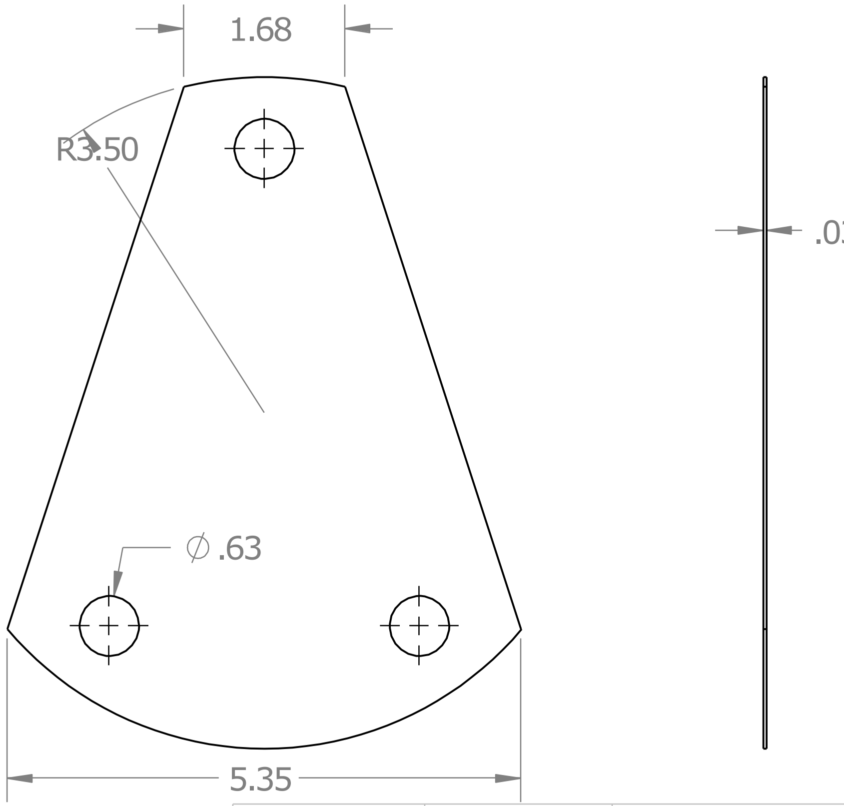
SIZE	DWG. NO.	REV
A	Rack, License Plate, Back Pl	

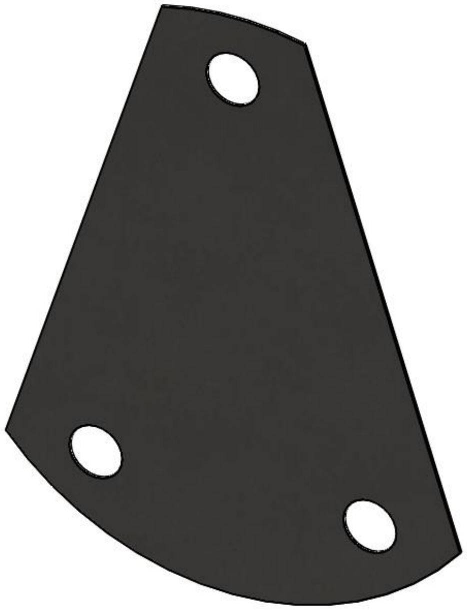
SCALE: 1:2 WEIGHT: SHEET 1 OF 1

2

1

B





NOTE:
22 GAUGE HOTROLLED
CNC PLASMACUT
5 ON 5.5IN. BOLTCIRCLE

A

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NEXT ASSY	USED ON

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

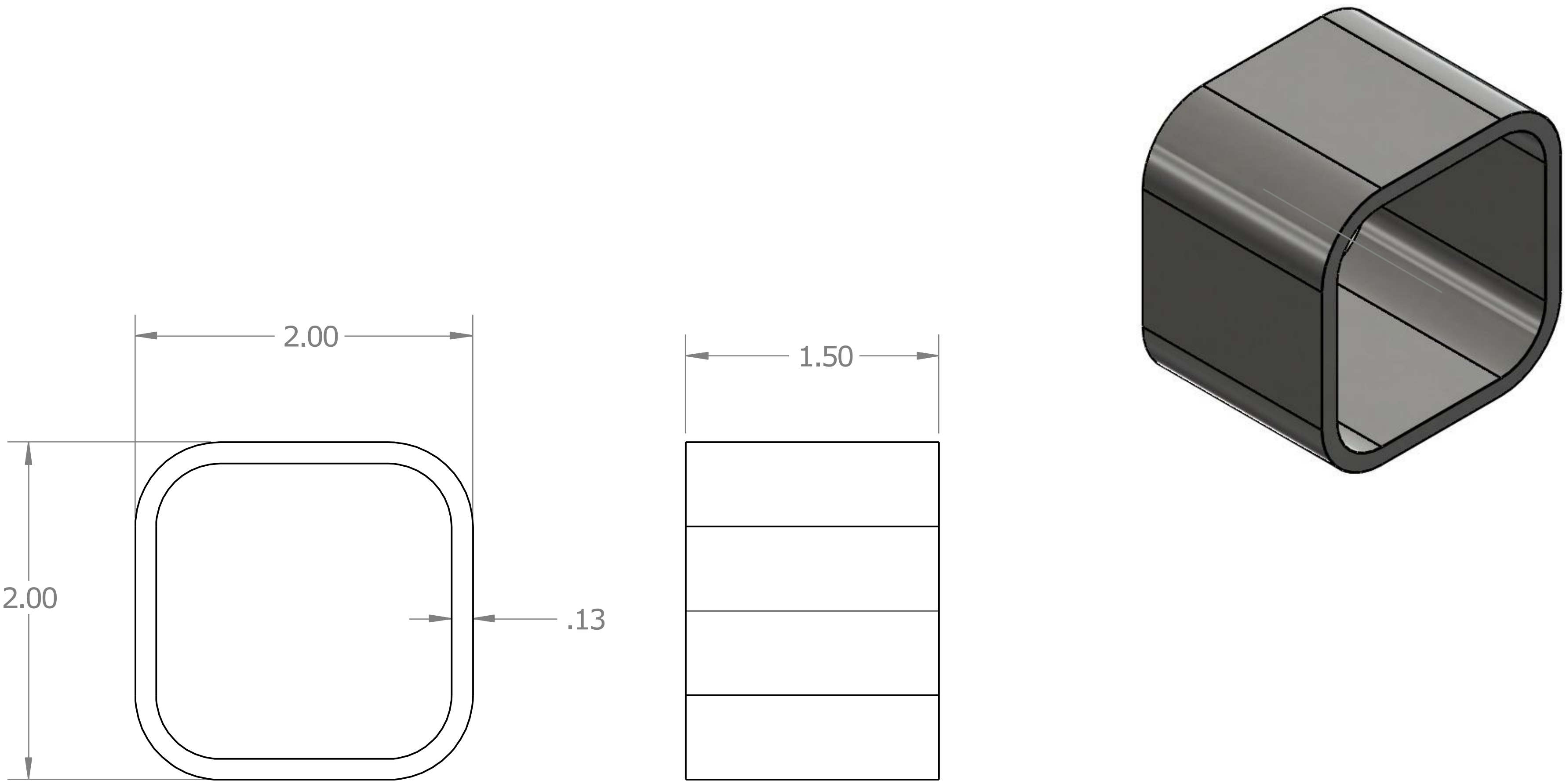
SIZE DWG. NO. REV

A

Rack, License Plate, Stud Pl

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

1



NOTE:
2IN. SQUARE TUBE

PROPRIETARY AND CONFIDENTIAL

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NEXT ASSY | USED ON

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

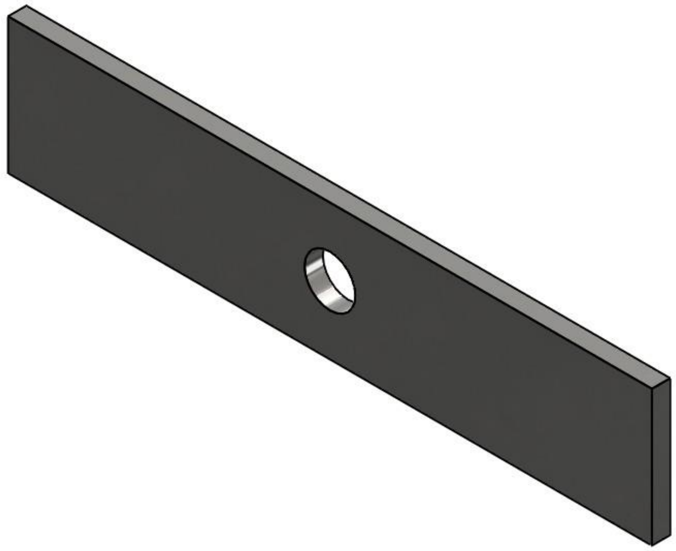
SIZE A | DWG. NO. Rack, Licens Plate, Stando | REV

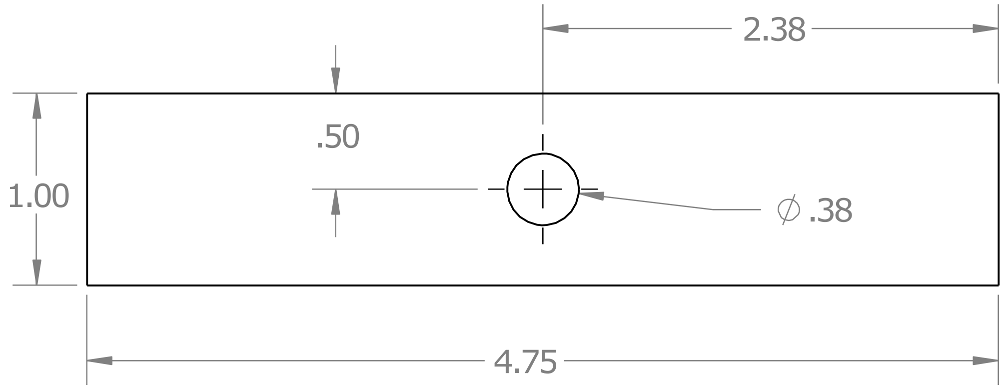
SHEET 1 OF 1

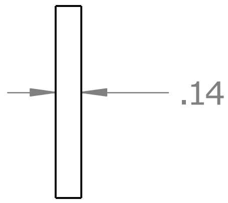
2 1

NOTE
10 GAUGE HOT ROLLED
SHEAR CUT
HOLE DRILLED VIA DRILL PRESS

B B







A A

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NEXT ASSY	USED ON

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE DWG. NO. REV
Rack, Flood Light, Bracke
A

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

1

APPENDIX E – Indented Parts List

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Tailgate		1
2	Bumper, Main		1
2.1		Sheet	-
3	Bumper, Step		1
3.1		Sheet	-
4	Rack Assembly		1
4.1	Rack, Arm		1
4.1.1		TUBE, RECTANGULAR 3.00 X 2.00 X .14	50
4.1.2		TUBE, SQUARE 2.00 X 2.00 X .13	19
4.2	Rack, Arm, Cap		1
4.2.1		Sheet	-
4.3	Rack, Hub		1
4.4	Rack, Hub, Strap		1
4.5	Rack, Stud Plate		1
4.5.1		Sheet	-
4.6	91257A748		3
4.7	Rack, Spindle Bushing		1
4.8	Tire		1
4.9	Rack, Toggle Clamp, Bracket		1
4.9.1		Sheet	-
4.1	Rack, Toggle Clamp		1
4.11	91251A337		4
4.12	Jerry Can mount		2
4.12.1		Sheet	-
4.13	Jerry Can mount - offhand		2
4.13.1		Sheet	-
4.14	Jerry Can		2
4.15	Rack, Corner Gusset, Large		2

4.15.1		Sheet	-
4.16	Rack, Corner Gusset, Small		2
4.16.1		Sheet	-
4.17	Rack, Flood Light, Bracket		2
4.17.1		Sheet	-
4.18	Rack, Lock Pin		1
4.18.1	Rack, Lock Pin, Pin		1
4.18.2	Rack, Lock Pin, Collar		1
4.18.3	98296A883		2
4.18.4	9657K293		1
4.19	Rack, Ware plate		1
4.19.1		Sheet	-
5	91257A998		1
6	2879T13		2
7	95030A320		1
8	6in Receiver Tube		1
9	Rack, Spindle, Gusset		1
9.1		Sheet	-
10	Back Plate		2
10.1		Sheet	-
11	Bumper, Main, Light Back		2
11.1		Sheet	-
12	Rack, Shelf		1
12.1	Rack, Shelf, Plate 2		1
12.1.1		Sheet	-
12.2	Rack, Shelf, Plate 1		1
12.2.1		Sheet	-
13	Rack, Toggle Clamp, Clasp		1
14	91251A337		2
15	Rack, Shelf, Plate 3		1
15.1		Sheet	-

16	Bumper, Main, Gusset		2
16.1		Sheet	-
17	Frame Bracket		2
17.1		Sheet	-
18	Bumper, D-ring		2
18.1	Bumper, D-ring, Ring		1
18.1.1		PIPE, SCH 40, .63 DIA.	12.5
18.2	Bumper, D-ring, Weld Link		1
19	Bumper, Tail Light		2
19.1	Bumper Tail Light, Light		1
19.2	Bumper, Tail Light, Grommet		1
20	Rack, Flood Light		2
20.1	Rack, Flood Light, Bucket		1
20.2	Rack, Flood Light, Lenses		1
21	Rack, License Plate		1
21.1	Rack, License Plate, Stud Plate		1
21.1.1		Sheet	-
21.2	Rack, License Plate, Back Plate		1
21.2.1		Sheet	-
21.3	Rack, License Plate, Standoff		1
21.3.1		TUBE, SQUARE 2.00 X 2.00 X .13	1.5
22	Rack, Lock Pin, Ramp		1

APPENDIX F – Receipts