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Ultra Light Split Board Bindings

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Ultralight Split Board Bindings

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CWU Mechanical Engineering Technology–
Cap Stone Project
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Introduction:

Motivation:

The motivation to design such a binding started with a prototype designed 2 years ago, this design was slow to clip boots in, heavy and prone to jamming. Therefor this concept of a binding system needs to be engineered to solve these issues.

Function:

A device is needed to accept alpine touring ski boots using AT (Alpine Touring) ski binding so that it can be used on a split board. It must be adjustable for different size AT boots. It must be able to link the two halves of a split board together for structural soundness.

Requirements:

A device is needed that has the following:

- This device must be under 600 grams for each binding.
- It must cost less than $500 to produce.
- It must not permanently deform during a 35 mph crash.
- It must be adjustable from a size 10-12 US.

Engineering Merit:

A calculation of the forces that will be present on the binding and fixture plates at 35mph and dropping from 15' with a .5 second impulse and estimated mass of $230lbs$ must first be calculated using Impulse=Mass x total change in velocity). Then the design can be analyzed using the buckling "critical stress" equation ($\sigma cr = \pi\text{^}2\ EI/(KL/r)\text{^}2$) to establish the minimal amount of material needed. Establishing the minimal amount of material needed will also require finding an acceptable moment of inertia (resistance to bending). Also finding the min. amount of material will require analyzing the stress concentrations present on the device using the equation ($\sigma max = K(Mc/I)$.

Success Criteria:

A successful design will incorporate the requirements such as weight, production cost. The video with show this device taking a 15ft vertical drop with rider onto compact snow and sustain a 35mph crash on compact snow.

Scope of device:

The scope of this effort is on the split board binding and it's fastening components.

DESIGN & ANALYSIS

Approach:

Aspects of the device such as functionality, durability and weight are the major contributors to the design and are the primary objectives. Secondary objectives of the devise are to include safety, price and adjustability. With the primary aspects in mind an approach to the problem can be started such as designing. And with a design one can analyze this device with standard statics, and strengths calculations.

Design Description:

The device will be a split board binding that will have two pre fastened brackets for the split board system that will be angled enough to accommodate for boot angle. It will weigh less than 350 grams each. The binding will be adjustable from a US size 10-12 boot using fastening components using machined holes where a heel and toe wire will clip in at these sizes as seen in Figure 1a. Tolerances must be within +/- .005" due to AT boot fitment for vibrations such as split board chatter and responsiveness. Refer to Appendix B for Figure 1a individual part drawings.

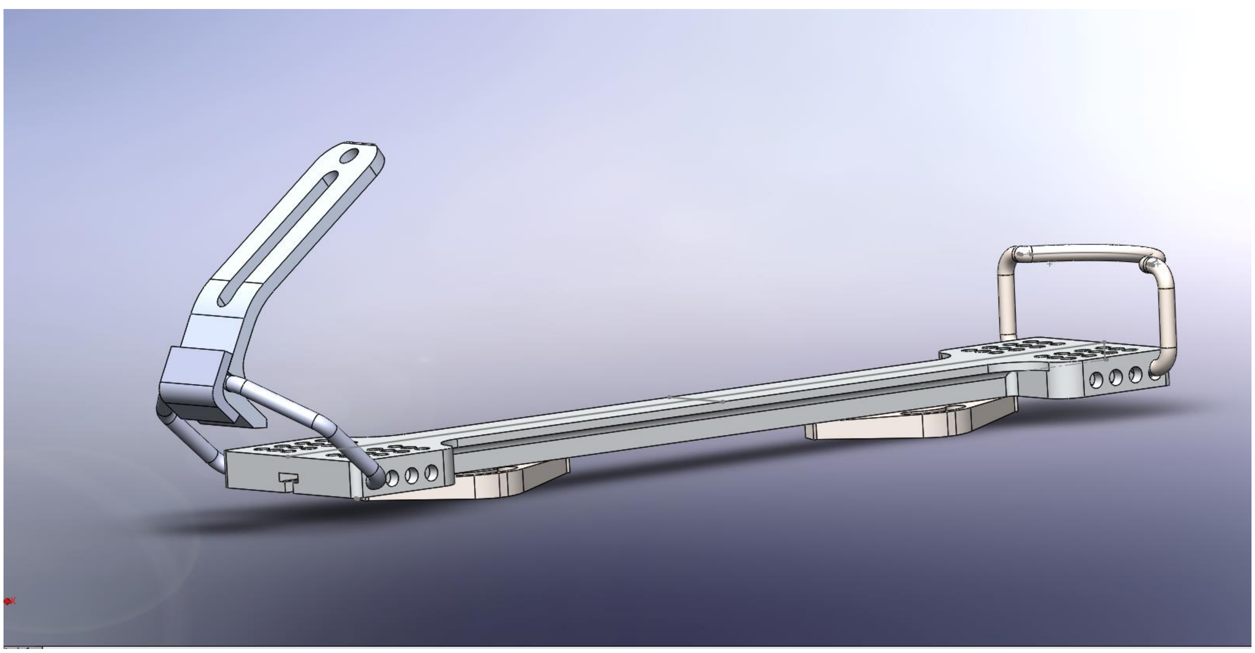


Figure 1a Split Board linking device

Benchmark:

There are split board bindings that are AT ski boot adaptable, however they are not ultralight in design and do not accommodate for ski boot angle. The models on the market utilize a Dynafit Speed Turn 2.0 or other similar toe piece that would lighten the weight of each step taken since the Dynafit toe piece allows the AT ski boot to pivot without adding weight to each step. The closest production binding is the Spark R&D Dyno it weighs approximately .86lbs not including the mounting plates as seen in Figure 1. The goal is to design a binding that is not over built nor under built in terms of strength and yet still be lighter than the Spark R&D Dyno.

Figure 1 Benchmark standard

Performance Predictions:
This design will work and perform better than the benchmark designs due to the light weight and flexibility.

Description of Analysis:
The analysis will be segmented off these requirements: the amount of the stress provided by the rider, gear on the binding at 35mph crash with a .5 sec impulse and from a 15 ft vertical drop onto 2ft soft snow. The analyses will be where the binding mates to the mounting brackets. Analysis will be on the mounting surface between the split board top and the mounting brackets held by 2 M6 bolts with stainless steel washers. Analysis will be on the binding plate where the heel and toe wires tie into the coupling beam and on the buckle that clamps the boot to the coupling beam.

Scope of Testing and Evaluation:
The scope of the testing will be done by first assembly and fitment and then by testing using strain gauges and a mobile data logger on the rider while being used in a real world mountain decent. The test data will then be tabulated to see how much stress/strain has been put on the binding devise and its fastening components and evaluated on the criteria of actual results versus the calculated results.

Analyses:
The first analysis as shown in Figure 2 Appendix A is the total amount of force provided by the rider onto the binding. First an impact at 35mph with a .5 second impulse was calculated, since in a real life event unless hitting a solid concrete wall there would be a

longer impulse time in which the force would be slightly dissipated through the softness of the snow, rider and shock absorbed by the split board. Since this device will be in conditions where it is critical it can take a harsh crash miles and possibly days away from a repair shop the goal is to emphasize an impact in the worst case scenario of a .5 second impulse. The impulse force is733^{lbs}.

The second analysis as shown Figure 3 is finding the impact force from a 7.5ft drop off a cliff into 2 feet of powder with an impulse of .5 seconds due to the velocity going forward and the board surface area on the snow spreading out the weight distribution as well as the human legs acting like a dampener much like a spring under pressure. The impact force is 1725^{lbs} .

The third analysis as shown in Figure 4 is finding the cross sectional area of the mounting plates. There are 4 mounting plates total with equal distributions of weight and force. The calculated cross sectional area was $.0168in^2$ however due to machining capabilities and calculation uncertainties the actual cross sectional area will be $.45in^2$

The fourth analysis as shown Figure 5 is of finding the required thickness at the section AA in the Figure. There are two supporting cross sectional areas. The material for use is Aluminum 7075 T6 Aluminum. Due to a combined loadings multiple calculations of bending and shear were used. However there will be more stress on the ends of the mounting plates so there will be a stress concentration at .2in from the edge. The calculated area was based by using .2in length know of area to solve for thickness. The resulting thickness is .1875in/ 2 sections gave a required thickness of .09375in.

The fifth analysis in Figure 6 is of finding the cross section thickness at BB in the figure. Much like the fourth analysis this was a secondary analysis to back up the calculations of section AA with different solving techniques. The resulting cross sections were at BB to be .205in and at AA to be .1027in.

The sixth analysis in Figure 7 is to make sure the buckle at cross section B in the figure will not break having the dimensions of .25in x 1in in cross section. The analysis concludes that the buckle will not break at cross section B as the resulting stress is 1/10 of the yield of Aluminum 7075 T6. However this thickness will have geometry changes above the hinge point and will have to be welded so additional material will be needed in this process to control heat issues such as distortion and blow through.

The seventh analysis in Figure 8 is to verify that 3/16 diameter Stainless 410 rod will hold up to the shear points where they pivot in the coupling beam. The highest yield strength is 47 ksi on the toe wire and 45 ksi on the heel wire. As these calculations are at the extremes of the binding the alloy 410 Stainless Steel has a 45 ksi yield strength. There for 3/16” rod using 410 Stainless Steel will work.

The eighth analysis in Figure 10 is to find the mounting angle at which the mounting plates should be machined. The angle was found to be 7.4 degrees.

The ninth analysis in Figure 11 is to find the bending stress on the coupling beam. The bending stress was determined using the flexture formula, the moment was determined then Solid works was used to compute the C value and inertial values to determine that the design was within the limits. The resulting bending stress from bending is 67 ksi and the yield strength of 7075 T-6 aluminum is 73ksi, therefor the design is within the limits.

Analysis ten was used to determine the clamping force to make sure a ski pole would be able to push it down to clamp the boots in place. A resulting force of 30.3 lbs. was determined to be acceptable.

Analysis eleven was used to determine the cross sectional thickness given the width was 1 inch. The resulting thickness was based on a safety factor of 3 and was determined that a thickness of .165” thick would be sufficient. The formula used was the flexture formula in determining the resulting stress of 70 ksi at the cross section BB in the analysis.

Analysis 12 was used to determine what cross sectional thickness would work at the hinge point. This was determined using a stress concentration factor of 2.53 determined by the geometry changes at this cross section. Then the safety factor was multiplied by the flexture formula to obtain a stress number of 31ksi determining that this buckle will not fail at this pivot point.

Device Styling:

The shape of the devise is of functionality and meeting the requirements. Physical appearance has nothing to do with the design besides the color it will be anodized to be.

Devise Assembly:

Tolerances:

Of primary issue when designing is stacking tolerances as the stacking of the tolerances, if the tolerances are too tight parts will not fit and if too loose parts will not function as intended.

Technical Risks Analysis:

Risks involved in the manufacturing of this device will be the machining of the part since more than likely it will be machined from Titanium which is financially risky since this material is so expensive to purchase and machine. Machining is usually done with coated carbides since, however this can be minimized using HSS (high speed tool steel) for such a low run number of parts. The first batch of parts will be machined from aluminum to dial in the manufacturing since it is readily available and it is cheap compared to that of titanium.

Safety Factors:
The safety factors are by the component rather than that of the system. Pieces such as the retaining pin will have a safety factor of 2 due to wear and spikes in pressures causing fatigue while the rest of the components will have a safety factor of 1.5 since they will experience less fatigue and wear. I chose 1.5 due to the fact that if this design fails there is an increased risk of injury for the rider and increase risk the rider may not be able to get out of the mountains.

Operation Limits:
Limits of the devise will be the size of the ski boot size 10-12 US. The type of impact the binding will experience will be limited to impacts of 732lbs per binding and to 15ft vertical of drop onto 2ft of soft snow. Temperature limitations are to -30 Celsius as at this point other factors such as the split board's construction will be compromised.

Methods and Construction

Construction:
This devise is composed of 22 total pieces not including fasteners. The 11 pieces will complete one coupling beam assembly of the two needed. The split board binding is composed of 11 pieces: Part # C1 (Coupling Beam), Part # T1 (Tow wire), Part # B3 (Toe Buckle), Part # B1 (Buckle Retainer), Part # B2 (Binding Pin), Part # H1 (Heel Wire), and Part # R1 (Retaining Rings). The fastening of C1 (Coupling Beam) is by means of part M1 (Mounting Plates). In Final assembly C1 will slide over M1 and retain it from movement once P1 (Locking Pin) is inserted thru C1 and M1 retaining holes.

The materials used by part number:
- M1 TI AL6-4V
- B3 AL 7075 T6
- B2 Stainless Steel 410
- T1 Stainless Steel 410

- H1 Stainless Steel 410
- R1 Spring Steel
- C1 AL 7075 T6
- B1 AL 7075 T6

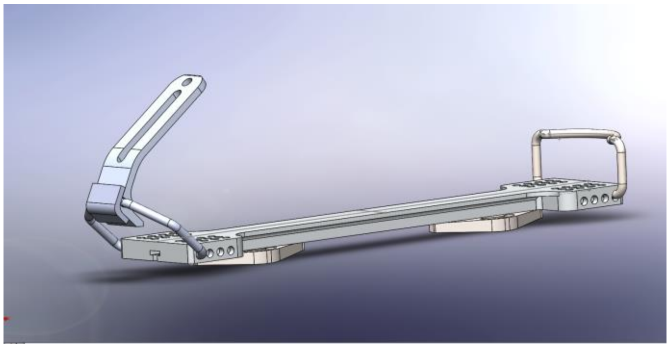


Figure 2 Non Complete Assembly Rendering

Drawing Tree:

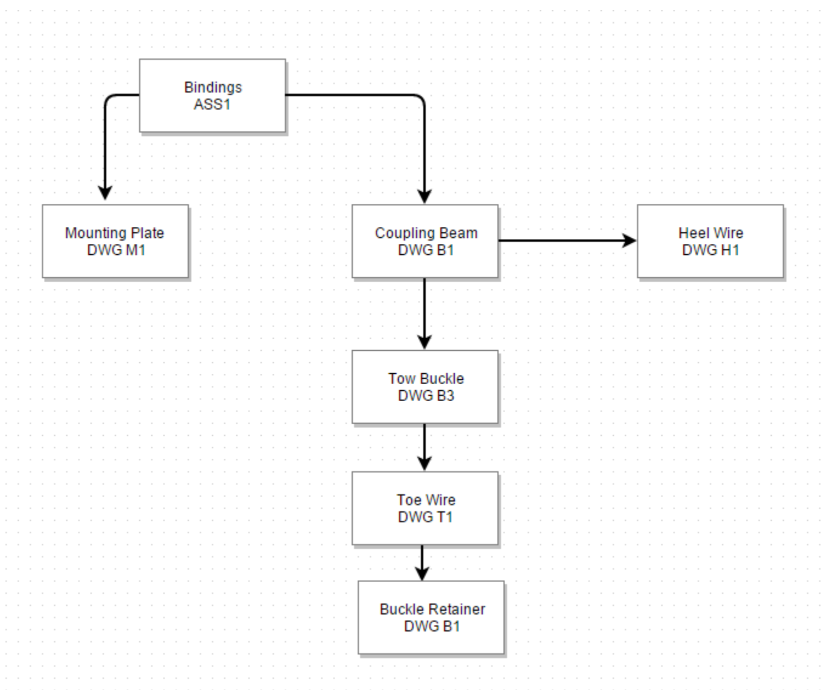


Figure 3 Drawing Tree

Manufacturing Issues:
Issues that will come up will be the tooling to manufacture the components on the 3 axis CNC Mill. These tooling issues may control the size of the end product as some dimensions may not be able to be cut by the mill such as inside square corners and some of the slots depending on the available tooling for the machine.

Testing Method:
Introduction:
Testing of the split board binding device will compose primarily of testing through the use of strain gauges to calculate the amounts of stress and strain on the devices to warrant it does not exceed the Titanium or Aluminums elastic limits causing permanent deformation or breakage. The strain gauges will be used for calculating torsion and axial loading and compression loading.

These strain gauges will be hooked up to a multiple channel data logger and be put through various tests using a hydraulic press with a psi gauge read out on it to calculate compressive forces axially. There will be two jigs made one for compressive force in the vertical Y axis and to test in the horizontal x axis. The data that is logged will be put into excel and plugged into conversion formulas using the resistance provided by the strain gauges. The final test will be what the actual amount of these forces is with a rider testing it on the mountain. There will be a comparison among the laboratory testing, rider testing and calculated analysis to fully analyze the design and functionality of the device.

Methods/ Approach:
The approach to this testing analyses will use the calculated perimeters to test verse the actual perimeters of torsion, stress, and strain found during laboratory testing and actual testing. Tools needed for analyses will include the following:

- 12 Strain gauges (Thin Film Type with Epoxy)
- Mobile multiple channel Data Logger
- Calipers
- Double acting Hydraulic press with PSI gauge
- 2 roles of thin Nickle based wire to link strain gauges to data logger
- Solder gun and Solder
- 1oz of Epoxy
- 8” of 6x6x.5” angle Iron for jig.
- Split Board
- GPS capable of recording speed

The test environment will be both at room temperature and in the snow tested in the morning being the most stable of temperature between first light for 2 hours after or until the temperature changes by 3-5 degrees. The device will need one jig to test both vertical and horizontal loadings to the specified impact forces in Figure 1 Appendix A.

Test procedure:
Lab testing procedure:

i. Vertical Y axis testing:

1. Load the AT Boot into the bindings and place the device with Jig 1.
2. Load boot into press in vertical upright position and zero the data logger and record temperature.
3. The testing with be in 50lb increments record to 850lb of force.
4. Download data into excel and delete data logger.

ii. Horizontal X axis loading

1. Load the AT Boot into the binding and place the device into Jig 1.
2. Load boot in the horizontal X direction and zero the data logger
3. The testing will be in 50lb increments with loading in the middle between the toe piece and the heel clip.
4. Record to 400lbs of force.
5. Download data into excel and delete data logger.

Real life testing procedure:

i. Record temperature and verify 2ft of powder for 15ft vertical drop or 1ft and 7.5ft of drop.
ii. Assemble the Bindings into the puck plates and clip board together at the tips
iii. Zero the data logger and clip AT boots into bindings.
iv. Ride the split board aggressively and intentionally crash at 35mph with the GPS as a reference for speed.
v. Ride off either a downhill cliff 15ft with 2ft of dry powder snow or 7.5ft and 1ft of powder snow.
vi. Download data into excel and delete data logger.

Compare data:

Make graphs of strain gauge readings in lab vs real life testing and calculated results.

Budget:
Proposed Budget:

The budget for this project will be under $500 not including labor or tooling costs. Refer to Appendix D for budget costs of parts and coatings.

Outsourcing rates:

Parts need anodizing which cost a minimum of $65. This is the only thing that needs to be outsourced.

Labor:

This product will have $0 of labor involved as the designer is a machinist and fabricator and all work is in house, besides anodize rates.

Estimate of total project cost:

The total cost of the project without donations will be in the ball park of $475.

Funding source:

Funding sources for this project are out of pocket, primarily composed of private and personal funding.

Project Schedule:
Out lined by the schedule in Appendix E the Gantt chart is the primary source of scheduling for the project to management. The schedule shows project completeness and hours needed to complete the projects design, analysis, rendering, and projected manufacturing of parts. The Gantt chart also keeps track of timing issues conflicts and deadlines in which the project must meet to be on track with the progress of this product. The total projected time for completion of the proposal is 59 days. Within the 59 day period scheduled to get the proposal done it will take

Human resources:
Primary human resources are those found at the CWU Mechanical Engineering dept. for student development through engineering practices.
Contributors to this project have been: Dr. Johnson, Ted Bramble, Matt Burvee, Charles Pringle.

Physical Resources:
Hogue Laboratories on Central Washington University campus in Ellensburg WA.

Conclusion:

This project is expected to be a successful due to design requirements such as weight, manufacturability of the components and experience of the machinist making the parts.

The weight will make this design successful due the weight reduction of this model of split board binding compared to that of the benchmark. Weight is of primary concern do to the alpine climbing style of today's split boarder seeking the lightest gear on the market.

The manufacturability will also make this project a success due to the limited use of expensive and tough materials such as titanium and stainless steel. Aluminum is the primary metal used in terms of volume of material being removed due to the high level of machinability and time to remove material from stock.

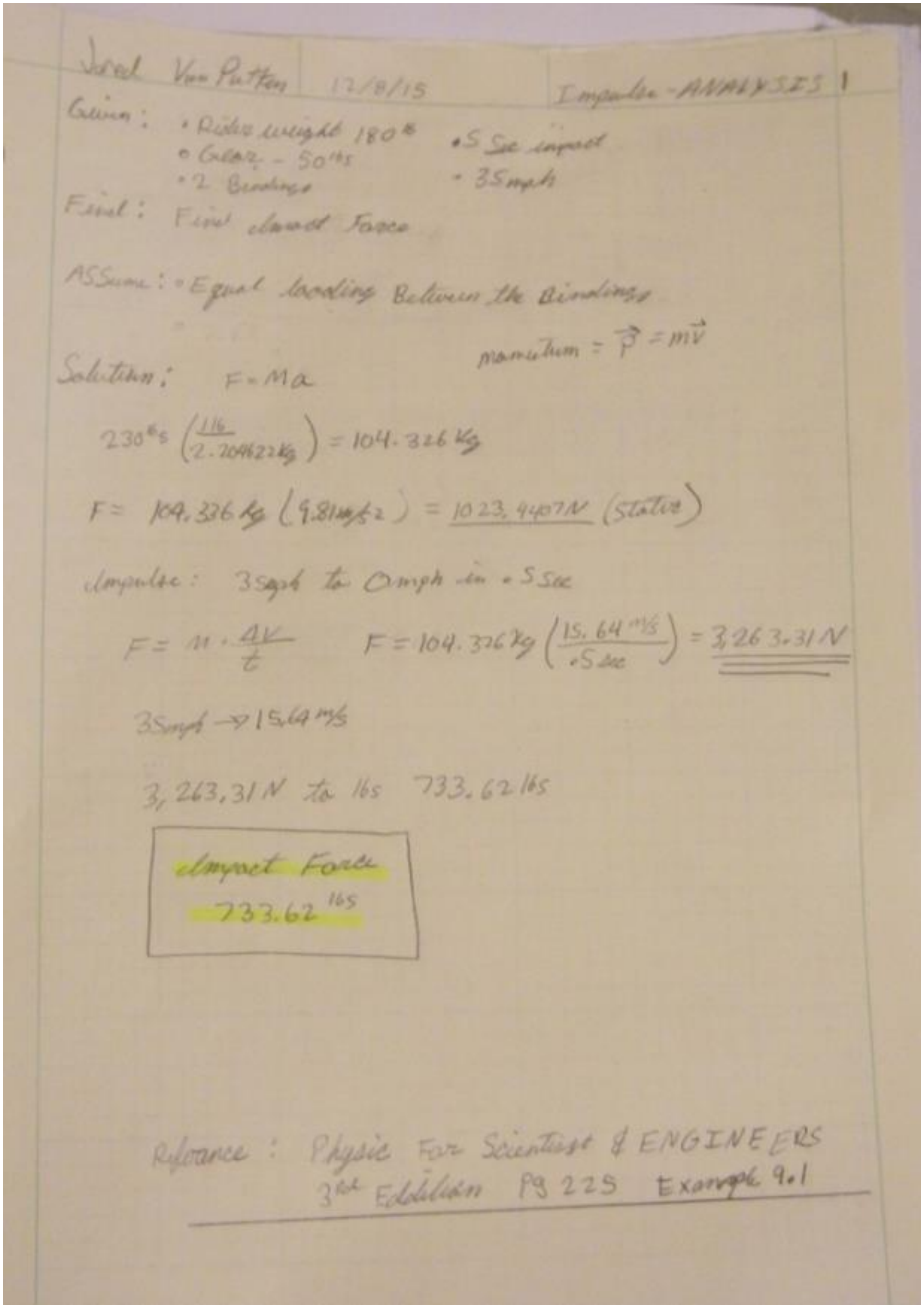
The experience of the machinist making the parts will make this project a success as he has 2 years of CNC programming and manual machining experience using CNC mills, manual mills, CNC Lathes and manual lathes. The Machinist is also an experienced fixture fabricator as he has 6 years of welding and fabricating experience.

Because of the weight and machinability of the product and the experience of the manufacture, this project is projected to be a success when completed in spring of 2016.

Acknowledgements:

- Matt Burvee's support regarding machinery and tooling.
- Dr. Johnson's support regarding the metallurgy and senior project critique.
- Charles Pringle's support for project and design critique.
- Central Washington Universities support for the shop use, machinery use, CAD program use.
- Ted Brambles support regarding help with CNC machinery and manual machinery and programming knowledge of CAD/CAM software.

APPENDIX A- Analyses



Jarel Van Putten 12/8/15 Impulse - ANALYSIS 1

Given: • Rider weight 180# • .5 Sec impact
• Gear - 50lbs • 35mph
• 2 Bindings

Find: Find clamp Force

ASSume: • Equal loading Between the Bindings

momentum = $\vec{P} = m\vec{v}$

Solution: $F = Ma$

$230^{lbs}\left(\frac{1lb}{2.204622kg}\right) = 104.326\ kg$

$F = 104.336\ kg\ (9.81\ m/s^2) = \underline{1023.4407N}$ (static)

Impulse: 35mph to 0mph in .5 Sec

$F = m \cdot \frac{\Delta V}{t}$ $F = 104.326\ kg\left(\frac{15.64\ m/s}{.5\ sec}\right) = \underline{\underline{3,263.31\ N}}$

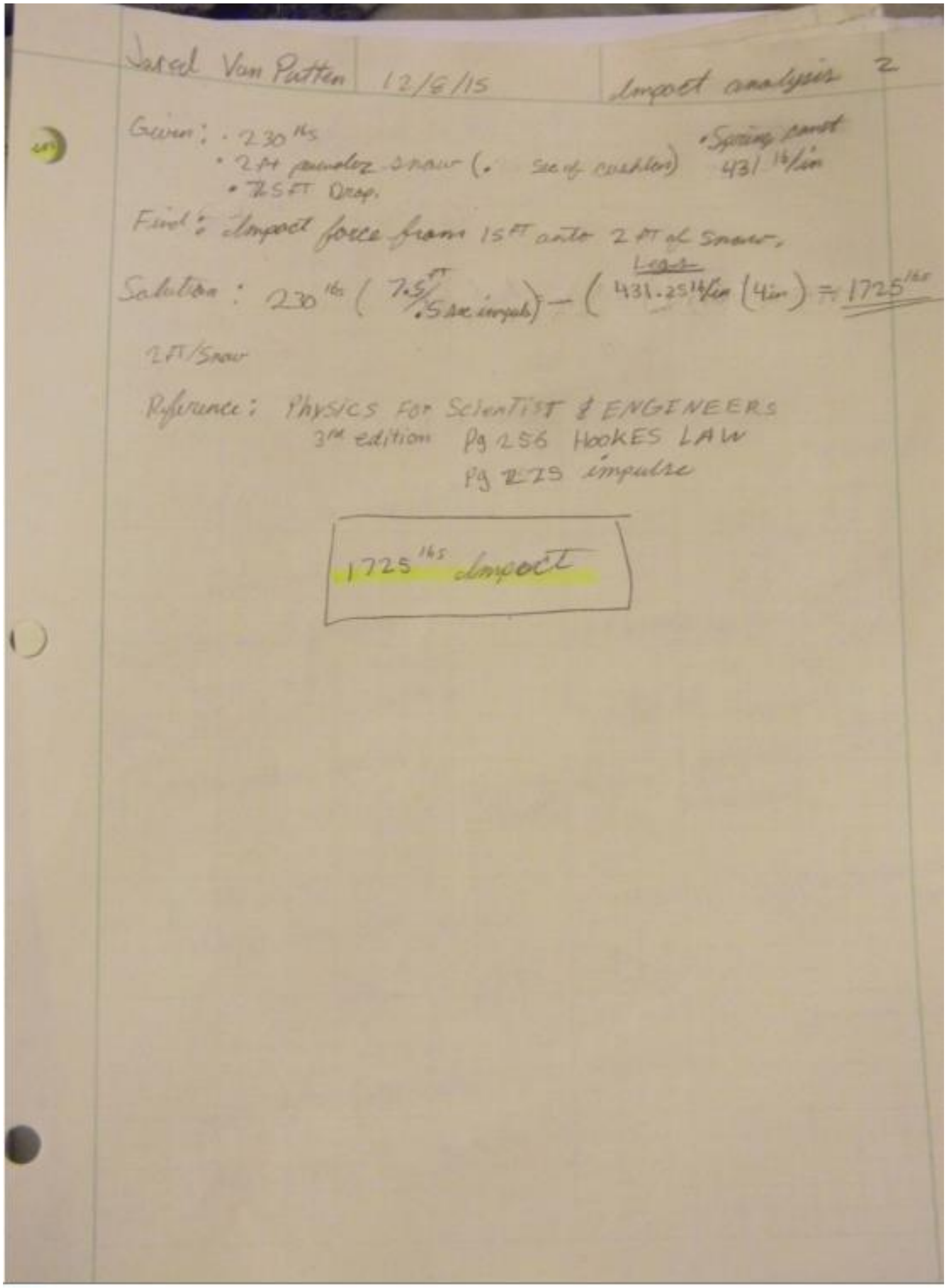
35mph → 15.64 m/s

3,263.31 N to lbs 733.62 lbs

$\boxed{\text{Impact Force } 733.62^{lbs}}$

Reference: Physic For Scientist & ENGINEERS
3rd Edition Pg 225 Example 9.1

Figure 4 Analysis 1



Jared Van Putten 12/6/15 Impact analysis 2

Given: • 230 lbs
• 2 ft powder snow (. see of cushion) • Spring const 431 lb/in
• 7.5 FT Drop.

Find: Impact force from 15 FT onto 2 FT of snow.

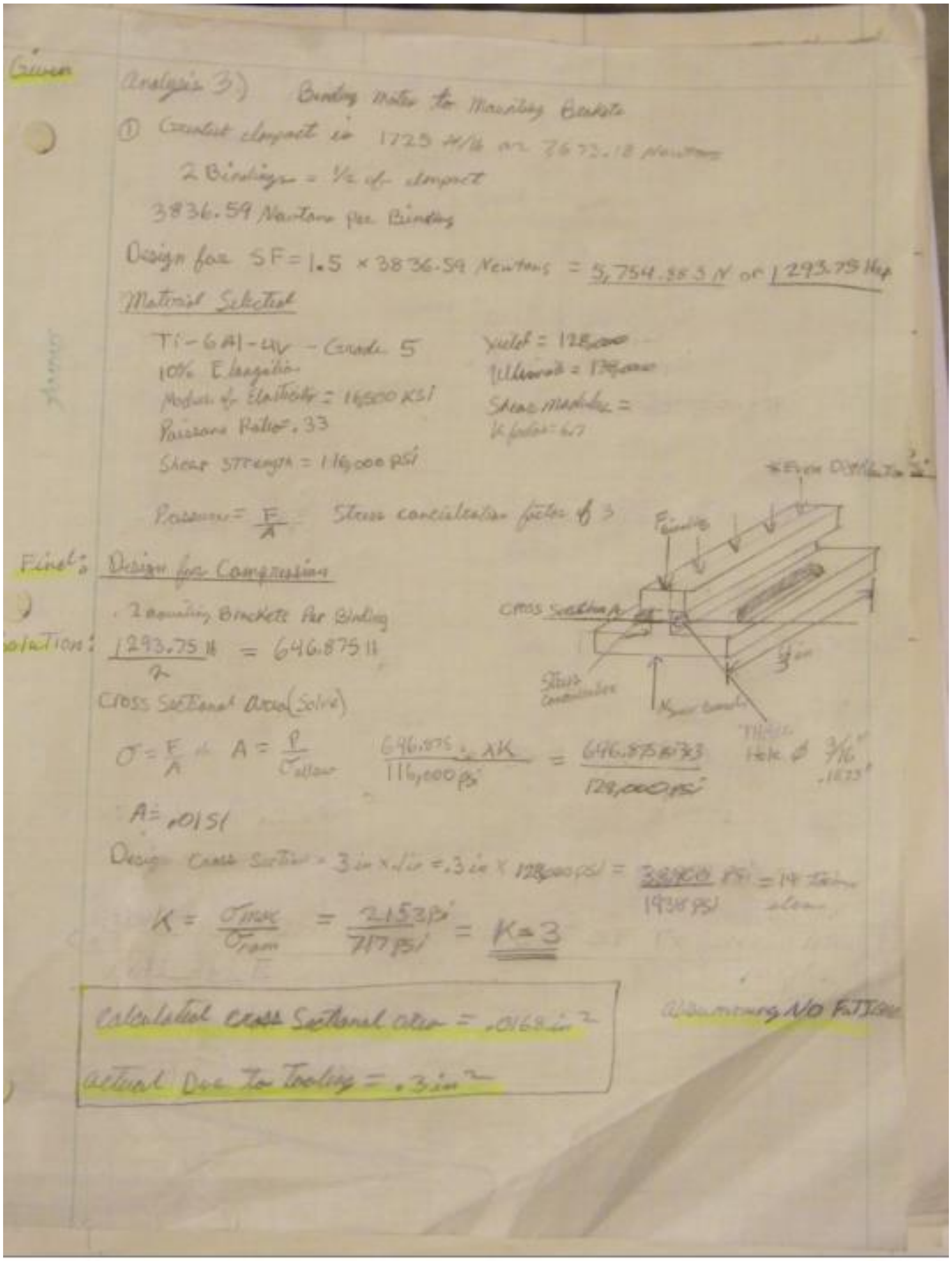
Solution: 230 lbs (7.5 FT / .5 sec impulse) − (Legs 431.25 lb/in (4 in)) = 1725 lbs

2 FT/Snow

Reference: PHYSICS FOR SCIENTIST & ENGINEERS
3rd edition Pg 256 HOOKES LAW
Pg 229 impulse

1725 lbs Impact

Figure 5 Analysis 2



Given

Analysis 3) Binding mate to Mounting Brackets

① Greatest impact is 1725 lb/ft or 7673.18 Newtons

2 Bindings = 1/2 of impact

3836.59 Newtons per Binding

Design for SF = 1.5 × 3836.59 Newtons = 5,754.883 N or 1293.75 lbf

Material Selected

Ti-6Al-4V - Grade 5

10% Elongation

Modulus of Elasticity = 16500 KSI

Poissons Ratio = .33

Shear strength = 116,000 psi

Yield = 128,000

Ultimate = 138,000

Shear modulus =

K factor = 6.7

Pressure = $\frac{F}{A}$ Stress concentration factor of 3

Find: Design for Compression

· 2 mounting Brackets Per Binding

Solution: $\frac{1293.75\ lb}{2} = 646.875\ lb$

Cross Sectional Area (Solid)

$\sigma = \frac{F}{A}$ ∴ $A = \frac{P}{\sigma_{allow}}$ $\frac{646.875 \times K}{116{,}000\ psi} = \frac{646.875 \times 3}{128{,}000\ psi}$

A = .0151

Design Cross Section = 3 in × 1 in = .3 in × 128,000 psi = 38,400 psi = 19 ton

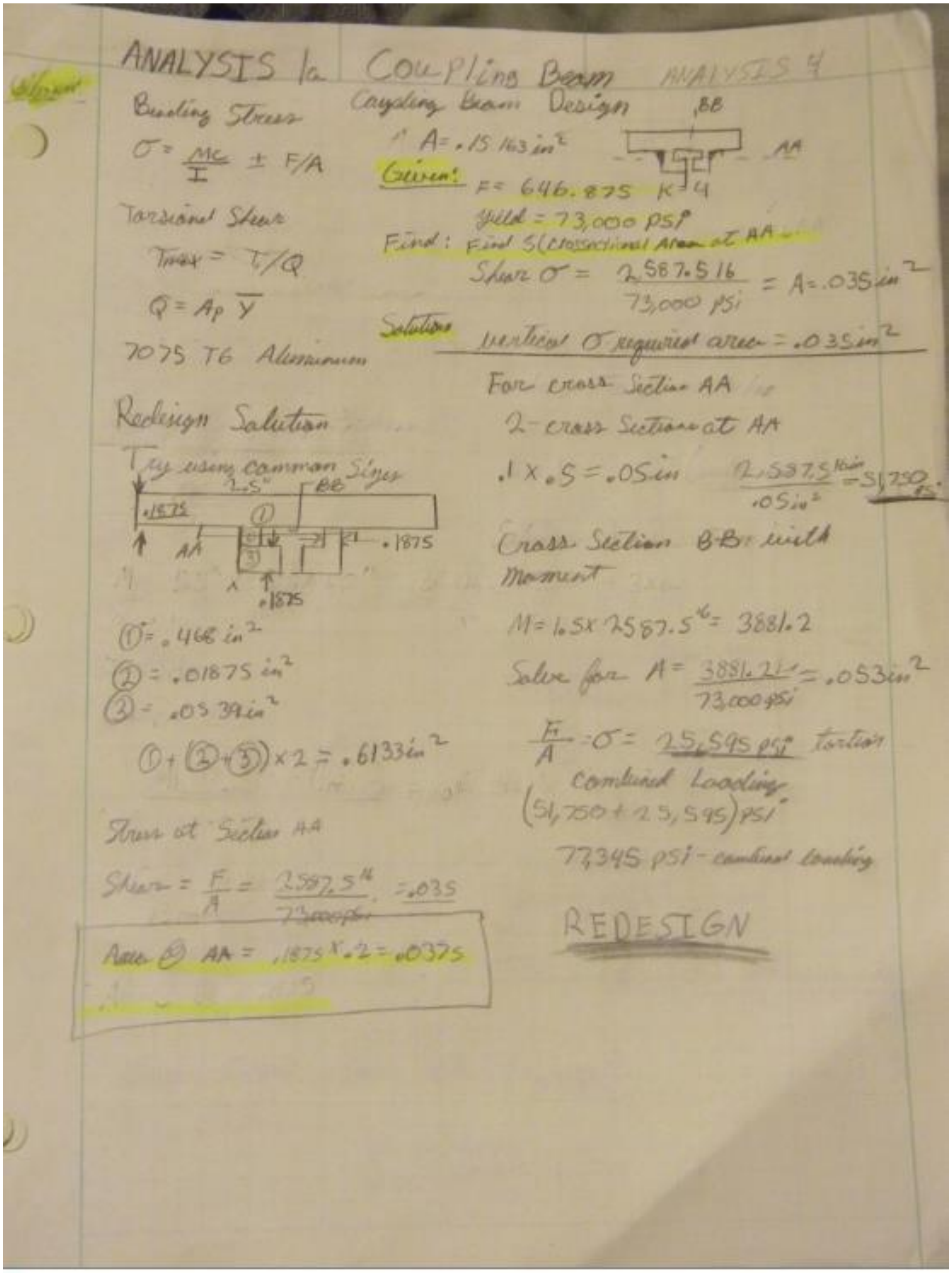
$K = \frac{\sigma_{max}}{\sigma_{nom}} = \frac{2153\ psi}{717\ psi} = \underline{K = 3}$

Calculated cross Sectional area = .0169 in²

actual Due To Tooling = .3 in²

Allowing NO FATIGUE

Figure 6 Analysis 3


ANALYSIS 1a Coupling Beam ANALYSIS 4

Bending Stress

$\sigma = \frac{Mc}{I} \pm F/A$

Torsional Shear

$\tau_{max} = T/Q$

$Q = A_p \bar{Y}$

7075 T6 Aluminum

Redesign Solution

Try using common Sizes

2.5" BB

.1875 ① AA ③ .1875

.1875

① = .468 in²

② = .01875 in²

③ = .0539 in²

① + (② + ③) × 2 = .6133 in²

Stress at Section AA

Shear = F/A = 2587.5 lb / 73000 psi = .035

Area @ AA = .1875 × .2 = .0375

Coupling Beam Design BB

A = .15163 in² AA

Given: F = 646.875 K = 4

yield = 73,000 psi

Find: Find S(crosssectional Area at AA

Shear σ = 2,587.5 lb / 73,000 psi = A = .035 in²

Solution: vertical σ required area = .035 in²

For cross Section AA

2-cross Sections at AA

.1 × .5 = .05 in   2,587.5 lb / .05 in² = 51,750 psi

Cross Section B-B with Moment

M = 1.5 × 2587.5 lb = 3881.2

Solve for A = 3881.2 / 73,000 psi = .053 in²

F/A = σ = 25,595 psi torsion

Combined Loading

(51,750 + 25,595) psi

77,345 psi - combined loading

REDESIGN

Figure 7 Analysis 4

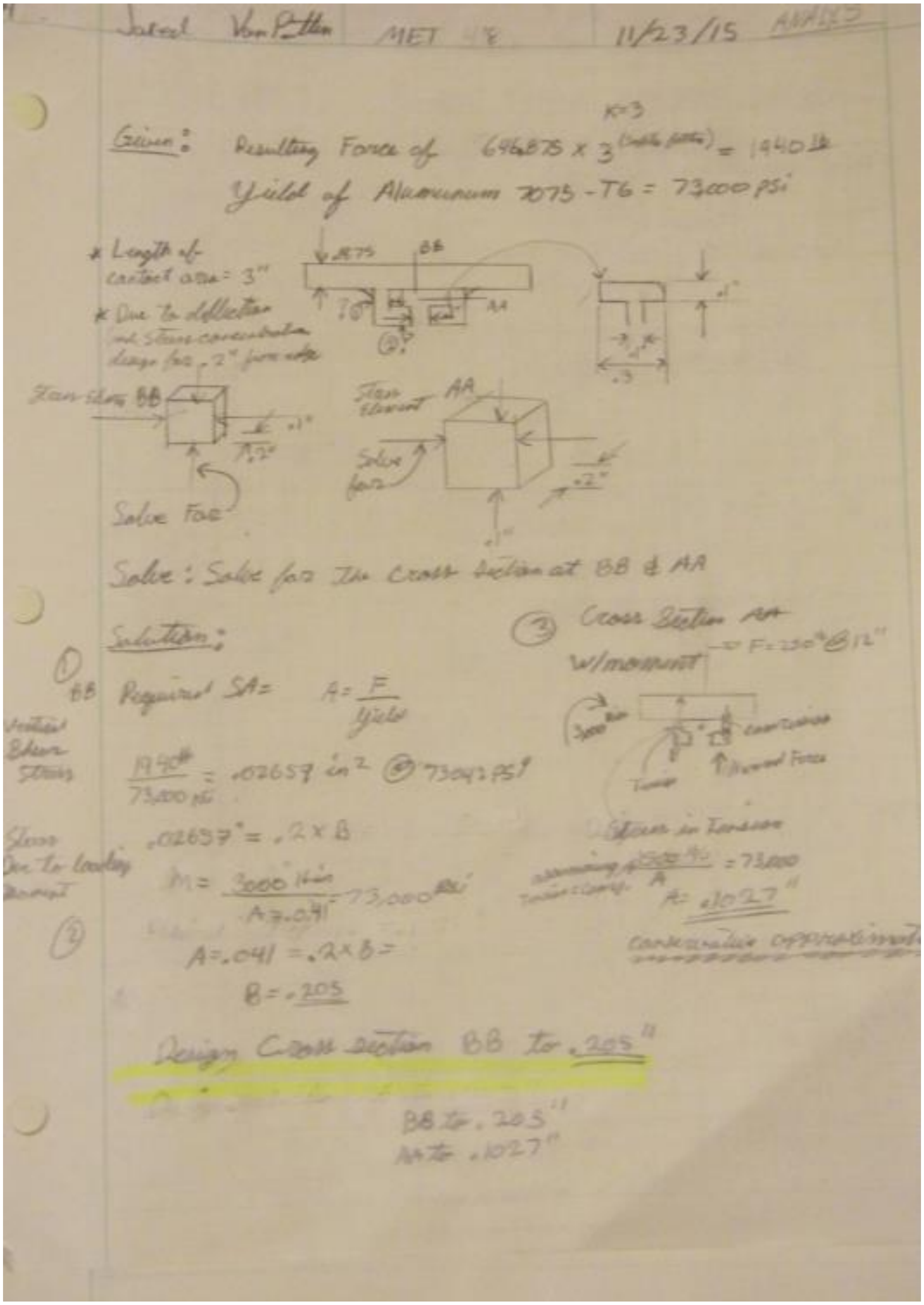


Figure 8 Analysis 5

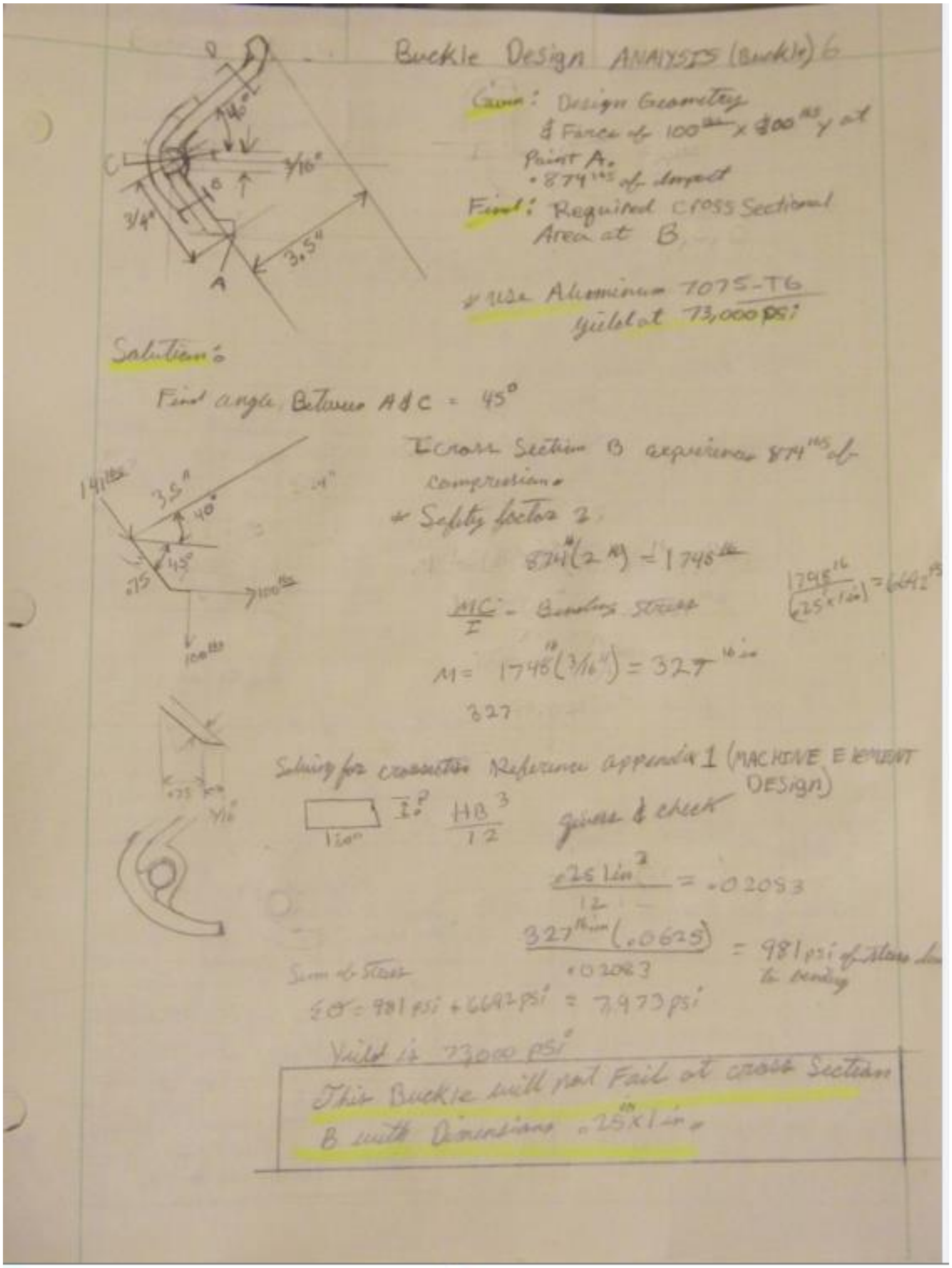
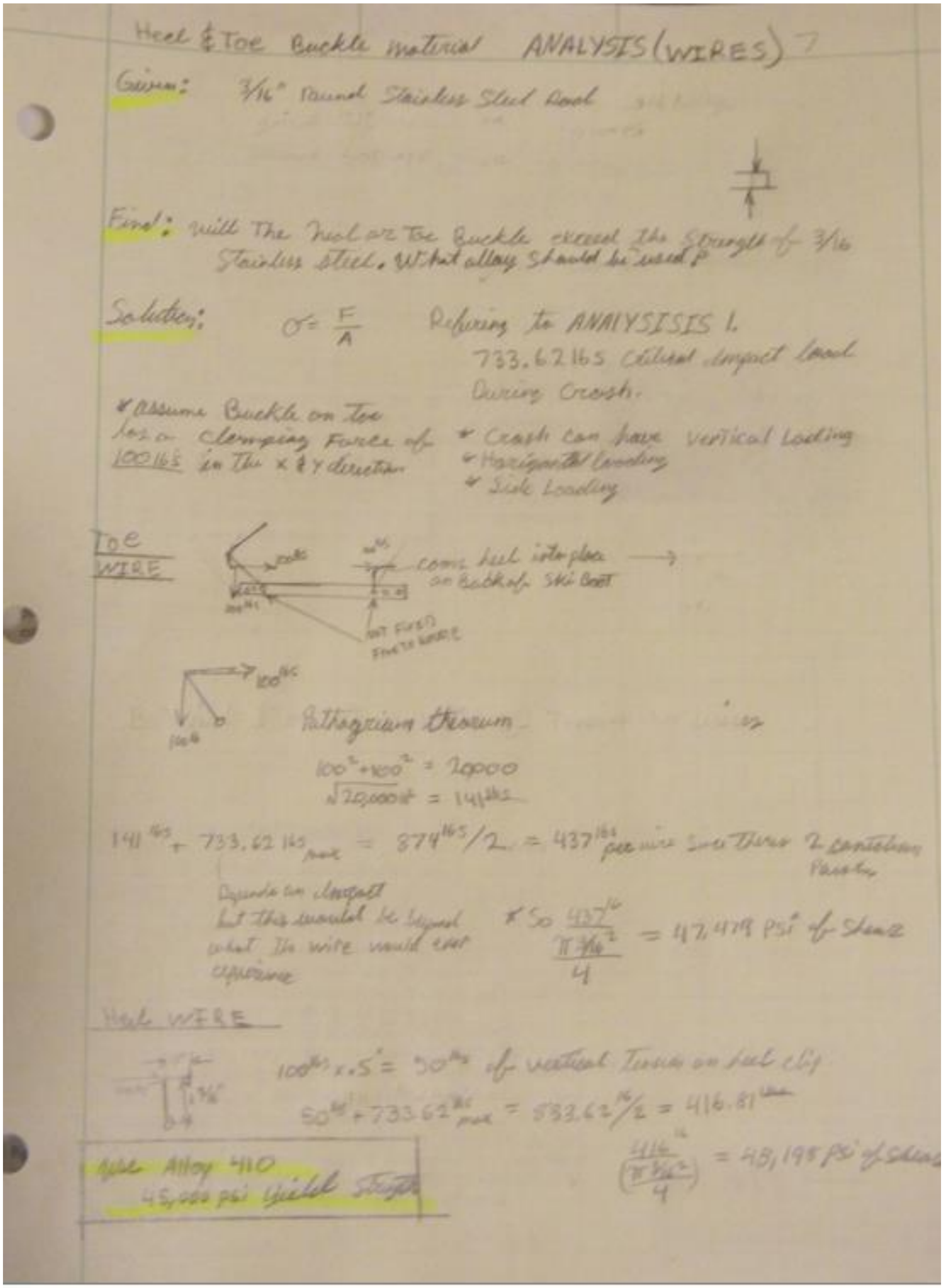


Figure 9 Analysis 6


Heel & Toe Buckle material ANALYSIS (WIRES) 7

Given: 3/16" round Stainless Steel Rod

Find: will the heel or toe buckle exceed the strength of 3/16 Stainless Steel. What alloy should be used?

Solution: $\sigma = \frac{F}{A}$ Refering to ANALYSISIS 1.
733.62 lbs critical impact load During Crash.

* assume Buckle on Toe has a clamping Force of 100 lbs in the x & y direction

* Crash can have vertical Loading
* Horizontal Loading
* Side Loading

Toe WIRE

comes heel into place on Back of Ski Boot

Pathagrian theorum

$100^2 + 100^2 = 20000$

$\sqrt{20{,}000} = 141^{lbs}$

$141^{lbs} + 733.62\ lbs_{max} = 874^{lbs}/2 = 437^{lbs}$ per wire since there 2 cantilever Parts

Depends on impact but this would be beyond what the wire would ever experience

* So $\frac{437^{lb}}{\frac{\pi\,{3/16}^2}{4}} = 47{,}479$ psi of Shear

Heel WIRE

$100^{lbs} \times .5 = 50^{lbs}$ of vertical Tension on heel clip

$50^{lb} + 733.62^{lbs}_{max} = 833.62^{lb}/2 = 416.81^{lbs}$

$\frac{416^{lb}}{\left(\frac{\pi\,{3/16}^2}{4}\right)} = 48{,}195$ psi of Shear

Use Alloy 410
45,000 psi yield Strength

Figure 10 Analysis 7

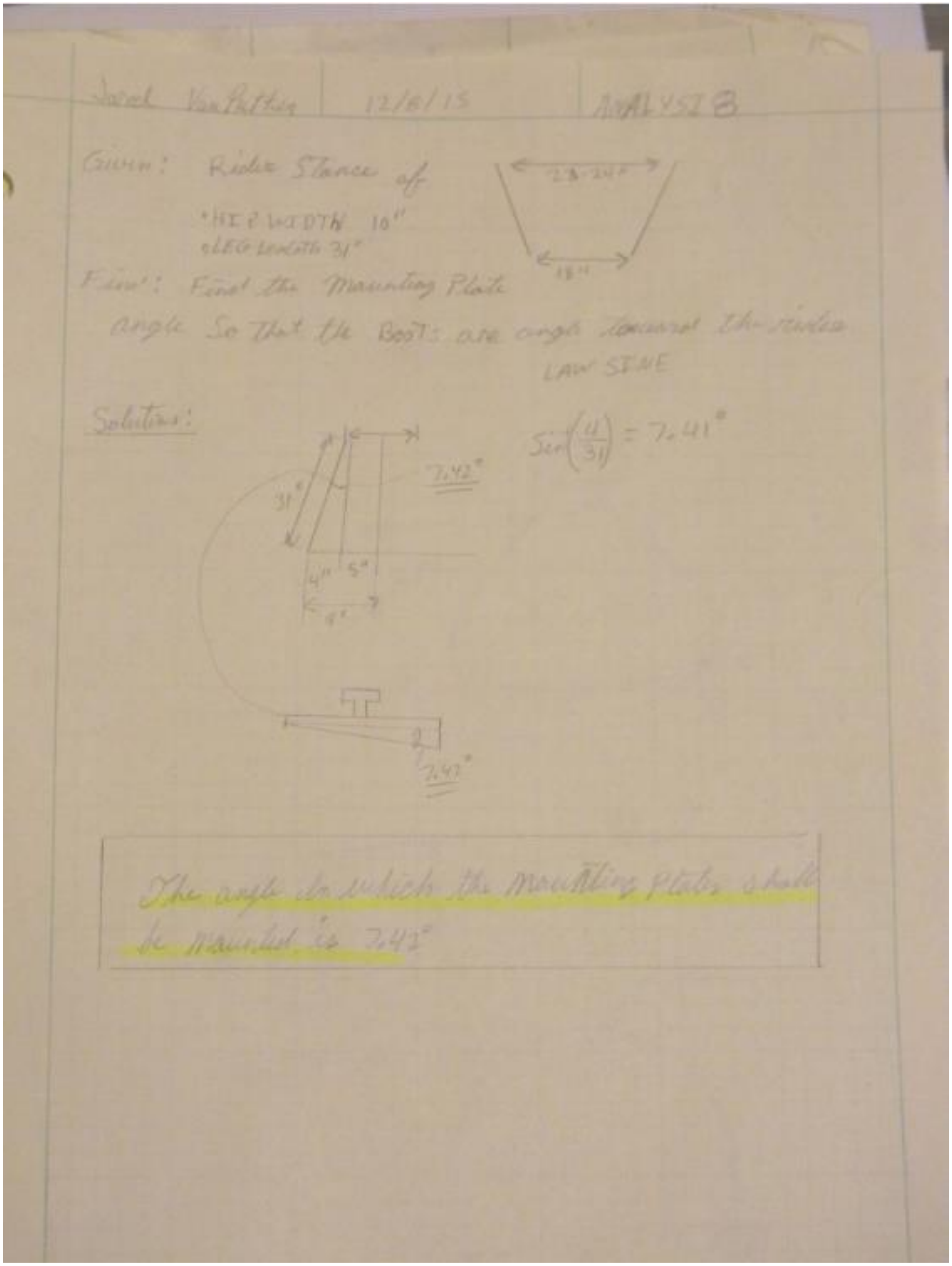
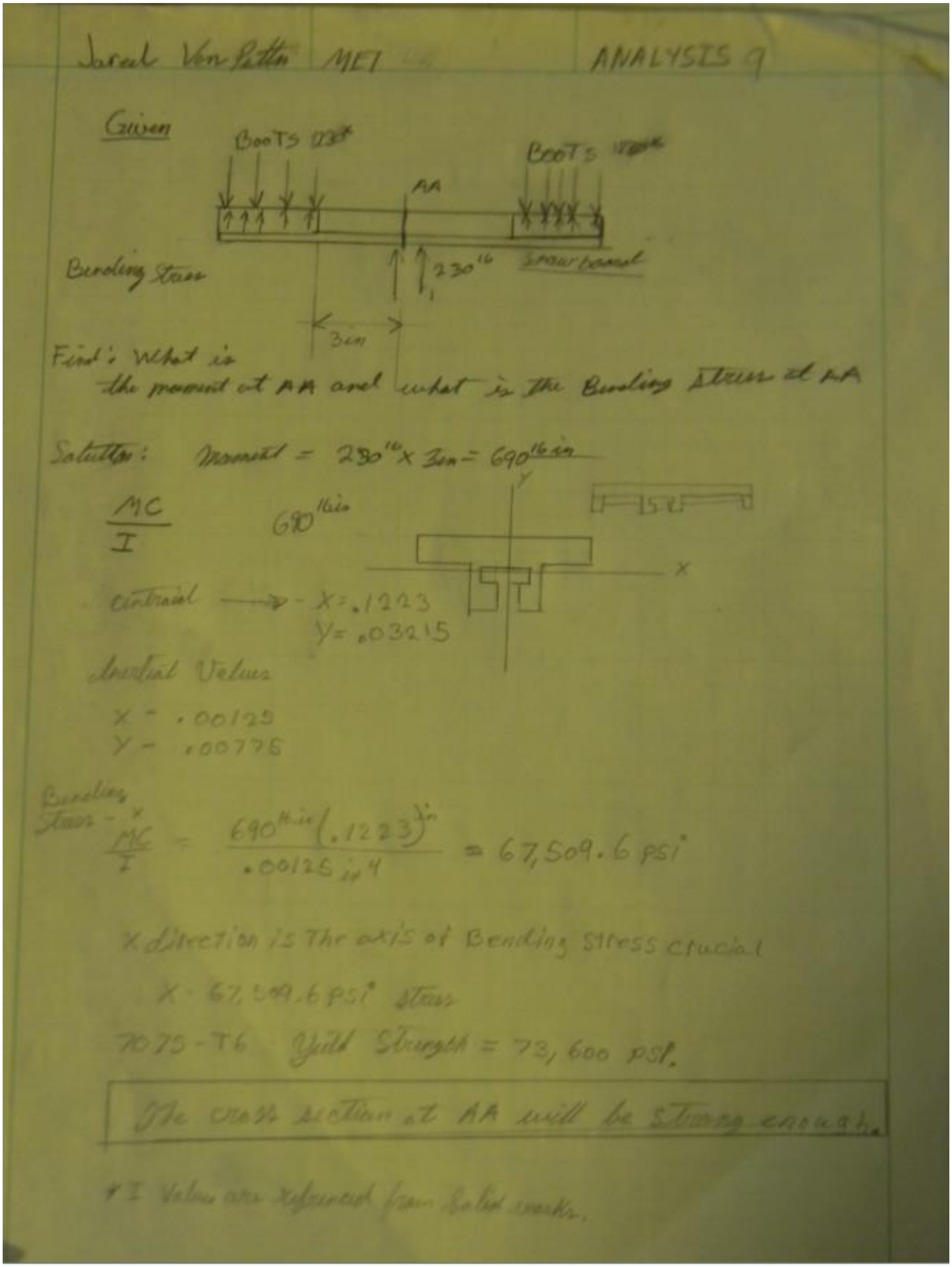


Figure 11 Analysis 8



Jarad Von Patten MET ANALYSIS 9

Given

BooTS 173# BooTS 173#

AA

Bending Stress

230 lb Snow board

3in

Find: What is the moment at AA and what is the Bending Stress at AA

Solution: moment = 230 lb x 3in = 690 lb·in

$\frac{MC}{I}$ 690 lb·in

centroid → X = .1223, Y = .03215

Inertial Values

X - .00125

Y - .00775

Bending Stress - X

$\frac{MC}{I} = \frac{690^{lb \cdot in}(.1223)^{in}}{.00125\ in^4} = 67{,}509.6\ psi^*$

X direction is the axis of Bending Stress crucial

X - 67,509.6 psi* stress

7075-T6 Yield Strength = 73,600 psi.

$\boxed{\text{The cross section at AA will be strong enough.}}$

*I Values are referenced from Solid works.

Figure 12 Analysis 9

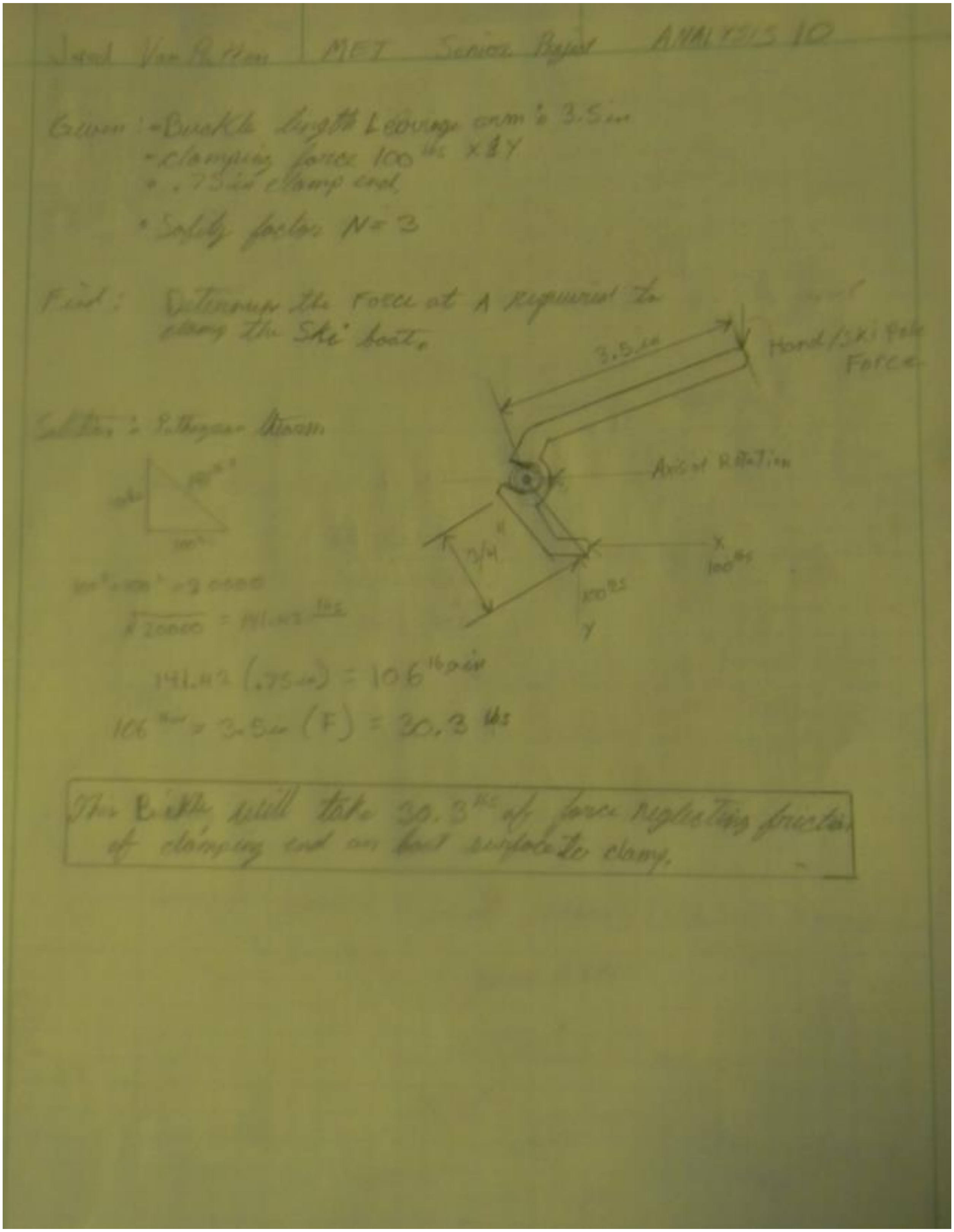


Figure 13 Analysis 10

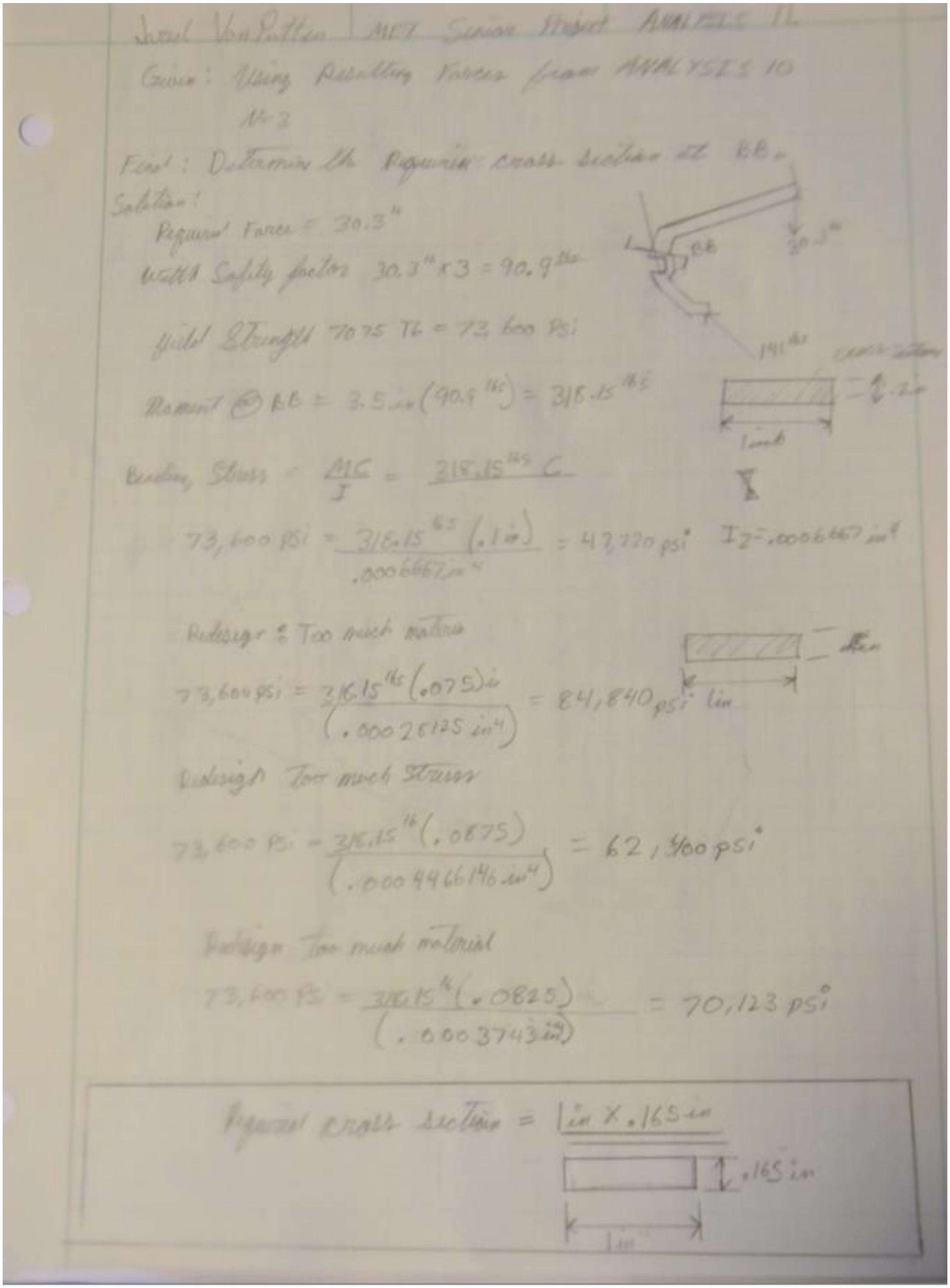


Figure 14 Analysis 1

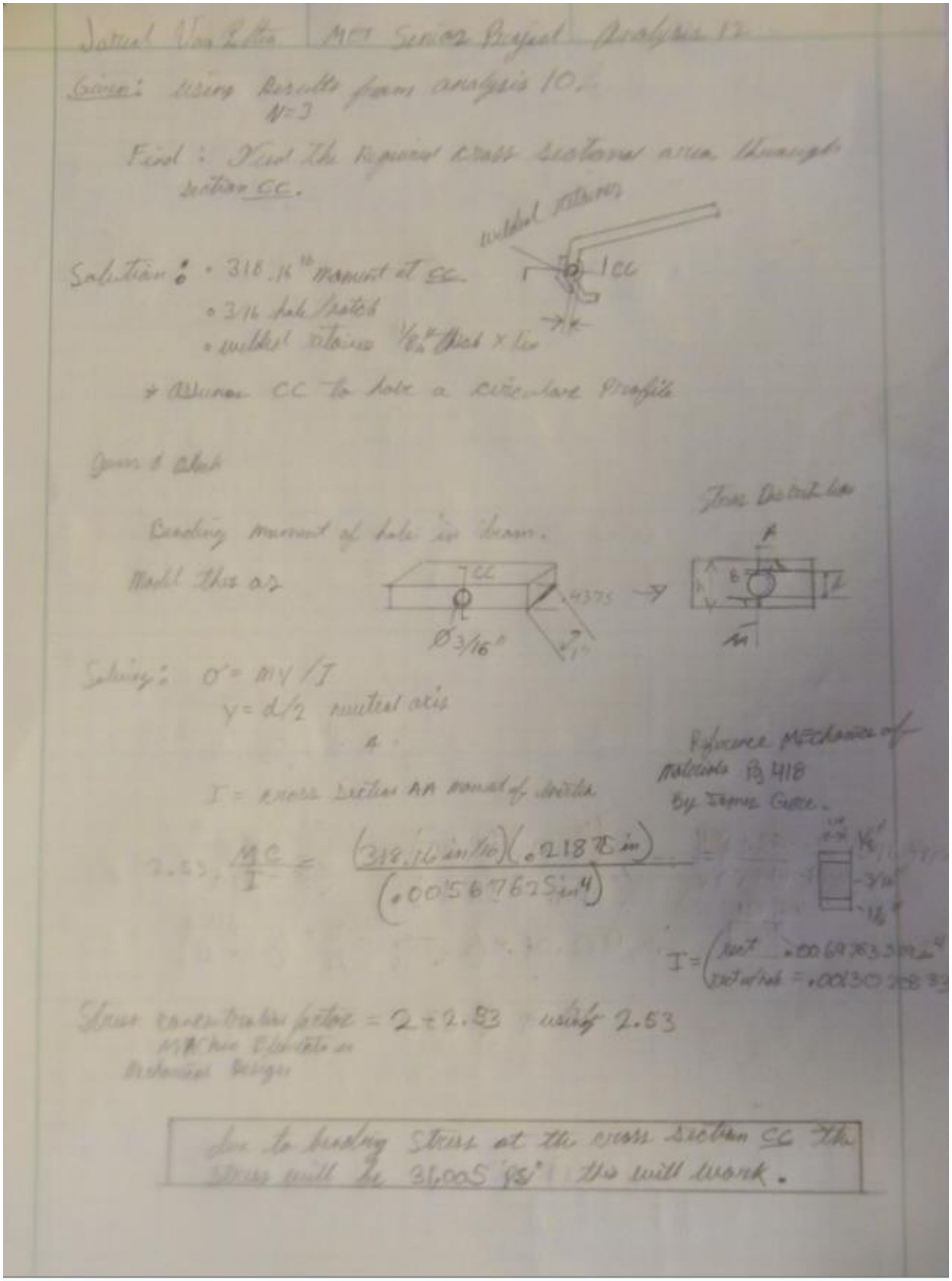
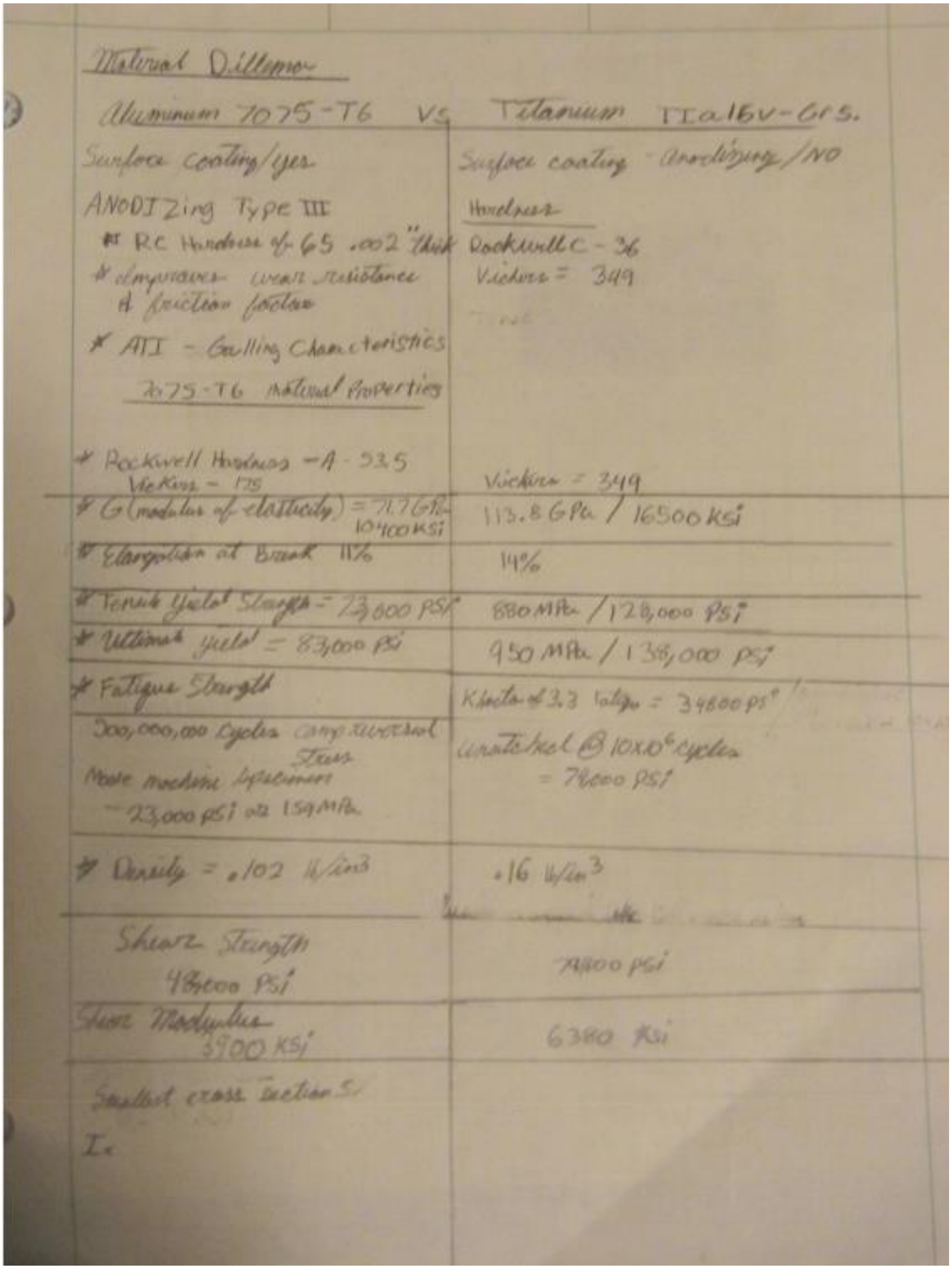


Figure 15 Anakysis 12



Material Dillemo

Aluminum 7075-T6 vs	Titanium TIal6V-Gr5.
Surface coating/yes	Surface coating - anodizing/NO
ANODIZing Type III	Hardness
RC Hardness of 65 .002" thick	Rockwell C - 36
* improves wear resistance * friction factor	Vickers = 349
* ATI - Galling Characteristics	
7075-T6 Material Properties	
* Rockwell Hardness - A - 53.5 Vickers - 175	Vickers = 349
* G (modulus of elasticity) = 71.7 GPa 10400 KSI	113.8 GPa / 16500 ksi
* Elongation at Break 11%	14%
* Tensile Yield Strength - 73,000 PSI	880 MPa / 128,000 PSI
* Ultimate yield = 83,000 PSI	950 MPa / 138,000 PSI
* Fatigue Strength	Kfactor of 3.3 fatigue = 34800 psi
500,000,000 cycles completed Stress	unnotched @ 10x10⁶ cycles
More machine specimen	= 78000 PSI
- 23,000 psi or 159 MPa	
* Density = .102 lb/in³	.16 lb/in³
Shear Strength 48,000 PSI	79800 psi
Shear Modulus 3900 KSI	6380 ksi
Smallest cross section S	
Ix	

Figure 16 Material Properties Mat Lab

Cross section Properties (Via Solid Works) Inertial Properties of Binding Beam (smallest cross section)

Section properties of the selected face of Part1
Area = 0.15165 inches^2
Centroid relative to output coordinate system origin: (inches)
X = -9e-005
Y = 0.03215
Z = 0
Moments of inertia of the area, at the centroid: (inches ^ 4)

Lxx = 0.00125	Lxy = 0	Lxz = 0
Lyx = 0	Lyy = 0.00775	Lyz = 0
Lzx = 0	Lzy = 0	Lzz = 0.009

Polar moment of inertia of the area, at the centroid = 0.009 inches ^ 4
Angle between principal axes and part axes = 0.01043 degrees
Principal moments of inertia of the area, at the centroid: (inches ^ 4)
Ix = 0.00125
Iy = 0.00775
Moments of inertia of the area, at the output coordinate system: (inches ^ 4)

LXX = 0.0014	LXY = 0	LXZ = 0
LYX = 0	LYY = 0.00775	LYZ = 0
LZX = 0	LZY = 0	LZZ = 0.00915

Cross section Properties (Via Solid Works) Inertial Properties of Mounting Bracket (smallest cross section)

Section properties of the selected face of Mounting bracket 7 degree angle

Area = 0.05921 inches^2

Centroid relative to output coordinate system origin: (inches)
X = 0.00017
Y = 0.24537
Z = -1.5

Moments of inertia of the area, at the centroid: (inches ^ 4)

Lxx = 0.0008	Lxy = 0	Lxz = 0
Lyx = 0	Lyy = 0.00025	Lyz = 0
Lzx = 0	Lzy = 0	Lzz = 0.00105

Polar moment of inertia of the area, at the centroid = 0.00105 inches ^ 4

Angle between principal axes and part axes = 90.26 degrees

Principal moments of inertia of the area, at the centroid: (inches ^ 4)
Ix = 0.00025
Iy = 0.0008

Moments of inertia of the area, at the output coordinate system: (inches ^ 4)

LXX = 0.13759	LXY = 0	LXZ = -2e-005
LYX = 0	LYY = 0.13347	LYZ = -0.02179
LZX = -2e-005	LZY = -0.02179	LZZ = 0.00462

APPENDIX B- Drawings

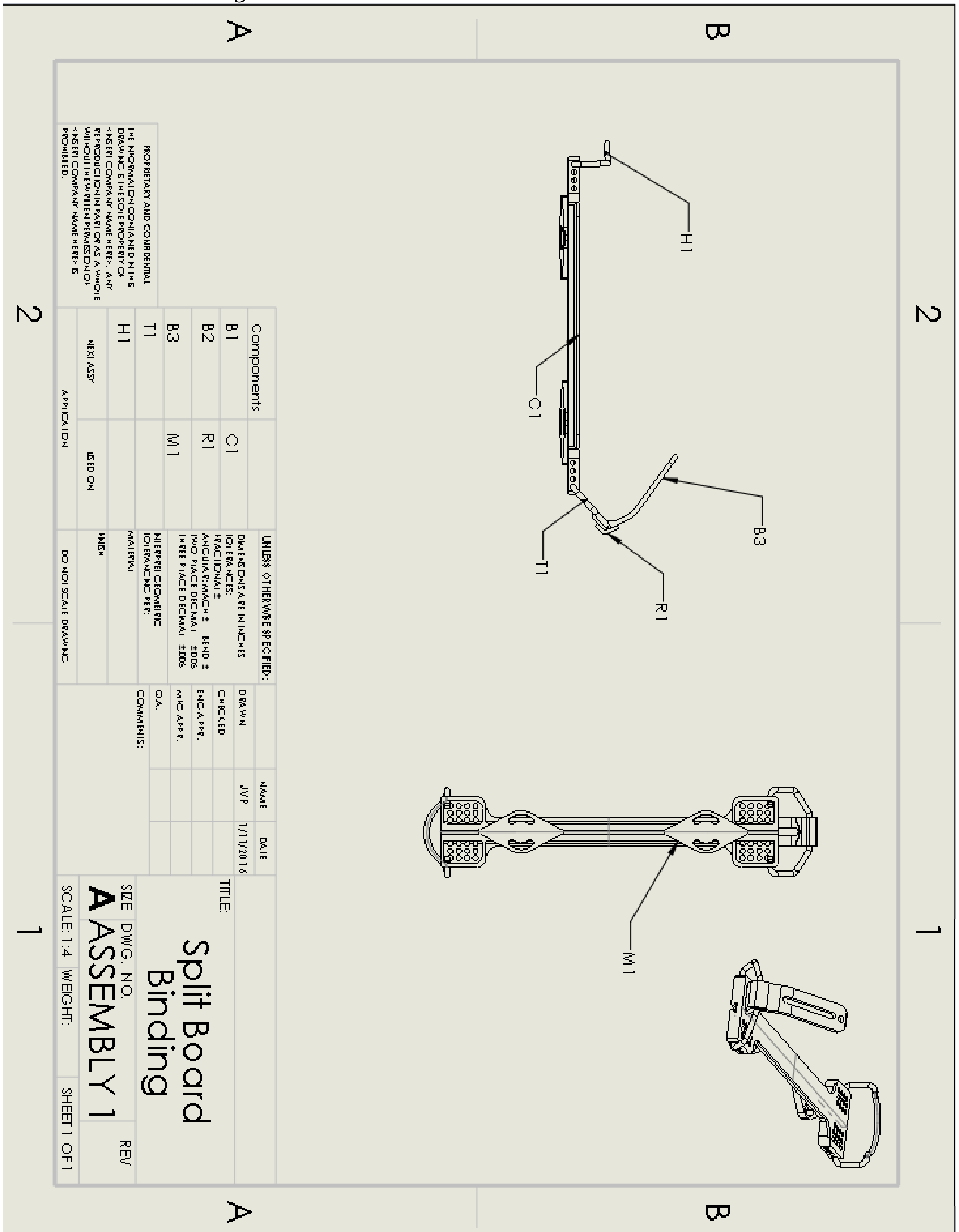


Figure 17 Assembly

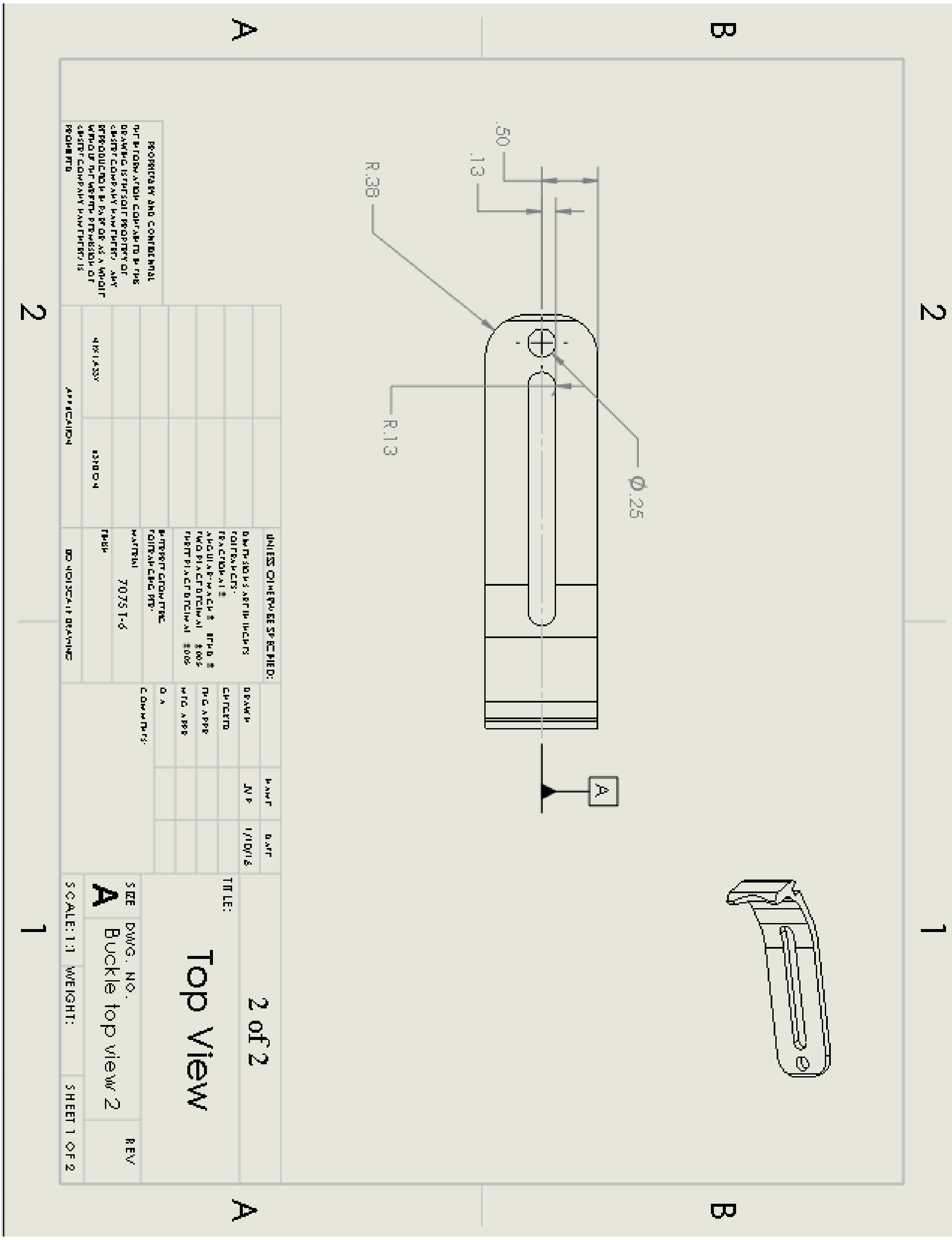


Figure 18 Top View Toe Buckle

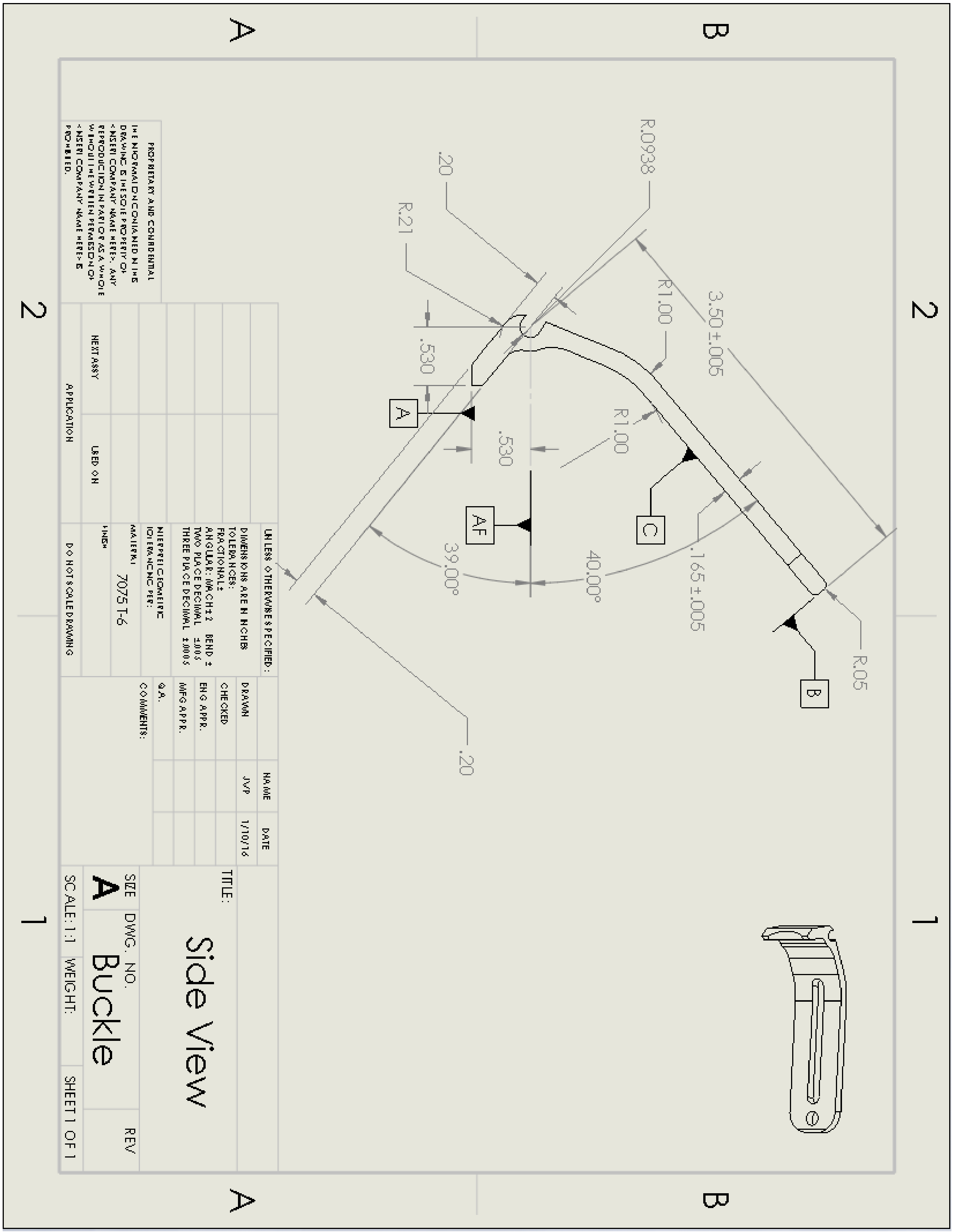


Figure 19 Side View Toe Buckle

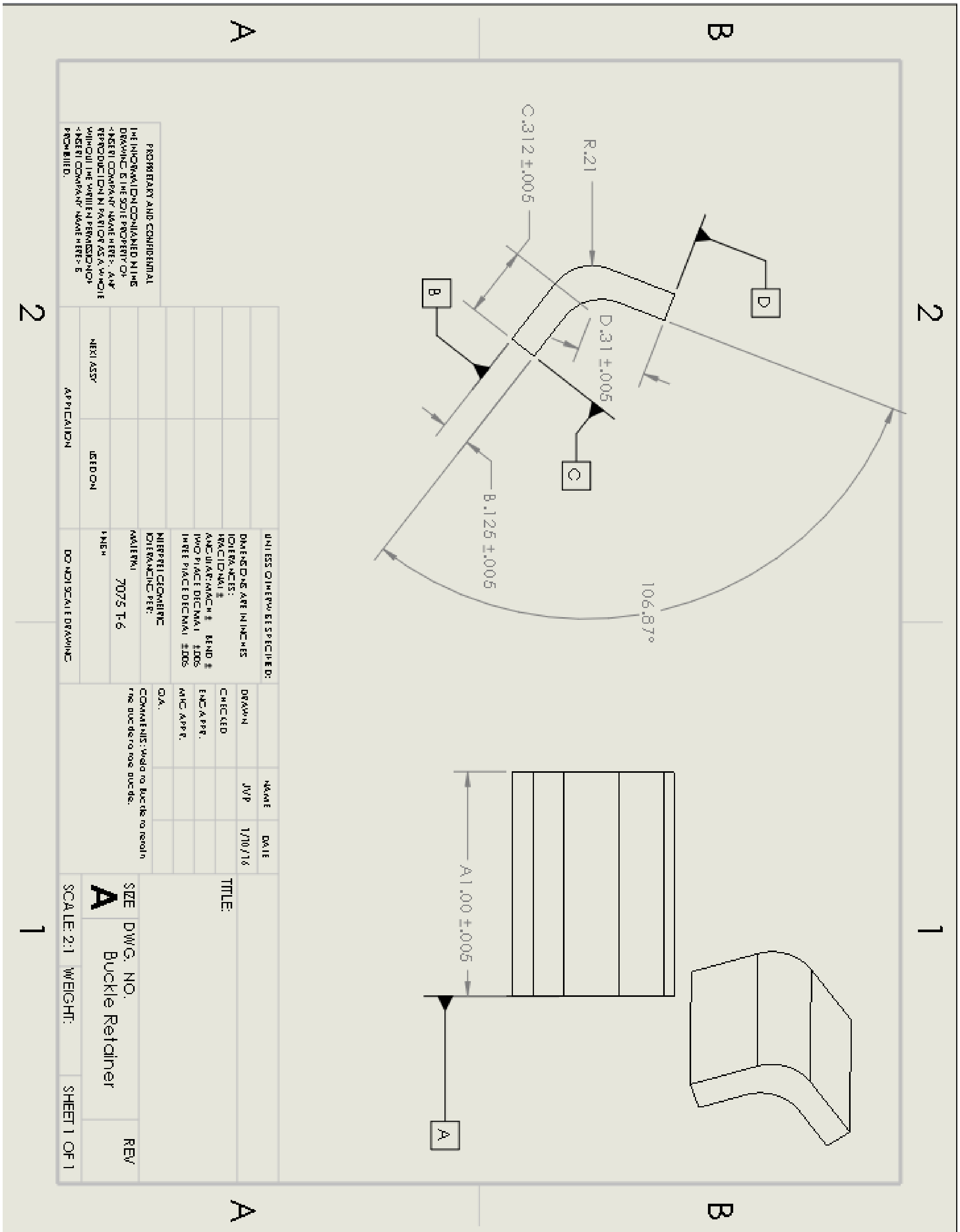


Figure 20 Buckle Retainer

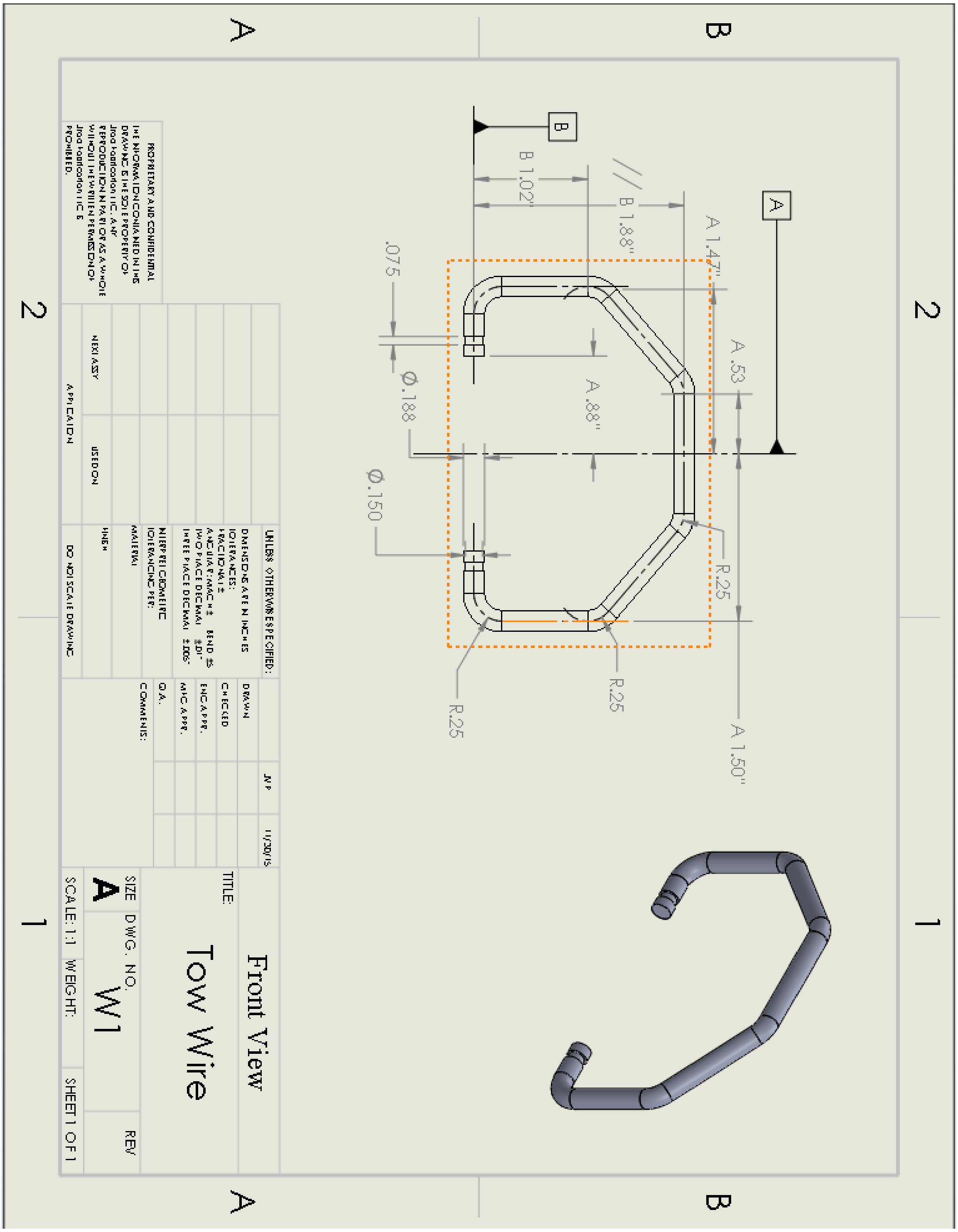


Figure 21 Toe Wire

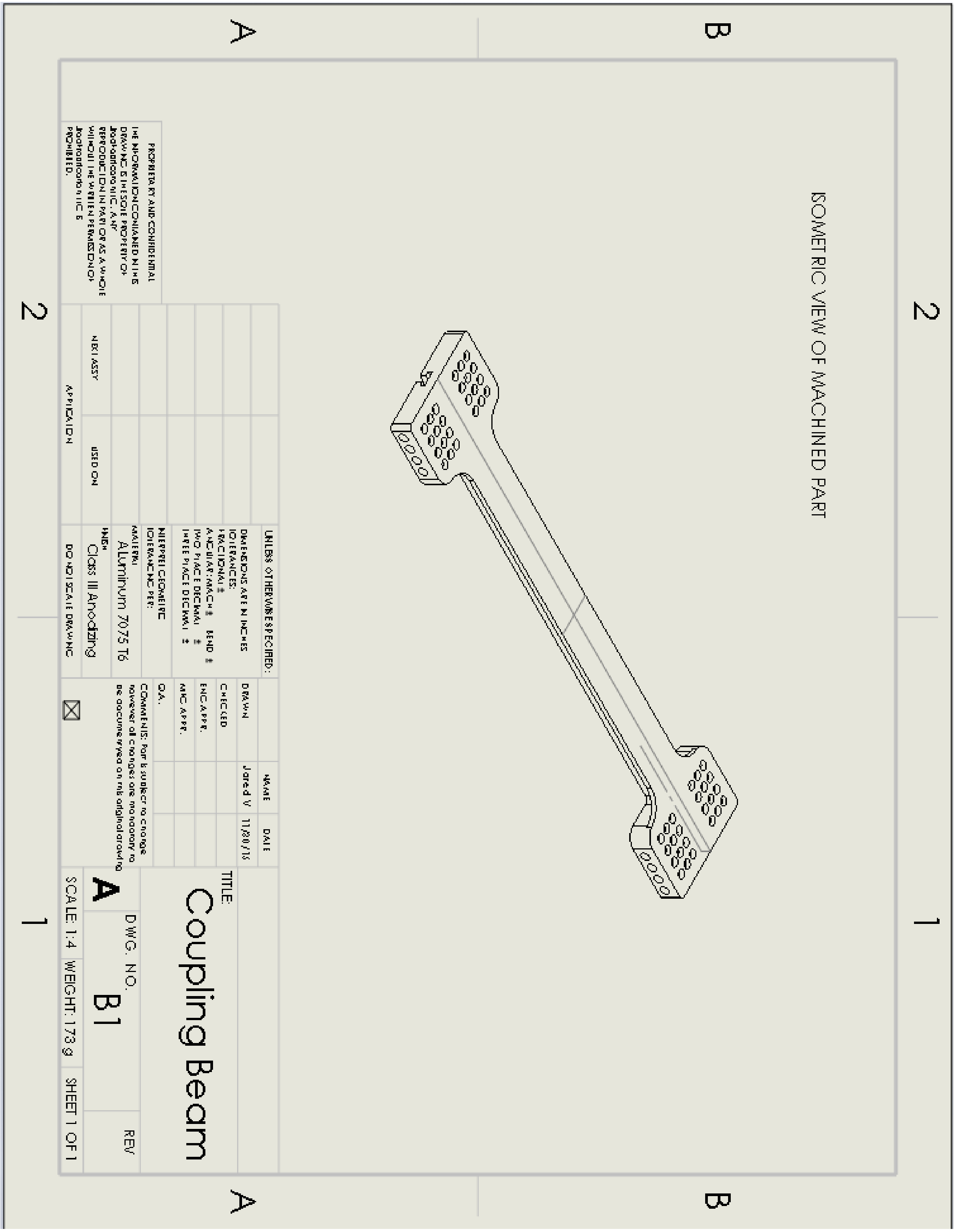


Figure 22Coupling Beam

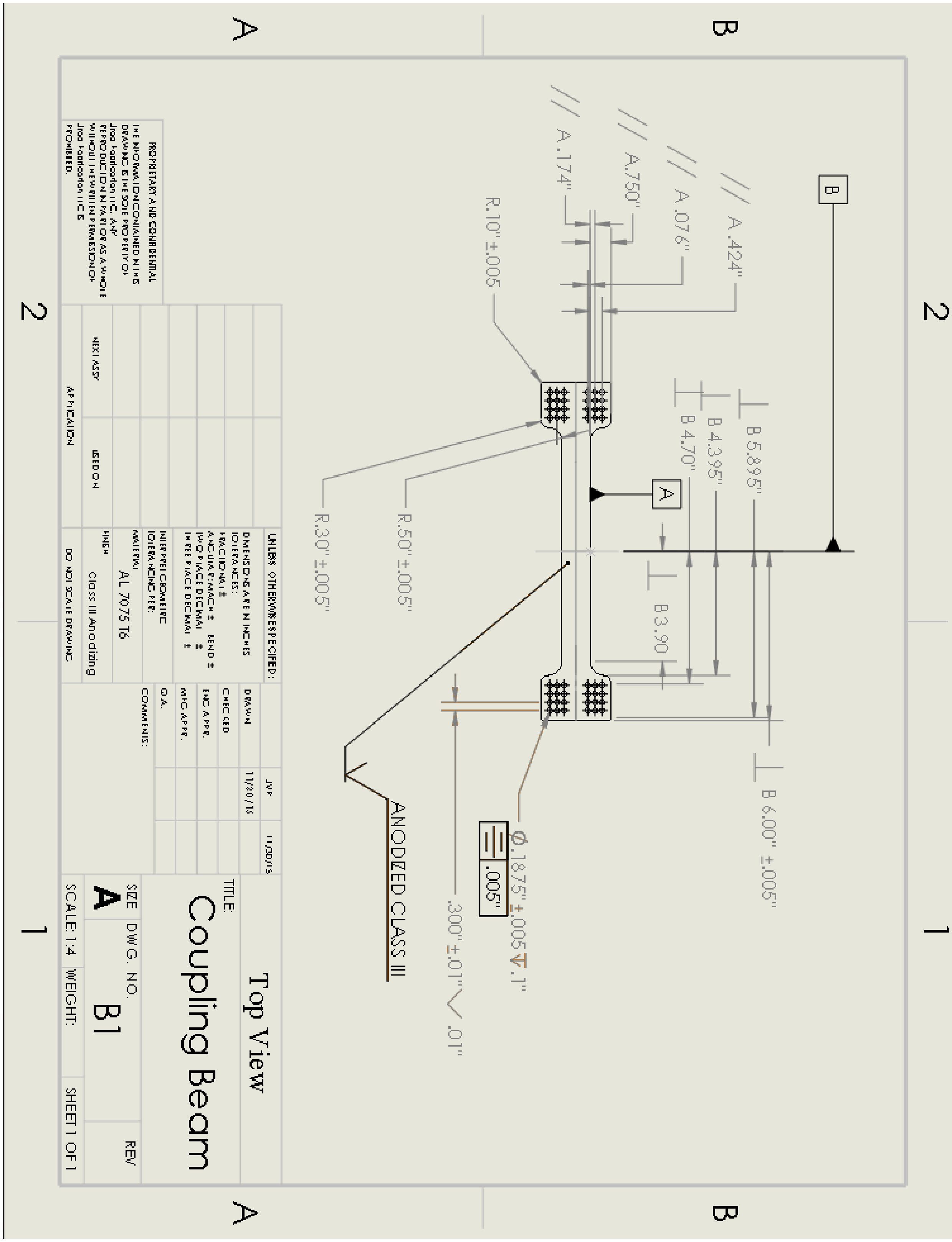


Figure 23 Top View Coupling Beam

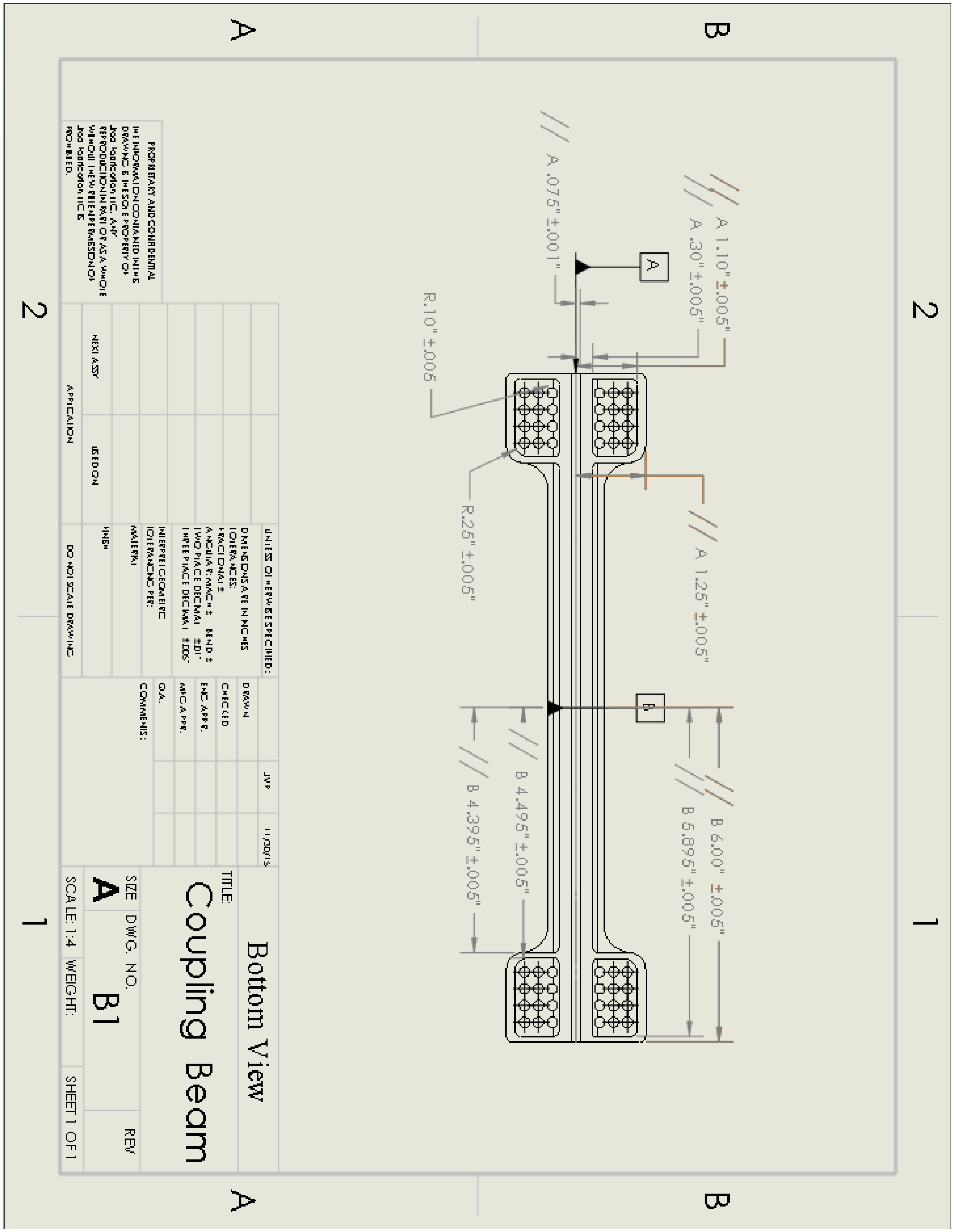


Figure 24 Coupling Beam Bottom View

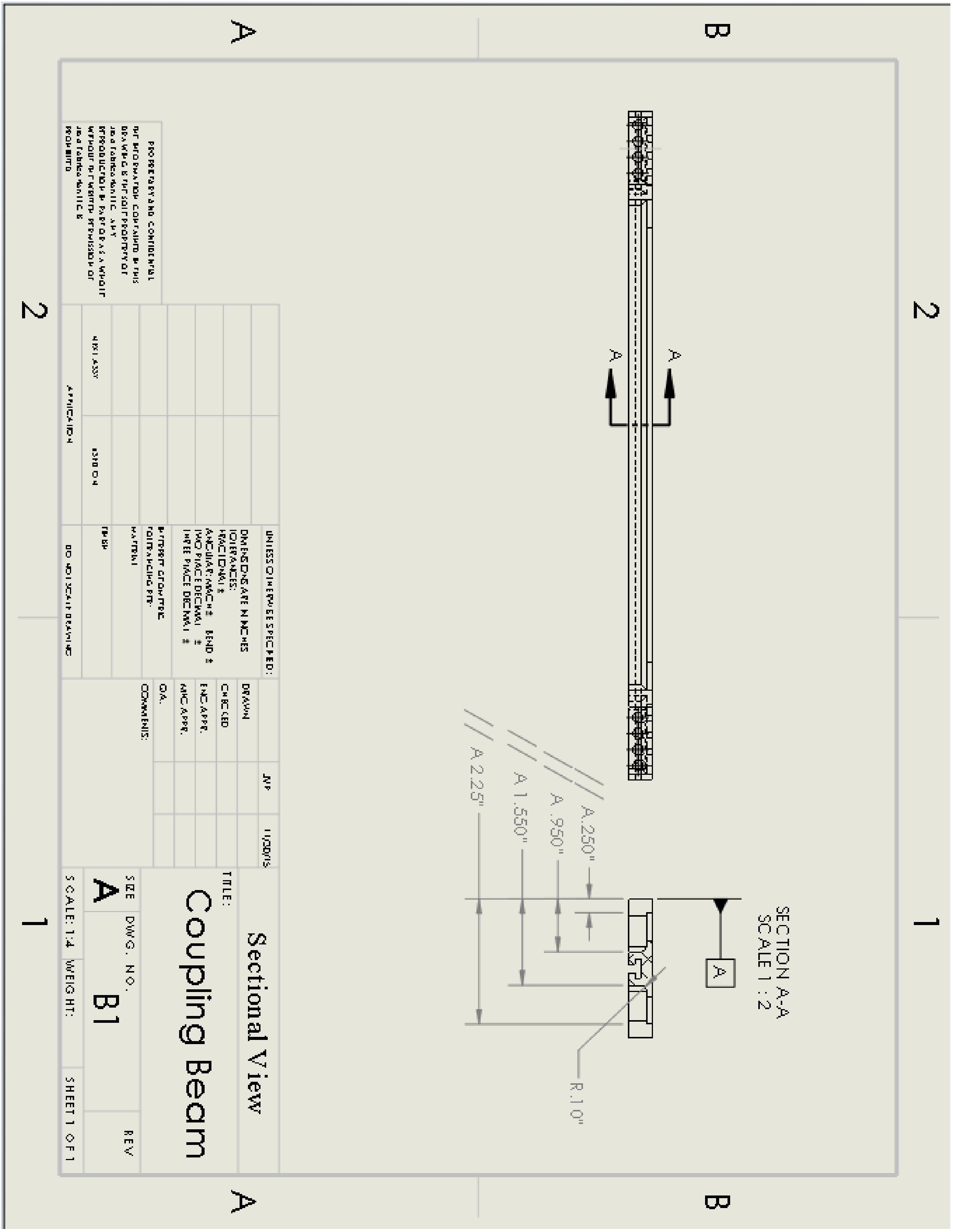


Figure 25 Coupling Beam Sectional View

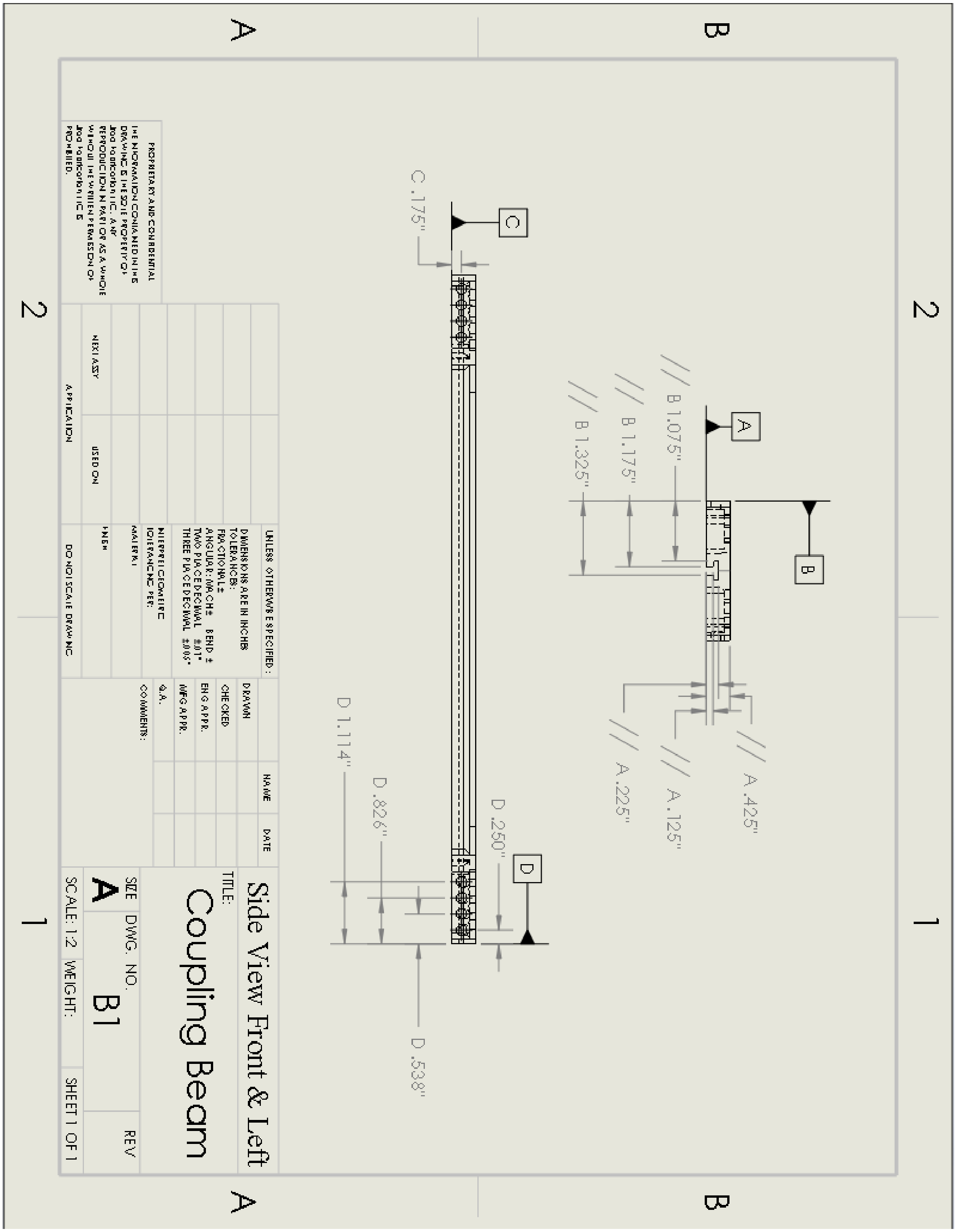


Figure 26 Side & Front View of Coupling Beam

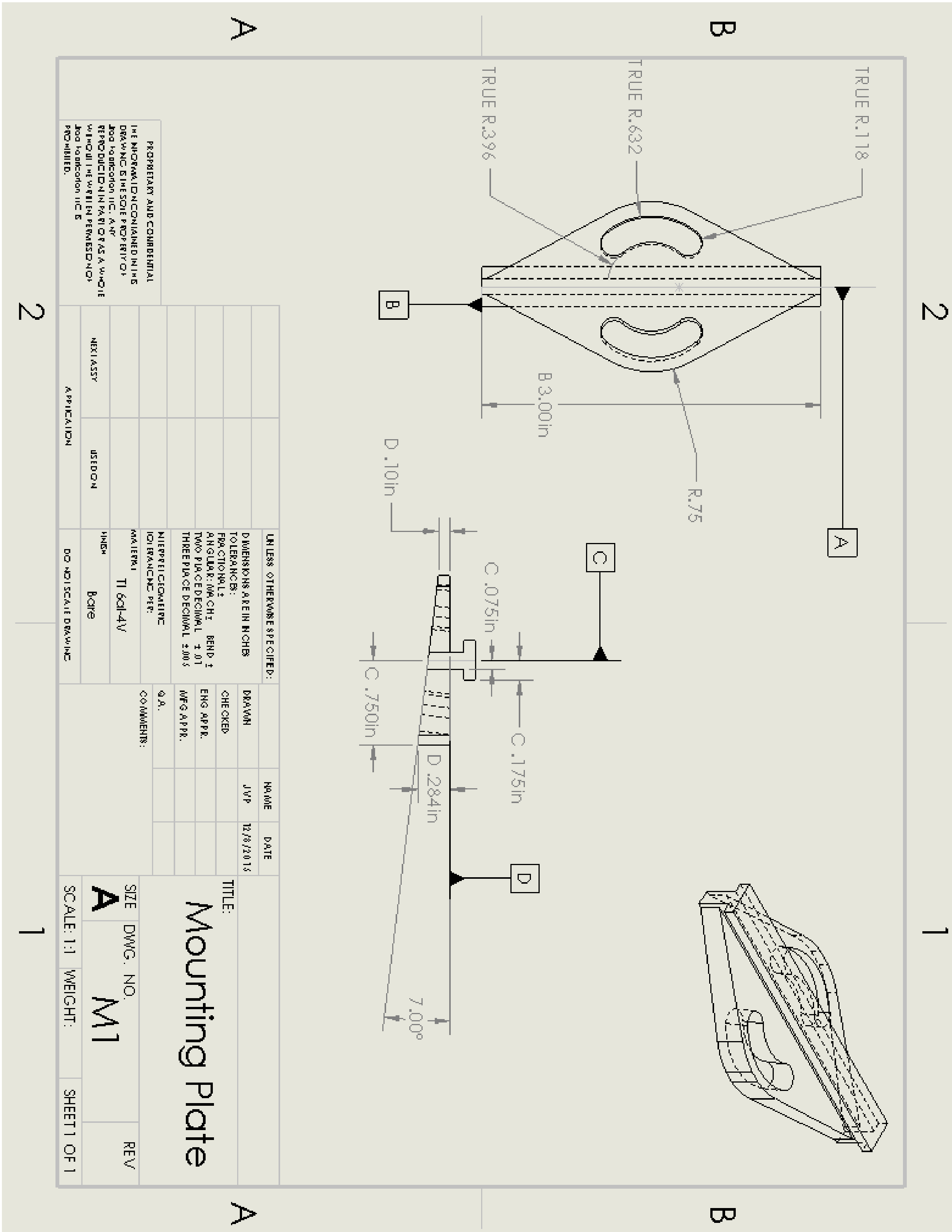


Figure 27 Mounting Plate

APPENDIX C- Parts List

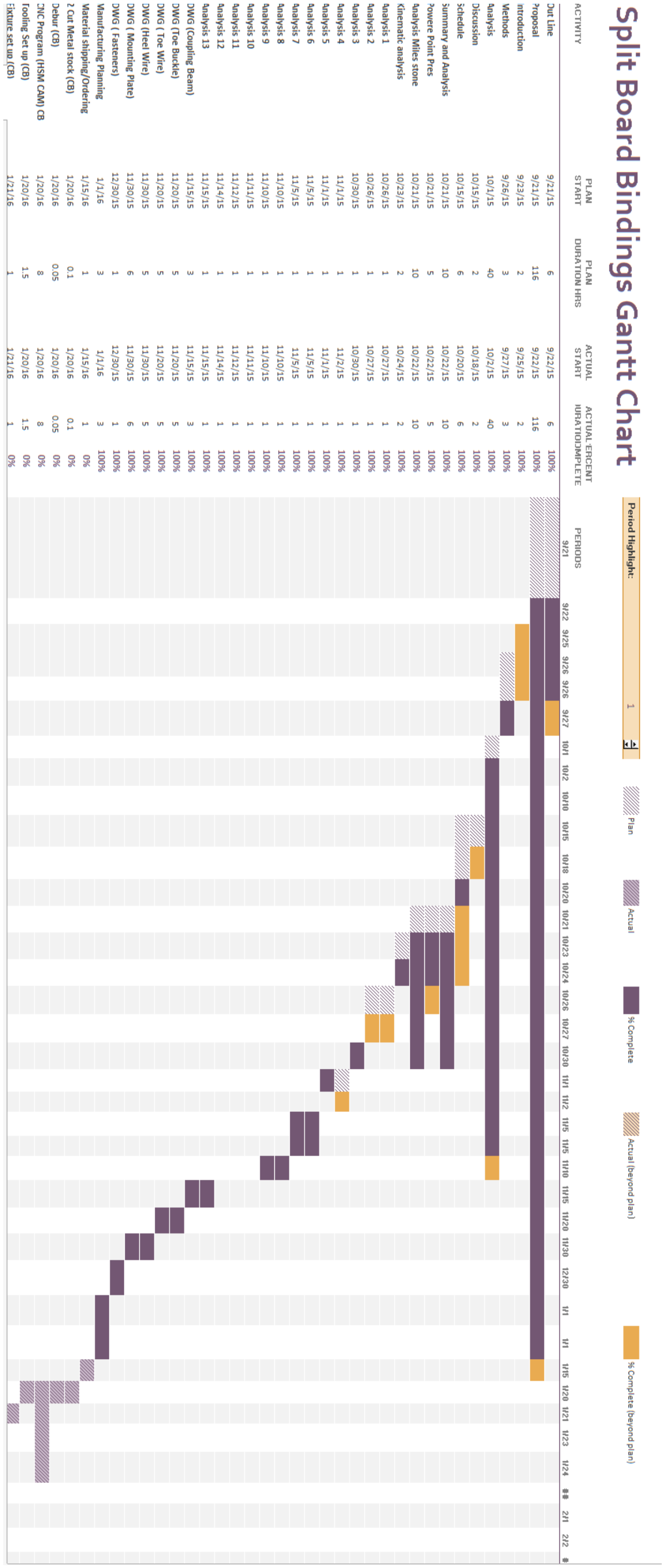
i. Parts List:

1) Split board Part # SPLT1
4) M6x6mm Part # F1
4) Mounting Plates Part # M1
2) Heel Wires Part # H1
2) Binding Pins Part # B2
2) Buckle Part # B3
2) Toe Wires Part # T1
4) Retaining Snap Rings Part # R1
2) Coupling Beams Part # C1
2) Buckle retainers Part #B1

j. Cost and Substantive cost:

Titanium Material Tial6 Source: WWW.Thomasnet.Com	$300
Hardware Source: Fastenal	$30
Stainless Steel Rod Source: Harvestco Fabricators	$10
Anodize (Including Shipping) Source: Spokane Coatings	$75
Aluminum (Demo Model) Source: Harvestco Fabricators	$40
Steel Angle Iron Source: Harvestco Fabricators	$20
Total-	$475

APPENDIX E- Schedule

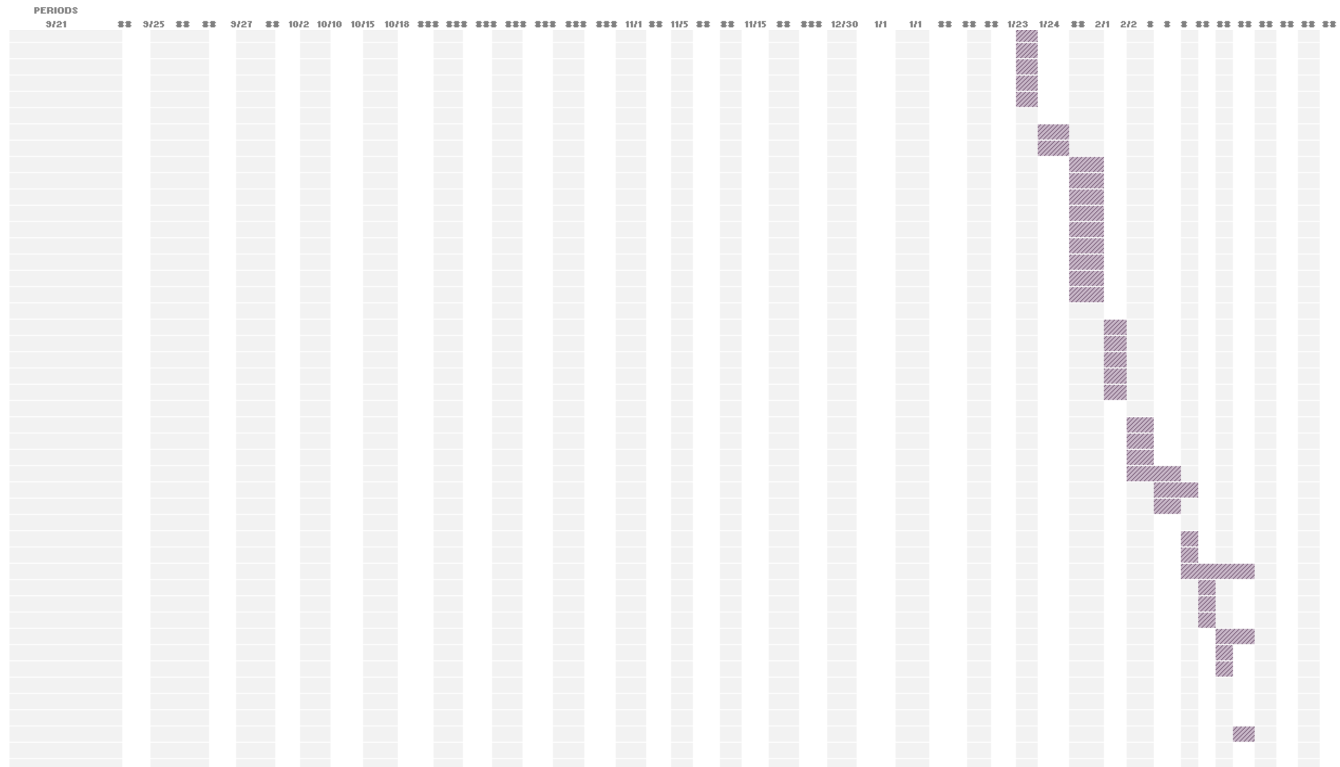


Split Board Bindings Gantt Chart

Period Highlight: 1

Plan | Actual | % Complete | Actual (beyond plan) | % Complete (beyond plan)

ACTIVITY	PLAN START	PLAN DURATION HRS	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Fixture set up (CB)	1/21/16	1	1/21/16	1	0%
CNC Set up (CB)	1/21/16	2	1/21/16	2	0%
Machining Time (CB)	1/21/16	0.5	1/21/16	0.5	0%
Deburing (CB)	1/21/16	0.05	1/21/16	0.05	0%
Clean up (CB)	1/21/16	1	1/21/16	1	0%
TOTAL (CB)		13.21			
2 Toe Buckle (TB)	1/23/16		1/23/16		0%
Cut Metal Stock (TB)	1/23/16	0.5	1/23/16	0.5	0%
CNC Program (HSM CAM) TB	1/24/16	4	1/24/16	4	0%
Tooling set up (TB)	1/24/16	1	1/24/16	1	0%
CNC Set up (TB)	1/24/16	1	1/24/16	1	0%
Fixture set up (TB)	1/24/16	1	1/24/16	1	0%
Machining (TB)	1/24/16	1	1/24/16	1	0%
Cutting Buckle off stock (TB)	1/24/16	0.2	1/24/16	0.2	0%
Flip and continue to machine	1/24/16	0.1	1/24/16	0.1	0%
Debur (TB)	1/24/16	0.1	1/24/16	0.1	0%
Clean up (TB)	1/24/16	1	1/24/16	1	0%
TOTAL (TB)		9.35			
2 Toe Wire (TW)	1/30/16		1/30/16		0%
Cut Material (TW)	1/30/16	0.05	1/30/16	0.05	0%
Debur (TW)	1/30/16	0.05	1/30/16	0.05	0%
Cut Groove for Ring retainer	1/30/16	0.2	1/30/16	0.2	0%
Bend angle in pipe bender (T	1/30/16	2	1/30/16	2	0%
TOTAL (TW)		2.3		2.3	
2 Heel Wires (HW)	2/1/16		2/1/16		0%
Cut material (HW)	2/1/16	0.05	2/1/16	0.05	0%
Cut Groove for Ring retainer	2/1/16	0.2	2/1/16	0.2	0%
Bend angle in pipe bender (H	2/1/16	2	2/1/16	2	0%
Build arch pressing JIG (HW)	2/2/16	4	2/2/16	4	0%
Bend arch in Press JIG (HW)	2/2/16	0.1	2/2/16	0.1	0%
Total		6.35			
4 Mounting Plate (MP)	2/5/16		2/5/16		0%
Cut Material stock (MP)	2/5/16	0.5	2/5/16	0.5	0%
CNC Programming (HSM CAM	2/5/16	6	2/5/16	6	0%
Tooling (MP)	2/6/16	1	2/6/16	1	0%
CNC Setup (MP)	2/6/16	1.5	2/6/16	1.5	0%
Fixture setup (MP)	2/6/16	0.5	2/6/16	0.5	0%
Machining (MP)	2/7/16	7	2/7/16	7	0%
Deburing(MP)	2/7/16	1	2/7/16	1	0%
Clean up	2/7/16	1	2/7/16	1	0%
tal		18.5			
Weld Buckle on Toe Wire	2/8/16	1.5	2/8/16	1.5	0%
Assemble Assembly	2/8/16	1.5	2/8/16	1.5	0%
CB Anodizing Class III (CB)	2/9/16	36	2/9/16	36	0%



APPENDIX G – Evaluation sheet

APPENDIX H – Testing Report

APPENDIX I – Testing Data

Appendix J –Resume

JARED VANPUTTEN

2904 N Airport Rd. Ellensburg, WA

Cell (509)760-8027 Email: Jradvanputten@gmail.com

Objective: To obtain a Mechanical Engineering Technology Position.

Work History:

Nov 2013 **Welder Fabricator, CAD Design**
To *Harvestco Fabricators*
Present *Ellensburg, WA*

Working here as a Welder and Fabricator as well as some Solid Works modeling and Auto CAD design. Here I build hay equipment and fabricate and design for custom jobs involving forklift masts, hay clamping equipment. Everything is built in shop and machined in shop. I have minimal machine experience running mills and lathes here as my position was as a welder. Items to be made or fixed were made from blue prints and or orthographic drawings. I was head of heavy metal fabrication, cast iron welding, on sight welding and painting. Welding processes used include TIG, MIG, ARC, and FCAW on various ferrous and non-ferrous metals. Tools used for fabrication include; AIR ARC, sheet metal breaks, metal sheers, PLASMA cutters, propane and acetylene torches, Iron workers, hydraulic presses, porta graphs and much more.

- Assembled Hydraulic systems
- Installed Hay squeezes
- Tig welded custom hydraulic cylinders
- Redrew preexisting AutoCad Files into Solid Works Models.
- Head Welder

Jun 2011 **Welder / Fabricator / Painter**
To *Western Metal Product*
Apr 2013 *Ellensburg, WA*

Fabricated and fixed structures, handrails, parts, equipment and maintained machinery. Items to be made or fixed were made from blue prints and orthographic drawings. I was head of heavy metal fabrication, cast iron welding, on sight welding and painting. Welding processes used include TIG, MIG, ARC, and FCAW on various ferrous and non-ferrous metals. Tools used for fabrication include; AIR ARC, sheet metal breaks, metal sheers, PLASMA cutters, propane and acetylene torches, Iron workers, hydraulic presses, porta graphs and much more.

- Head Painter
- Head of heavy metal fabrication
- Obtained a 3g & 4g FCAW welding cert.

Dec 2010 **Welder/Fabricator**
To *Central Washington University*
Jun 2011 *Ellensburg, WA*

I was hired to assist both students and professors in the fabrication of metal objects. This also included setting up student labs, CNC equipment. Job ended due to lack of government funding to school.

- Successfully kept labs and equipment maintained
- Aided as help for students who needed advice in machining and welding

Jun 2010 **Production Welder**
To *Genie Lifts*
Sept 2010 *Moses Lake, WA*

Welded man lift booms, riser tubes, and jibs for Z-60, 65, 85 and super boom models. I left because school started in Ellensburg at CWU.

Jun 2009 **Warehouse and store stockman**
To *Basin Feed*
Jun 2010 *Moses Lake, WA*

I stocked both the warehouse and store with livestock feed and supplies. I assisted as a retail clerk and customer service attendant, forklift operator.

- Kept an accurate inventory

EDUCATION

Sep 2010 **Central Washington University**
To *Ellensburg, WA*
Present *Mechanical Engineer of Technology*

I am currently a senior in my MET program at CWU, but plan to finish the program this year in 5 months. The program is both hands on and theory based. This program is a mix of CAD software, CNC equipment, physics, thermal dynamics, hydraulics, and chemistry.

I have taken the CNC programming courses as well as basic machining courses which is the course I want to take my career.

Sep 2006	**Moses Lake High School**
To	*Moses Lake, WA*
Jun 2010	*Obtained High School Diploma*

Software Skills

Microsoft Word 2007 & 2010	G-Code Programming
Microsoft Excel	Master Cam
Microsoft Power Point	
Auto CAD	
Solid Works	

References

Ryan Fletcher	Alonzo Galegoes	Matt Burvee
Western Metal Product	Genie Industries	Central Washington University
Ellensburg , WA	Moses Lake, WA	Ellensburg, WA
(509) 760-8027	(509) 750-6482	(509) 510-8616

Erik Duncan
Dave Duncan & Sons
Ellensburg, WA
(509) 607-0964