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Dynamometer Stabilizer

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Dynamometer Stabilizer

By

Derek LaMarche

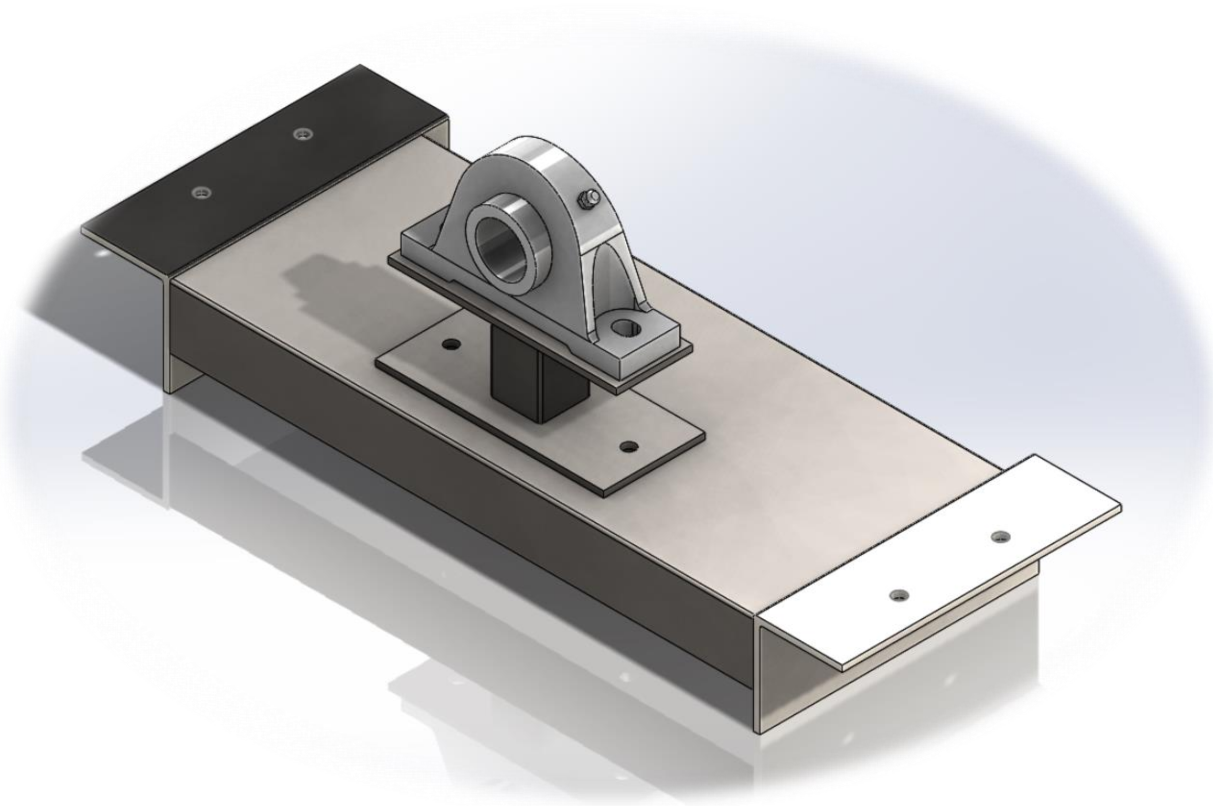


Table of Contents:

1: INTRODUCTION

Motivation:

Overhauling the CWU small engine Dynamometer in the CWU power lab will make it more ridged during the measurement of power in these engines. The goal of the project is to have the dyno used in the Small engines class run by professor (Name) and to be run by the students. The dynamometer does not work within the specified limits making it impractical to perform during lab.

Function Statement:

A modification to the dynamometer is needed, the attachment will support the load applied at the end of the crank and it will adapt to other engines with different output shaft heights.

Requirements:

The engine dynamometer must meet these requirements in order to fulfill its function:

- The attachment must be able to transmit up to 120 horsepower.
- The attachment must be able to rotate a maximum of 4,500 RPM.
- The attachment must not exceed .5 degrees of deflection or large loss of power will result.
- The attachment must be able to adapt to different engine sizes up to 3 cylinders and output shaft heights of up to 8 inches.
- The dynamometer must read horsepower of a specified engine within ±10% horsepower.
- The attachment must weigh under 30 pounds.
- The attachment must fit on the cart 24 inches wide by 24 inches tall.
- The attachment must cost less the $300.

Success Criteria:

The attachment will be successful when it connects to the dynamometer, the dynamometer reads its standard deviation in horsepower, and the dynamometer can be used by students in a lab using only the lab instructions provided in the lab guide.

Scope of Effort:
The project is narrowed down to the support of the dynamometer while the engine is being tested the output shaft that leaves the engine is too far from the actual dyno. This needs to be supported while being able to adapt to other engine shafts. The dyno does not support other engines, this is because the adapter from the engine to the dyno is specific to that engine and that the shaft height is incorrect for them.

Benchmark:
The dyno reads within its specified range of ±10% of engines horsepower number according to the DYNO-mite dynamometer (#075-200-1K) technical specifications.

2: DESIGN & ANALYSIS

Proposed Solution:
The proposed solution is to create an attachment that secures the output shaft increasing rigidity. By using a steel frame under a bearing which would hold the shaft, this would reduce any play within the system. With a pillow block bearing on top of the steel frame the rigidity would be greatly increased.

Figure 1: Original design of the attachment on the dyno

Description:

The attachment will be made of steel and will have a bearing of some sort on the top of the assembly (Figure 1). Being bolted to the cart the attachment can be moved for different output shafts. (See Appendix A for an analysis) one of the analysis analyses the internal moment created by the attachment. The other shows how thick of material is needed.

Primary Requirements:

The engine dynamometer must meet these requirements in order to fulfill its function

- The dynamometer must read horsepower of a specified engine within ±10% horsepower.
- The attachment must weigh under 30 pounds.
- The attachment must cost less the $300.

Analysis:

The analysis that will be used to simulate deflection along with equations of bending and material property calculation will be Finite element analysis (FEA) this will provide an estimate on how much deflection and stress will be present. Choosing the material to use for the attachment is first, followed by the thickness of the material using the moment of inertia formula for the material shape chosen. Shapes, sizes and bearings will be chosen due to requirements that restrict some materials, shapes, and methods of producing. (See appendix A)

Finite Element Analysis for calculating shape needed, if supports are needed at angles from bearing.

The analysis in SolidWorks was successful, even after applying a load double of the load expected, the analysis gave a safety factor of 18.38 deeming the project safe in terms of handling load in the expected direction.

Moment of inertia of C channel steel.

Prediction of Performance:

The attachment will reduce the moment in the output shaft, and resist deflection in the whole system. The attachments performance has been predicted to comply with the original specifications for horsepower loss of 10%. The process of building this attachment will take approximately 10 hours, five hours for layout and preparation 3 hours of cutting and sizing, and 2 hours of welding and fitment. The cost for the material and man hours will remain under $300.

3: METHODS & CONSTRUCTION

Description:

The attachment will be made from C channel steel and square steel tubing. The base of the attachment will be made from the C channel to bolt to the cart (Appendix B) this base will have 4 holes drilled, 2 on each side for mounting to the cart with grade 8 bolts. In the center of the channel the square steel tubing to mount the second part into (Appendix B). There is a piece of square tubing with a plate attached to the top, this will hold the bearing. The first and second parts interact by sliding into the square tubing of part one being pinned there for the given shaft height. (See Appendix B)

Drawing ID's

The Attachment will be made in three sections the first section the bottom AT-01 in Appendix B will be the base of the attachment with its sub assembly pieces CC-01, LB-01. Also in Appendix B. This will hold up the riser and the bearing, the riser is also in Appendix B named AT-02 with its sub assembly pieces RBP-01, RST-01, and RTP-01. The bearing modeled by McMaster Carr is in Appendix B as well titled 2722T42.

Parts lists:

Located in appendix C is the list of parts needed to assemble the attachment. This list shows all parts needed, it shows the quantity needed, the cost of each part and where the part can be purchased from. Each part/ assembly has a drawing associated with it and will be tracked through the building process.

Manufacturing issues:

There are many ways to go about manufacturing the attachment, however it will be a fabricated part joined together by welding. All of the parts are relatively easy to acquire and fabricate in to a useable part by this assembly. (See Appendix C for parts chart) Another issue is the bearing needs to be concentric with the shaft, however the parts in all of the in the assembly have a tolerance of .01 and if the bearing is .01 inches off of concentricity it will work against the engine. The issue here is getting the weldment to be within tolerance, since heating and cooling metals rapidly can cause it to warp and come out of spec, shims will need to be used. If this product was to be made over and over from a manufacturing standpoint each and every attachment will need a different size shim to make the shaft concentric.

Assembly and Sub-assembly parts:

The first part of the attachments assembly will be the base, the base is a 23in long piece of C channel steel that will be bolted to the frame of the dyno cart. See (drawing 1). Attached to the base by welding is the 3 inch piece of square steel tubing, this will house the pillow block bearing mount and the sliding piece of smaller square steel tube. (See drawing 2) the base and the pillow block mount will be held together later on by a pin that can be pulled out to later on accommodate for different shaft heights.

4: TESTING METHODS

Introduction:

To determine if the attachment is successful, it will be put through a series of tests that will determine if it will be useful to the CWU staff and students in the power lab. The tests will be performed in the CWU power lab where it will remain until it is no longer needed as an attachment on the dynamometer.

Testing:

The succeeding list are the tests the will be performed on the attachment to calculate its usefulness to the dynamometer and the students and staff of the CWU power lab.

1. The first test to be performed will be a deflection test, this test will be performed by attaching the stabilizer to the dynamometer cart. Making sure to align the pillow block bearing with the shaft to have perfect concentricity before bolting it down. After setting the attachment a protractor and a camera will be set right above the shaft. The dynamometer will run through a full test of the engines horsepower, at the same time going through the footage to see the max deflection at the point of maximum torque delivered by the engine.
2. The second test will be a torque and horsepower test. The dynamometer will be run without the attachment to see how much power the dynamometer will read, then it will be compared to the test with the attachment installed. After the tests have been run the results will be compared to the success criteria of a 10% horsepower loss or less, this is compared to the engines proven power output given by the manufacture. This will prove its usefulness to the dynamometer in acquiring horsepower reliably and efficiently.
3. The third test will be ease of removal. The attachment has been designed to be removed by anyone who wants to replace an engine or part on the dynamometer cart easily. Due to class being 50 minutes the attachment needs to be able to be removed in a timely manner. A CWU staff member should be able to remove/install the attachment in less than 10 minutes proving its ease of removal and install.

Testing Procedure:
The following instructions are how the above tests will be performed in the order that they will be performed.

Test 1: Deflection test
1. Install the attachment to the dynamometer cart.
2. Loosen the pillow block bearing bolts to align for concentricity.
3. Attach a protractor to cart of dynamometer.
4. Attach camera to location of protractor to keep error of the reading down.
5. Turn on camera and run dynamometer through a full power cycle.
6. Go over footage and note angle of deflection.

Test 2: Torque and Horsepower test
1. Start the engine and make a base test of the dynamometer without the attachment.
2. Record the torque and horsepower.
3. Install the attachment.
4. Loosen the pillow block bearing bolts to align for concentricity.
5. Run the dynamometer again with the attachment installed.
6. Take the results from the first test and compare it to the second to see power gained
7. Use results from second test to compare with the manufacture specific horsepower rating.

Test 3: Ease of removal
1. Set a timer to 10 minute.
2. Have attachment available and ready to install.
3. Start the timer and start the install of the attachment.
4. When the attachment is installed and ready to be tested pause the timer
5. Record the time
6. Set timer back to 10 minutes
7. Remove the attachment and set it back to its ready state.
8. Record the time

Deliverables:
All of the tests can be found in appendix G, these tests will analyze the actual torque horsepower, time to install and remove and the deflection, and compare it to the success criteria created for this device.
The tests will prove if the attachment is successful in the areas presented to prove that it will assist the professors and students in the CWU power lab.

5: BUDGET AND SCHEDULE

Proposed Budget:

This project is sponsored by CWU, all decisions and parts will need to be run by Nathen Wilhelm a member of the CWU staff who is overlooking my project and its parts.

The original budget was 300 dollars, the budget is set as such because CWU has some if not all of the necessary materials for the creation of this attachment. The parts for the attachment cannot exceed the 300 dollars, but still needs to fulfill its task of holding the shaft of the dynamometer. The C channel steel costs $26.42 before shipping this is a good start for the budget, the 2" x 1.760" steel Square tubing costs $4.78. The other square tubing is optional if it is decided that there will multiple shaft heights costs $3.42, the other necessary part is the plate A-36 steel, this costs $26.42 for a 12x12 plate, this is all from "Speedymetals.com" the total cost from Speedy Metals is $154.00 after shipping and packaging fee. The four ½x13x2" bolts cost $10.00 after shipping from "albanycountyfasterners.com". The last piece needed is the pillow block bearing it costs $111.14 and $16.45 for shipping making the total $127.59 from "Fastenal.com" The grand total comes out to be $291.59 from a the sites mentioned. The data can be seen in a table in Appendix D.

Schedule:

The schedule which is in the form of a Gantt Appendix E, this list breaks down the project into parts and milestones which can be easily followed to see how long each segment should take and when it should be completed by. Each task has an estimated number of hours needed to complete next to it. This table will help the project along and will be modified as necessary to show assumed hours needed vs. actual hours needed. It will keep the project moving and be a summation of the entire project. The schedule is flexible and will be changed as the project progresses. The entire project is estimated to take around 144 hours to complete.

Project Management:

Human Resource

The project engineer, fabricator, and designer is Derek LaMarche. The project overseer is Nathen Wilhelm. The project engineer will be responsible for designing the attachment, sourcing out parts, getting prices, calculating stresses, and finding requirements for the project. The overseer will provide some insight on how it should look and some guiding references and resources.

Physical Resources

The projects physical elements will be constructed at CWU in the welding and power labs where the building and fabricating will take place. There are more than enough resources in these labs to create a part that will withstand the dynamometers forces.

Soft Resources
The design of the attachment will be done on SolidWorks 3D modeling program where various tests will be performed. All of the drawings will also be created in SolidWorks complying with industry standards.

Financial Resources
The financer for the project is CWU's mechanical engineering department. All parts purchased will be covered by the engineering department while staying within the budget presented.

6: DISSCUSSION

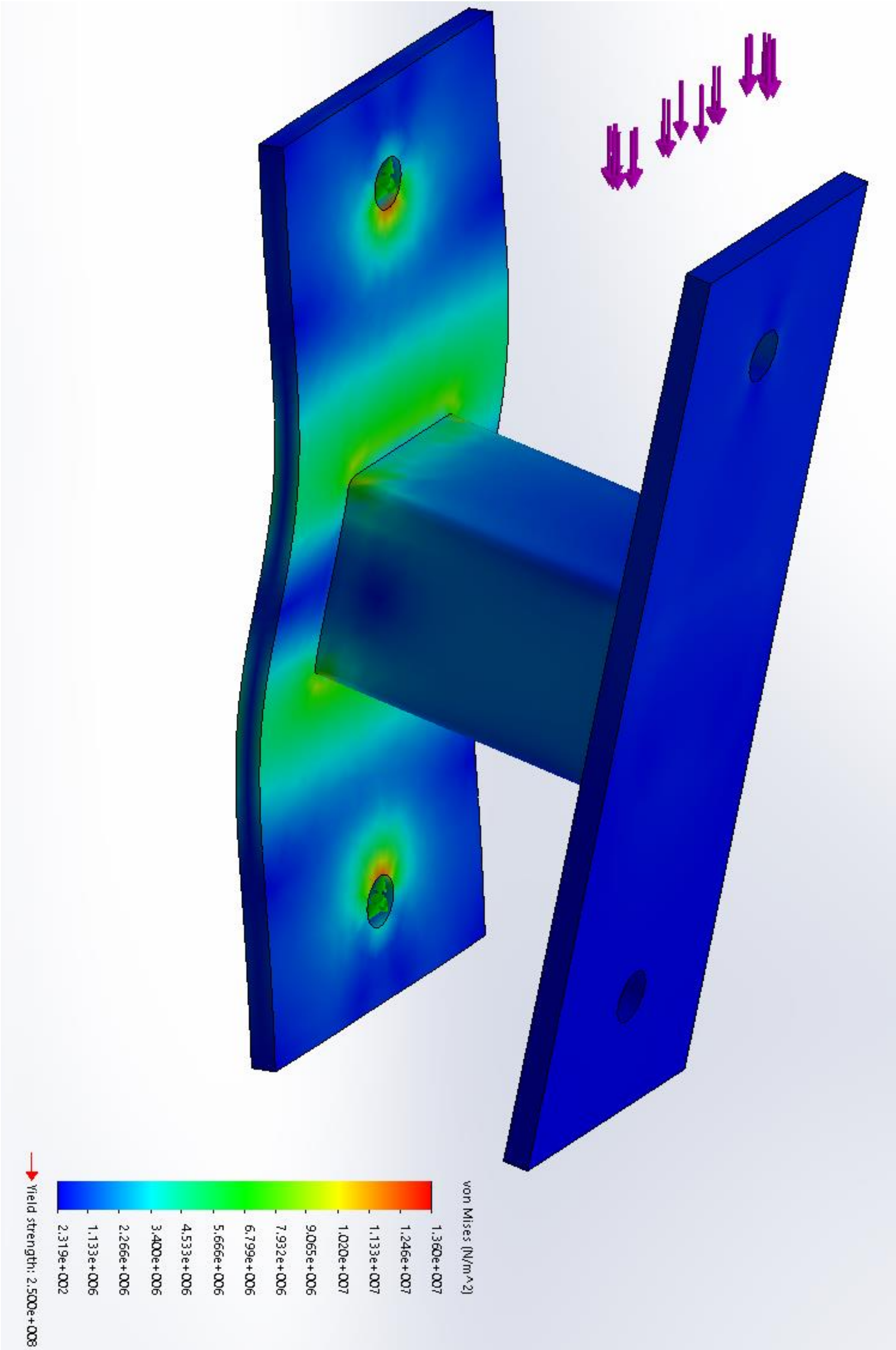
Evolution:
The initial design of the attachment was very rough and had little calculations to support it, the design went through many design modifications different materials such as aluminum to steel. Some of the design requirements evolved as well, some of the components could not handle the requisites set for it so they had to be modified to fit the properties of the components. One of the requisites was that the attachment should be able to achieve 18,000 RPM, the bearing that was chosen was already a "high speed bearing" this bearing was capable of 4,500 RPM max. Bearings that size aren't made to spin at such a high RPM, thankfully the engine we will use to test spins up to 3,600 RPM this gives us a safety factor of 1.25 which is desirable so the bearing doesn't fail after the project is complete. Another requirement that needed to be changed was its 15 degrees of deflection, the goal is 0 degrees of deflection after calculating the actual deflection without the attachment the system sees a total of ~2.5 degrees (analysis in appendix A) so a total of 15 degrees would be way too much about 1.5 inches this would cause a failure. This is why the requirement was changed to one half of a degree. Other modifications such as the height of the bearing were calculated as well, (in appendix A) two more calculations are present, one for the 14 inch bearing height and one for the 5 inch bearing height. There is a height difference due to the size of the bearing and where the square tube is located. The forces on the 14 inch square tube are right around 120 lbs. of force which is acceptable. However after recalculating the length to 5 inches (also in appendix A) the forces went way down to less than half of the values previously calculated 43.47 lbs. This is even better for the whole system to reduce the force on the cart by half.

Conclusion:
The dyno attachment was a success, the first requirement of the engine achieving the specified horsepower ±10% was obtained, the engine showed a gain from 28 without the attachment to 33 with the attachment from the 35 horsepower that is only a loss of 5.72% which is under the requirement of 10%/. The second major requirement is that the attachment only weight 30 lbs. the attachment weighs 24.7lbs. The third major requirement was that the attachment cost under 300 dollars, the attachment cost $261.94 and fulfills the 300 dollar requirement. Another aspect that was achieved is the attachments ability to handle torque is very good, the attachment has the

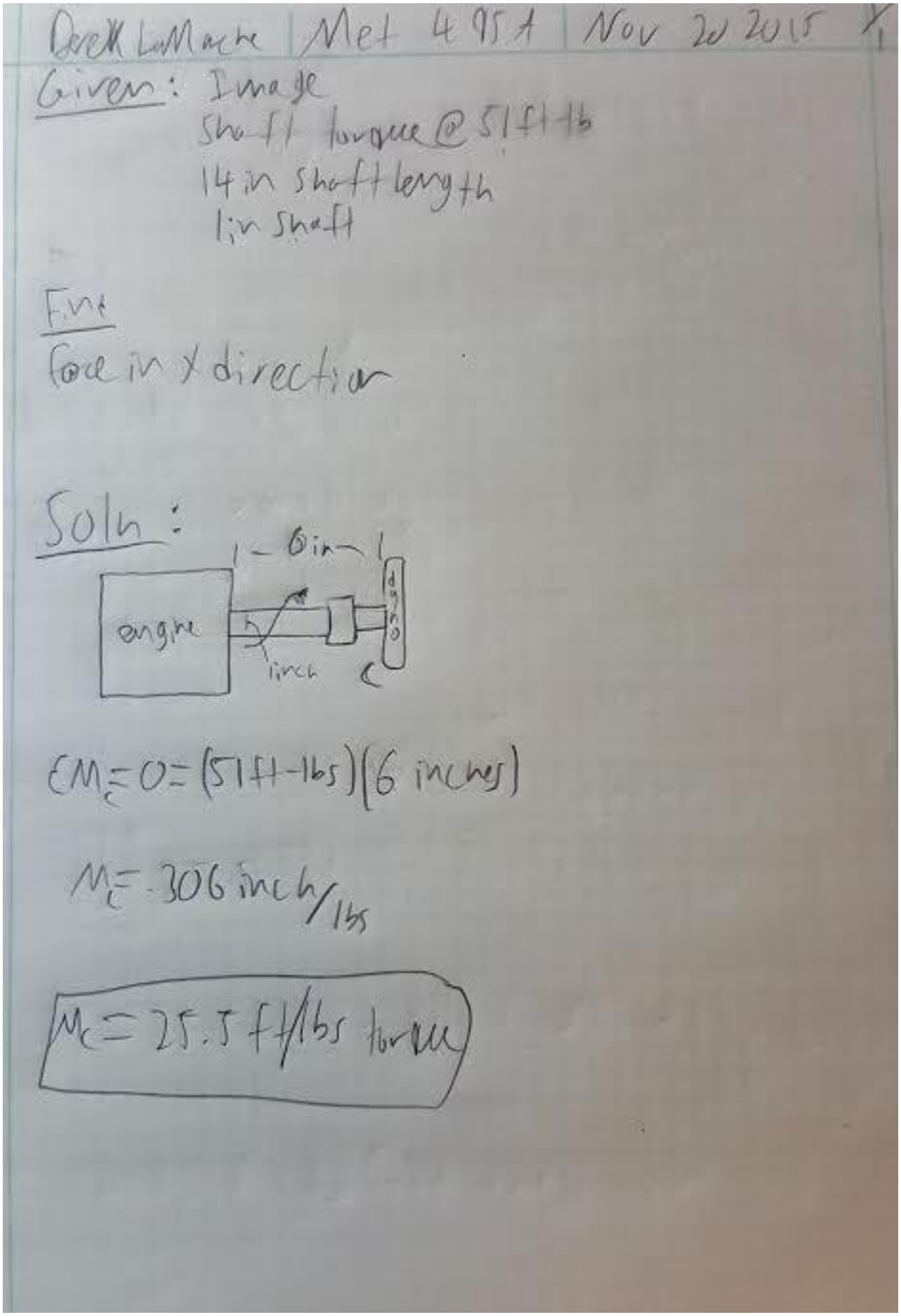
ability to take roughly 15x the torque then what is being applied. With a safety factor of ~18, the attachment is safe to use and will be safe for the duration of its life. The completed project will be the best available, all resources are allocated and material is prepped for construction.

Acknowledgements:
Acknowledgements go to CWU for funding this project and helping achieve a successful project. Acknowledgements also go to Dr. Johnson and Professor Pringle for being there whenever guidance and words of advice were needed, helping by thinking out of the box. A thanks also goes out to Nathen Wilhelm for his guidance, help fabricating and words of wisdom. Thank you also to Ted Bramble and Matt Burvee for remaking the adapter where the attachments bearing would mate with the system and for helping purchase the parts needed to create this part.

APPENDIX A:
Analysis through Solid works



Green sheet calculation for Moment force



Derek LaMarche | Met 495A | Nov 20 2015 1/1

Given: Image
Shaft torque @ 51 ft-lb
14 in shaft length
1 in shaft

Find
Force in X direction

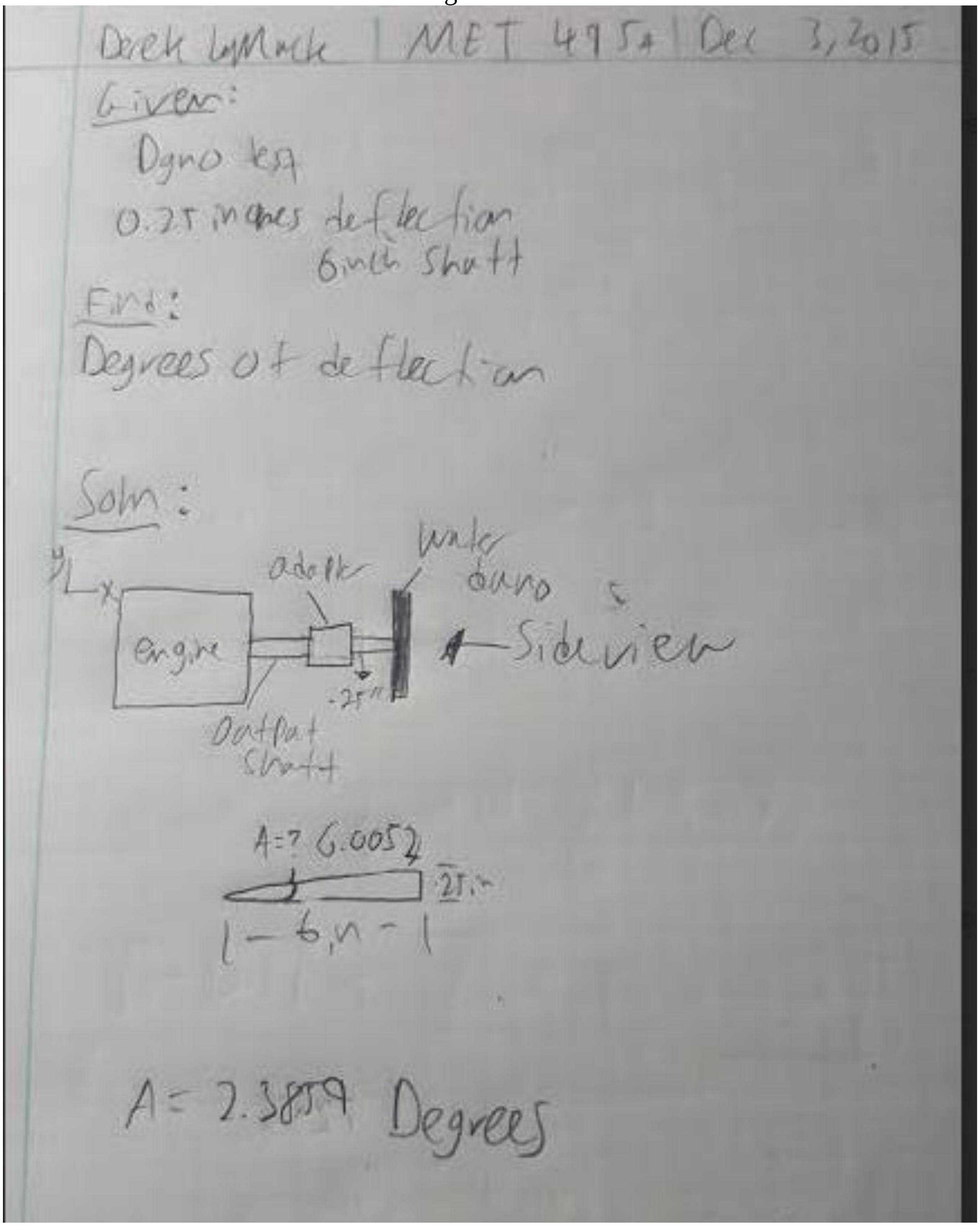
Soln:

$\Sigma M_c = 0 = (51 \text{ ft-lbs})(6 \text{ inches})$

$M_c = 306 \text{ inch/lbs}$

$M_c = 25.5 \text{ ft/lbs torque}$

Green sheet calculation for Deflection angle.



Derek LyMack | MET 4754 | Dec 3, 2015

Given:

Dyno test

0.25 inches deflection
6 inch Shaft

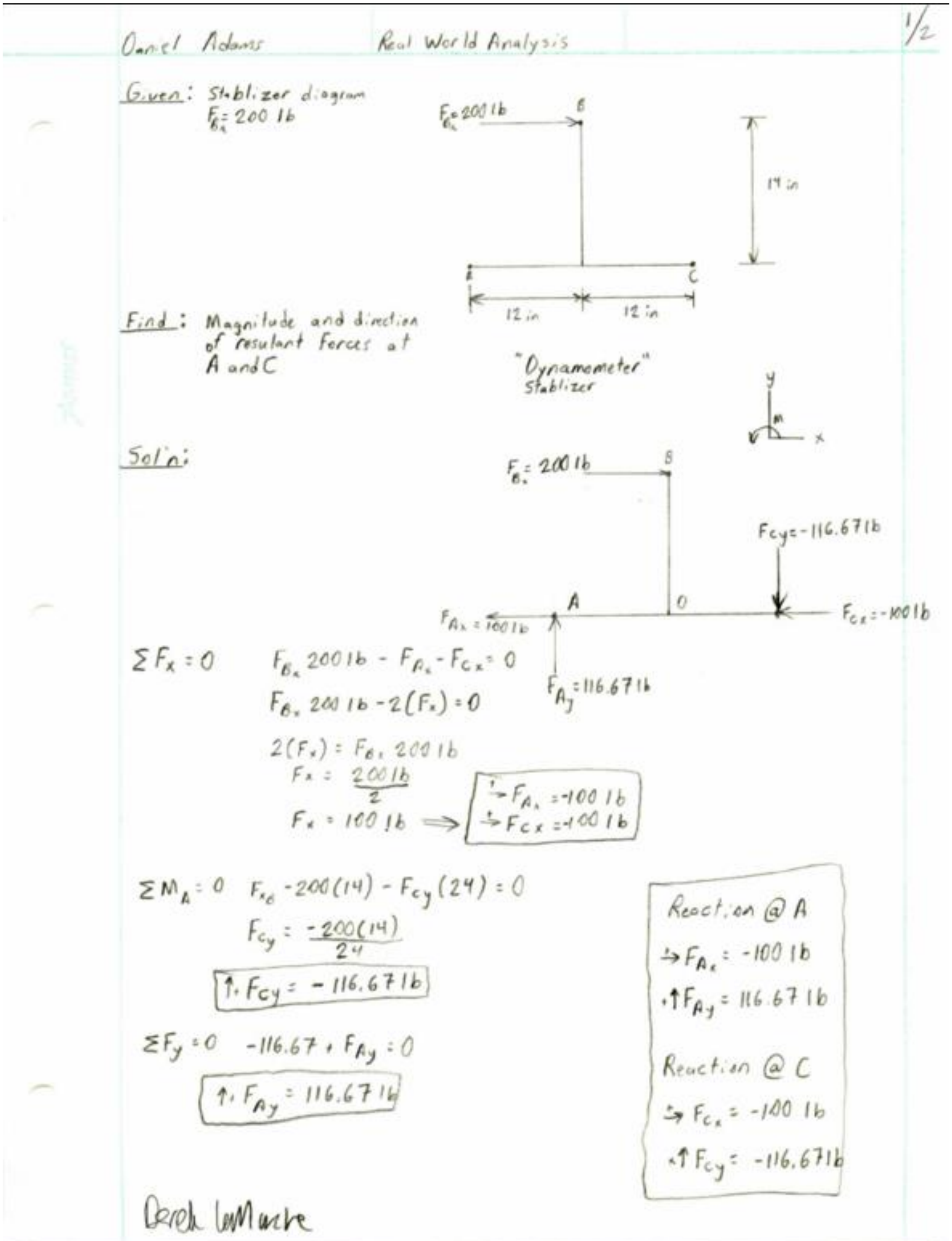
Find:

Degrees of deflection

Soln:

A= 2.3859 Degrees

Green sheet calculation for Reaction forces 14"



Daniel Adams   Real World Analysis   1/2

Given: Stablizer diagram
$F_{B_x} = 200\ lb$

Find: Magnitude and direction of resulant forces at A and C

"Dynamometer" Stablizer

Sol'n:

$\Sigma F_x = 0 \quad F_{B_x}\ 200\ lb - F_{A_x} - F_{C_x} = 0$

$F_{B_x}\ 200\ lb - 2(F_x) = 0$

$2(F_x) = F_{B_x}\ 200\ lb$

$F_x = \frac{200\ lb}{2}$

$F_x = 100\ lb \Rightarrow$ $\rightarrow F_{A_x} = -100\ lb$, $\rightarrow F_{cx} = -100\ lb$

$\Sigma M_A = 0 \quad F_{x_B} - 200(14) - F_{cy}(24) = 0$

$F_{c_y} = \frac{-200(14)}{24}$

$\uparrow F_{cy} = -116.67\ lb$

$\Sigma F_y = 0 \quad -116.67 + F_{A_y} = 0$

$\uparrow F_{A_y} = 116.67\ lb$

Reaction @ A

$\rightarrow F_{A_x} = -100\ lb$

$\uparrow F_{A_y} = 116.67\ lb$

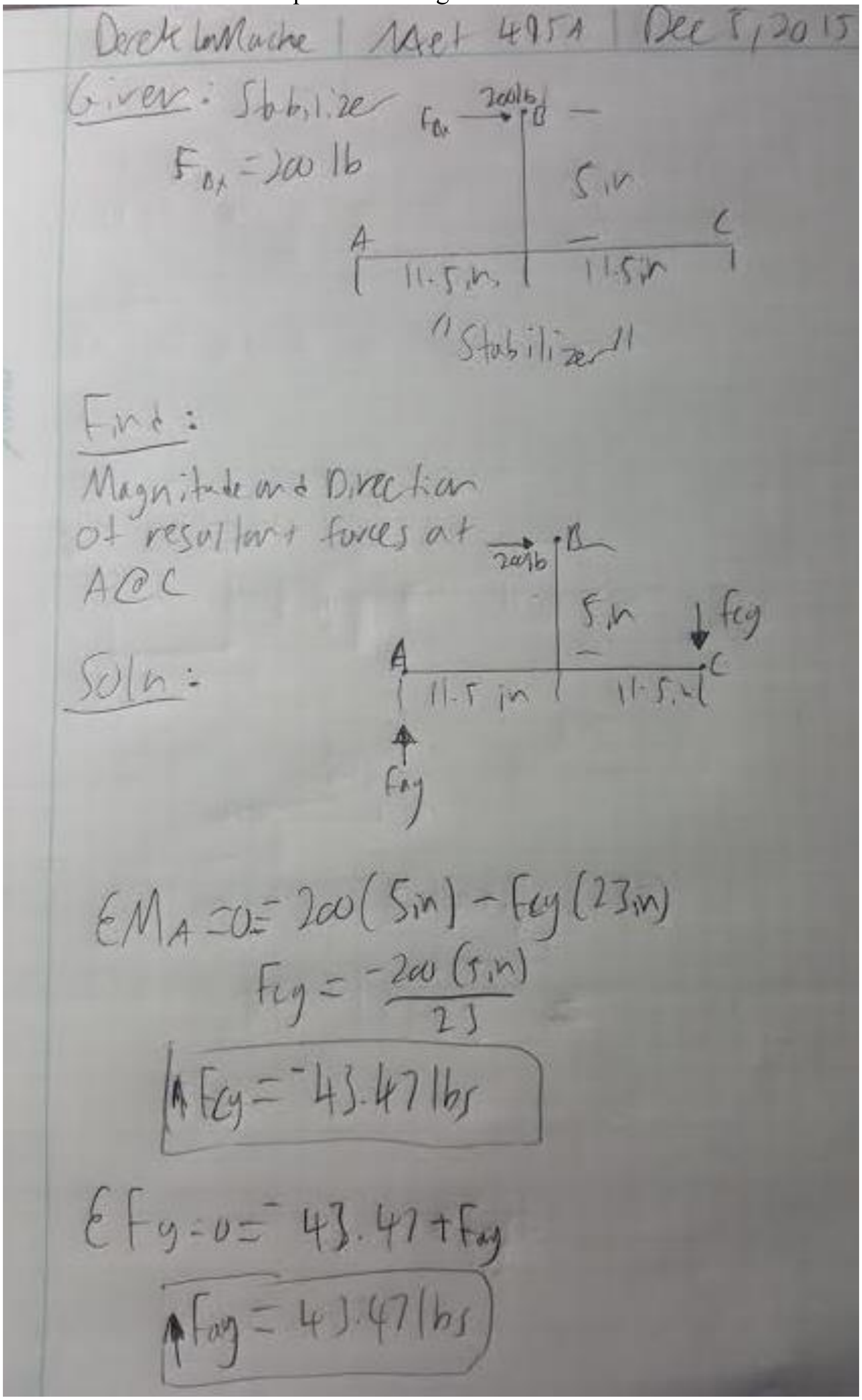
Reaction @ C

$\rightarrow F_{c_x} = -100\ lb$

$\uparrow F_{c_y} = -116.67\ lb$

Derek LaMarche

Calculation for modified Square tube length 3”



Derek LaMache | Met 495A | Dec 5, 2015

Given: Stabilize

$F_{Bx} = 200$ lb

Find:

Magnitude and Direction of resultant forces at A @ C

Soln:

$\Sigma M_A = 0 = 200(5in) - F_{cy}(23in)$

$F_{cy} = \frac{-200(5in)}{23}$

$F_{cy} = -43.47$ lbs

$\Sigma F_y = 0 = -43.47 + F_{ay}$

$F_{ay} = 43.47$ lbs

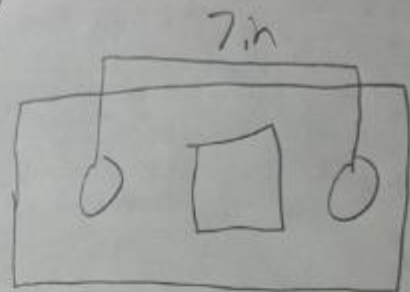
Calculation on moment of riser assembly

Derek LaMuche | Met 495A | Dec 6, 2015 | 1

Given: Model of
Riser assembly
400 lbs = X

Find: Calculate Moment
Of Riser assembly

Soln:

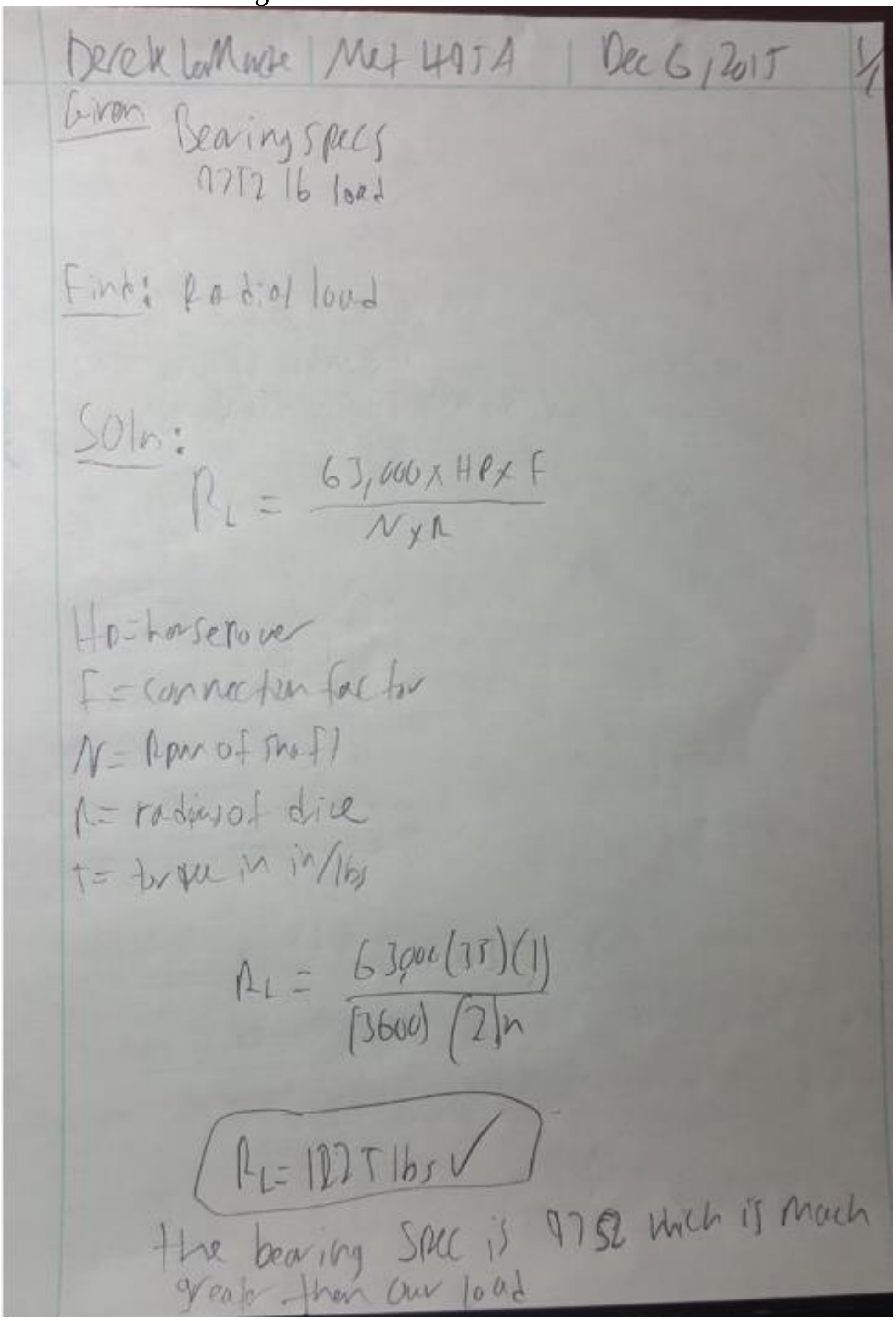


3.5 in
400 lbs

400 lbs x 3.5 in

116.67 lbs on mounting holes

Calculation on bearing radial load



Derek LaMunze | Met 495A | Dec 6, 2015 | 1/1

Given: Bearing specs
9752 lb load

Find: Radial load

Soln:

$$R_L = \frac{63{,}000 \times HP \times F}{N \times R}$$

HP = horsepower
F = connection factor
N = Rpm of shaft
R = radius of disc
T = torque in in/lbs

$$R_L = \frac{63{,}000(75)(1)}{(3600)(2)\pi}$$

$R_L = 1827$ lbs ✓

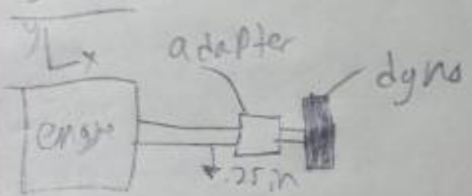
the bearing spec is 9752 which is much greater than our load

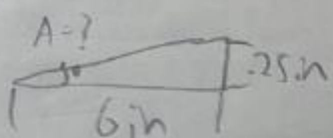
Derek LaMarche | MET 495A | Dec 9, 2015 | 1/1

Given: .25 in Play in Shaft missalignment

Find:
If bearing will support the missalignment and Max missalignment

Soln:



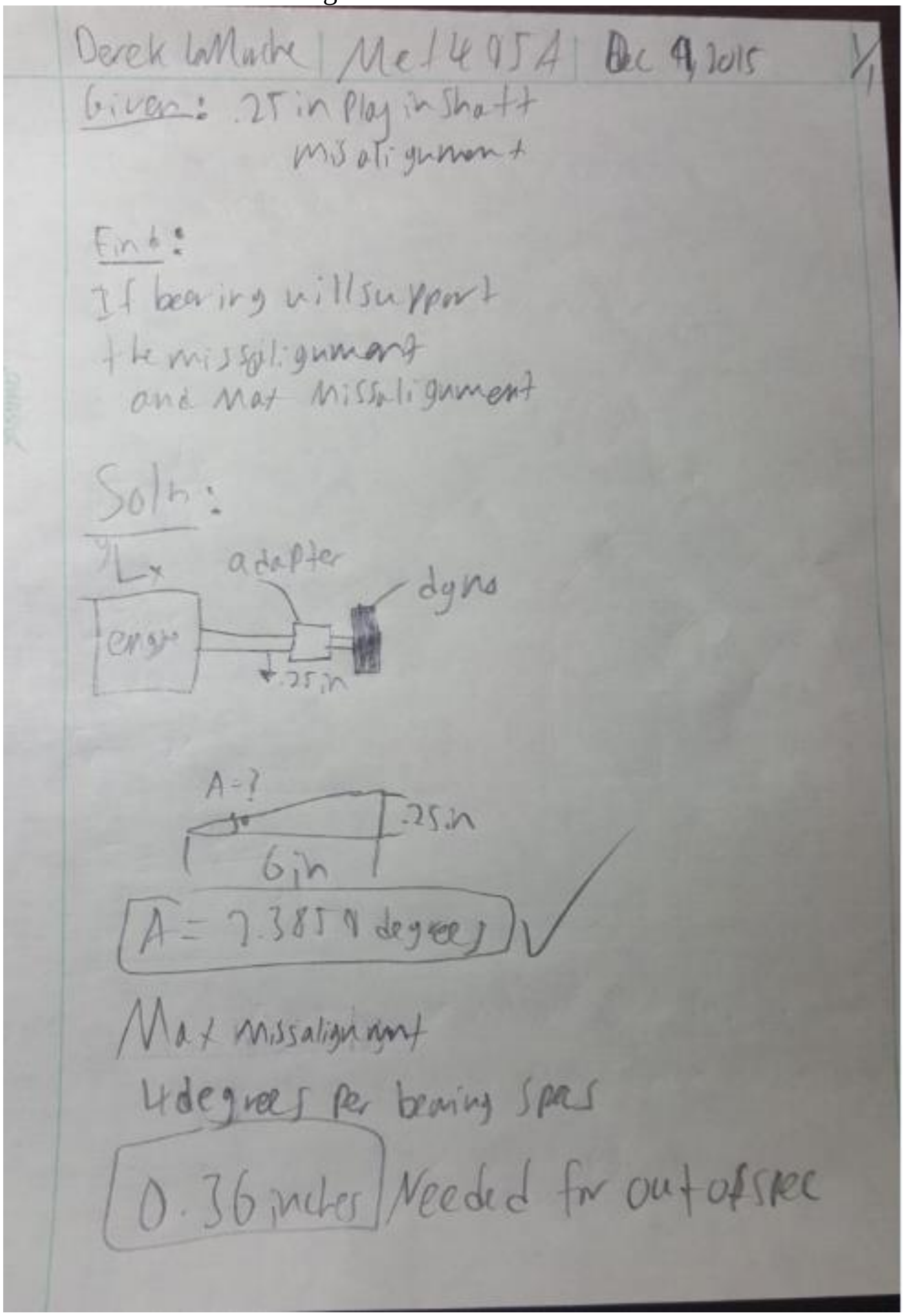


A = 2.3859 degrees

Max missalignment
4 degrees per bearing spec

0.36 inches Needed for out of spec

Calculation on Shaft misalignment


Derek LaMarche | Me 495A | Dec 9, 2015 1/1

Given: .25 in Play in Shaft misalignment

Find:
If bearing will support the missaligument and Max missaligument

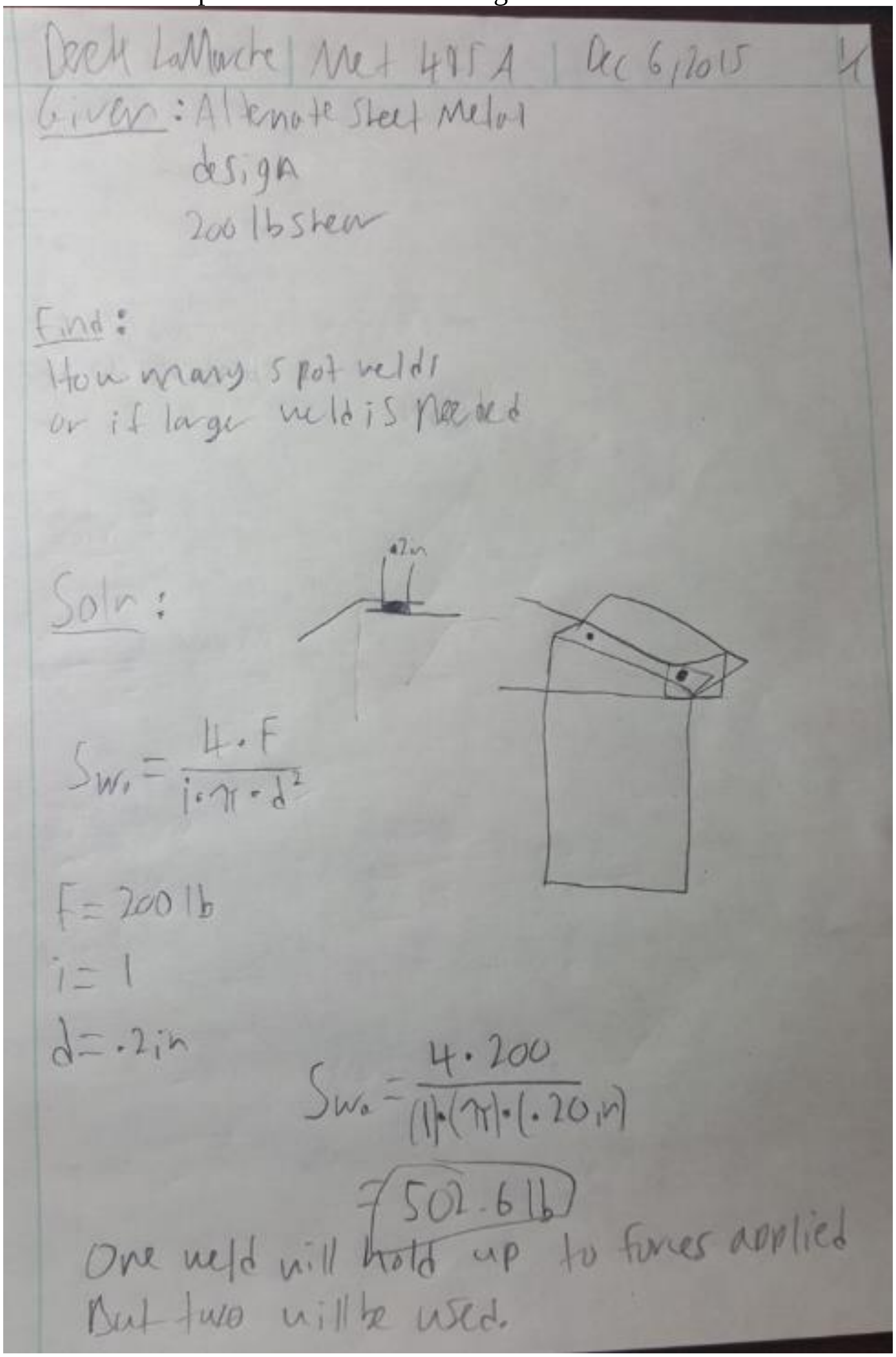
Soln:

A = 2.3859 degrees

Max missalignment
4 degrees per bearing spec

0.36 inches Needed for out of spec

Calculation on Spot weld sheet metal design



Derek LaMarche | Met 415A | Dec 6, 2015 4

Given: Alternate Sheet Metal design
200 lb shear

Find:
How many spot welds
or if large weld is needed

Soln:

.2in

$$S_{w_o} = \frac{4 \cdot F}{i \cdot \pi \cdot d^2}$$

$F = 200\,lb$

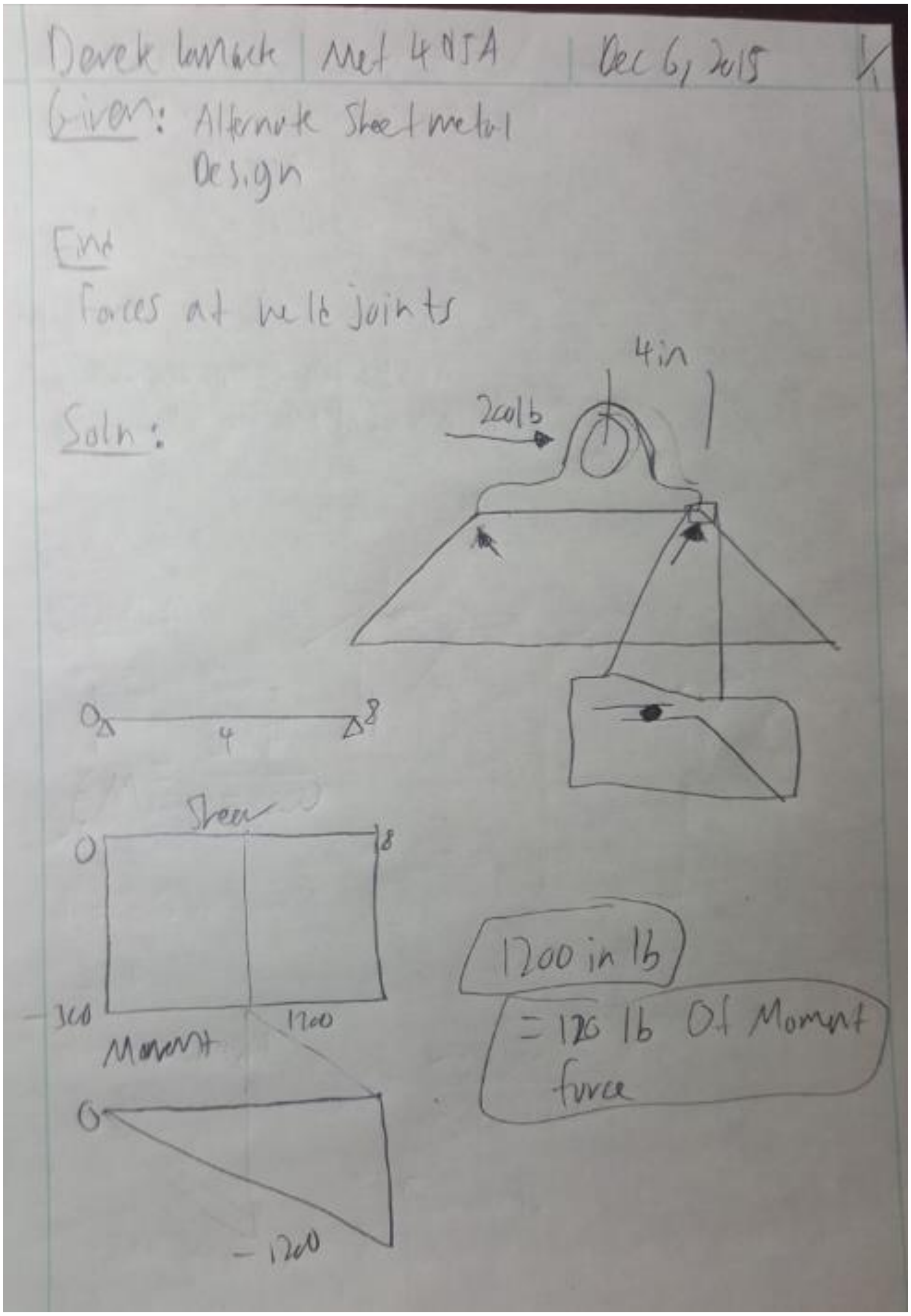
$i = 1$

$d = .2in$

$$S_{w_o} = \frac{4 \cdot 200}{(1) \cdot (\pi) \cdot (.20 in)} = 502.6\,lb$$

One weld will hold up to forces applied
But two will be used.

Calculation on Sheet metal weld forces



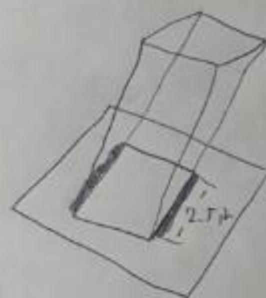
Calculation on Square tube riser weld

Derek LaMach | Met 445A | Dec 5, 2015 | 1/1

Given: 400 lb load
2.5 in weld
depth .10 in

Find:
Load weld can handle, if 4, or only 2 welds are needed

Soln:



$$\sigma_{\perp} = \frac{6 \cdot M}{a \cdot L^2}$$

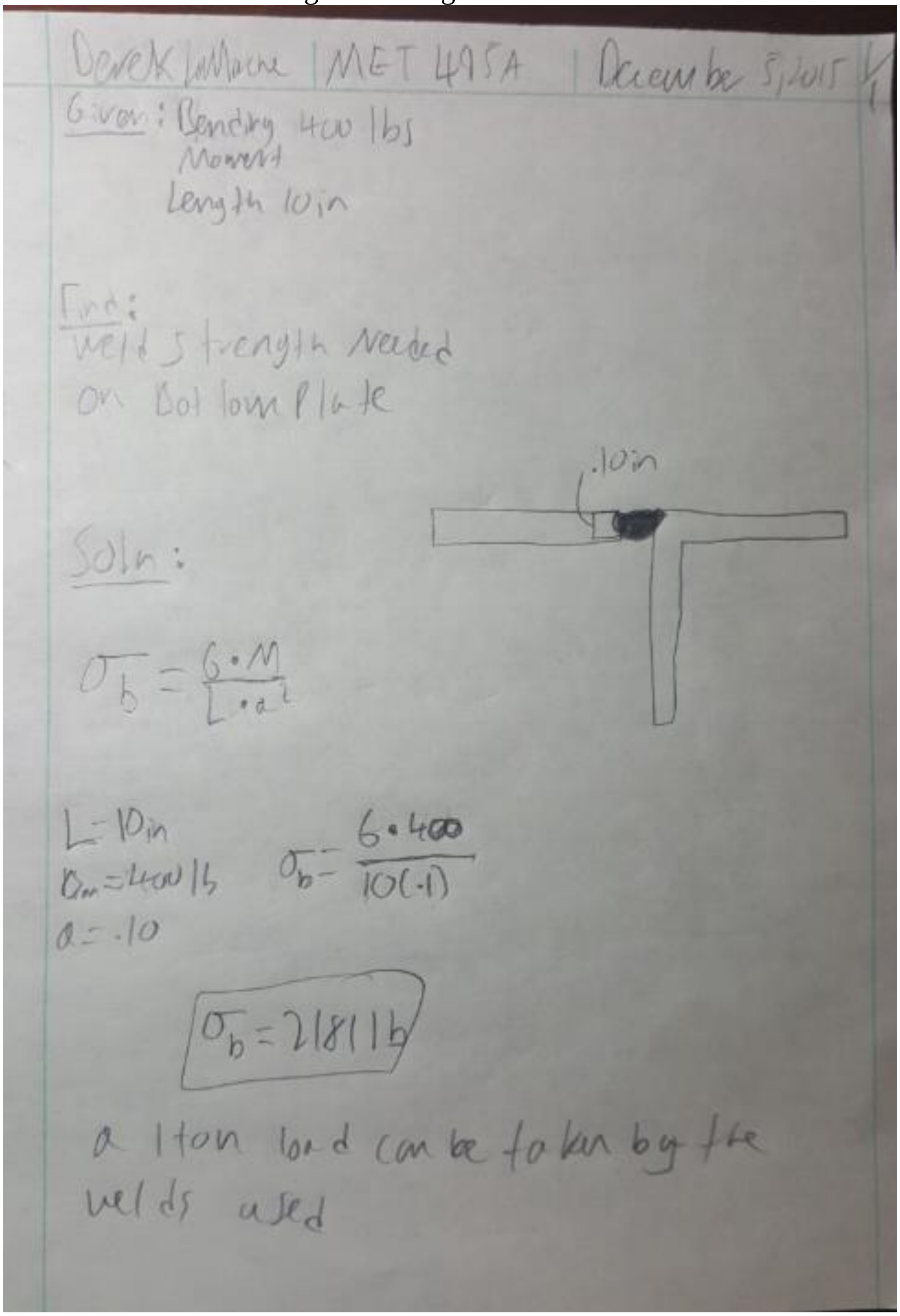
$M = 400$
$a = .10$ in
$L = 2.5$ in

$$\sigma_{\perp} = \frac{6 \cdot 400}{.10\,(2.5)} = 9600 \text{ lb}$$

Load support 9600 lb ✓

Only 2 needed

Calculation on weld strength from angle iron



Derek LaMache | MET 495A | December 5, 2015 1/1

Given: Bending Moment 400 lbs

Length 10 in

Find:
weld strength needed on bottom plate

.10 in

Soln:

$$\sigma_b = \frac{6 \cdot M}{L \cdot a^2}$$

L = 10 in

B_m = 400 lb

a = .10

$$\sigma_b = \frac{6 \cdot 400}{10(.1)}$$

$$\boxed{\sigma_b = 2181\ lb}$$

a 1 ton load can be taken by the welds used

Calculation on Alternate sheet metal design Full weld bead

Derek Lanoracke | Met 495A | Dec 6, 2015 | 1/1

<u>Given:</u> Alternate Sheet Metal design
6 in length
400 lb normal force

<u>Find:</u>
Will full length welds be needed

<u>Soln</u>

$\sigma = \frac{F_n}{L \cdot a}$

$L = 6in$

$a = .10$

$F_n = 400$

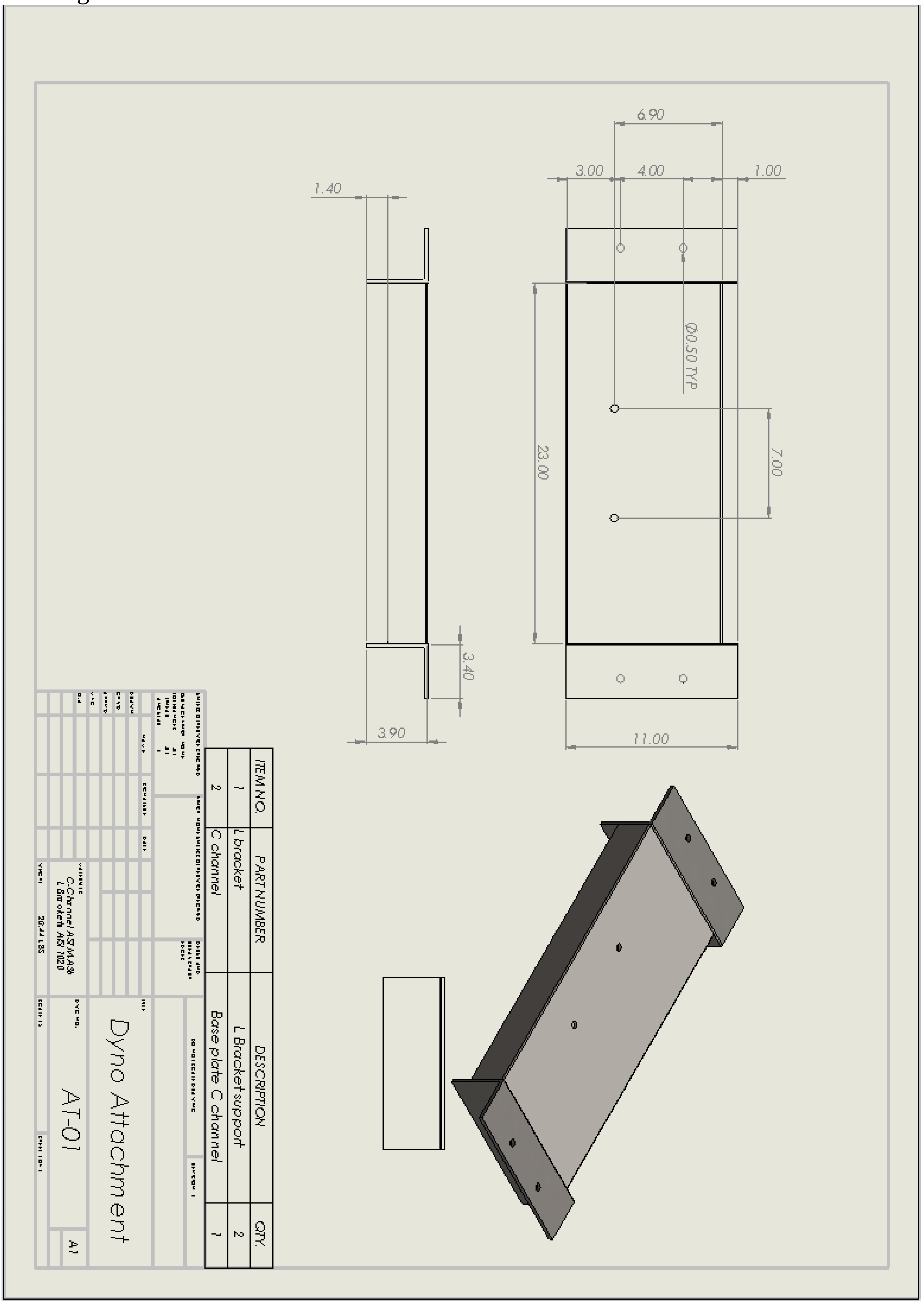
$\sigma = \frac{400}{6(.10)}$

The weld can handle 666 lbs of force that is much more then necessary

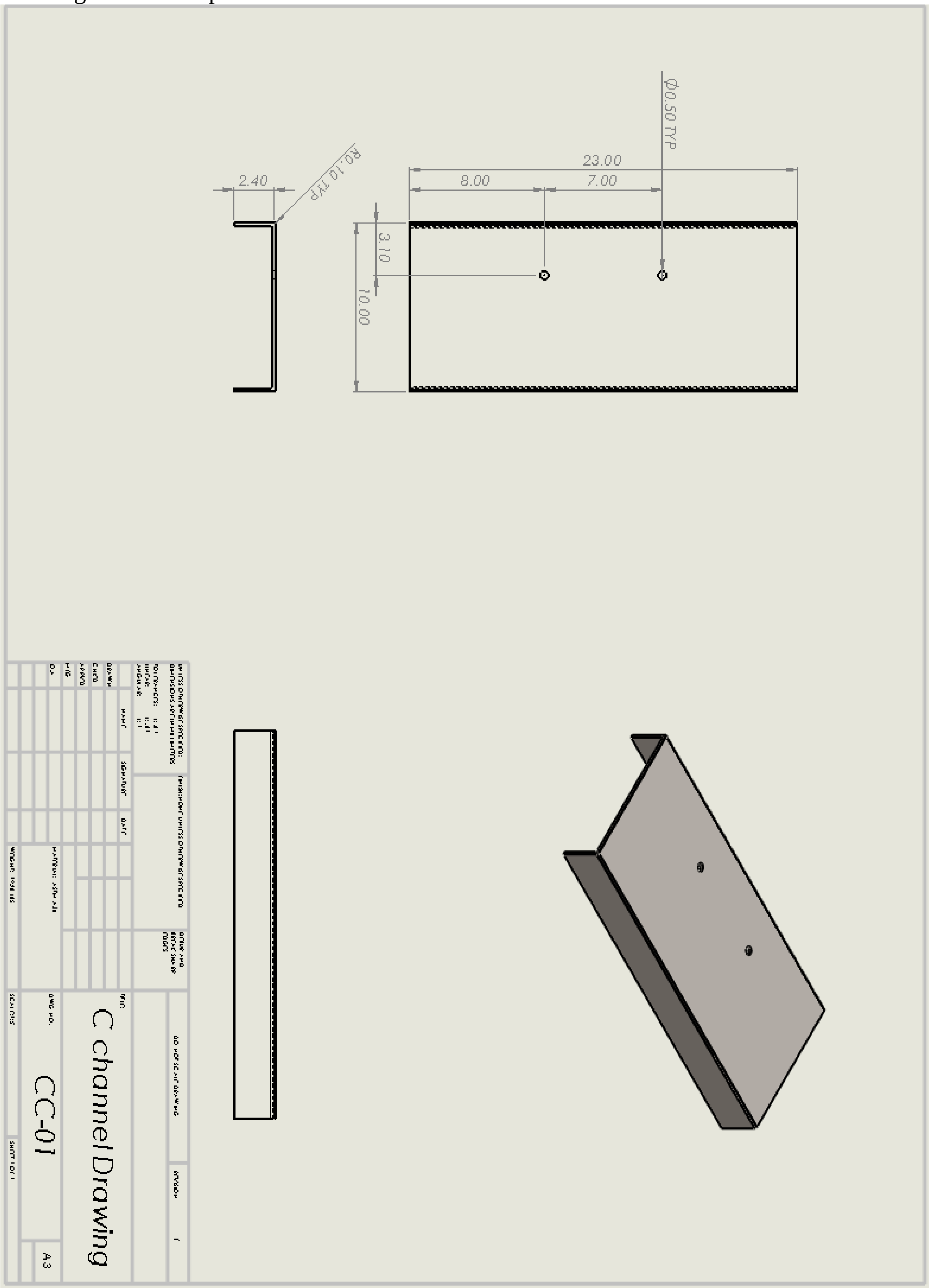
Safety factor of 3.33

APPENDIX B:

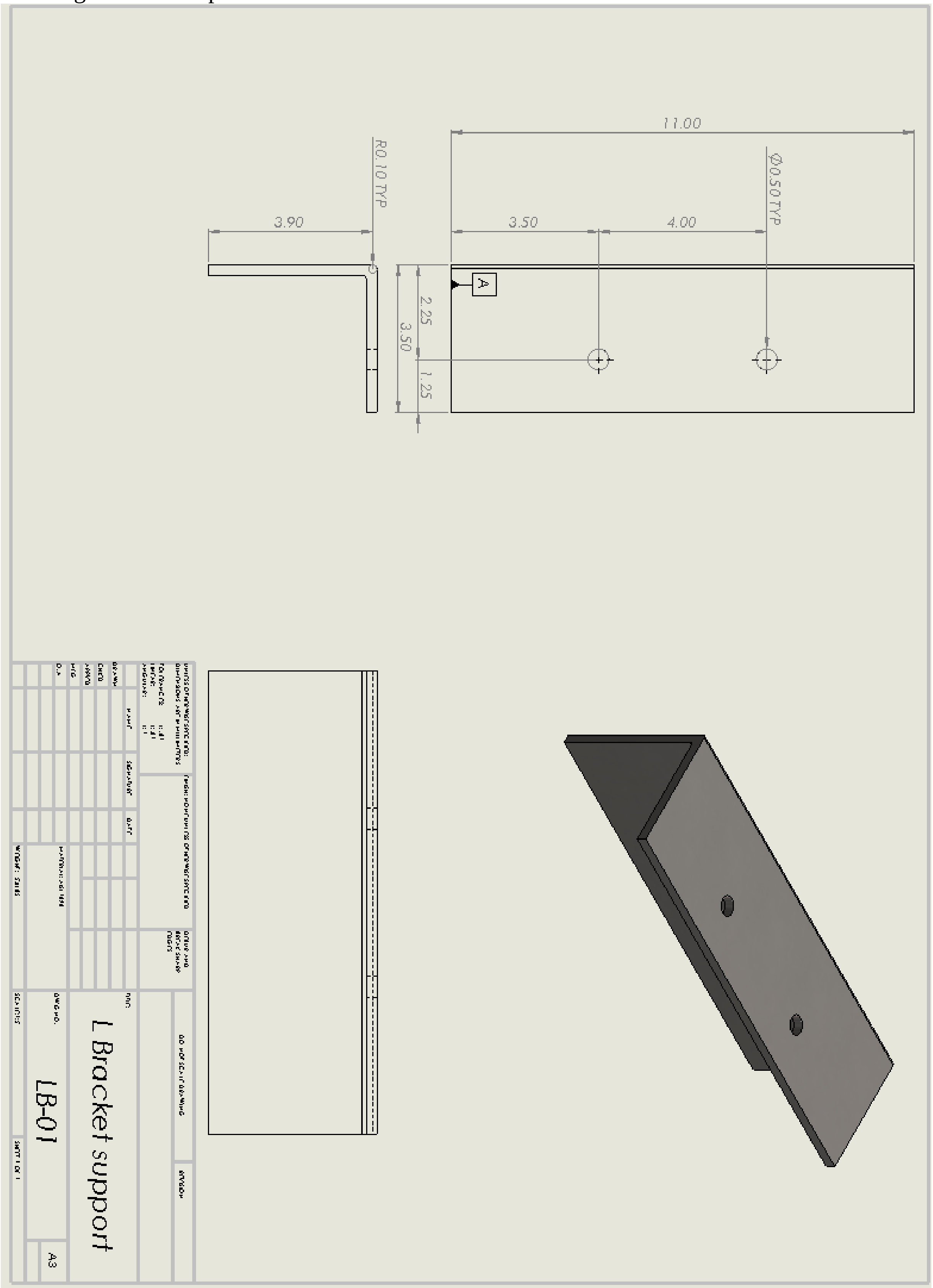
Drawing of Base



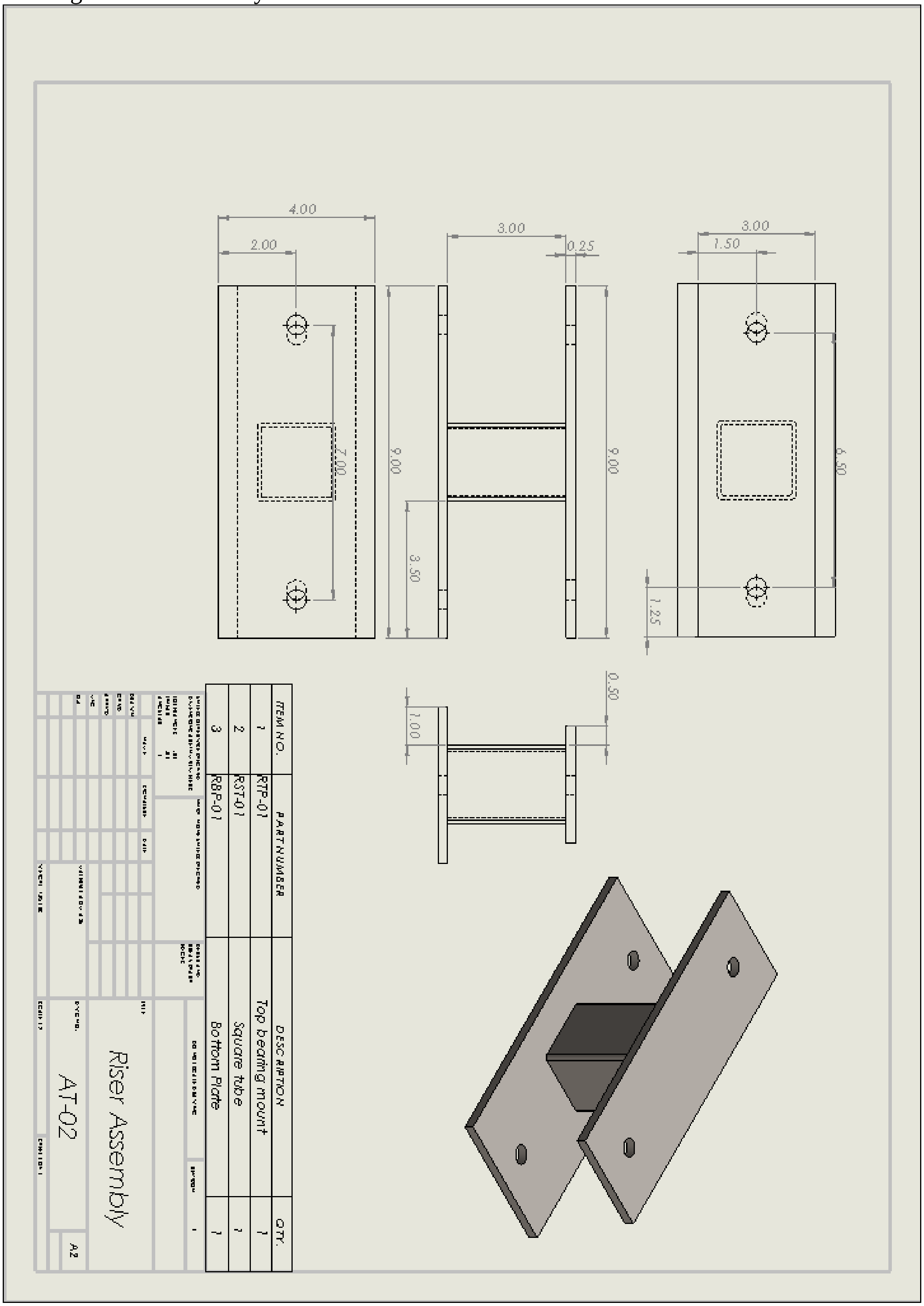
Drawing of base sub part C-Channel



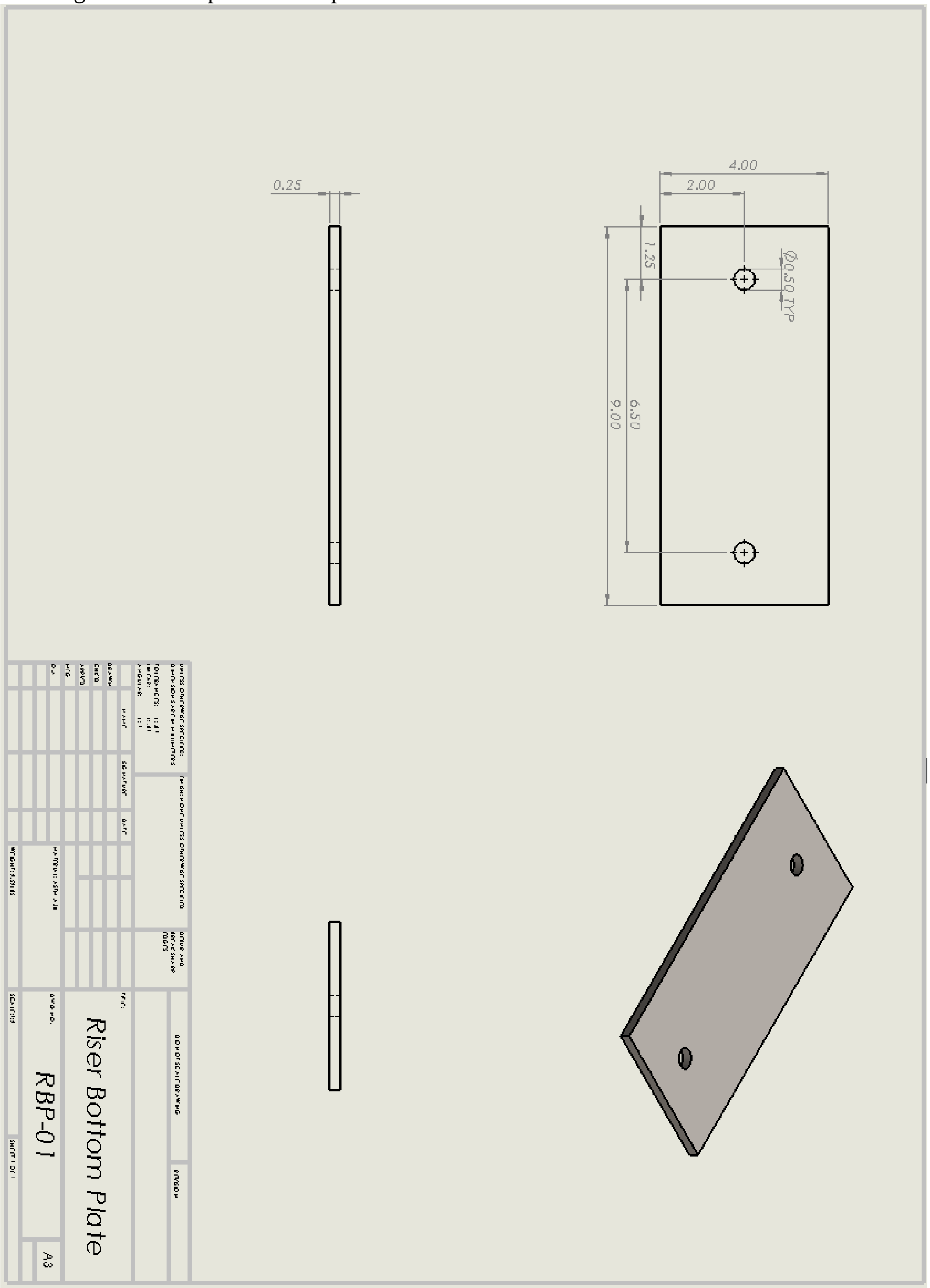
Drawing of base sub part L-bracket



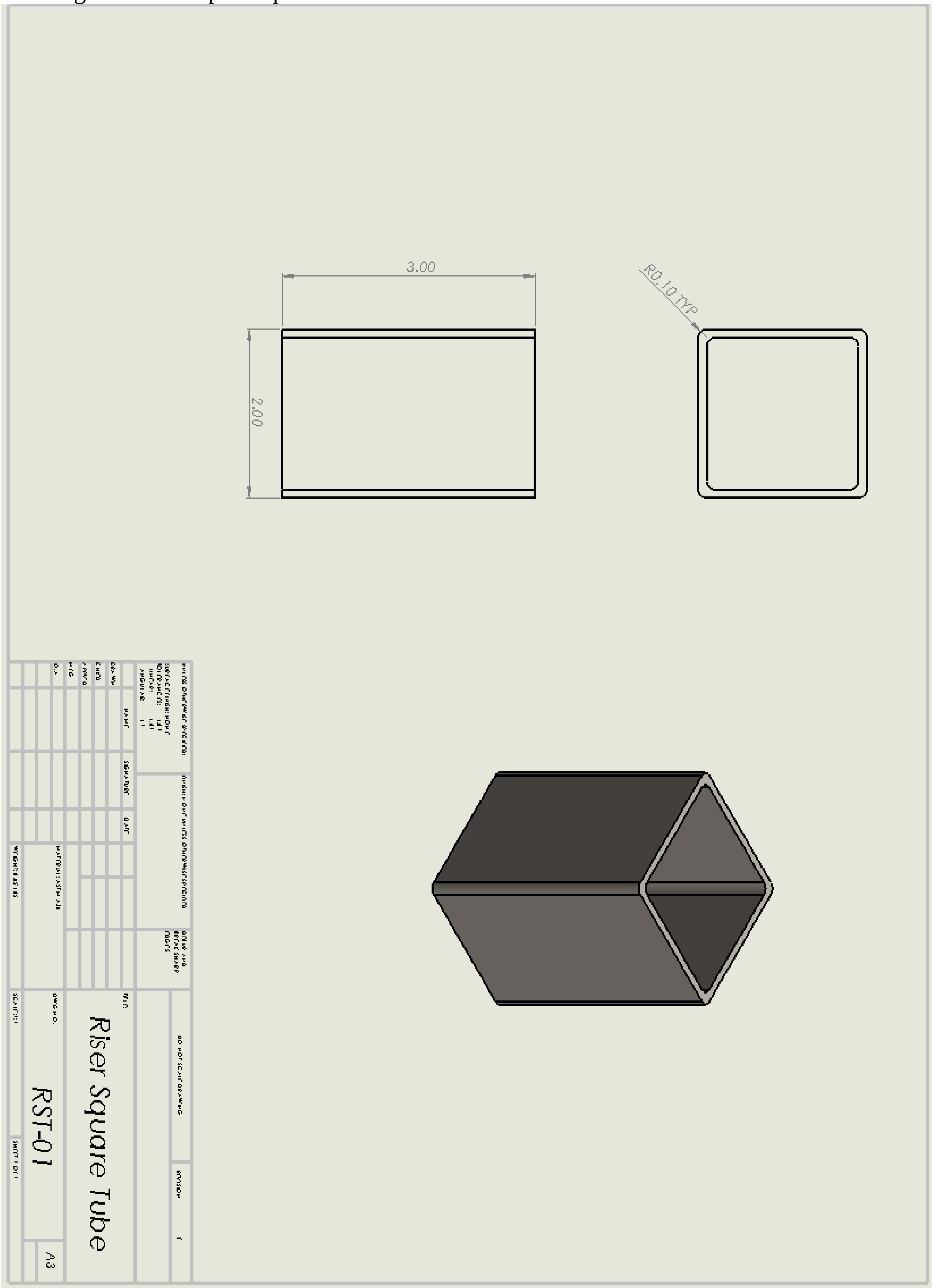
Drawing of Riser assembly



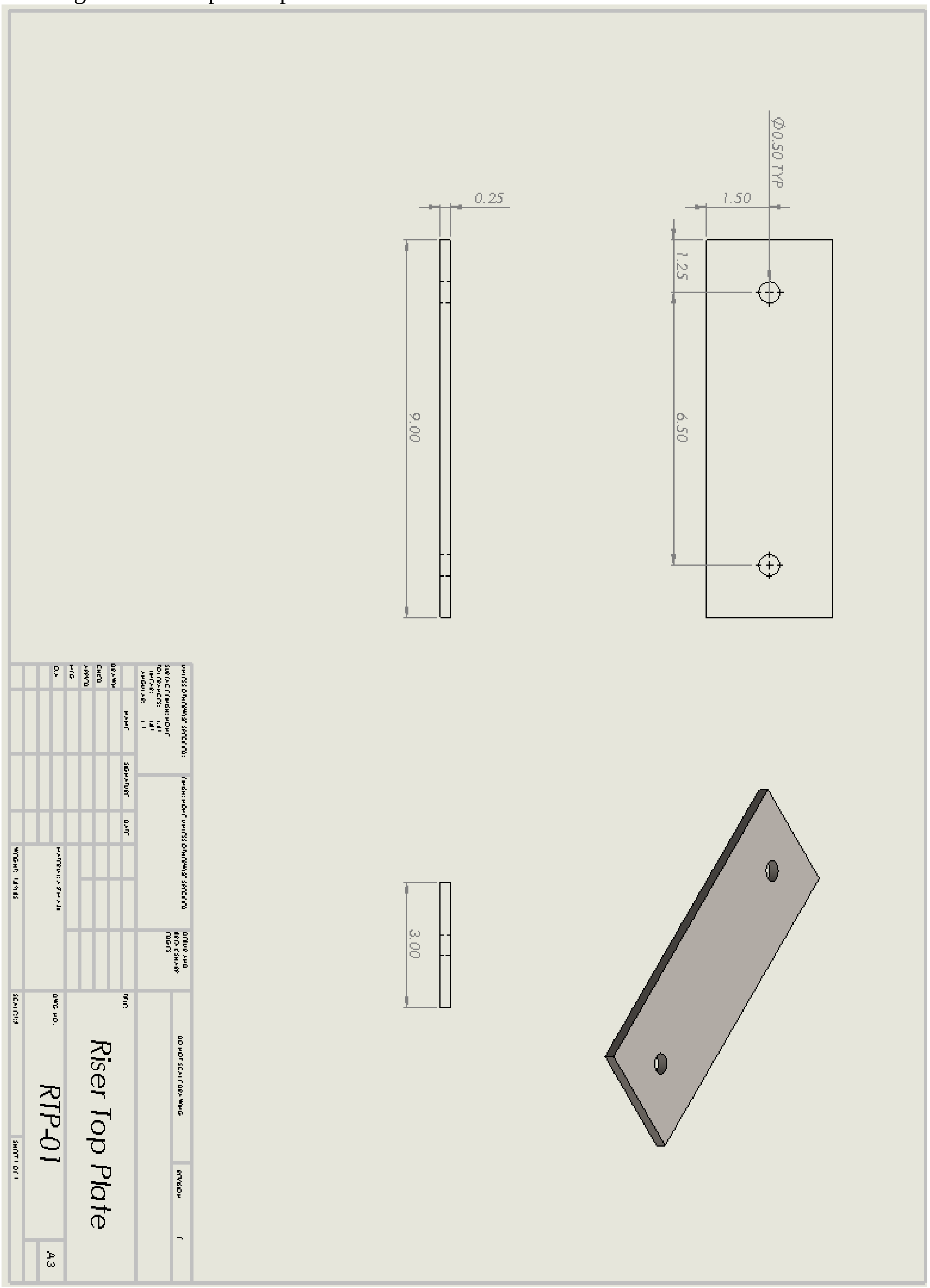
Drawing of riser sub part Bottom plate



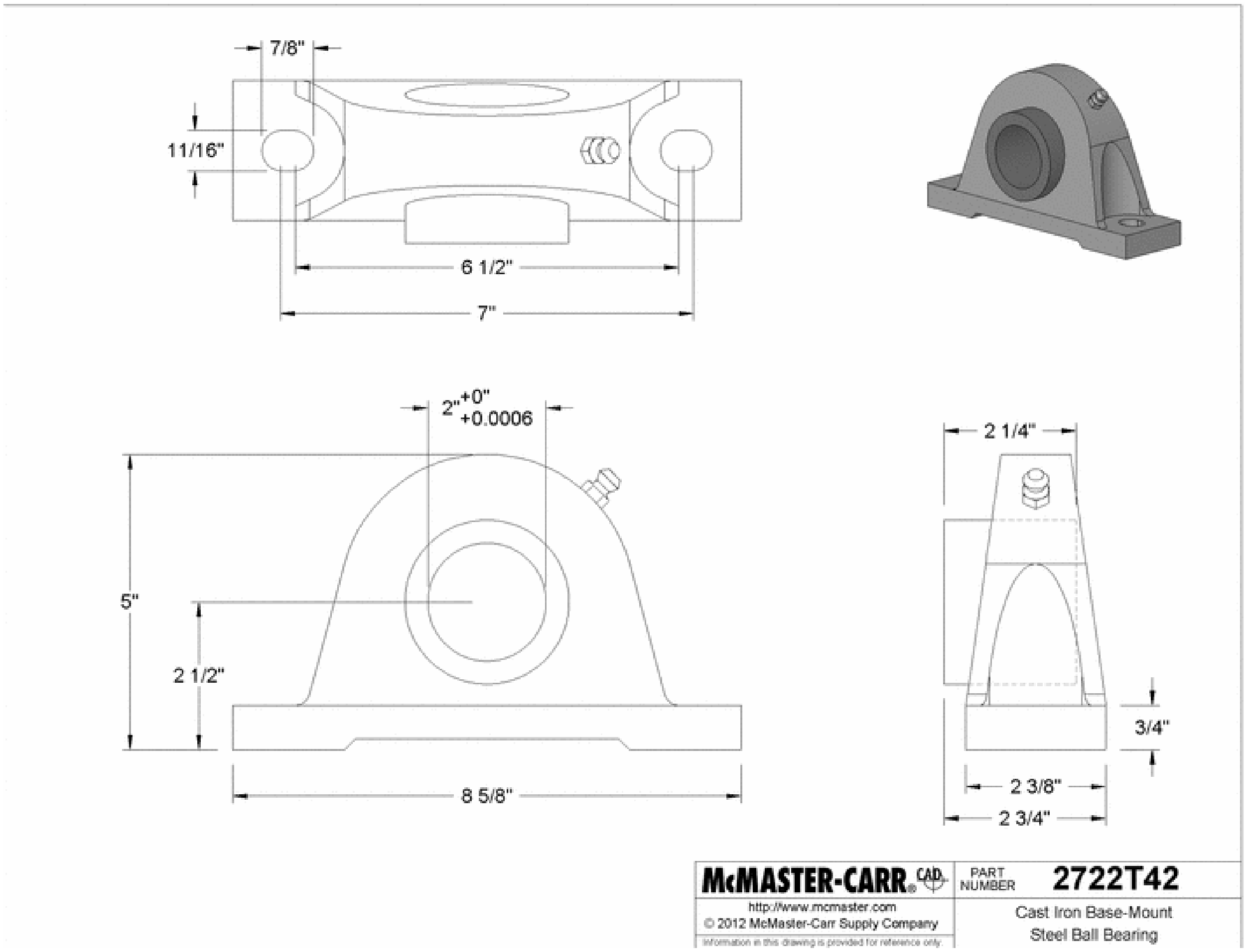
Drawing of riser sub part Square tube



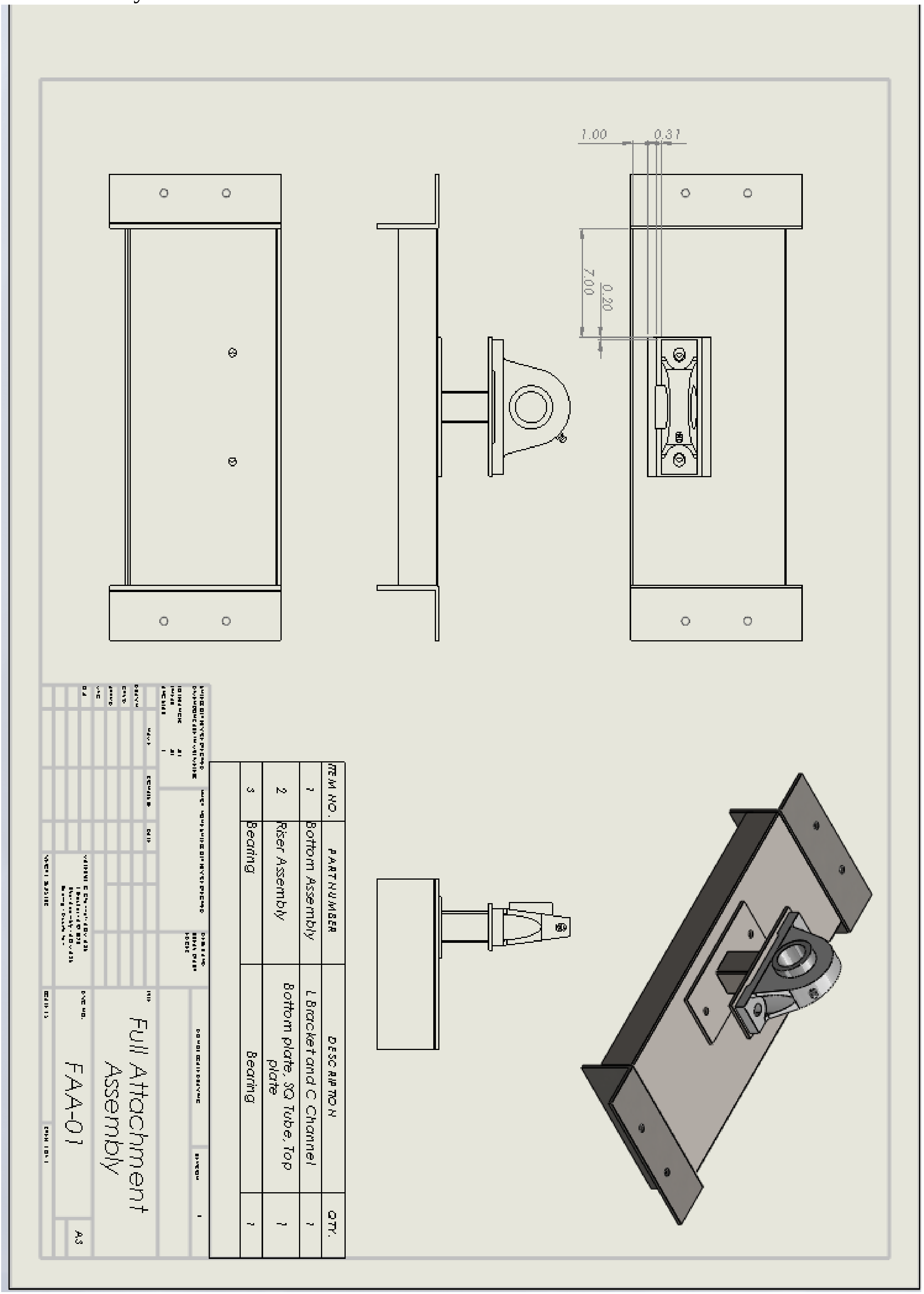
Drawing of riser sub part Top Plate



Drawing of bearing (Drawing 3)

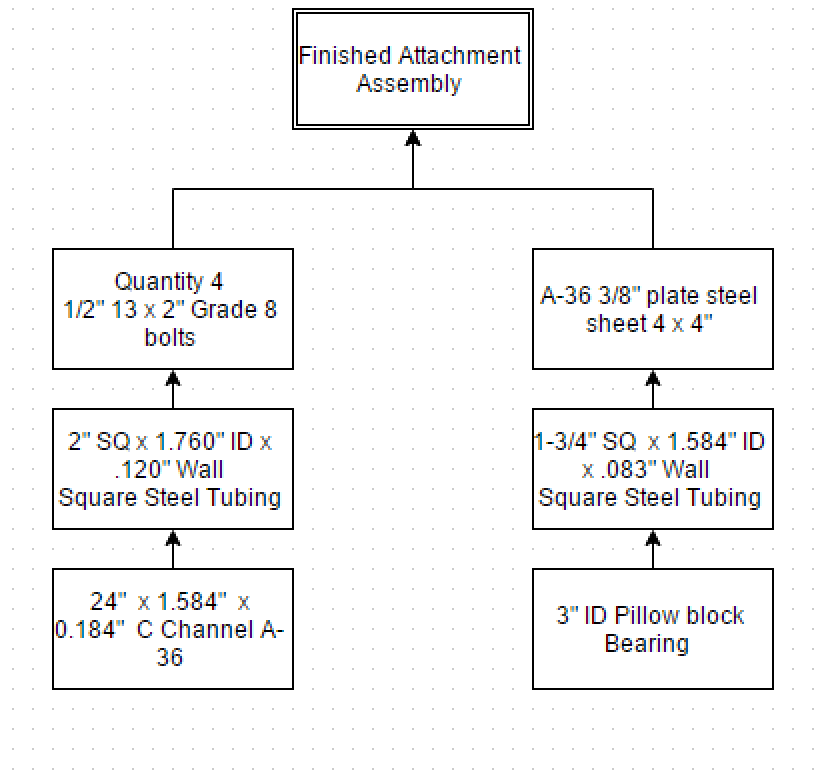


Full Assembly



APPENDIX C:

Part list/diagram needed for assembly.



Appendix D:

Part	Drawing #	Quantity	Part cost	Ship cost	TOTAL	Site
1/2" 13x2" bolts	-	4	1.25	5	10.00	albanycountyfasteners.com
2"SQ 1.760" Id x.120 Square Tubing	RST-01	1	4.78	8.06	12.84	Speedymetals.com
1-3/4 SQ x 1.584" ID x.083 Squre Tubing	-	1	3.42	8.06	11.48	Speedymetals.com
24" x 1.584 x .184 C Channel A-36	-	1	26.42	8.06	34.48	Speedymetals.com
A-36 3/8 Plate steel sheet 12x12	RBP-01	1	14.6	80.6	95.20	Speedymetals.com
3" id Pillow Block Bearing	2722T42	1	111.14	16.45	127.59	fastenal.com
				Grand total	**291.59**	

Appendix E:

Sr Project: Dynamometer stabilizer

Creator: Derek LaMarche

September October November December January February March April May June

Task ID:	Task Dsescription	Time	# of weeks Actual time
1	**Proposal**		
11	Introduction	3	3
12	Design Analysis	5	6
13	Website	6	4
14	Methods	3	4
15	Construction	4	7
16	Testing Method	3	5
17	Budget schedule	6	4
18	Discussion	3	5
19	Summary	4	3
19.9	Appendix	10	10
	Total for section	**47**	**51**
2	**Manufacturing**		
20	Locate and acquire raw material	0.5	1.5
21	Cut C Channel to length	0.5	1
22	Cut L Bracket to length x2	0.5	0.5
23	Cut Square Steel Tube to length	0.5	0.5
24	Cut out steel plate 9x3	2	
25	Cut out steel plate 9x4	2	
26	Drill holes in C channel	0.5	
27	Drill holes in L Bracket	0.5	
28	Drill hole in steel plate x2	0.5	
29	Weld L bracket to C Channel x2	2	
30	weld Square tube to steel plate x2	2	
31	Bolt riser assembly to C Channel	0.25	
32	Bolt Assembly to dyno cart	0.25	
33	Bolt Pillow block bearing to Assembly	0.25	
	Total for section	**11.75**	
4	**Analysis**		
41	Analysis of Stabilizer	3	
42	Dyno test w/o Stabilizer	4	
43	Analysis of moment	2	
44	Analysis of bearing	5	
45	Analysis of Deflection	5	
	Total for section	19	0
5	**Green sheets/Docs**		
51	Drawing of stabilizer	4	6
52	Drawing of bearing	3	2
53	Statics analysis	2	5
54	FEA of stabilizer	5	5
	Total for section	14	18
6	**Project Modifications**		
61	Schedule	5	8
62	Parts needed	2	3
63	Features	2	3
64	Budget	2	3
	Total for section	11	17
7	**Testing**		
71	Set up Attachment	2	
72	Set up all needed equipment	2	
73	Run dyno	2	
74	pictures, measurements	1.5	
75	problems needing fixing	5	
76	Update website	5	
	Total for section	17.5	0
8	**495 Requirements**		
81	Report	5	25
82	Presentation	4	
	Finalize Website	3	
	Finalize Gantt chart	2	5
	Update resume	3	
	Go over all material	6	
	Total for section	23	30
	TOTAL FOR PROJECT	143.25	

Weeks: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37