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Custom Designed Wall Mounted Shop Crane

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Shop Jib Crane

By

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MET489

Abstract

The objective of this project was to design and fabricate a custom wall mounted jib crane to specific, non-standard dimensions. The crane was designed to be industry rated for 2000 pounds, rotate at least 180 degrees, and be designed to have a maximum boom length tailored to the specific installation site. Two potential installation sites and purposes were selected for construction: inside the bay doors of a fabrication shop, intended to transfer large pieces of material to and from a plasma table, and inside a car maintenance garage, intended to lift and remove engines and transmissions from cars.

Design of the crane revolves primarily around the mounting assembly that consists of rotating hinge brackets made from ½, ¾ inch 532 steel plate, and 2 inch diameter structural tubing. Based on the material properties of the steel used, the highest stress point on the crane has a 1.6 minimum factor of safety, assuming a 12 foot boom arm.

After installation, testing resulted in successful rotation of the boom arm through a range of motion of at least 180 degrees, and lifting of 2000 pound loads with less than 1/16th of an inch of deflection at the end of the boom arm.

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1. Introduction

a. Description: The fabrication shop at Lewis Field Service performs numerous metal working, fabrication, and repair services every day. One of the more recent additions to this shop's repertoire is the ability to cut parts from sheet metal easily and quickly using a plasma table. Unfortunately due to the shop's layout and the position of said plasma table, the placement and removal of material into the table to be cut into parts is difficult and tedious, requiring multiple workers, forklifts, and a substantial section of the shop floor to be cleared beforehand. Designing a more efficient method of placing sheet metal into the plasma table would drastically increase productivity and efficiency.

b. Motivation: The motivation for this project is to improve the efficiency and autonomy of the plasma table functions of the Lewis Field Service fabrication shop. This crane will allow for a single worker to operate, moving substantially larger material in and out of the plasma table without additional assistance, lessening the workload overall.

c. Function Statement: A device is needed that can lift loads and articulate said loads.

d. Requirements:
The device will conform to the following requirements

  i. Able to lift a minimum of 1500 pounds with no loss of structural integrity.
  ii. Able to rotate out of bay doors and back into the bay, est. 246 degree arc.
  iii. Main boom long enough to reach outside doors, but shorter than the width of the bay doors (13 feet).
  iv. Total height shorter than bay doors; 13 feet.

e. Engineering Merit: The majority of equations needed for this project will consist of stress calculations; torsion, tension, compression, and shear.

f. Scope of Effort: The scope of this project includes the design of the crane, fabrication of all necessary components, construction of the crane, and installation onsite.

g. Success Criteria: The project will be a success if it is able to improve the efficiency of the transportation of material to and from the plasma table, which includes all of the requirements by default.

h. Benchmark: Freestanding jib cranes vary dramatically in cost, size, and load capacity, from smaller models costing just over one thousand dollars and lifting just 250 pounds, to massive structures for industrial facilities worth several thousand that lift multiple tons. Free standing jib cranes rated for 2000 pounds vary in price from 2300 dollars up to around 4000.

2. Design and Analyses

a. Approach: To approach the problem of moving large stock plate and sheet metal from one point to another, the decision to design a crane to solve this issue was simple. Any other device would need floor space that is severely limited, and take up space that needs to be clear for the movement of other machines and work on the shop floor. A jib crane would allow the movement of such materials without permanently limiting the actual floor space of the areas that the crane is operating within.

b. Design Description: The design of this crane consists of a pulley hoist connected to a strait boom arm that extends from a vertical support beam. This vertical support is attached to a pillar by hinges that allow the whole crane to rotate more than 180 degrees. The pillar is supported and anchored to the ground using a foot plate with concrete anchor bolts.

c. Performance Predictions: The crane is designed to operate safely with up to 2000 pound loads, even when the load is placed at the very end of the boom arm. This means that as the hoist moves closer to the wall where the crane is mounted, the factor of safety increases, and the load that the crane could theoretically hold safely also increases. This is only a theoretical increase in load capacity, due to the fact that all loads will be held by a magnet at the end of the cable, rated for 1500 pound loads. If a piece of material is heavier than the rating of the magnet, the magnet simply will not lift the material off the ground.

d. Description of Analyses: Due to the nature of this project, being a structural crane, the vast majority of the analyses required are structural in nature. The maximum load predicted to be used by the crane, plus a factor of safety appropriate to each piece individually determines the forces that each piece must withstand during regular operation. The maximum load predicted to be used by this crane is 1500 pounds, or ¾ of a ton. The crane’s pieces will be rated to safely carry a full 1 ton load, or 2000 pounds. For this reason, all stress analyses are done assuming the crane is loaded with 2000 pounds, plus a factor of safety on top of that.

e. Scope of Testing and Evaluation: The testing and evaluation of a crane is entirely straightforward, lift a load of maximum predicted capacity, and operate. If the crane can hoist 1500 pounds off the ground, and rotate as intended, then the crane is successful in its purpose.

f. Analyses
    i. Design Issue:
        1. The primary design issue this crane needs to overcome is the floor space that most jib cranes take up, being mounted on a free

        standing pillar. This wall mounted design will only take up a few additional inches of floor space as the pillar that the crane is to be mounted on will be reinforced with a steel shell.

    2. Tolerance of some of the machined parts, particularly the pin tubes that are part of the bracket assemblies was also a design issue. During the manufacturing process, the brackets that are intended to weld directly onto the pin tube are cut out of sheet steel using a plasma table, including the hole that is intended to fit over the pin tube, and weld onto it. The plasma table's cuts resulted in holes that were too small to properly fit over the tube. This issue is resolved by machining a shoulder into the pin tube, reducing its size by a mere ten thousandths of an inch, allowing them to fit together properly.

ii. Calculated Parameters: The parameters that this crane are required to operate within are the size of the doors it must swing through, the total range of motion it must move through, and the weight it must carry. The size of the doors are roughly 13 feet tall and wide, meaning that the crane must be at most under 13 feet long, as well as 13 feet tall. The total arc needed to rotate through is well over 180 degrees, with current estimates being around 210 degrees. As stated elsewhere, the max load applied to the crane will be no more than 1500 pounds.

g. Device: Parts, Shapes and Conformation: The primary pieces that make up the crane will be made of construction steel; I-beams, flat bar, brackets, steel cable, box tube, plate, bolts, welds, etc.

h. Device Assembly, Attachments: The majority of assembly will be welding pieces together, with two bolts holding the hinges together and anchor bolts into the concrete underneath the baseplate.

i. Tolerances, Kinematics, Ergonomics, etc.: Most of the tolerances required for this crane's construction will not need to be any more precise than 1/16th of an inch, with the few exceptions being the hinge assemblies, which will require significantly more precise tolerances due to the fact that their placement and position relative to each other will affect the friction of the hinges, as well as the neutral position of the crane as a whole if they are off balance. Ergonomics are unnecessary, as the crane itself is not something a human hand must be comfortable with grasping. The only pieces people will actually handle are the magnet on the end of the cable, and the hoist itself, which is a simple chain winch.

j. Technical Risk Analysis, Failure Mode Analyses, Safety Factors, and Operation Limits: The primary safety factors used in this crane revolve around the lowest safety factor in the crane: the magnet at the end of the cable hoist. The operational limit of this magnet, and the safety factor are the same in this case; a factor of safety of 1 and a capacity of 1500 pounds. All other pieces are measured to have greater factors of safety that the magnet, which will not lift any objects heavier than the maximum load of 1500 pounds.

3. Methods and Construction

a. Construction:

   i. Description: The construction process of this crane will consist primarily of cutting and shaping stock parts, and welding them together to assemble the crane structure, attach it to the hinges, and attach the hinges to the pillar casing. The hinge assembly is a simple tube and bolt system that can be assembled by hand tools. The pillar casing and foot plate will be placed and mounted to the support beam and the floor around it, then welded and bolted.

   ii. Discussion of assembly, sub-assemblies, parts, drawings: All of the drawings are of individual parts that are assembled into one assembly. There are a total of 11 unique parts, with the pin brackets being duplicated a total of 4 times, pin tubes duplicated twice, the pin bracket 2 is duplicated twice as well resulting in a total of 17 parts in the final assembly drawing.

   iii. Refinement and revisions: During the process of manufacturing, the factor of safety for the crane's boom arm was decided to be lower than desired and more deflection than what was considered safe. To correct this issue, support pieces were added to the boom arm structure to reinforce and more directly transfer energy from the boom arm into the support brackets. These webbing supports are made of half inch 532 steel plate, cut to size and welded directly into the webbing of the boom arm and vertical support to create structural reinforcement in places where the ends of the triangle support, vertical support and the boom arm meet. Additional structures have been added to the crane in the form of end caps. These caps connect to both ends of the vertical support, and the far end of the boom arm. These plates assist in maintaining the structure of the boom arm, and the endplate also doubles as a stop for the hoist mechanism, preventing it from rolling off the end of the boom arm.

4. Testing Method

a. Introduction: This crane has two primary functions; to lift 1500 pound loads, and to rotate between the loading area outside the doorframe it is to be mounted to, and the plasma table it was place things onto. Testing these two functions will consist of operating the crane normally.

b. Method/Approach: The method used to evaluate the jib crane will be to operate the crane as it is intended to be operated using the maximum estimated load of 1500 pounds.

c. Test Procedure description:

   1. Attach cable to example piece weighing roughly 1500 pounds.
   2. Lift piece off the ground/forklift forks/truck bed.
   3. Rotate boom arm inside shop to position over plasma table.
   4. Lower example piece onto plasma table.
   5. Detach magnet from example piece.

d. Deliverables: All testing criteria are binary go/no-go tests, meaning that the deliverable will be a single test sheet with marked check boxes of rotation and load capacity, with an attached photo of the crane during operation.

5. Budget, Schedule, and Project Management

a. Proposed Budget:

   i. Discuss part suppliers, substantive costs and sequence or buying issues: By far the largest cost in this project will be the raw materials going into its construction, which is a result of a large portion of the materials used being either proprietary hardware, like concrete anchors, or stock material only sold in large quantities, like plate stock sold by the square foot.

   ii. Determine labor or outsourcing rates & estimate costs: Estimated labor costs are roughly $20 dollars per hour, with an estimated maximum of 15 hours of labor for fabrication and construction of the crane. This results in $300 of the budget going toward labor of the crane itself.

   iii. Estimate total project cost: The budget for this crane is roughly the same as it would be to purchase a standard jib crane, because if this project cannot be completed within that cost band, there would be no point in the project to begin with.

   iv. Funding source: All funding comes from Lewis Field Service, the company that has commissioned this project.

b. Proposed schedule: See appendix E

   i. Testing schedule: Testing the final design of the custom wall crane created only minor issues due to the disjointed nature of the offsite installation of the crane. However, these issues were resolved by simply having those available at the installation site perform the tests, then send the testing results electronically to the author for validation and evaluation. Timing of the testing resulted in little issue, as the large gap between individual testing deadlines and the short nature of the testing required to evaluate the crane generated a lax testing schedule. Each test only requires an absolute maximum of 20 minutes to complete, meaning that they do not need to interfere with the standard operation of the crane during the working hours of the installation site.

c. Project Management:

   i. Human Resources: The author is the primary human resource for design, manufacturing, and construction of this project. Other resources include design assistance given by both CWU faculty and Jason Lewis, the customer for the proposed crane.

   ii. Physical Resources: Machines and processes used during manufacturing of this crane include welding, milling, band saw cutting, and drilling.

iii. Soft Resources: Primary software resources used include Microsoft Word, Microsoft Excel, and SolidWorks.

iv. Financial Resources: Funding for this project comes from the customer, Lewis Field Service, who is commissioning the project.

6. Discussion

a. Design Evolution / Performance Creep: This design has been primarily devoid of performance creep, the specifications have been the same from inception, when the crane was given specific standards to meet. The standards are the rotation between the lifting area and the table it is designed to transfer material to and from, and the load bearing requirements of 1500 pounds. The design went through a few iterations as alternate designs were considered based on designs of similar jib cranes found online. Such designs included cable supports above the boom arm, no triangle support, an upside-down variant with the triangle support above the boom arm, and a potential design of having the hinges allow the crane to slide around the support beam it is to be mounted on. All of these designs were either too complex to be considered for the budget and time constraints given, or did not meet the projected structural requirements efficiently enough.

b. Project Risk analysis: The primary risks involved in this project are during operation. Heavy loads capable of causing severe harm if they were to fall onto a person or damage objects. This is mitigated with the use of a magnet anchor at the end of the hoist, which will prevent dropping heavy loads by either lifting loads within its capacity and holding them securely for the duration, or it will not lift the load at all. In addition to this, the crane’s primary function, transferring material to and from the plasma table means that loads will not need to be lifted higher than the plasma table’s height of 33 inches. There is no point during operation that the crane will need to lift any loads above head height.

c. Project Documentation: All documentation of the project will be performed personally by the author during the fabrication and construction processes.

7. Conclusion

The results of this project will substantially increase the productivity and efficiency of any job requiring the use and operation of the plasma table. A crane capable of more effectively moving material into the front of the fabrication shop than any other means currently available while also reducing the amount of labor and effort needed to transfer said material, thereby increasing the productivity of the shop at large. This project meets all requirements for a successful senior project, including:

1. Having substantive engineering merit in both motion analysis and structural areas

2. Size and cost within acceptable parameters

3. Being of great interest to the principle investigator.

The design of this device adequately achieves all design specifications including arc of rotation, size constraints, load capacity, and hoist capability.

8. Acknowledgements

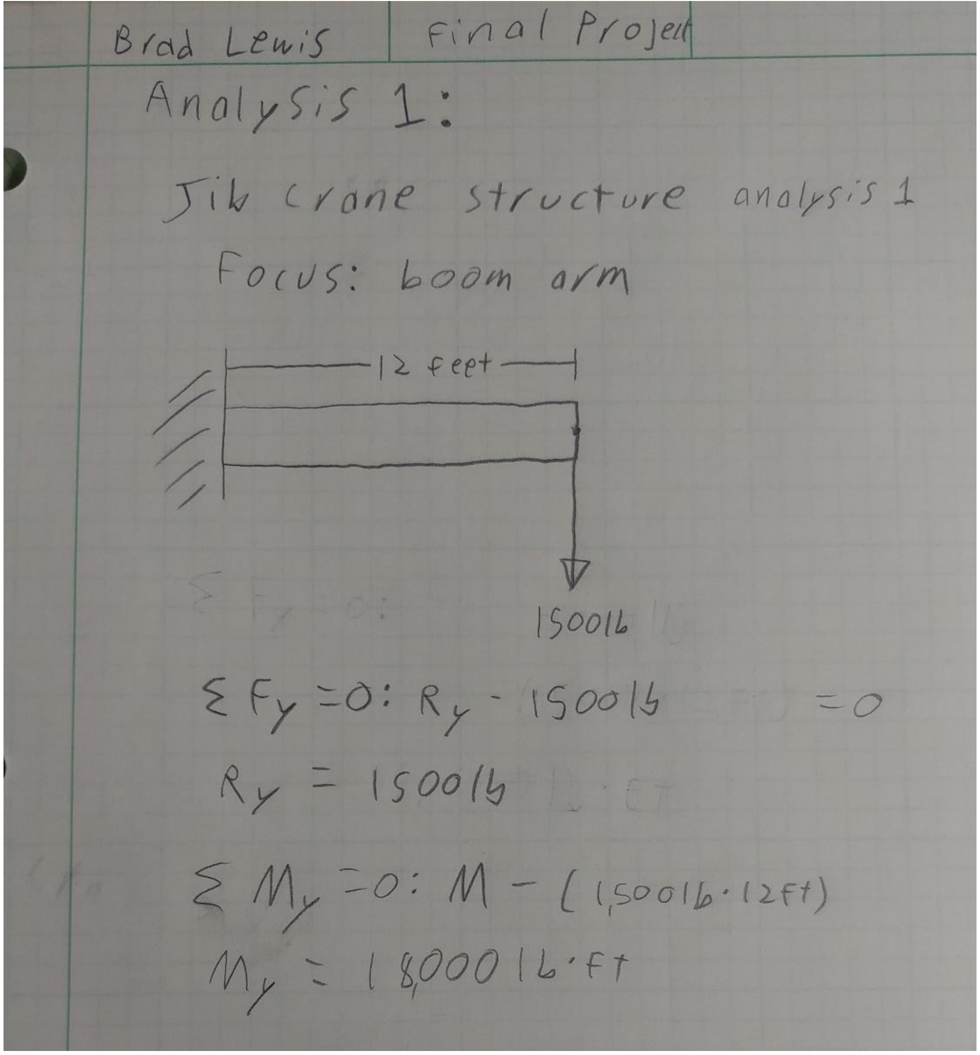
a. Jason Lewis of Lewis Field Service commissioned and sponsored this project

b. Dr. Craig Johnson and Professor Charles Pringle mentored the principle engineer

Appendices

Appendix A: Design Analysis

a. Fig. A-1: Jib Crane Max Load Analysis



Brad Lewis | Final Projec

Analysis 1:

Jib crane structure analysis 1

Focus: boom arm

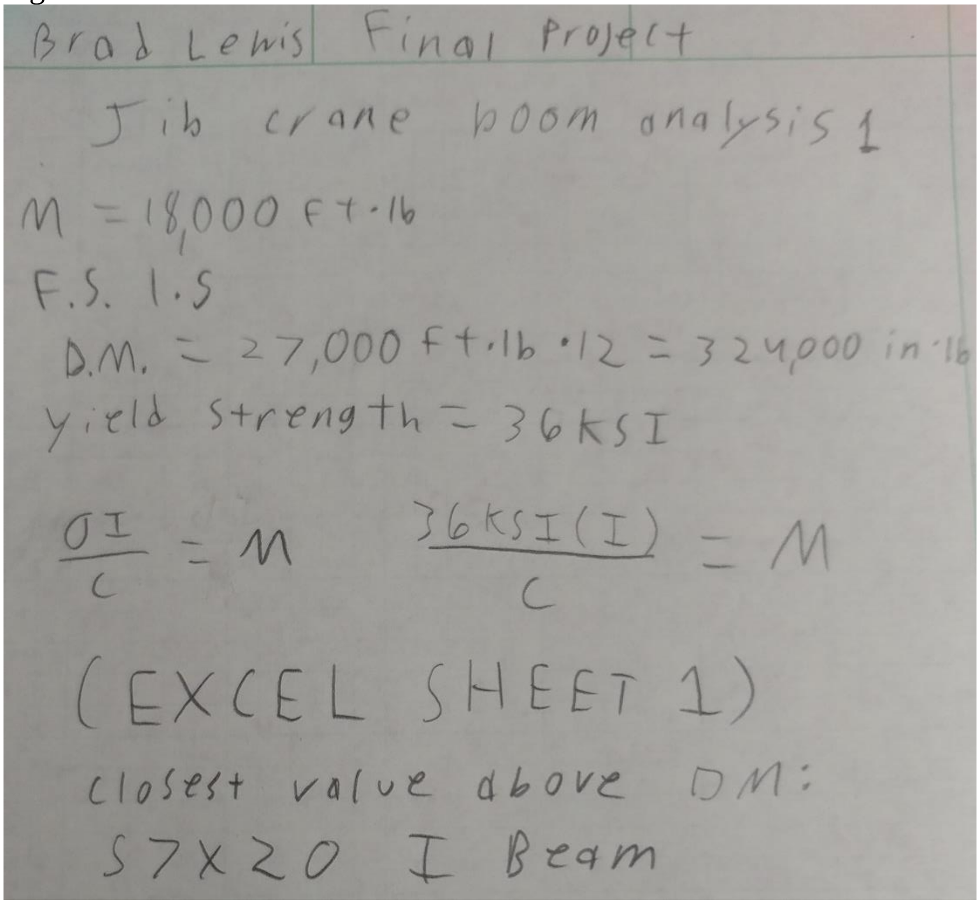
$\Sigma F_y = 0: R_y - 1500lb = 0$

$R_y = 1500lb$

$\Sigma M_y = 0: M - (1{,}500lb \cdot 12ft)$

$M_y = 18{,}000 lb \cdot ft$

b. Fig. A-2: I-beam size estimation



Brad Lewis | Final Project

Jib crane boom analysis 1

$M = 18{,}000$ ft·lb

F.S. 1.5

D.M. $= 27{,}000$ ft·lb $\cdot 12 = 324{,}000$ in·lb

yield strength = 36 KSI

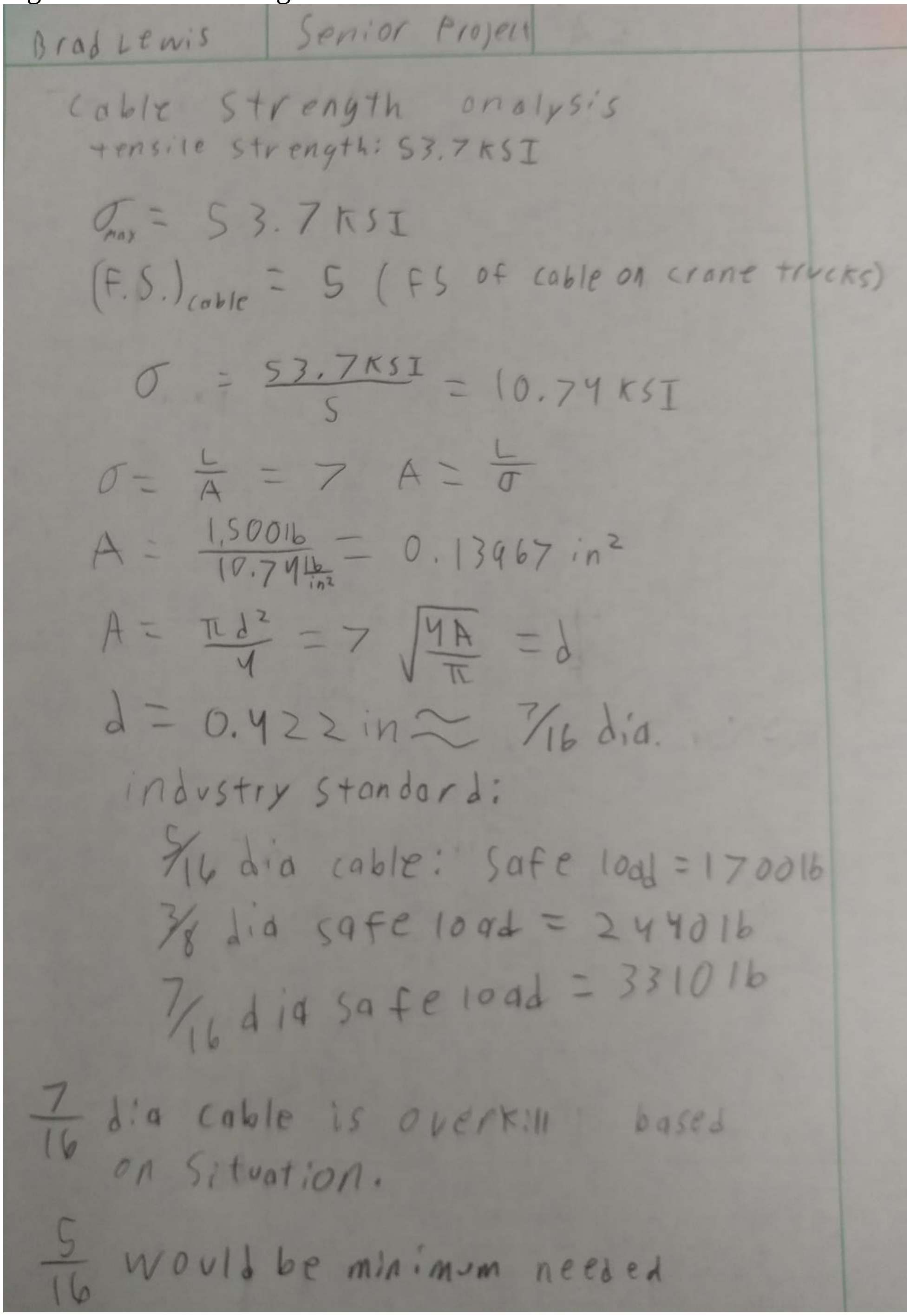
$$\frac{\sigma I}{c} = M \qquad \frac{36\text{KSI}(I)}{c} = M$$

(EXCEL SHEET 1)

closest value above DM:

S7X20 I Beam

c. Fig. A-3: Tensile Strength cable determination



Brad Lewis | Senior Project

Cable Strength analysis
tensile strength: 53.7 KSI

$\sigma_{max} = 53.7\ \text{KSI}$

$(F.S.)_{cable} = 5$ (FS of cable on crane trucks)

$$\sigma = \frac{53.7\ \text{KSI}}{5} = 10.74\ \text{KSI}$$

$$\sigma = \frac{L}{A} \Rightarrow A = \frac{L}{\sigma}$$

$$A = \frac{1{,}500\text{lb}}{10.74\frac{\text{lb}}{\text{in}^2}} = 0.13967\ \text{in}^2$$

$$A = \frac{\pi d^2}{4} \Rightarrow \sqrt{\frac{4A}{\pi}} = d$$

$d = 0.422$ in $\approx$ 7/16 dia.

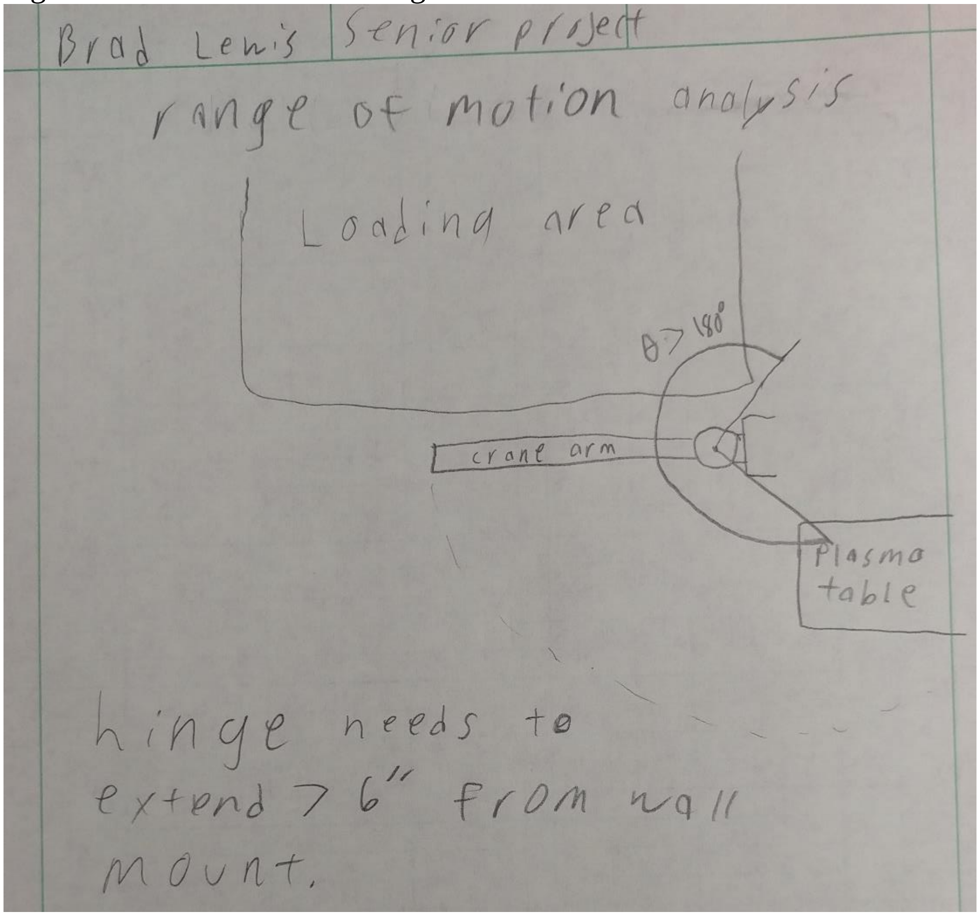
industry standard:

5/16 dia cable: Safe load = 1700lb
3/8 dia safe load = 2440lb
7/16 dia safe load = 3310lb

7/16 dia cable is overkill based on situation.

5/16 would be minimum needed

d. Fig. A-4: Rotation minimum angle estimation

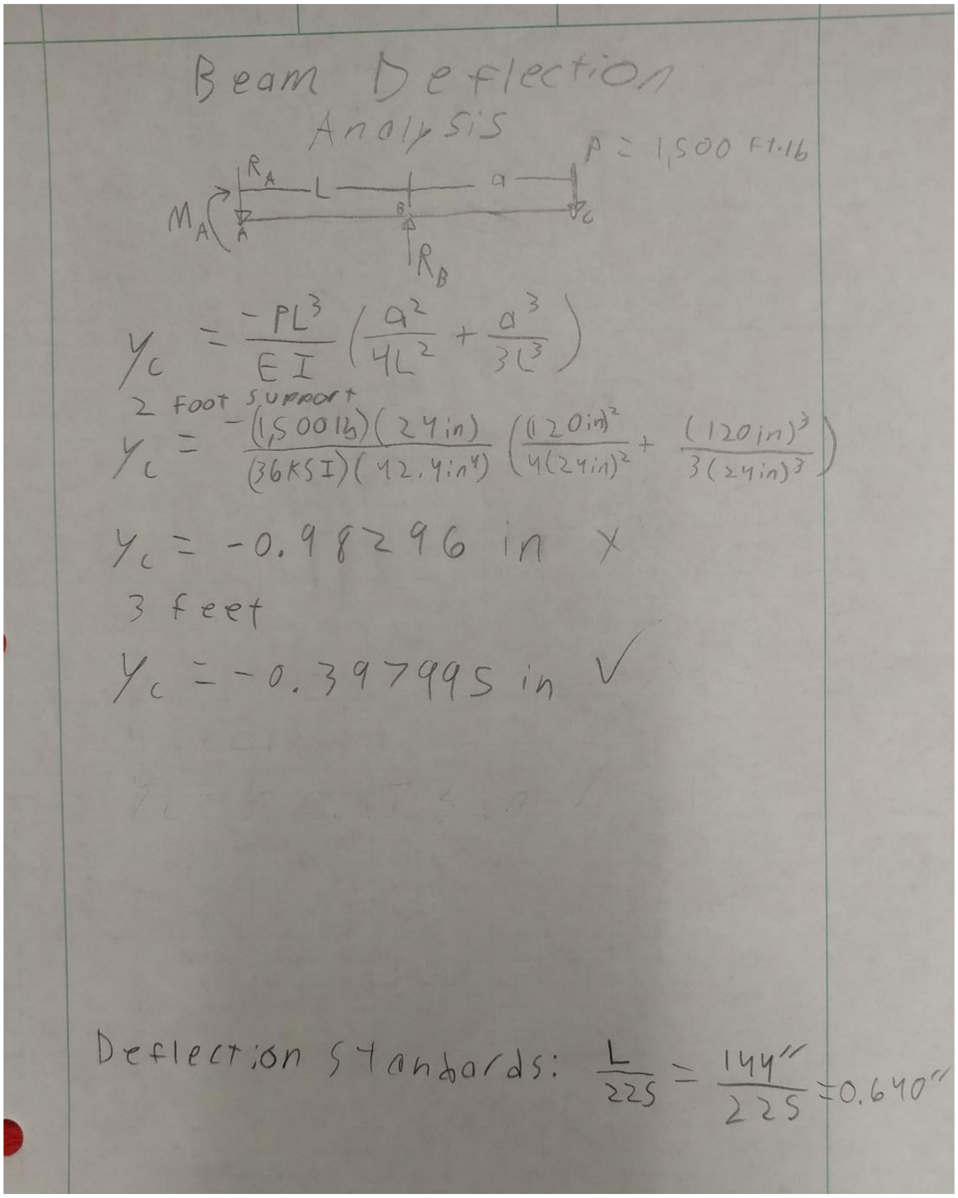


Brad Lewis | Senior project

range of motion analysis

hinge needs to extend > 6" from wall mount.

e. Fig. A-5: Deflection analysis of main boom arm, determining triangle support beam size



Beam Deflection Analysis

$$y_c = \frac{-PL^3}{EI}\left(\frac{a^2}{4L^2} + \frac{a^3}{3L^3}\right)$$

2 Foot support

$$y_c = \frac{-(1{,}500\,\text{lb})(24\,\text{in})}{(36\,\text{KSI})(42.4\,\text{in}^4)}\left(\frac{(120\,\text{in})^2}{4(24\,\text{in})^2} + \frac{(120\,\text{in})^3}{3(24\,\text{in})^3}\right)$$

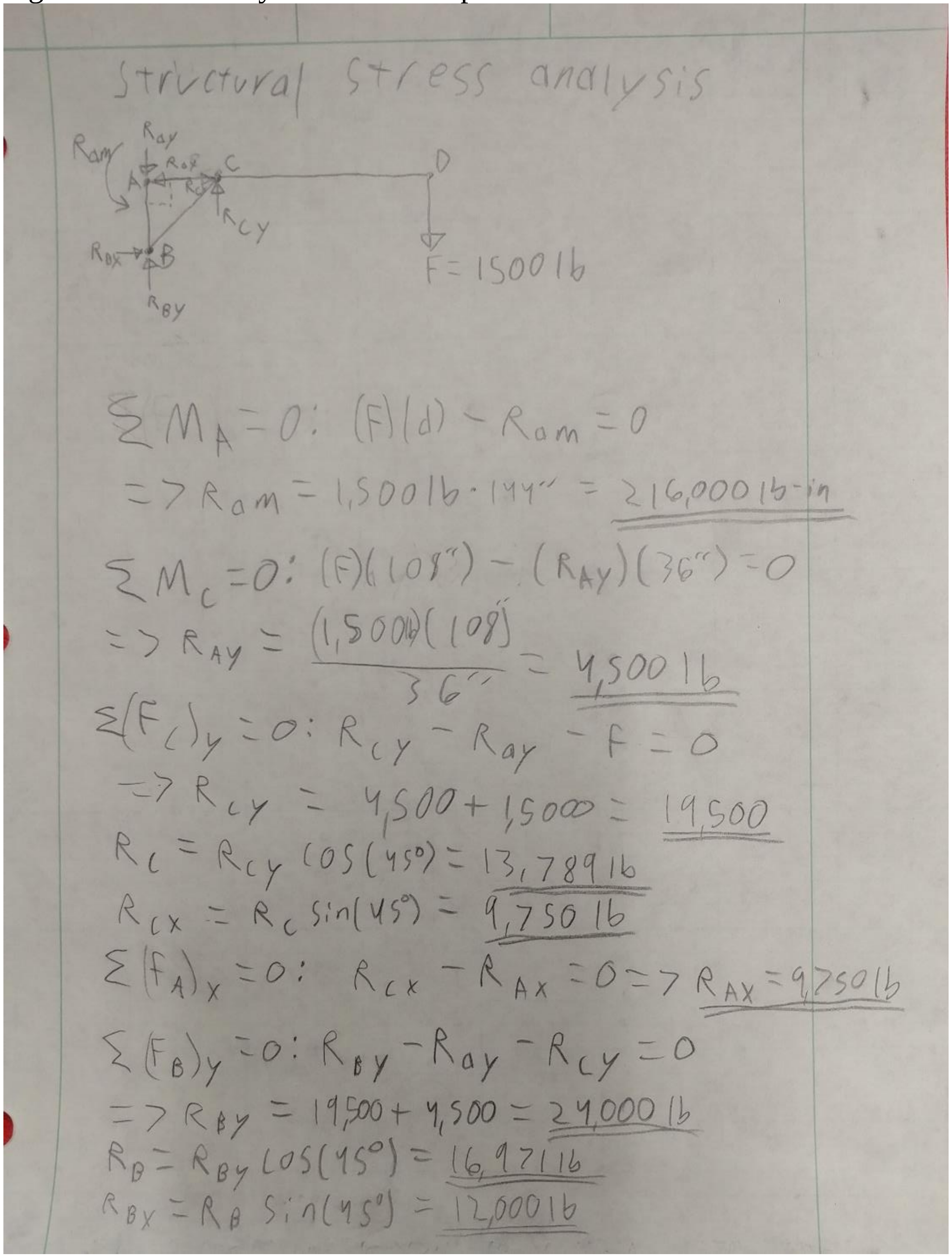
$y_c = -0.98296$ in ✗

3 feet

$y_c = -0.397995$ in ✓

Deflection Standards: $\frac{L}{225} = \frac{144''}{225} = 0.640''$

f. Fig. A-6: Stress analysis of basic shape of crane structure



Structural stress analysis

$$\sum M_A = 0: (F)(d) - R_{am} = 0$$

$$\Rightarrow R_{am} = 1{,}500\,lb \cdot 144'' = \underline{\underline{216{,}000\,lb\text{-}in}}$$

$$\sum M_C = 0: (F)(108'') - (R_{Ay})(36'') = 0$$

$$\Rightarrow R_{Ay} = \frac{(1{,}500\,lb)(108'')}{36''} = \underline{\underline{4{,}500\,lb}}$$

$$\sum (F_C)_y = 0: R_{cy} - R_{ay} - F = 0$$

$$\Rightarrow R_{cy} = 4{,}500 + 1{,}5000 = \underline{\underline{19{,}500}}$$

$$R_c = R_{cy} \cos(45^\circ) = \underline{\underline{13{,}789\,lb}}$$

$$R_{cx} = R_c \sin(45^\circ) = \underline{\underline{9{,}750\,lb}}$$

$$\sum (f_A)_x = 0: R_{cx} - R_{Ax} = 0 \Rightarrow \underline{\underline{R_{Ax} = 9{,}750\,lb}}$$

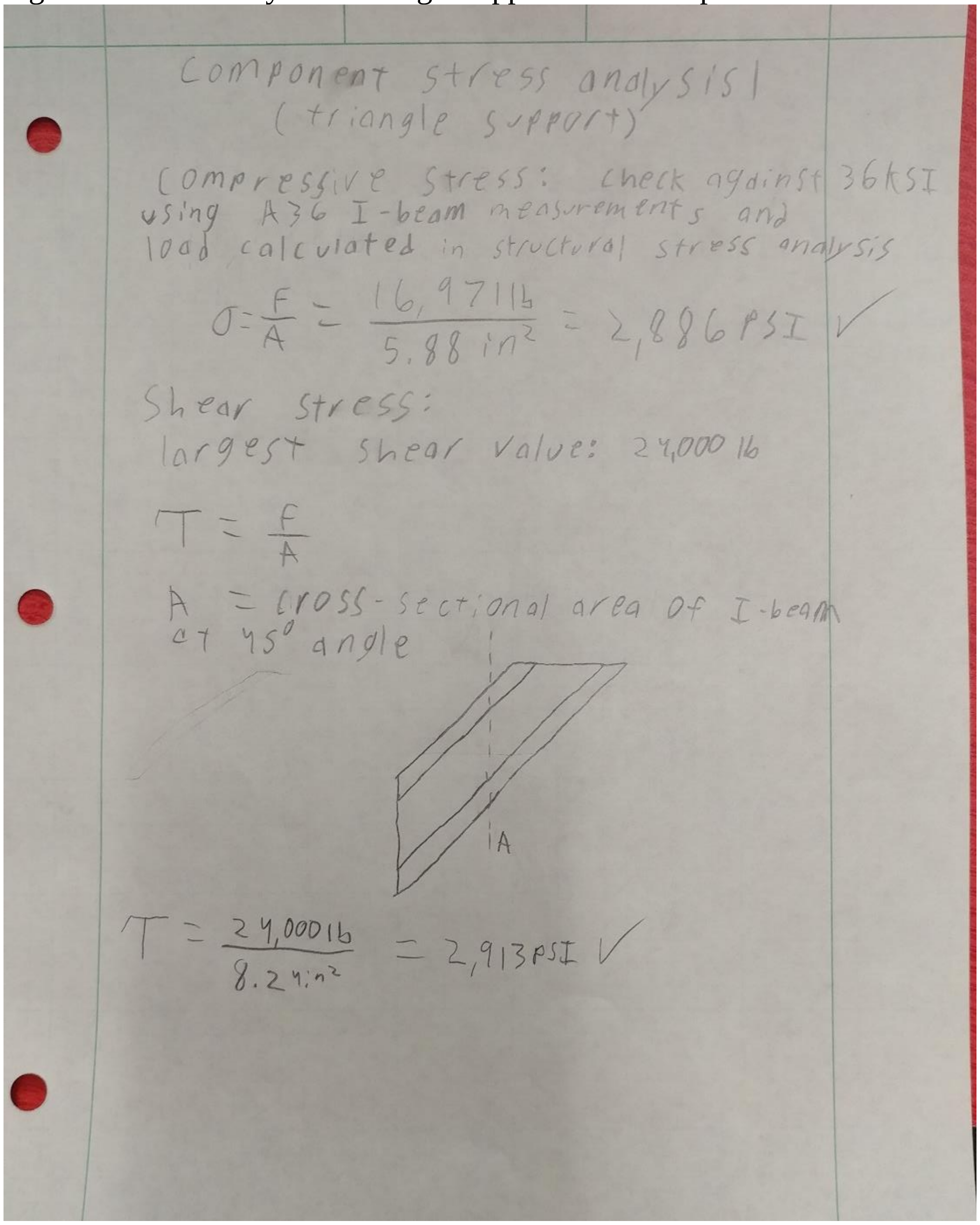
$$\sum (F_B)_y = 0: R_{By} - R_{ay} - R_{cy} = 0$$

$$\Rightarrow R_{By} = 19{,}500 + 4{,}500 = \underline{\underline{24{,}000\,lb}}$$

$$R_B = R_{By} \cos(45^\circ) = \underline{\underline{16{,}971\,lb}}$$

$$R_{Bx} = R_B \sin(45^\circ) = \underline{\underline{12{,}000\,lb}}$$

g. Fig. A-7: Stress analysis of triangle support beam component



Component stress analysis |
(triangle support)

Compressive stress: check against 36kSI using A36 I-beam measurements and load calculated in structural stress analysis

$$\sigma = \frac{F}{A} = \frac{16,971 lb}{5.88 in^2} = 2,886 PSI$$ ✓

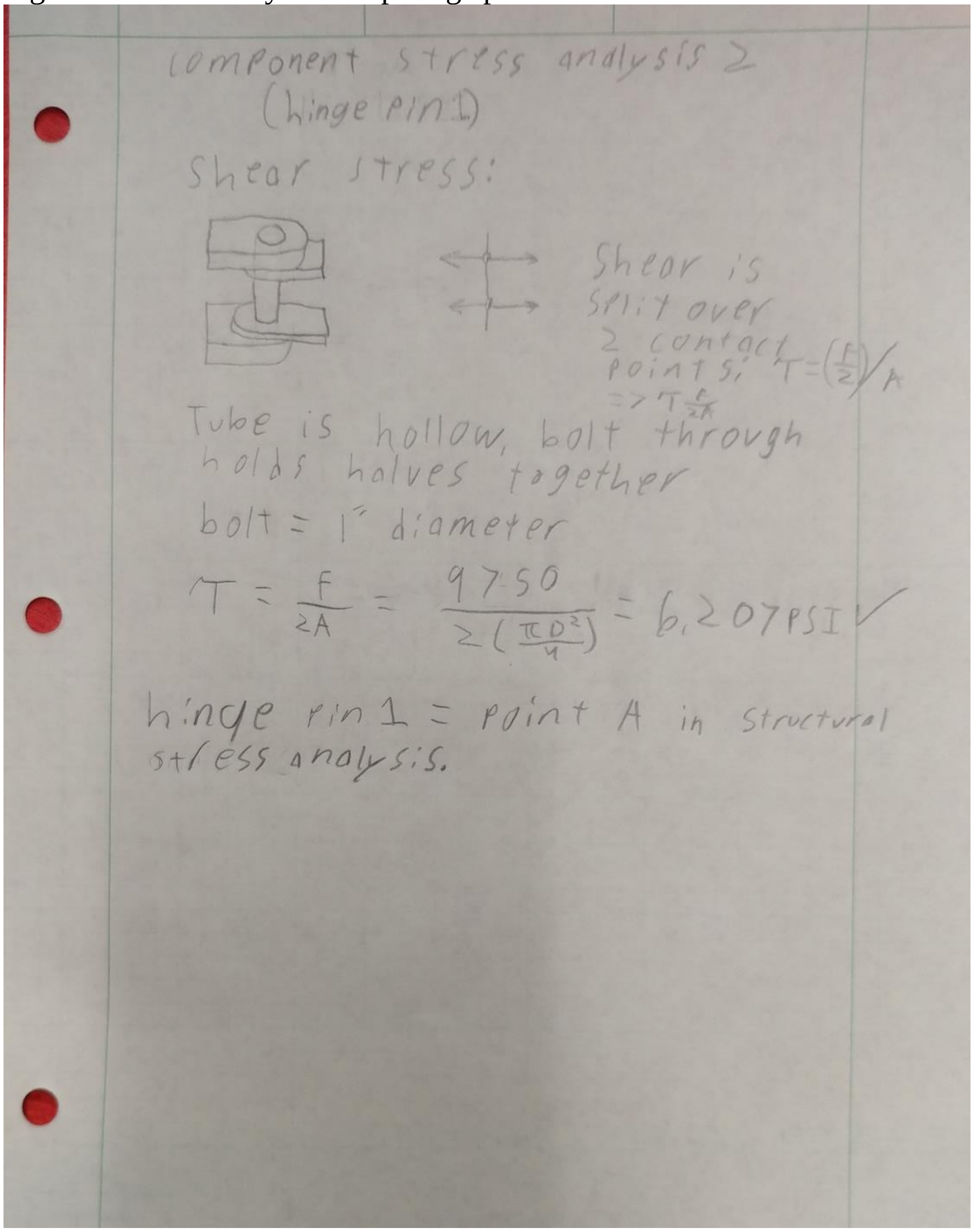
Shear stress:
largest shear value: 24,000 lb

$$\tau = \frac{F}{A}$$

A = cross-sectional area of I-beam at 45° angle

$$\tau = \frac{24,000 lb}{8.24 in^2} = 2,913 psI$$ ✓

h. Fig. A-8: Stress analysis of top hinge pin



component stress analysis 2
(hinge pin 1)

Shear stress:

Shear is split over 2 contact points; $\tau = \left(\frac{F}{2}\right)/A$
=> $\tau \frac{F}{2A}$

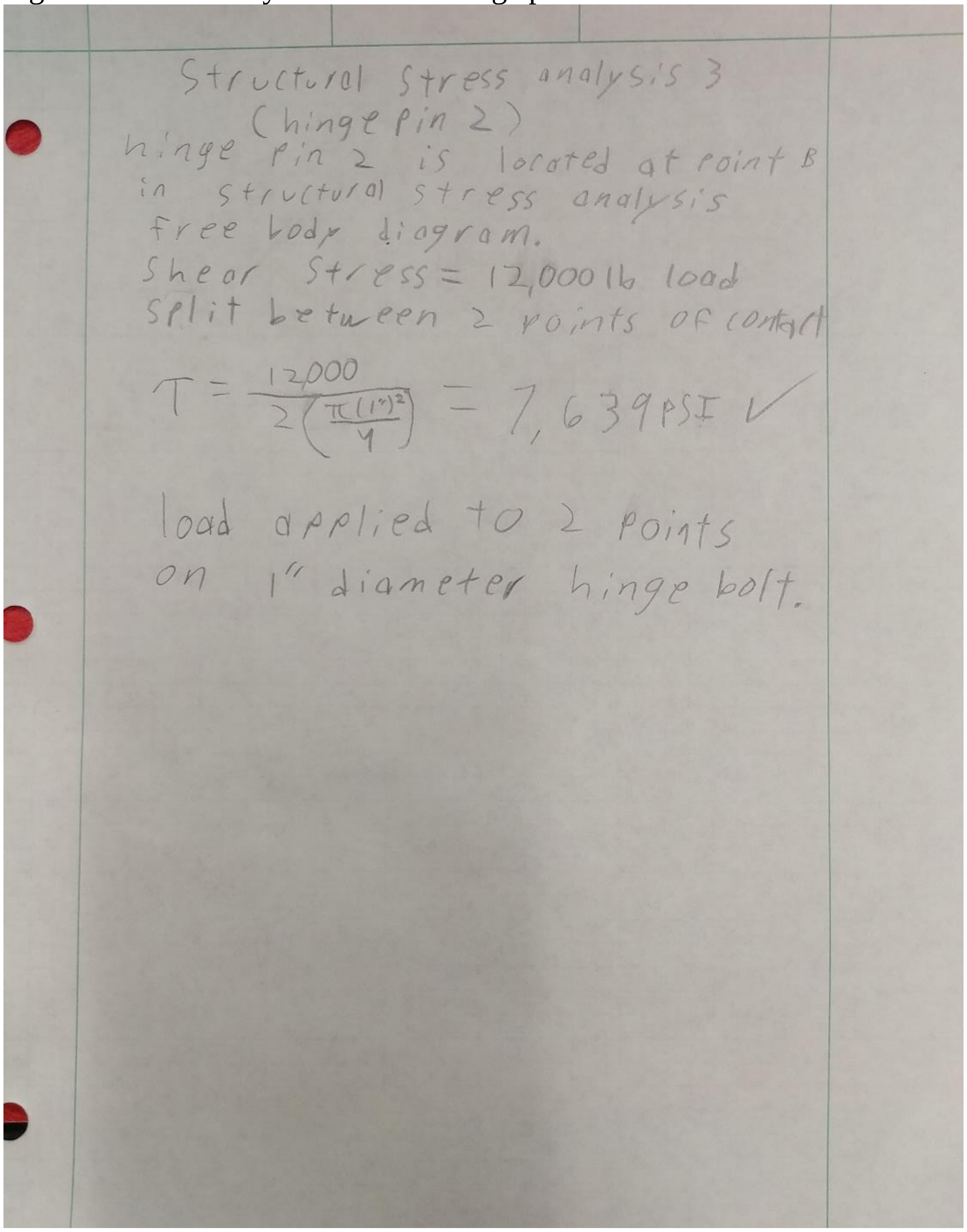
Tube is hollow, bolt through holds halves together

bolt = 1" diameter

$$\tau = \frac{F}{2A} = \frac{9750}{2\left(\frac{\pi D^2}{4}\right)} = 6{,}207 \text{PSI} ✓$$

hinge pin 1 = point A in structural stress analysis.

i. Fig. A-9: Stress analysis of bottom hinge pin



Structural Stress analysis 3

(hinge pin 2)

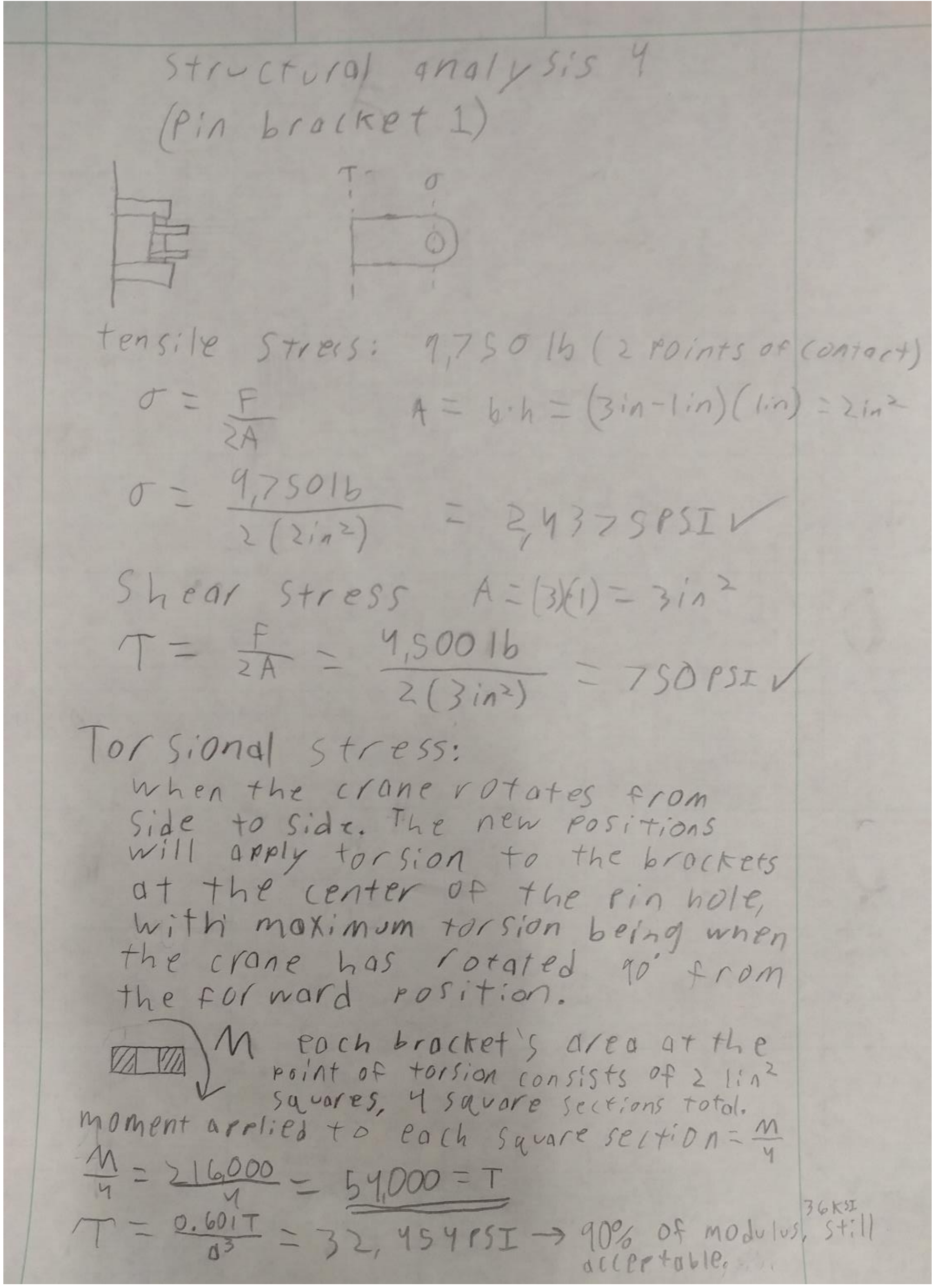
hinge pin 2 is located at point B in structural stress analysis free body diagram.

Shear Stress = 12,000 lb load split between 2 points of contact

$$\tau = \frac{12000}{2\left(\frac{\pi(1")^2}{4}\right)} = 7,639 \text{ PSI} \checkmark$$

load applied to 2 points on 1" diameter hinge bolt.

j. Fig. A-10: Stress analysis of top pin bracket



Structural analysis 4
(Pin bracket 1)

tensile stress: 9,750 lb (2 points of contact)

$\sigma = \frac{F}{2A}$ $A = b \cdot h = (3in - 1in)(1in) = 2in^2$

$\sigma = \frac{9{,}750 lb}{2(2in^2)} = 2{,}4375 PSI$ ✓

Shear stress $A = (3)(1) = 3in^2$

$T = \frac{F}{2A} = \frac{4{,}500 lb}{2(3in^2)} = 750 PSI$ ✓

Torsional stress:

when the crane rotates from side to side. The new positions will apply torsion to the brackets at the center of the pin hole, with maximum torsion being when the crane has rotated 90° from the forward position.

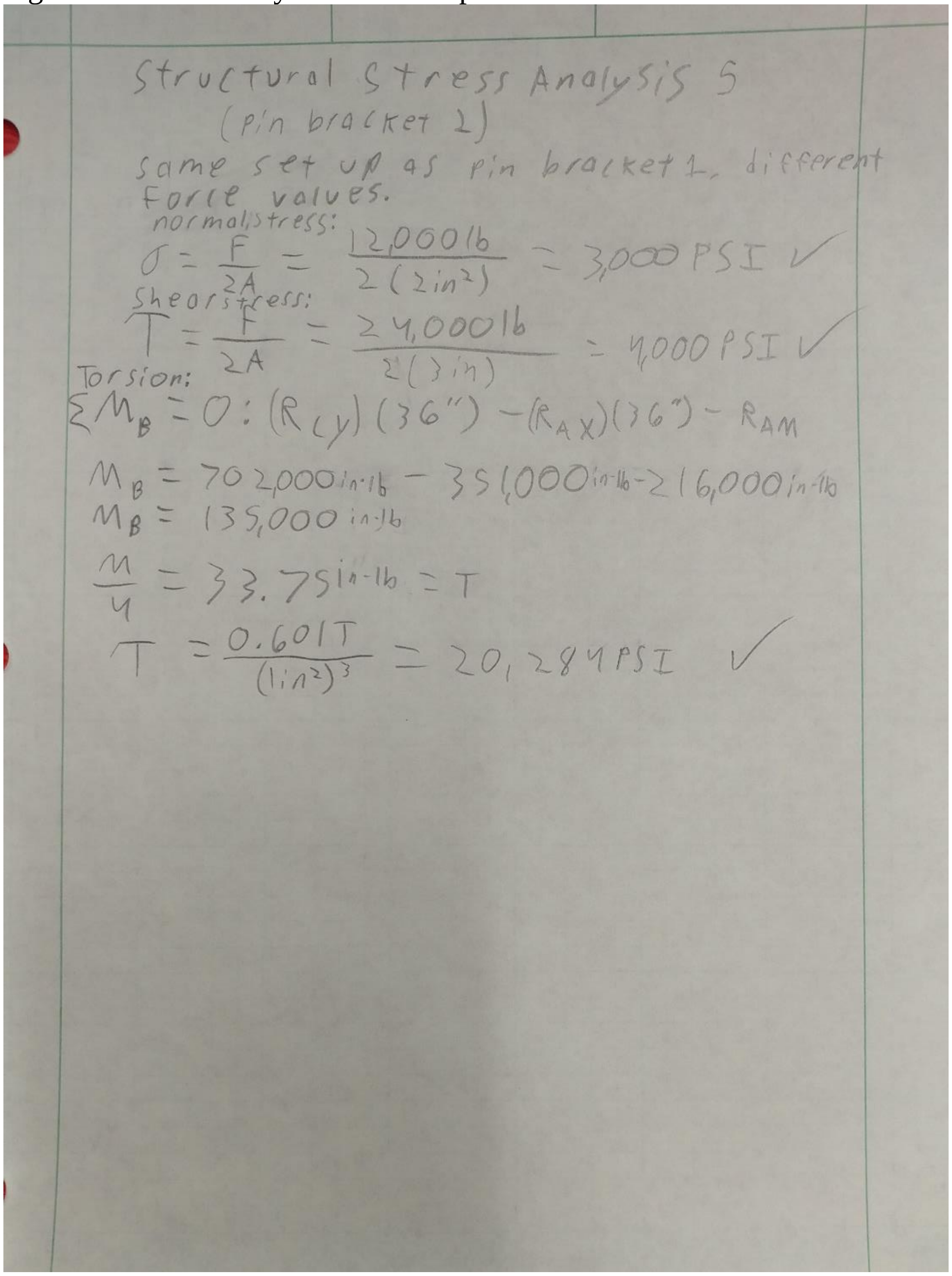
each bracket's area at the point of torsion consists of 2 $1in^2$ squares, 4 square sections total.

moment applied to each square section $= \frac{M}{4}$

$\frac{M}{4} = \frac{216{,}000}{4} = \underline{\underline{54{,}000 = T}}$

$T = \frac{0.601T}{a^3} = 32{,}454 PSI \rightarrow$ 90% of modulus 36KSI, still acceptable.

k. Fig. A-11: Stress analysis of bottom pin bracket



Structural Stress Analysis 5

(pin bracket 2)

same set up as pin bracket 1, different Force values.

normal stress:

$$\sigma = \frac{F}{2A} = \frac{12{,}000\,lb}{2(2in^2)} = 3{,}000\ PSI$$ ✓

Shear stress:

$$\tau = \frac{F}{2A} = \frac{24{,}000\,lb}{2(3in)} = 4{,}000\ PSI$$ ✓

Torsion:

$$\Sigma M_B = 0 : (R_{Cy})(36'') - (R_{AX})(36'') - R_{AM}$$

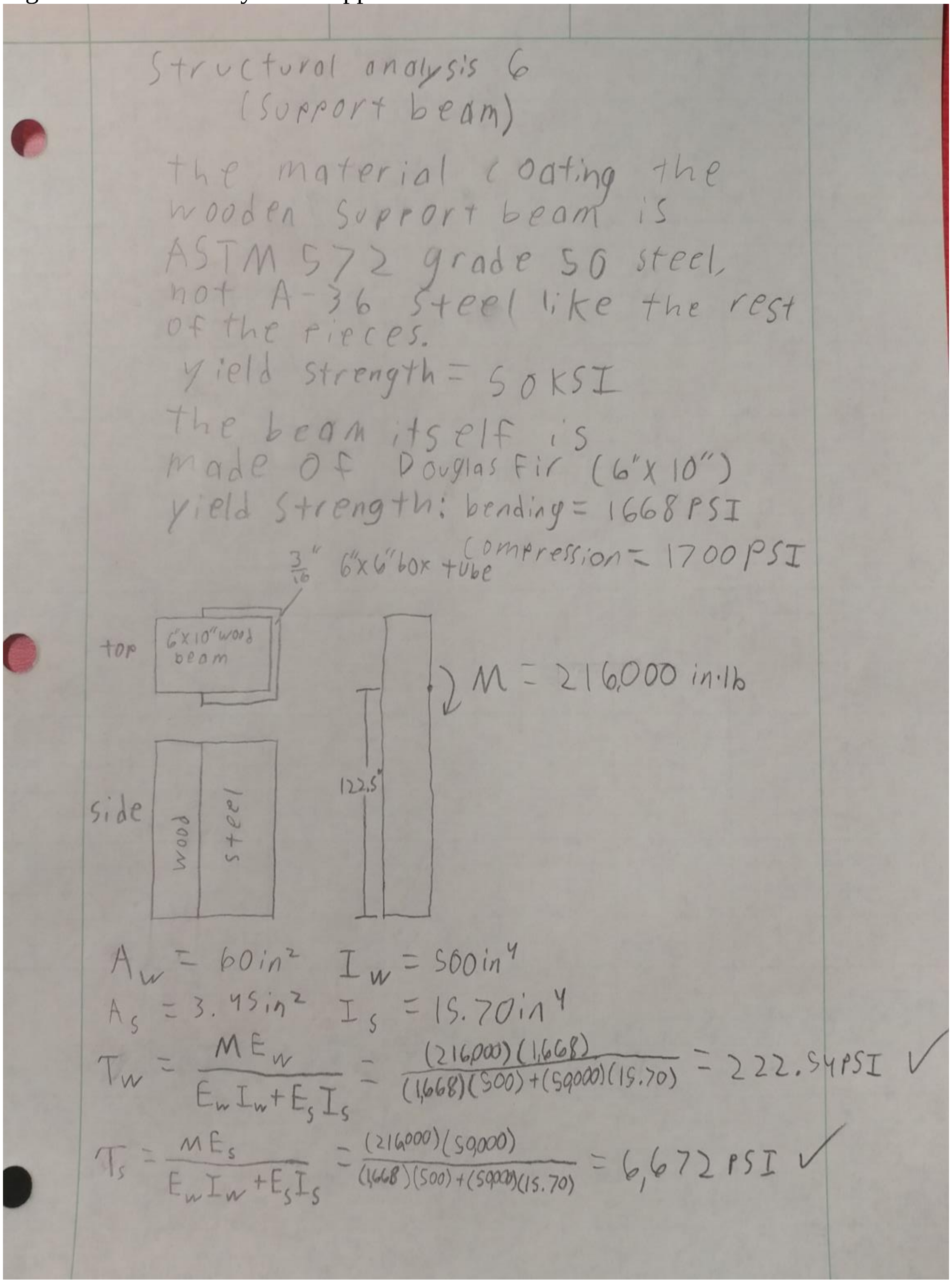
$$M_B = 702{,}000\,in\text{-}lb - 351{,}000\,in\text{-}lb - 216{,}000\,in\text{-}lb$$

$$M_B = 135{,}000\,in\text{-}lb$$

$$\frac{M}{4} = 33.75\,in\text{-}lb = T$$

$$\tau = \frac{0.601T}{(1in^2)^3} = 20{,}284\ PSI$$ ✓

l. Fig. A-12: Stress analysis of support beam



Structural analysis 6
(Support beam)

the material coating the wooden support beam is ASTM 572 grade 50 steel, not A-36 steel like the rest of the pieces.

yield strength = 50KSI

the beam itself is made of Douglas Fir (6"x 10")

yield Strength: bending = 1668 PSI

compression = 1700 PSI

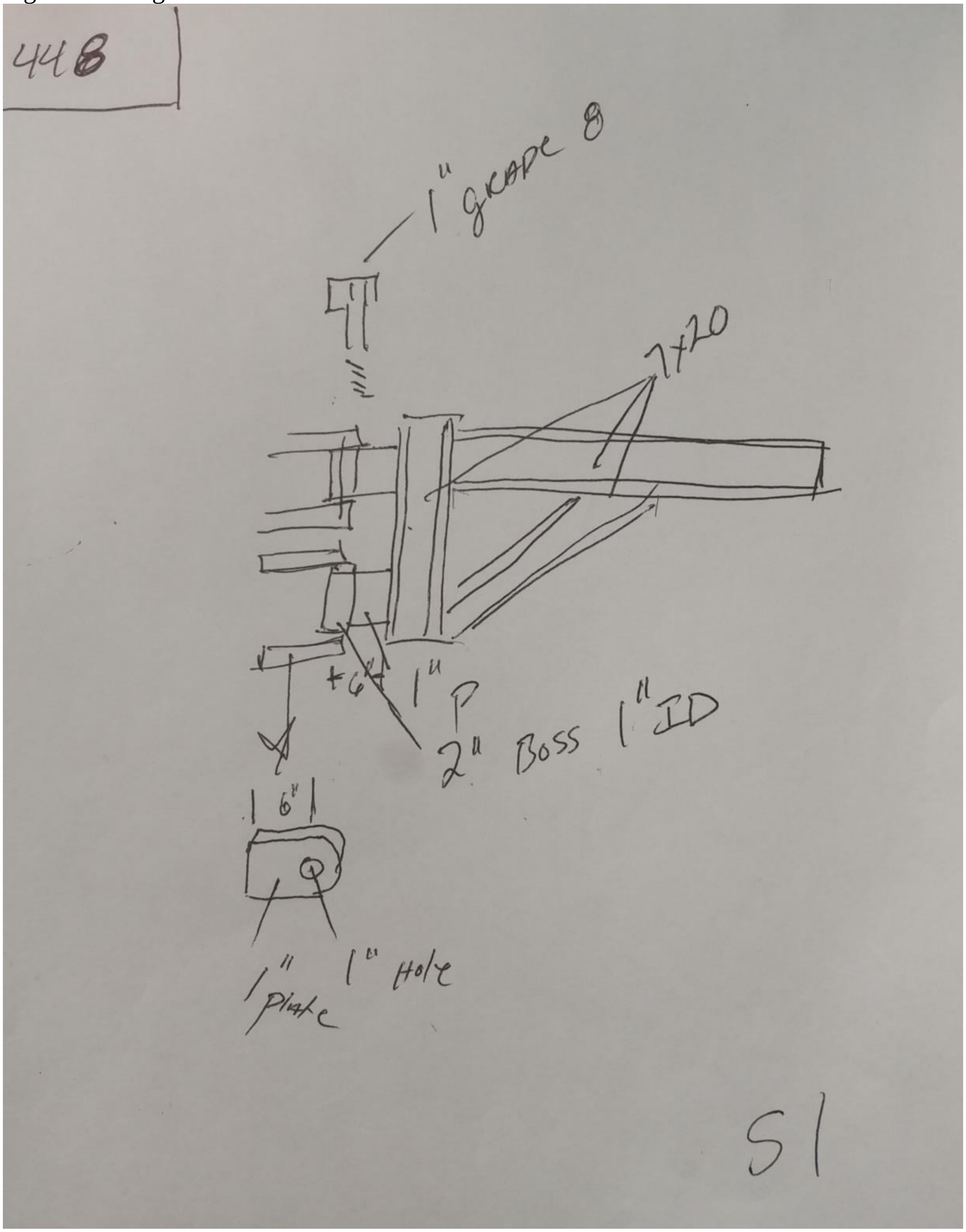
$A_w = 60 in^2$ $I_w = 500 in^4$

$A_s = 3.45 in^2$ $I_s = 15.70 in^4$

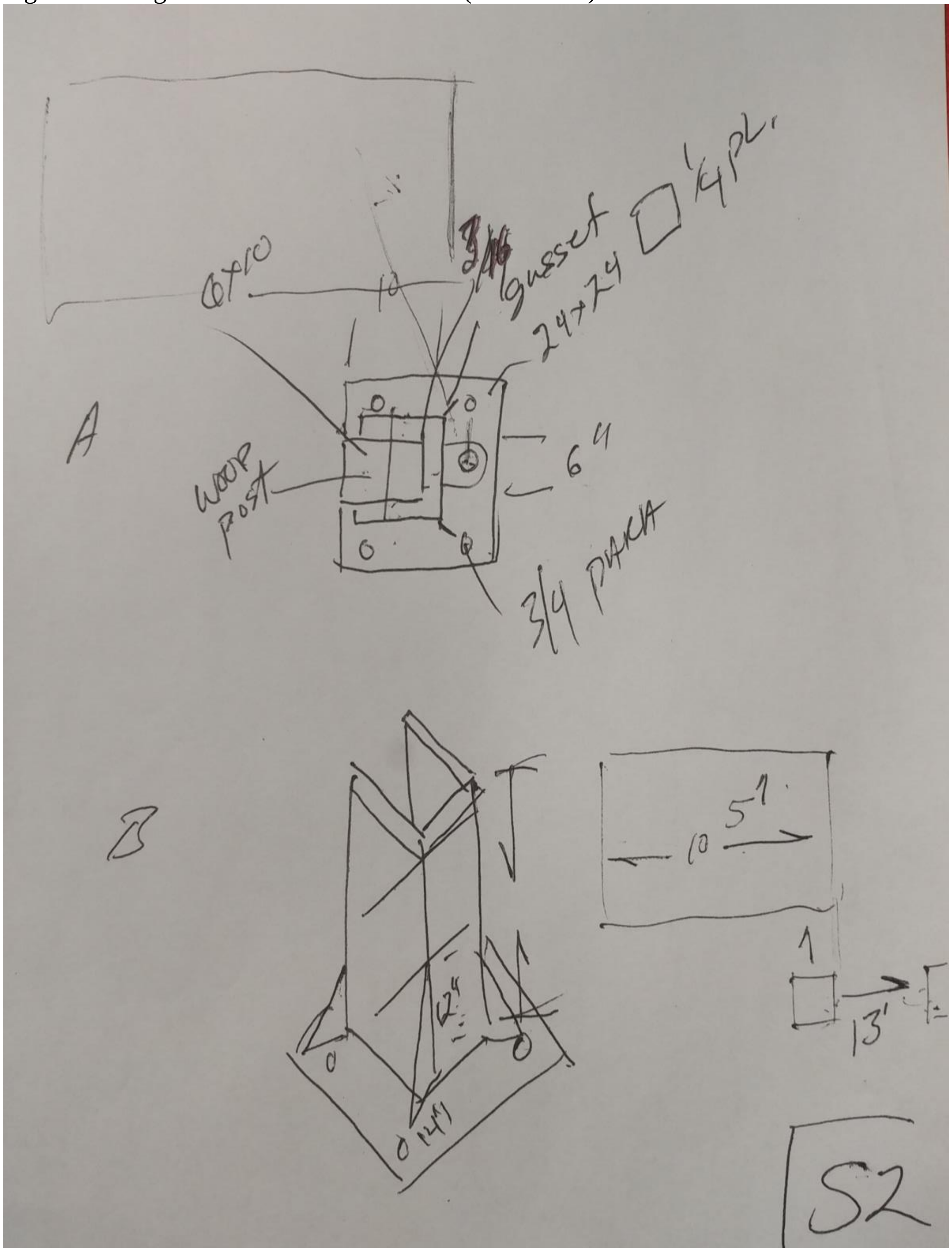
$$T_w = \frac{M E_w}{E_w I_w + E_s I_s} = \frac{(216,000)(1,668)}{(1,668)(500)+(59000)(15.70)} = 222.54 PSI ✓$$

$$T_s = \frac{M E_s}{E_w I_w + E_s I_s} = \frac{(216000)(59,000)}{(1668)(500)+(59000)(15.70)} = 6,672 PSI ✓$$

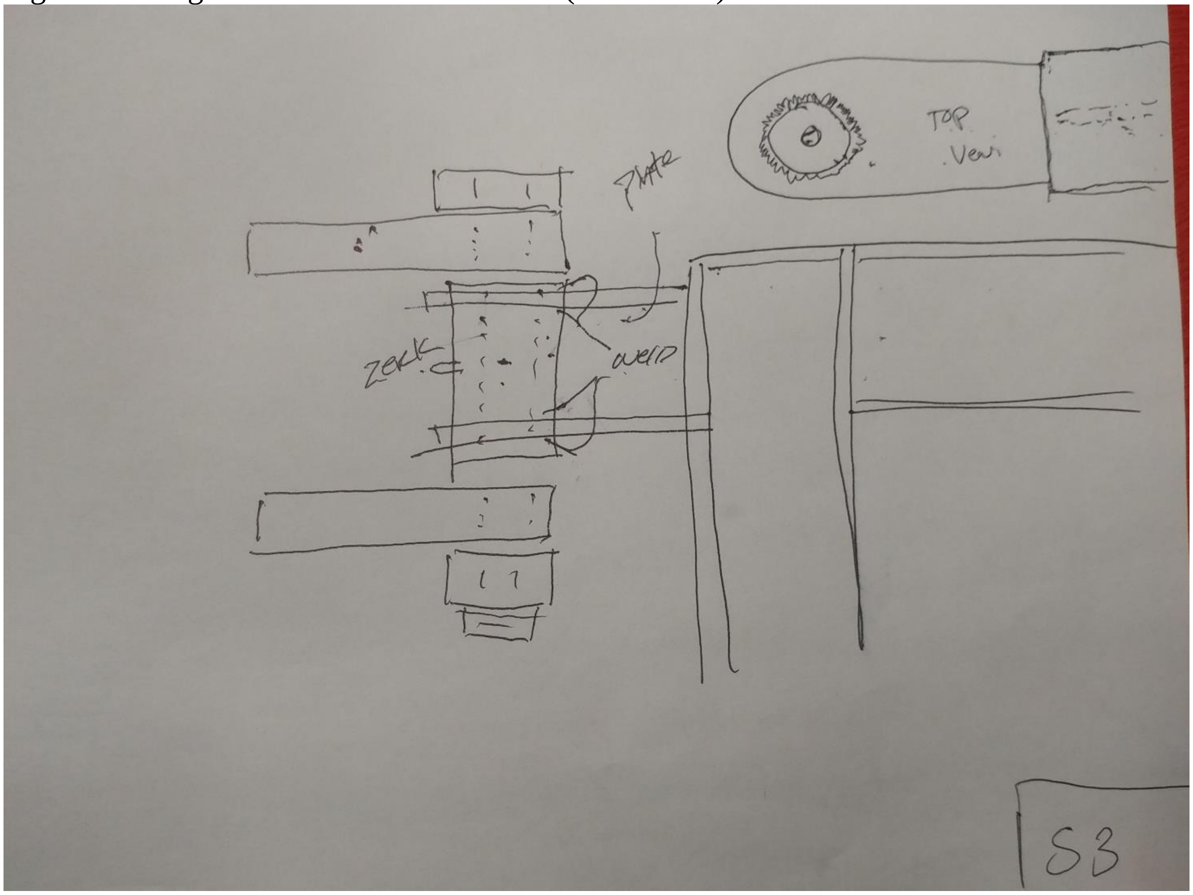
m. Fig. A-13: Original Sketch From Customer



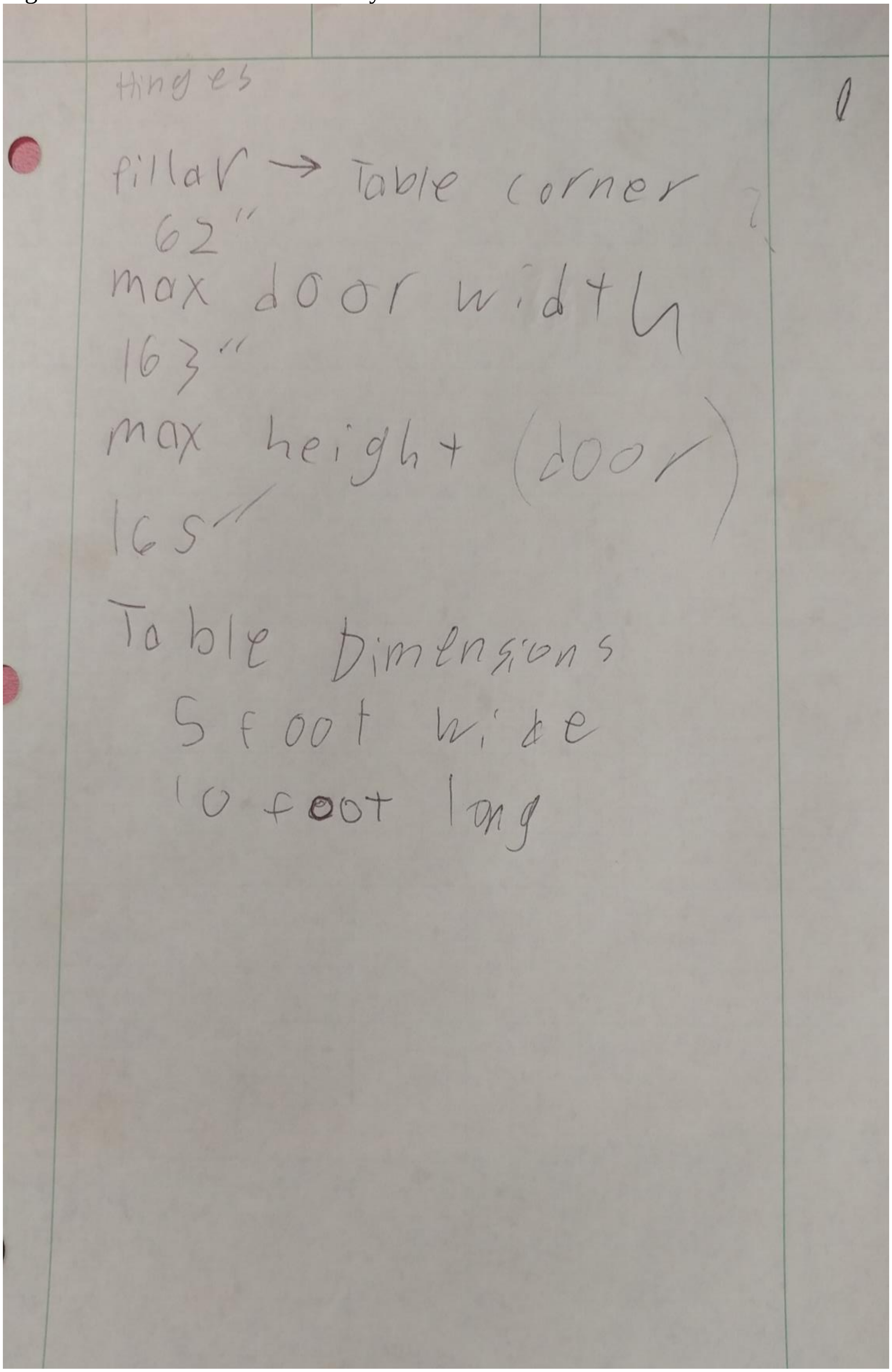
n. Fig. A-14: Original Sketch From Customer (Continued.)



o. Fig. A-15: Original Sketch From Customer (Continued.)



p. Fig. A-16: On-Site Positional Analysis



Hinges

pillar → Table corner
62"

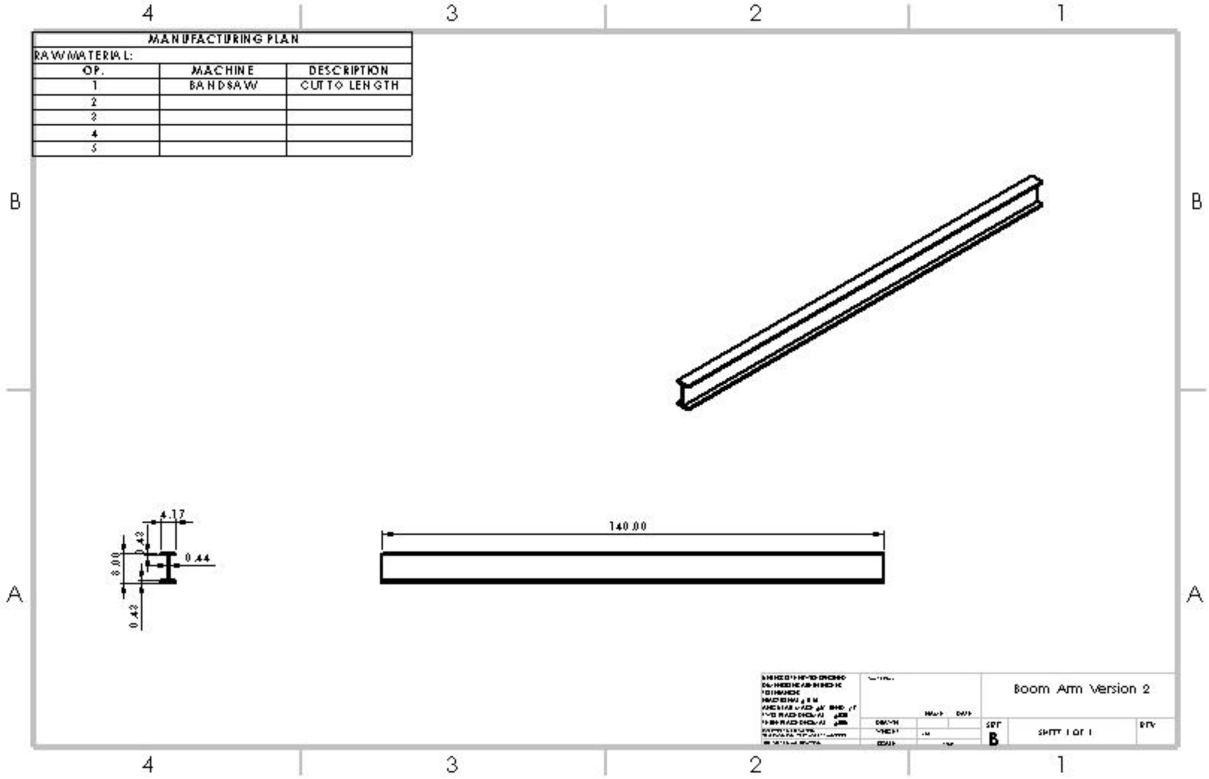
max door width
163"

max height (door)
165"

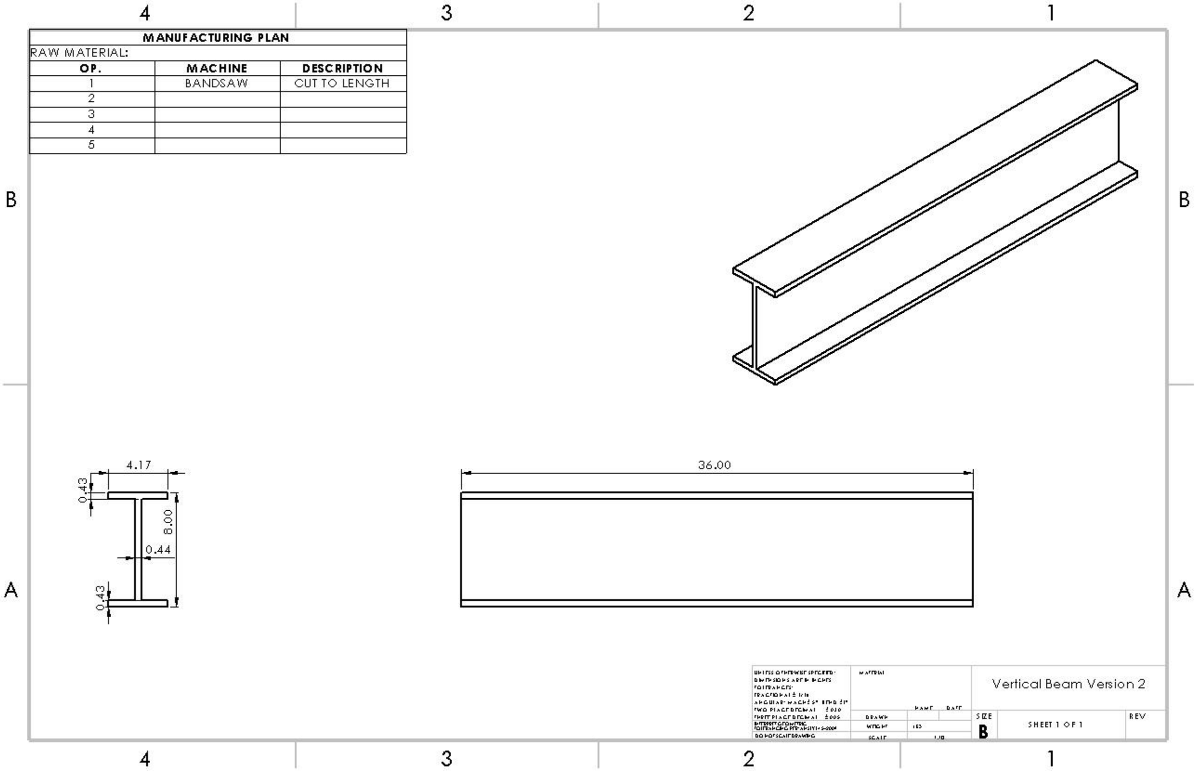
Table Dimensions
5 foot wide
10 foot long

Appendix B: Part Drawings

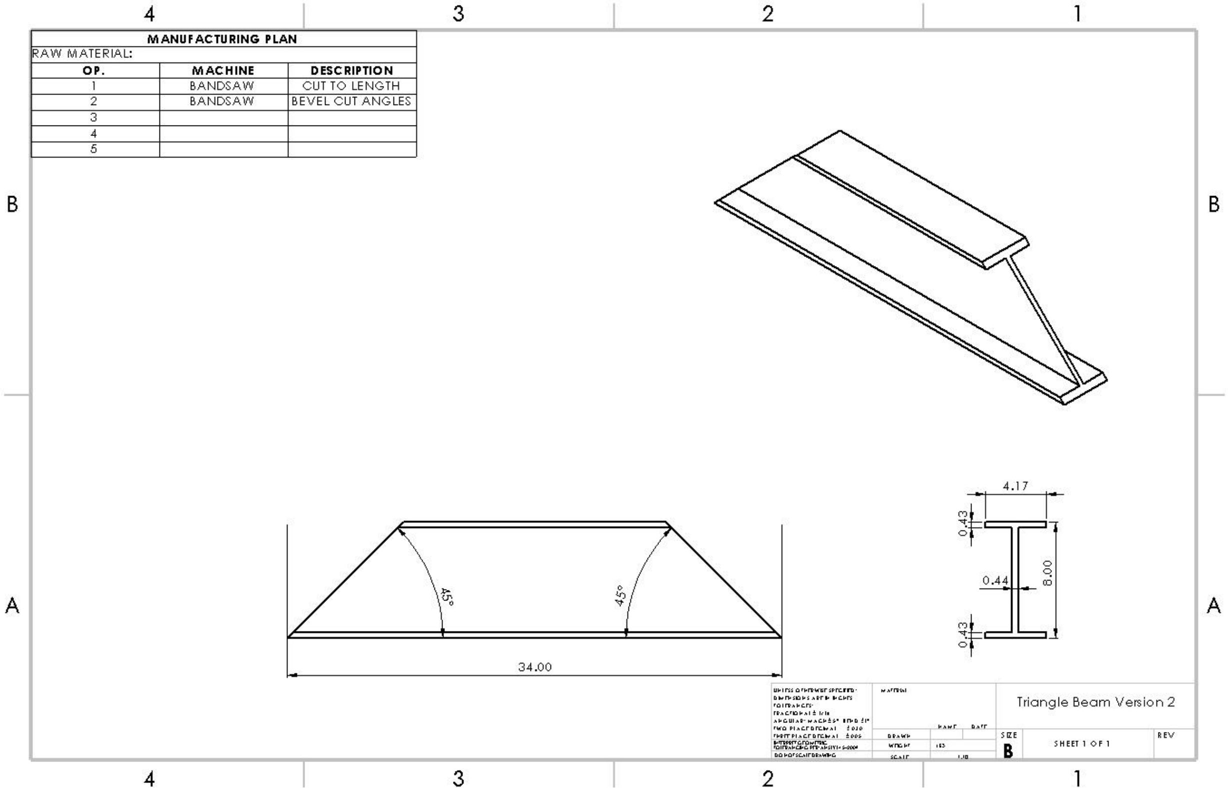
a. Drawing B-1: Proposed I-beam size and dimensions



b. Drawing B-2: Vertical Beam Support

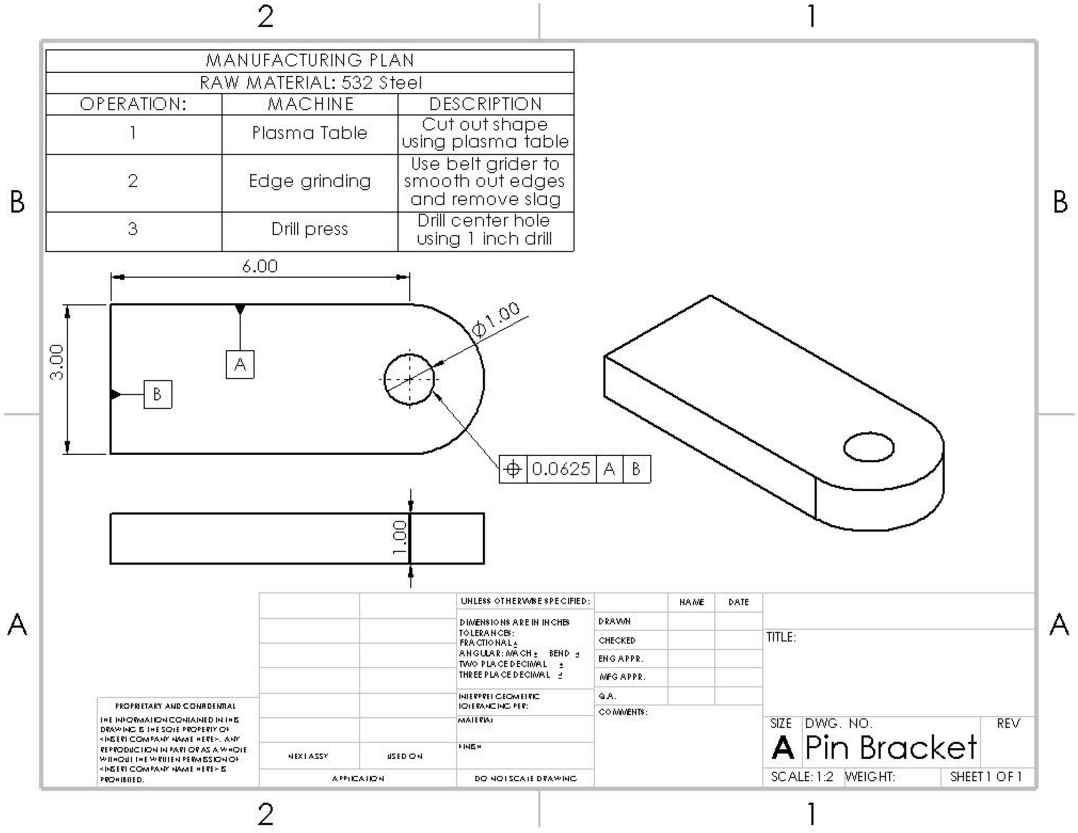


c. Drawing B-3: Triangle Beam Support



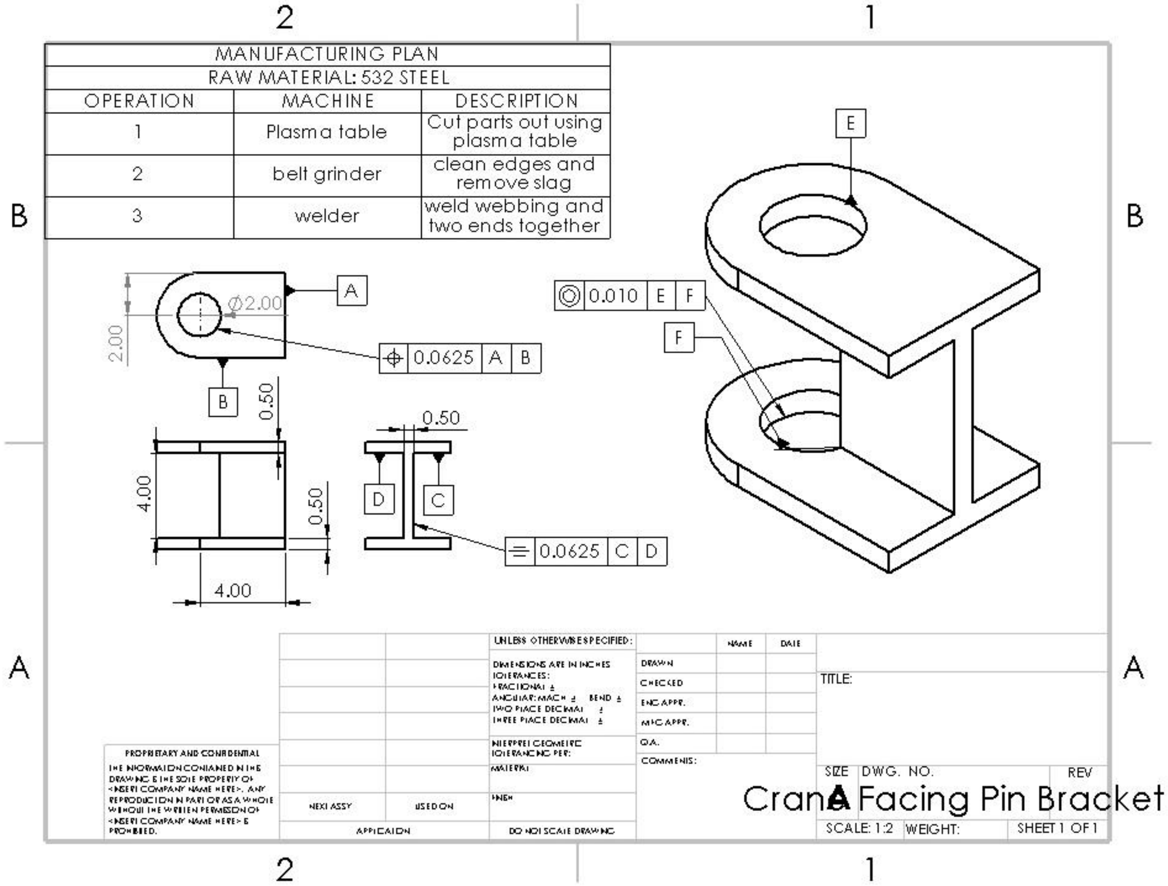
MANUFACTURING PLAN		
RAW MATERIAL:		
OP.	MACHINE	DESCRIPTION
1	BANDSAW	CUT TO LENGTH
2	BANDSAW	BEVEL CUT ANGLES
3		
4		
5		

d. Drawing B-4: Wall Facing Pin Bracket



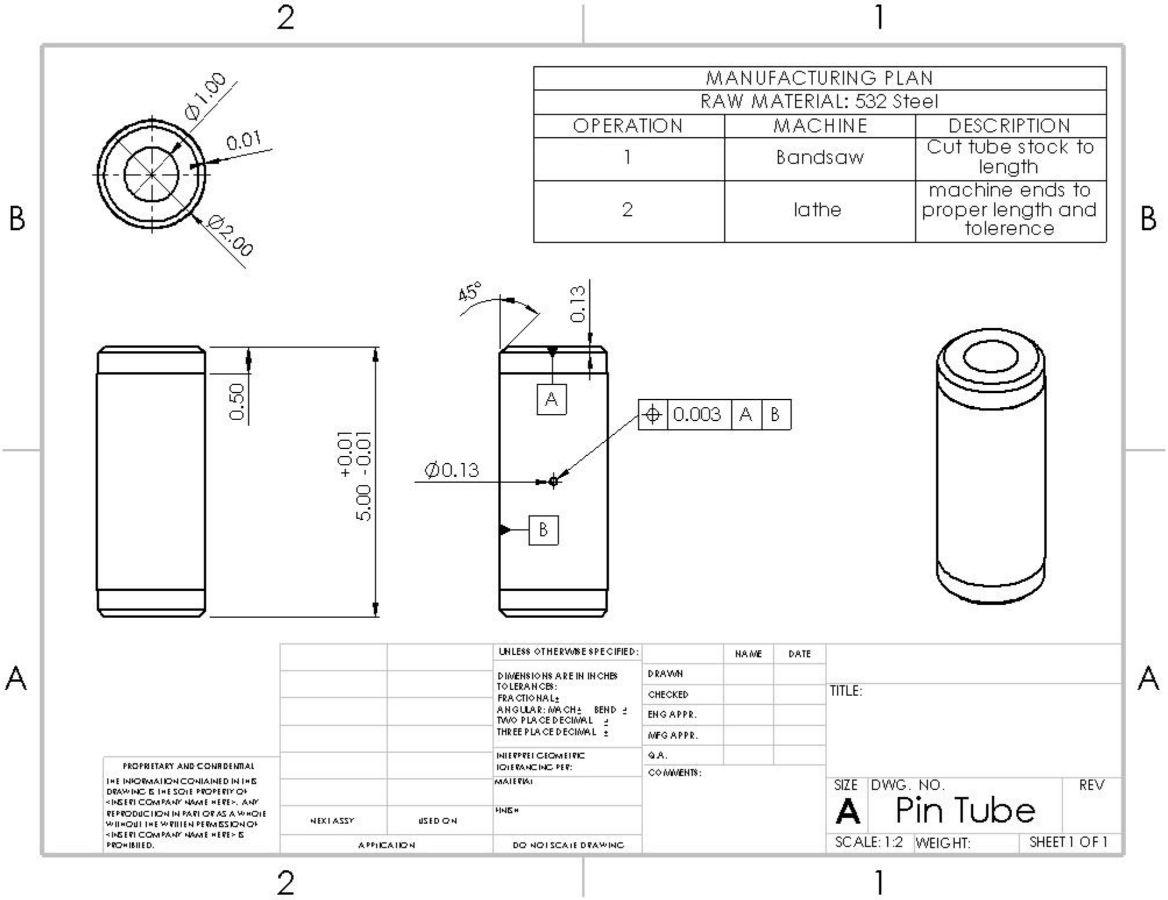
MANUFACTURING PLAN		
RAW MATERIAL: 532 Steel		
OPERATION:	MACHINE	DESCRIPTION
1	Plasma Table	Cut out shape using plasma table
2	Edge grinding	Use belt grider to smooth out edges and remove slag
3	Drill press	Drill center hole using 1 inch drill

e. Drawing B-5: Crane Facing Pin Bracket



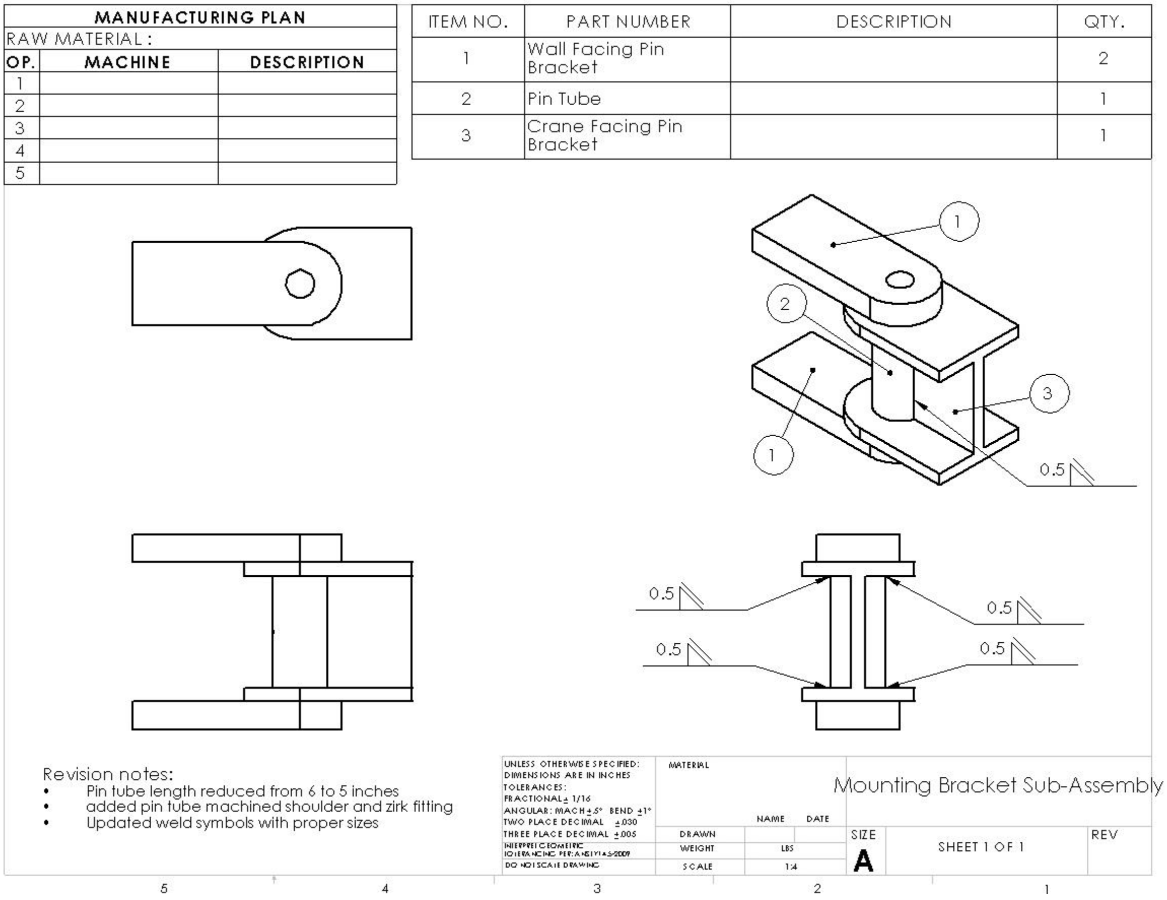
MANUFACTURING PLAN		
RAW MATERIAL: 532 STEEL		
OPERATION	MACHINE	DESCRIPTION
1	Plasma table	Cut parts out using plasma table
2	belt grinder	clean edges and remove slag
3	welder	weld webbing and two ends together

f. Drawing B-6: Pin Tube



MANUFACTURING PLAN		
RAW MATERIAL: 532 Steel		
OPERATION	MACHINE	DESCRIPTION
1	Bandsaw	Cut tube stock to length
2	lathe	machine ends to proper length and tolerence

g. Drawing B-7: Mounting Bracket Sub-Assembly



MANUFACTURING PLAN		
RAW MATERIAL :		
OP.	MACHINE	DESCRIPTION
1		
2		
3		
4		
5		

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Wall Facing Pin Bracket		2
2	Pin Tube		1
3	Crane Facing Pin Bracket		1

Revision notes:

- Pin tube length reduced from 6 to 5 inches
- added pin tube machined shoulder and zirk fitting
- Updated weld symbols with proper sizes

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL± 1/16
ANGULAR: MACH ±.5° BEND ±1°
TWO PLACE DECIMAL ±.030
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-2009
DO NOT SCALE DRAWING

	NAME	DATE
MATERIAL		
DRAWN		
WEIGHT	LBS	
SCALE	1:4	

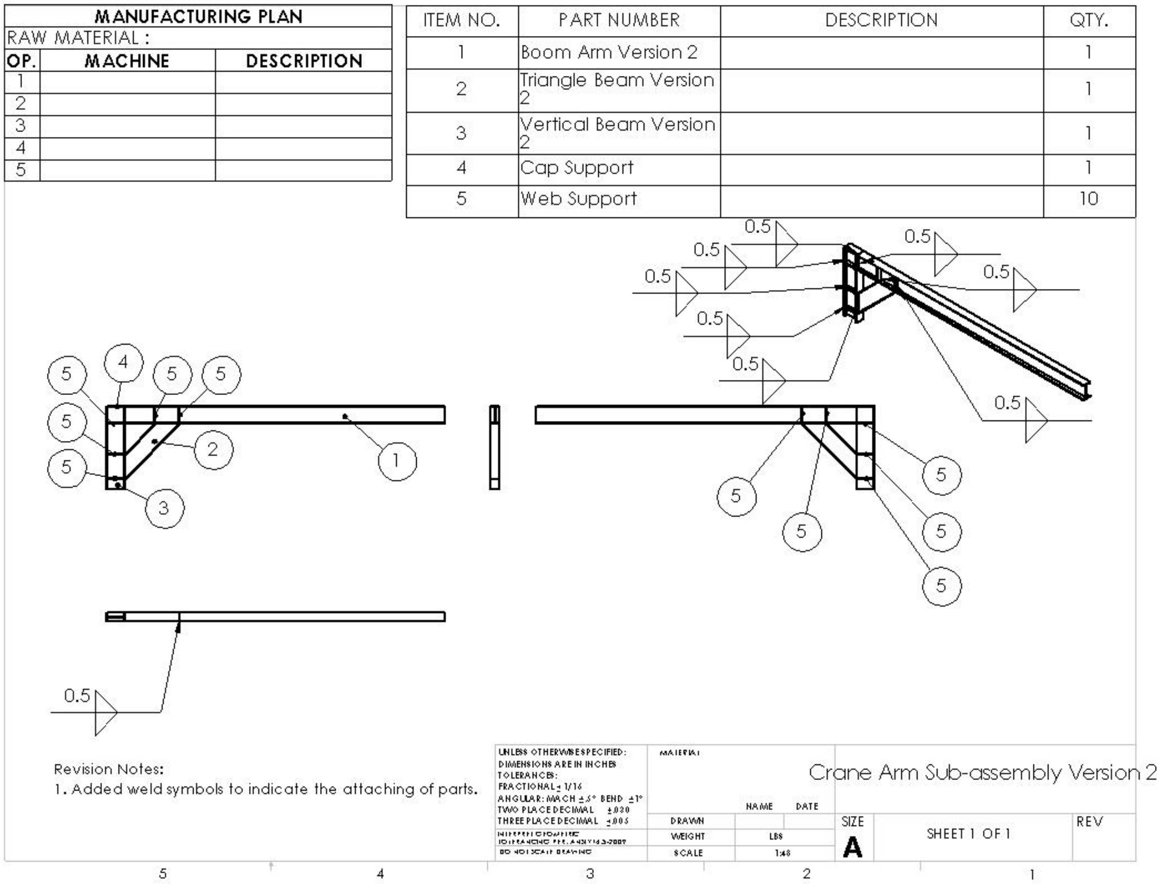
Mounting Bracket Sub-Assembly

SIZE A

SHEET 1 OF 1

REV

h. Drawing B-8: Boom Arm Sub-Assembly



MANUFACTURING PLAN		
RAW MATERIAL :		
OP.	MACHINE	DESCRIPTION
1		
2		
3		
4		
5		

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Boom Arm Version 2		1
2	Triangle Beam Version 2		1
3	Vertical Beam Version 2		1
4	Cap Support		1
5	Web Support		10

Revision Notes:
1. Added weld symbols to indicate the attaching of parts.

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16
ANGULAR: MACH ±.5° BEND ±1°
TWO PLACE DECIMAL ±.030
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-2009
DO NOT SCALE DRAWING

MATERIAL

	NAME	DATE
DRAWN		
WEIGHT	LBS	
SCALE	1:48	

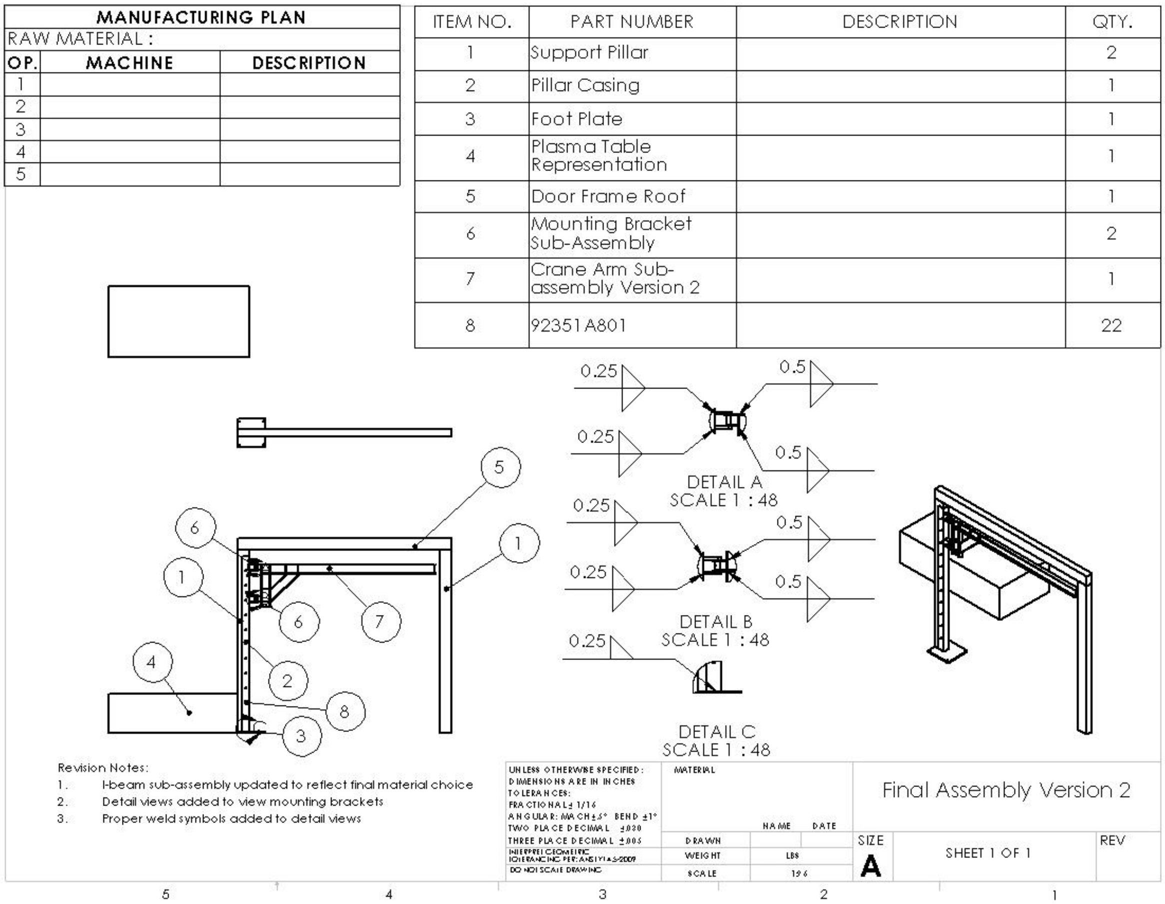
Crane Arm Sub-assembly Version 2

SIZE A

SHEET 1 OF 1

REV

i. Drawing B-9: Final Assembly



MANUFACTURING PLAN		
RAW MATERIAL :		
OP.	MACHINE	DESCRIPTION
1		
2		
3		
4		
5		

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Support Pillar		2
2	Pillar Casing		1
3	Foot Plate		1
4	Plasma Table Representation		1
5	Door Frame Roof		1
6	Mounting Bracket Sub-Assembly		2
7	Crane Arm Sub-assembly Version 2		1
8	92351A801		22

Revision Notes:
1. I-beam sub-assembly updated to reflect final material choice
2. Detail views added to view mounting brackets
3. Proper weld symbols added to detail views

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL± 1/16
ANGULAR: MACH±.5° BEND ±1°
TWO PLACE DECIMAL ±.030
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5-2009
DO NOT SCALE DRAWING

MATERIAL
NAME DATE
DRAWN
WEIGHT LBS
SCALE 1:96

Final Assembly Version 2

SIZE A
SHEET 1 OF 1
REV

Appendix C: Parts List

Parts List:

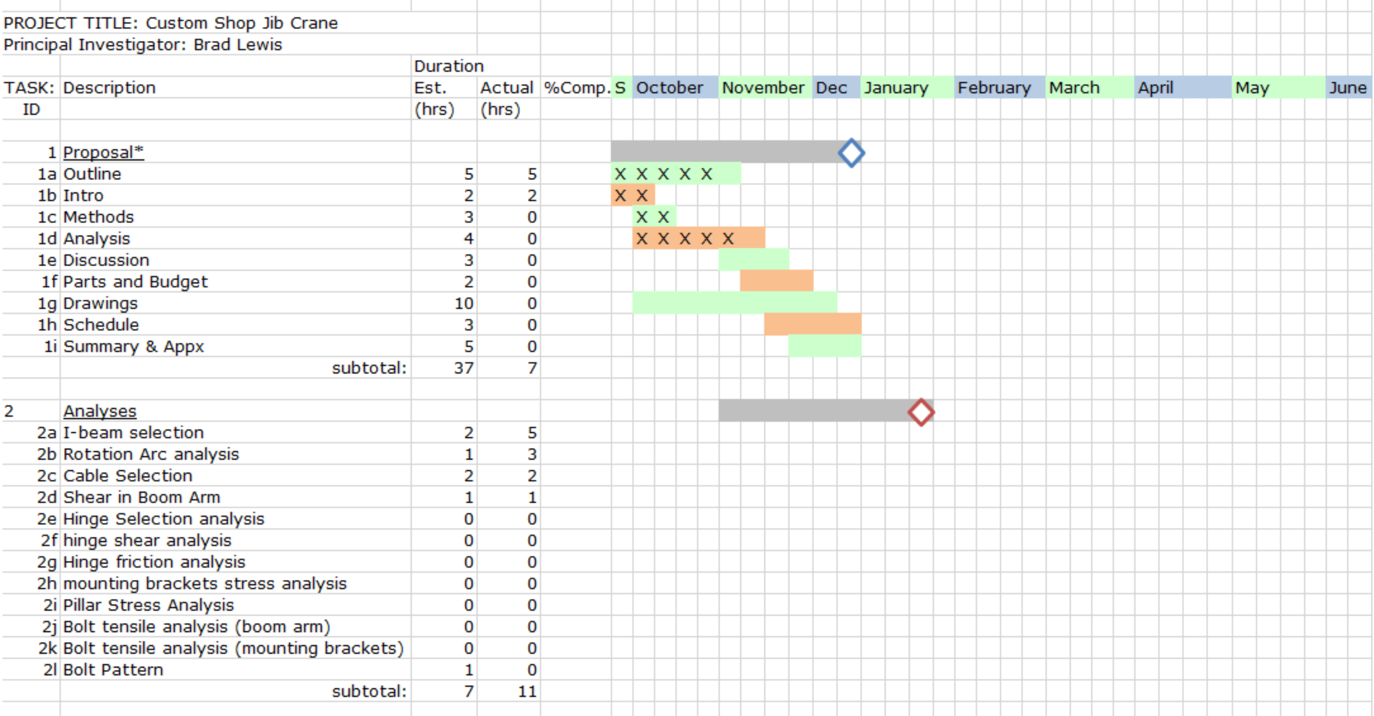
Part Name	Part Cost
A36 Steel I-beam, 7X20 (20 ft.)	$400
5/16 steel cable (100 ft.)	$75
Pulley system	$250
3/16” a572 grade 50 plate (5x10)	$382
12 Concrete Anchor Bolts	$36
1/4” plate (2x2 ft.)	$57
8 1” grade 8 bolts (12”)	$40
2” OD 1” ID structural tubing (6 ft.)	$150
1” plate	$50

Appendix D: Budget

Expense	Cost	Total
Parts	$1440	$1440
Manufacturing	10 hours @ $20/hour = $200	$1640
Construction	3 hours @ $20/hour = $60	$1700
Budget	$2000	$300 under budget

Appendix E: Schedule

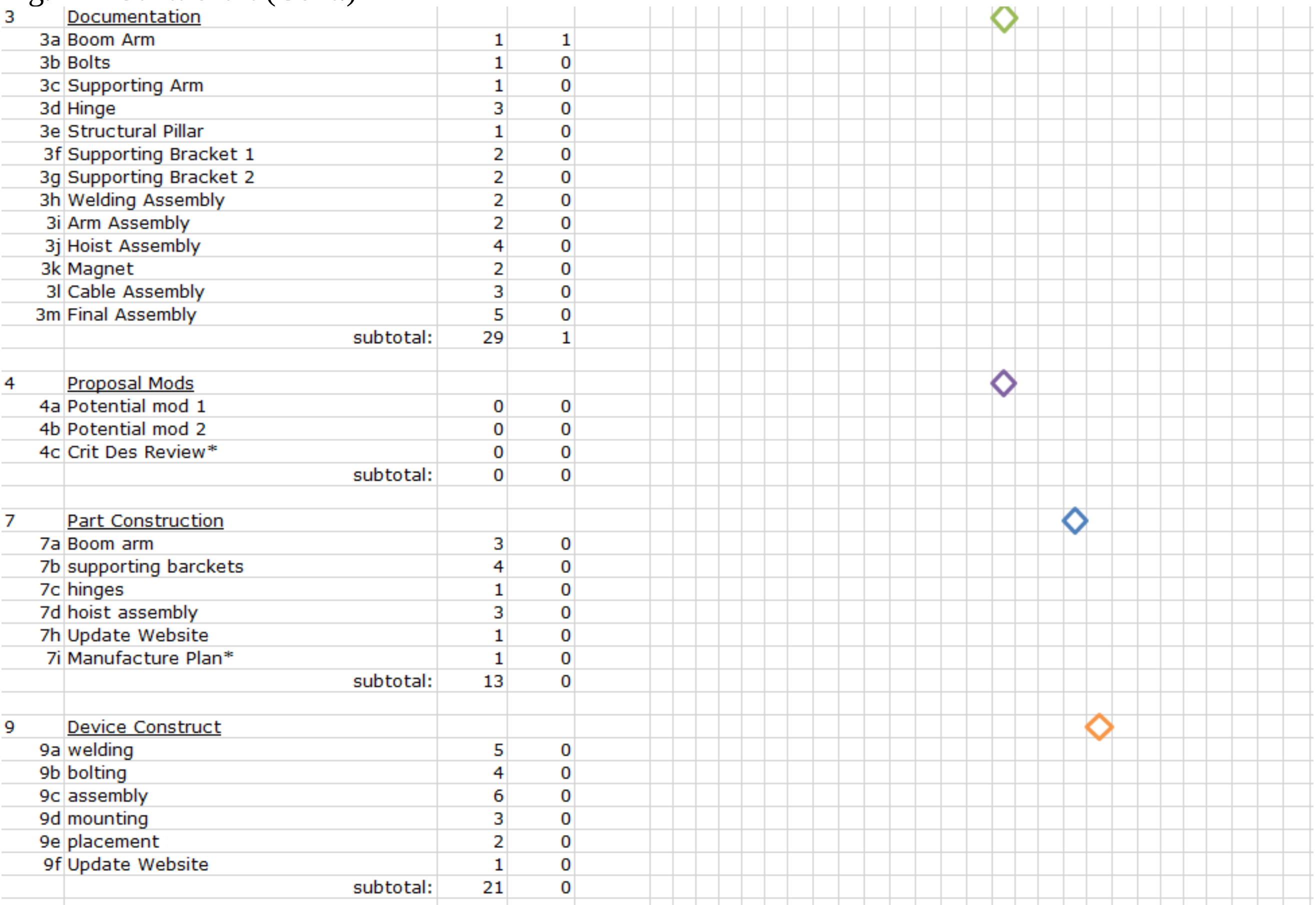
Fig. E-1: Gantt chart



PROJECT TITLE: Custom Shop Jib Crane
Principal Investigator: Brad Lewis

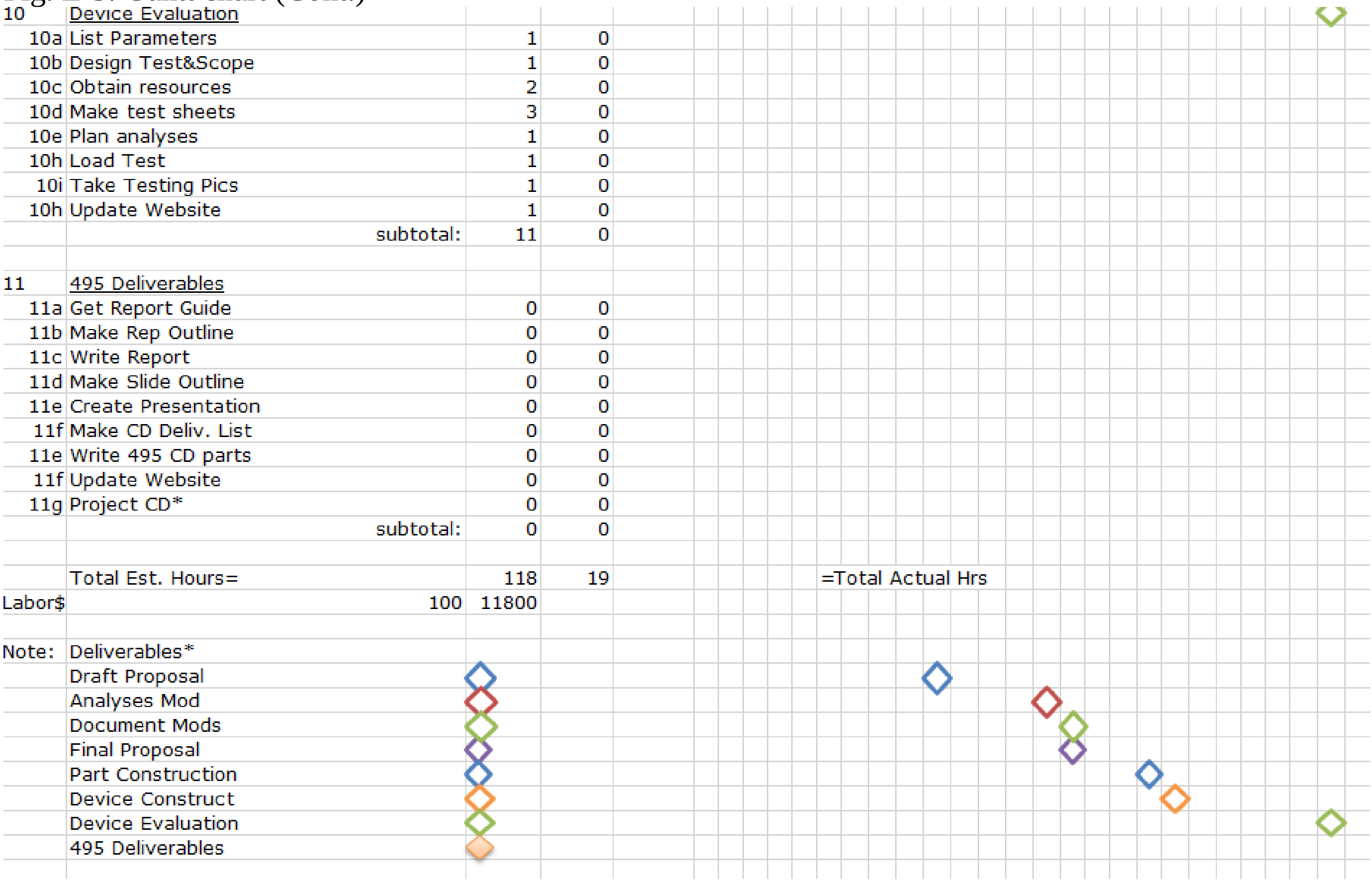
TASK: ID	Description	Duration Est. (hrs)	Actual (hrs)	%Comp.
1	Proposal*			
1a	Outline	5	5	
1b	Intro	2	2	
1c	Methods	3	0	
1d	Analysis	4	0	
1e	Discussion	3	0	
1f	Parts and Budget	2	0	
1g	Drawings	10	0	
1h	Schedule	3	0	
1i	Summary & Appx	5	0	
	subtotal:	37	7	
2	Analyses			
2a	I-beam selection	2	5	
2b	Rotation Arc analysis	1	3	
2c	Cable Selection	2	2	
2d	Shear in Boom Arm	1	1	
2e	Hinge Selection analysis	0	0	
2f	hinge shear analysis	0	0	
2g	Hinge friction analysis	0	0	
2h	mounting brackets stress analysis	0	0	
2i	Pillar Stress Analysis	0	0	
2j	Bolt tensile analysis (boom arm)	0	0	
2k	Bolt tensile analysis (mounting brackets)	0	0	
2l	Bolt Pattern	1	0	
	subtotal:	7	11	

Fig. E-2 Gantt chart (Cont.)



3	Documentation		
3a	Boom Arm	1	1
3b	Bolts	1	0
3c	Supporting Arm	1	0
3d	Hinge	3	0
3e	Structural Pillar	1	0
3f	Supporting Bracket 1	2	0
3g	Supporting Bracket 2	2	0
3h	Welding Assembly	2	0
3i	Arm Assembly	2	0
3j	Hoist Assembly	4	0
3k	Magnet	2	0
3l	Cable Assembly	3	0
3m	Final Assembly	5	0
	subtotal:	29	1
4	Proposal Mods		
4a	Potential mod 1	0	0
4b	Potential mod 2	0	0
4c	Crit Des Review*	0	0
	subtotal:	0	0
7	Part Construction		
7a	Boom arm	3	0
7b	supporting barckets	4	0
7c	hinges	1	0
7d	hoist assembly	3	0
7h	Update Website	1	0
7i	Manufacture Plan*	1	0
	subtotal:	13	0
9	Device Construct		
9a	welding	5	0
9b	bolting	4	0
9c	assembly	6	0
9d	mounting	3	0
9e	placement	2	0
9f	Update Website	1	0
	subtotal:	21	0

Fig. E-3: Gantt chart (Cont.)

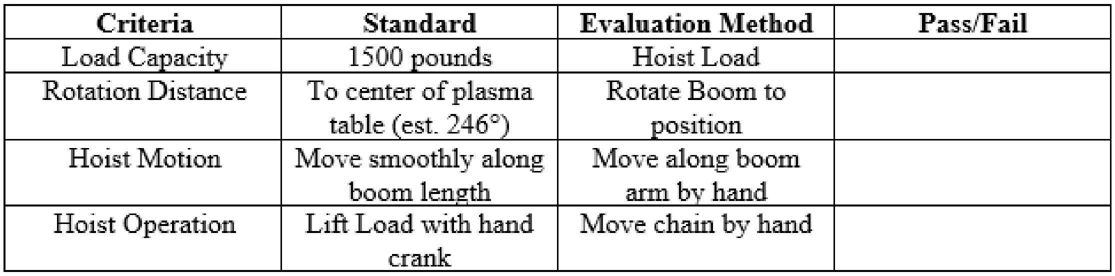


10	Device Evaluation			
10a	List Parameters	1	0	
10b	Design Test&Scope	1	0	
10c	Obtain resources	2	0	
10d	Make test sheets	3	0	
10e	Plan analyses	1	0	
10h	Load Test	1	0	
10i	Take Testing Pics	1	0	
10h	Update Website	1	0	
	subtotal:	11	0	
11	495 Deliverables			
11a	Get Report Guide	0	0	
11b	Make Rep Outline	0	0	
11c	Write Report	0	0	
11d	Make Slide Outline	0	0	
11e	Create Presentation	0	0	
11f	Make CD Deliv. List	0	0	
11e	Write 495 CD parts	0	0	
11f	Update Website	0	0	
11g	Project CD*	0	0	
	subtotal:	0	0	
	Total Est. Hours=	118	19	=Total Actual Hrs
Labor$	100	11800		
Note:	Deliverables*			
	Draft Proposal	◇		
	Analyses Mod	◇		
	Document Mods	◇		
	Final Proposal	◇		
	Part Construction	◇		
	Device Construct	◇		
	Device Evaluation	◇		
	495 Deliverables	◆		

Appendix F: Expertise and Resources

The primary sources of expertise and knowledge on the subjects involved with designing this crane are the author, Brad Lewis, the intended recipient of the crane and owner of Lewis Field Service, Jason Lewis, the CWU MET faculty; Professors Charles Pringle, Dr. Craig Johnson, and John Choi. Resources used in the development of this project include digital resources provided by the faculty, and textbooks on mechanical design, statics, strengths of materials, and dynamics.

Appendix G: Evaluation Sheet



Criteria	Standard	Evaluation Method	Pass/Fail
Load Capacity	1500 pounds	Hoist Load	
Rotation Distance	To center of plasma table (est. 246°)	Rotate Boom to position	
Hoist Motion	Move smoothly along boom length	Move along boom arm by hand	
Hoist Operation	Lift Load with hand crank	Move chain by hand	

Appendix H: Testing Report

The testing of the complete crane test was a success, the load was successfully lifted, and rotation angle achieved, hoist motion as predicted, and hoist operation successful.

a. Test Procedure: lift load
   - Summary/overview: In this test, the primary focus is the lifting capacity of the crane in order to test structural integrity.
   - Specify time, duration: The testing should take no longer than 15 minutes to complete.
   - Place: The location of testing is dictated by the location of installation of the crane.
   - Resources needed: data recording sheet, approx. 1500 pound test load.
   - Specific actions to complete the test:
     i. Acquire testing load weighing approximately 1500 pounds
     ii. Place load under crane
     iii. Securely attach load to winch
     iv. Lift load at least 4 feet off the ground
     v. Lower load onto the ground
     vi. Disconnect load from winch

Test 2:

The second test had the primary purpose of analyzing ease of use of the crane by a single operator. Primary concerns of the test include how tight the bolts in the hinges are tightened, the level of grease in the hinges, and total weight of the crane which all contribute to how difficult the crane would be to rotate by hand. If the crane is difficult to maneuver and operate while unloaded, the issues will only amplify with higher and higher loads applied to the crane. The results of the test indicated that the crane was easily able to be rotated through its entire range of motion with little effort on the individual operator moving the crane by hand. Note that the rotation of the crane is not motorized, and as a result the only force being used to rotate the crane is that applied by the operator, requiring that the crane be easily movable by hand.

Risk, safety, evaluation readiness: Primary safety concern is failure to lift testing load, resulting in drop of the load. Secure the load with lifting straps.

Appendix I: Job Hazard Analysis

JOB HAZARD ANALYSIS
Jib Crane Operation

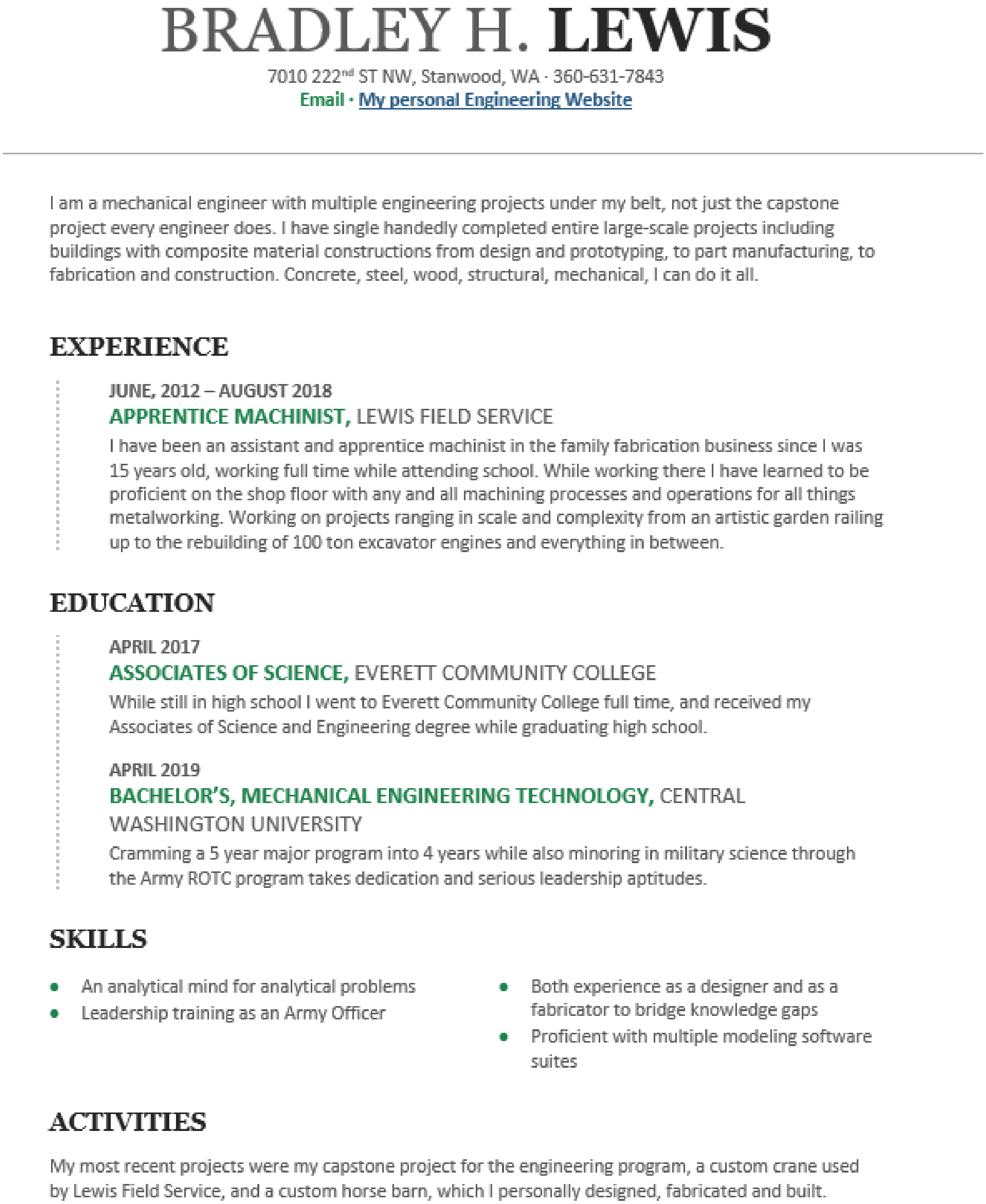
Name: Brad Lewis	Reviewed by: Approved by:

Location of Task:	Lewis Field Services Machine Shop
Required Equipment / Training for Task:	Proper crane operation training
Reference Materials as appropriate:	

Personal Protective Equipment (PPE) Required (Check the box for required PPE and list any additional/specific PPE to be used in "Controls" section)						
Gloves	Dust Mask	Eye Protection	Welding Mask	Appropriate Footwear	Hearing Protection	Protective Clothing
☐	☐	☐	☐	☒	☐	☐
Use of any respiratory protective device beyond a filtering facepiece respirator (dust mask) is voluntary by the user.						

PICTURES (if applicable)	TASK DESCRIPTION	HAZARDS	CONTROLS
	Attaching magnet to load	Unbalanced load may detach from magnet	Measurements of sheet to find center point of contact
	Heavy loads lifted in the air	Loads close to or exceeding magnet weight limit may detach from magnet	Do not lift loads greater than rated capacity of magnet
	Easing load onto worktable	Heavy loads generate crushing hazards	Ensure worktable is clear of debris and ready to receive material.

Appendix J: Resume



BRADLEY H. **LEWIS**

7010 222nd ST NW, Stanwood, WA · 360-631-7843
Email · **My personal Engineering Website**

I am a mechanical engineer with multiple engineering projects under my belt, not just the capstone project every engineer does. I have single handedly completed entire large-scale projects including buildings with composite material constructions from design and prototyping, to part manufacturing, to fabrication and construction. Concrete, steel, wood, structural, mechanical, I can do it all.

EXPERIENCE

JUNE, 2012 – AUGUST 2018

APPRENTICE MACHINIST, LEWIS FIELD SERVICE

I have been an assistant and apprentice machinist in the family fabrication business since I was 15 years old, working full time while attending school. While working there I have learned to be proficient on the shop floor with any and all machining processes and operations for all things metalworking. Working on projects ranging in scale and complexity from an artistic garden railing up to the rebuilding of 100 ton excavator engines and everything in between.

EDUCATION

APRIL 2017

ASSOCIATES OF SCIENCE, EVERETT COMMUNITY COLLEGE

While still in high school I went to Everett Community College full time, and received my Associates of Science and Engineering degree while graduating high school.

APRIL 2019

BACHELOR'S, MECHANICAL ENGINEERING TECHNOLOGY, CENTRAL WASHINGTON UNIVERSITY

Cramming a 5 year major program into 4 years while also minoring in military science through the Army ROTC program takes dedication and serious leadership aptitudes.

SKILLS

- An analytical mind for analytical problems
- Leadership training as an Army Officer
- Both experience as a designer and as a fabricator to bridge knowledge gaps
- Proficient with multiple modeling software suites

ACTIVITIES

My most recent projects were my capstone project for the engineering program, a custom crane used by Lewis Field Service, and a custom horse barn, which I personally designed, fabricated and built.