Multiple Apple Box Lift 1/10th Scale Model

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Multiple Apple Box Lift (1/10TH Scale)

By

Kyle Burlingame

Table of Contents

Introduction

Motivation

Van Doren Sales builds fruit packaging equipment. One of their customers, Chelan Fruit approached the company with a problem. They currently store their apples in cardboard boxes stacked on pallets that are several rows high. After they take the apples out of storage they need to check the quality of the apples to ensure they are in good condition. Currently they check the apples by using a mobile staircase to climb to the top of the pallet. Then they grab a top level box and carry it back to a mobile cart where it is inspected. After the apples are shipped to the customers there have been complaints that the apples in the middle rows are not as good of quality. Chelan Fruit wants Van Doren Sales to develop a way that they can get access to a middle box of apples on the pallet before it is shipped.

Function Statement

A mobile device is needed that can lift multiple boxes of apples.

Requirements 1/10th Scale

The requirements for this project are as follows:

- The device must cost less than $400 dollars
- The device must provide a proof of concept at a 10th scale.
- The device must weigh less than 2 pounds.
- The device must be able to lift 2 pounds of weight.
- The device must cost less than $400 dollars, not including labor or design time to unsure a profitable product.

Engineering Merit 1/10th Scale

Additional engineering merit has gone in to redesigning a 10th scale model. Engineering merit has taken place with the redesign of a scale model and figuring out how to prove the concept of the large scale device using a smaller scale.

Scope of Effort 1/10th Scale

The project funding was cut for this project. The scope of this project is to prove the functionality of this device at a 10th scale.

Success Criteria 1/10th Scale.

The success criteria is to have a working 1/10th scale model of this device by March 9th, 2016. This will prove that the concept of the design should work similarly on the larger scale design.

Design and Analysis

Proposed Solution 1/10th Scale

Since project funding was cut, the new solution is to 3D print a 10th scale model to prove the function of the design. All the original parts for the full sized model will be scaled down and 3D printed with minor adjustments. Lego Pneumatic cylinders and linear actuators will replace the full sized components.

Description

The first proposed design to lift the multiple levels of apples boxes can be seen below in figure 2. It has two plates used to squeeze the boxes, which are attached to their component lever arms. The lever arms are attached to the top frame as a pivot point. Connected to the top of the lever arm is an air cylinder used to apply the necessary force to squeeze the box. Attached to the top frame is a vertical frame that moves up and down to provide the lifting force by using electronic linear actuators. Finally, wheels are attached to the bottom of the device to allow mobility.

Benchmark

There are two bench marks for this project and one is a forklift. The reason a forklift cannot be used in this situation is because of the limited space. In the warehouse one pallet of apples is surrounded by other pallets of apples with only 36 inches between pallets. They store the apples as tight as possible because they have limited warehouse space.

The other benchmark is a robot that uses a squeezing mechanism to lift single boxes and stack them on pallets. There are companies already using this technique in the fruit industry. For the first design something similar to this concept will be used to squeeze multiple boxes at one time.

Figure 1: This is a picture of the robot that gave me the idea for my squeezing technique.

Performance Predictions 1/10th Scale

These are the following predictions made for the project and what they are based on.

- After completing a Solid Works rendering, the predicted volume will end up at about 30in^3.
- After completing the Solid Works rendering the device should weigh about 1.2 lbs.
- After looking at the cost of parts and 3D printing this is approximately a $400 dollar project.
- The device should be completed in 1 week once 3D printing begins.

Description of Analyses

First of all the different stacking patterns will be collected. Next determine how much each box configuration weighs and the surface area for lifting. All maximums and minimum values will be taken in to consideration for the calculations of the device. Key factors here are determining what surface area is available to squeeze and how much weight will be lifted. Once this is determined the plates of the design can be optimized to the correct size. After the plates are sized, the force required to squeeze the boxes without slipping can be calculated from the weight of each pattern and the respective surface area. From there the torque required from the lever arm can be calculated as well. The air cylinders have to make the needed force to apply this torque to the arm. Once the weight of the boxes is known, the force needed to lift the boxes can be calculated. After these calculations are completed, the structure will need to be optimized to handle these forces and stresses without failure. Hopefully the forces and stressors are small enough to use a light weight material such as aluminum in order to meet the weight requirements and the ease of transportation. However, if this is not the case and a heavier material is needed the device may have to be redesigned to be a powered device.

Description of Analyses 1/10th Scale

The description of analyses is very similar for the 10th scale model it is just at a smaller scale.

Scope of Testing and Evaluation 1/10th Scale

The 10th scale model will be tested to prove the functionality of the design. Other things that will be tested are how much pressure the plates exert on the boxes and the weight of the device.

Analysis

Approach: Proposed Sequence

Design: 1, 2, 3, & 4

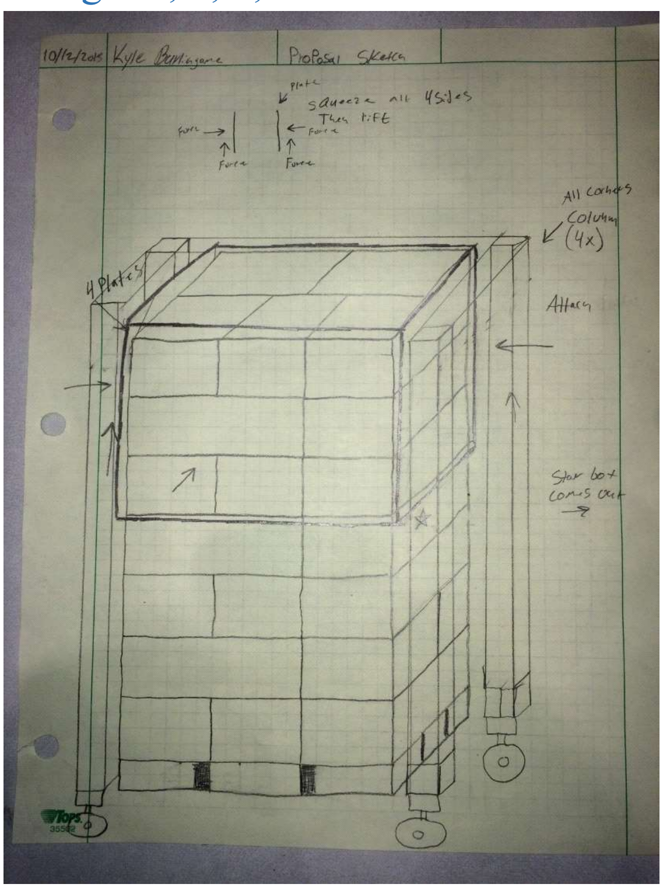


Figure 2: This is the first proposed design for this project.

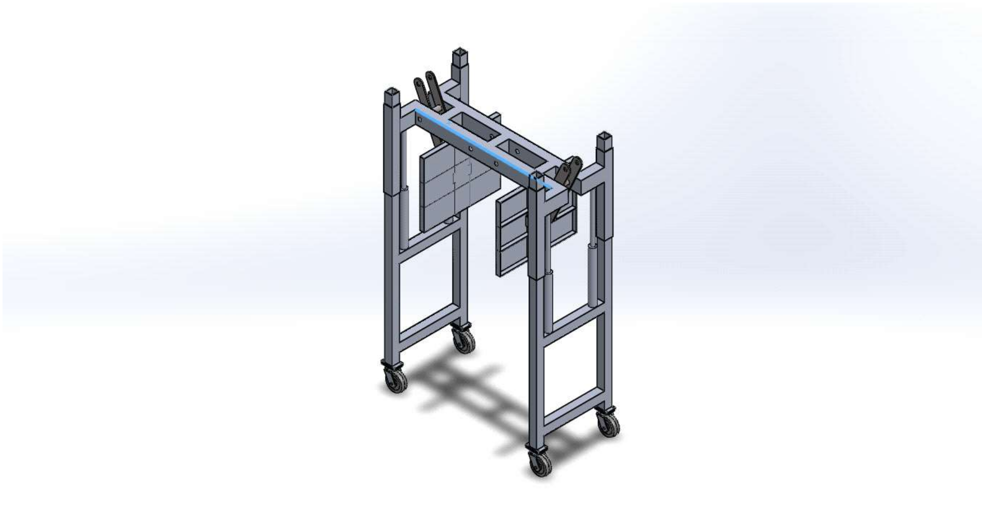


Figure 3: This is the second proposed design for this project. At this point the design still needed a way to apply a squeezing force.

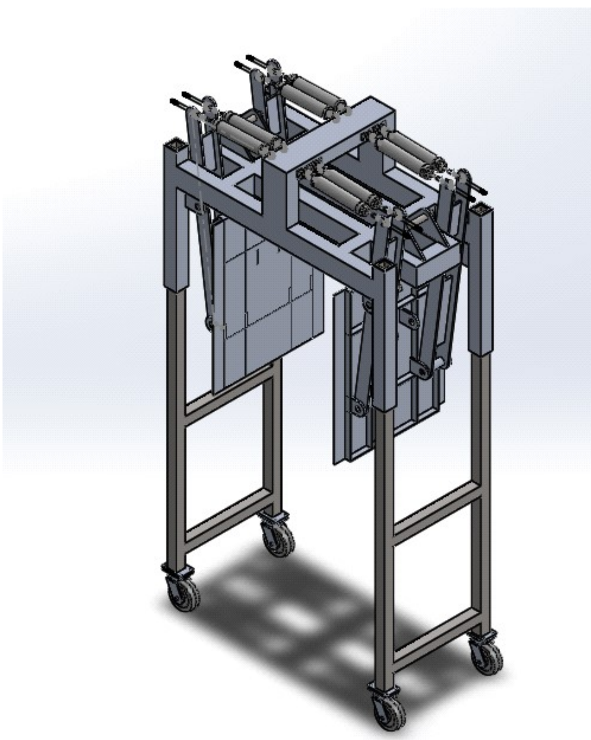


Figure 4: This is the third proposed design for this project. The design still needs minor parts added to the device and the electronic linear actuators. The customer has a few modifications that they want to make to this design and after that is done this will be the design that will be built.

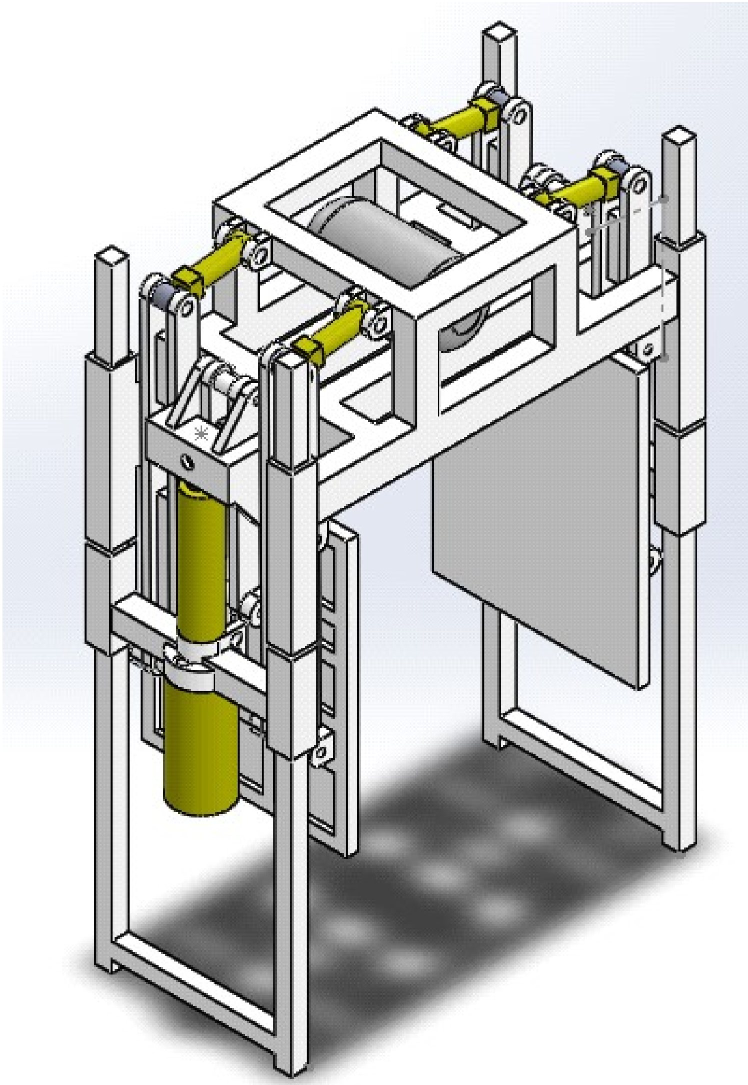


Figure 5: This is the 4th proposed design for this project and this is at a 10th scale. The Lego air cylinders and Lego actuators are colored yellow.

Device Shape 1/10th Scale:

The device shape will now be a 10th scale of the original and modified slightly to accommodate using Lego air cylinders, actuators and small cardboard boxes.

Device Assembly, Attachments 1/10th Scale

The device will now be assembled using 1/8 in pins, 3/16" pins and glue. The remainder of the parts will be connected in the 3D printing process.

Tolerances, Kinematic, Ergonomic, etc.

Tolerance is important on this device. The holes drilled in the lever arm must be centered on both the x and y axis of the arm. They cannot be out of tolerance by more than .030in. Also the distance between the three holes needs to be within tolerance of .010in. That way when the distances are used to calculate forces and torque the values are precise. Also, when welding together the structure, all 90 degree connections cannot be out of tolerance by more than ½ a degree to insure even loading to the structure.

Tolerances, Kinematic, Ergonomic, etc. 1/10th Scale

Tolerance is really important when 3D printing the parts because the printer only has a .010" resolution. The parts must be designed accordingly to produce good parts.

Technical Risk Analysis, Failure Mode Analyses, Safety Factors,

The pneumatics system and electrical system will be purchased components and will be installed by the Van Doren pneumatics team and the Van Doren electronics team.

Methods and Construction 1/10th Scale

The 10th scale device will be built at the CWU campus. It will be printed using their 3D printers. Other minimal machining operations will take place in the CWU machine shop.

Description 1/10th Scale

This device is held together by 3D printed parts, glue and pins. Everything else will remain the same except at a 10th scale.

Drawing Tree 1/10th Scale

The drawing tree shows the main assembly and all the parts needed to make the assembly. All the part drawings and assembly drawings can be referenced by the part number in Appendix B.

Parts List and Labels

The parts list is referenced in appendix C. In that appendix the part number and quantity needed to build each part to successfully build one Multiple Apple Box Lift and one 10th scale model apple box lift can be found. Also, all the drawings corresponding to these part numbers can be referenced in appendix B based on the part number.

Manufacturing Issues 1/10th Scale

The main manufacturing issue so far with the 10th scale model is the 3D printing resolution. The parts that need to be printed are small. The way the printer prints the parts leaves space in the material making them weak. Also the printer prints holes undersized and with an oval shape. This will result in having to drill and ream all the holes. Another manufacturing issue is the printed parts sometimes have bent features and will somehow have to be straightened out.

Discussion of Assembly, Sub-Assemblies, Parts, Drawings 10th Scale

The assembly of this device became much simpler now that it's only a 10th Scale model. All the parts will be printed at the same size and then assembled with glue and pins.

Testing Method

Introduction 1/10th scale

The testing of this device will take place at Central Washington University, specifically in the hydraulics lab. In the hydraulics lab, they have the necessary pressure gauges hoses and fittings.

Method/Approach

These are the methods used to test the deliverables and how they compare to the predicted values.

The weight of the device will be weighed on a scale and the actual weight will be compared to the prediction made from the solid works rendering.

The pressure on the plates will be measured by using a pressure gauge and the value will be compared to the calculated value and must be less than 1psi, so it does not crush the apples or apple boxes.

The load capacity will be tested by lifting a load that is greater than any load the customer will be lifting with a safety factor of 1.25. This number will be computed from the total weight of the apple boxes being lifted plus the portion of the device being lifted multiplied by 1.25. If the device can lift that weight without failure this test will be a success.

The lateral force to move the device will be tested by using a scale and then compared to the calculated value.

The cycle time of the device will be measured with a stopwatch.

Test Procedure

Weighing the Device:
Materials: Scale, multiple apple box lift
Procedure:

- Zero the scale.
- Use forklift to lift the device on the scale. (do not try to lift device manually)
- Make sure the device is stable on the scale and remove the forklift
- Record Weight
- After weight is recorded use a fork lift to lift the device off the scale

Making sure the device can lift the required load.
Materials: 2lbs of something inside of boxes, pallet, multiple apple box lift
Procedure:

- Stack boxes with weight inside them on a pallet in such a way the device can lift up the boxes.
- Apply enough squeezing force so the boxes don't slip and then lift the boxes up.

Recording the cycle time
Materials: Stopwatch, multiple apple box lift
Procedure:

- Place the multiple apple box lift in a location close to the pallet of apple boxes.
- Start stopwatch
- Record the total cycle time. 1 cycle consists of positioning the device; squeezing and lifting the apple boxes, having an employee remove an apple box from a middle row, complete their inspection of the apples in that box, replace the apple box, and then lower the boxes back on to the stack. Then the cycle time is complete.

Measuring the lateral force
Materials: Force measuring device, multiple apple box lift
Procedure:

- Attach the force measuring device to the multiple apple box lift.
- Pull on the force measuring device and record the amount of force it took for the device to start rolling.

Deliverables

These are the deliverables that will be found from testing.

- Squeezing pressure
- Load capacity
- Cycle time
- Required lateral force to move the device
- Weight of the device

Budget/Schedule/Project Management

Estimate total project cost 1/10th scale.

The estimated total cost of the 10th scale model is about $400. $100 has already been spent on a Lego pneumatics kit, another $30 on Lego electric actuators and $80 on Lego motors. The remainder of the device will be printed from the 3D printer. The device will use at least 30in^3 of plastic material which will cost about $180. Pins have been donated so there is no cost for the pins for this project. There is about a $40 dollar buffer for unforeseen costs and any parts that have to be reprinted.

Funding source(s) 10th scale

This project will be funded by Kyle Burlingame.

Proposed schedule 10th scale.

A new project schedule for the 10th scale model has been placed in appendix E.

Project Management

Human Resources:

These are some of the human resources and mentors available for this project.

Greg Kemp: Engineer
Patrick O'Brian: Lead sales project estimator
Steve Cochran: Lead Research and Development.
Lance Web: Lead Electronics engineer
Several fabricators and welders on staff.
Brett Pittsigner: President
Brian Huan: CEO

Physical Resources:

The machines available for this project with operators include: 3D printer, lathes, mills, laser cutter, press brake, band saw, welders and many other tools.

Discussion

This project was a huge task to take on as a senior project. Even with the support of a well-established company with much knowledge and support this project has been difficult. The time spent on this project was far more than expected, many hours have been put into the design, analysis and proposal of this project. It was quite devastating to hear they would not be moving forward with the proposed design and would be cutting the funding to the project. However, a lot was learned from this experience. Always try to be ahead of the game and make sure the right people are giving you the design requirement. Overall the 10^{th} scale redesign of this project has been a success, after several hours of redesigning and finding parts that would work for a 10^{th} scale model. The scale model should be able to prove the concept of how the device would have worked at full scale. This has been a huge setback because several hours had to go back into the proposal phase and planning phase.

Design Evolution / Performance Creep

The design evolution of this device is quite interesting. The basic movements of the device have been established from almost day 1. The device will squeeze and lift the boxes of apples. The part of the device that continues to be changed and redesigned is how the lift and squeeze technique will be performed. The first idea for this project was that the squeeze and lift would be driven by hydraulics. This quickly changed because the fruit company did not like the idea of hydraulic fluids being around the fruit. Also a hydraulic system was overkill for the amount of load the device needed to lift. The next idea was to move to pneumatics to drive the squeeze and lift force. This then came up for discussion because air is a compressible fluid. Before any lifting or squeezing occurs the device has to be able to be positioned so that the plates start at a certain height for that specific box configuration. Using air would make it hard to pin point certain heights for different box configurations since when adding air to a cylinder the movement is quite jerky. Also the layers of boxes have some glue between the layers so before the boxes could be lifted, air would be compressing in the cylinders until the glue bond between layers was broken resulting in uncontrolled lift acceleration. This potentially could cause boxes to tip over. After all this was taken into account the company decided that pneumatics would be the best solution for the squeeze force of this device and that the lifting force would be provided by a linear electric actuator. The linear actuator provided precise, smooth movement. The only thing left to be determined on this device is it will need its own batteries and compressors to run the device. There will be a lot of help from the Van Doren Electric and pneumatic team for sizing batteries and compressors. Lastly, the funding of the project was cut and now it is redesigned at a 10^{th} scale.

Success $1/10^{th}$ Scale

This project will be successful if the device proves the concept of how the full scale model could work.

Next Phase $1/10^{th}$ Scale

The next phase for this project is to 3D print the 10^{th} scale model parts and then prove the concept of the design.

Conclusion

The full-sized Multiple Apple Box Lift is 100% ready to be taken to the manufacturing phase. The device was designed by an engineer who is graduating from an accredited engineering program in June 2016. This project is also backed by several human resources who are experienced in certain fields pertaining to specific parts of this project. Most importantly this project is backed by Van Doren Sales the experts in fruit packaging equipment since 1946. However, since the original customer that wanted this device rejected the proposal, a 10^{th} scale model is being built to prove the concept of the design and the full-sized drawings will be placed in the Van Doren archives to be possibly sold to different customers or slightly redesigned.

Acknowledgements:

Several people have helped with the design stage of this project.

One of the most important people helping with this device is Jeff Burlingame. He has helped with some of the ideas and designs for this project. He has also been available to bounce ideas off of and discuss potential problems. Jeff also helped with some preliminary pressure tests.

Greg Kemp has been another important individual in the development of this design. He has been around to critique and offer suggestions on the design. He also has been the go to guy to get things done that need to happen within the Van Doren Company.

Patrick O’Brian is another individual who has helped critique and offer suggestions to the design of the device.

Bret Pittsinger is also very important with the development of the device. Bret is the reason this project was able to happen, he met with the customer who needed the device. He is also taking care of all of the cost of this project. With the backing of Bret and the Van Doren Company this device has the potential to make it to a mass production

phase of making 18-100 of these devices if the device is successful.

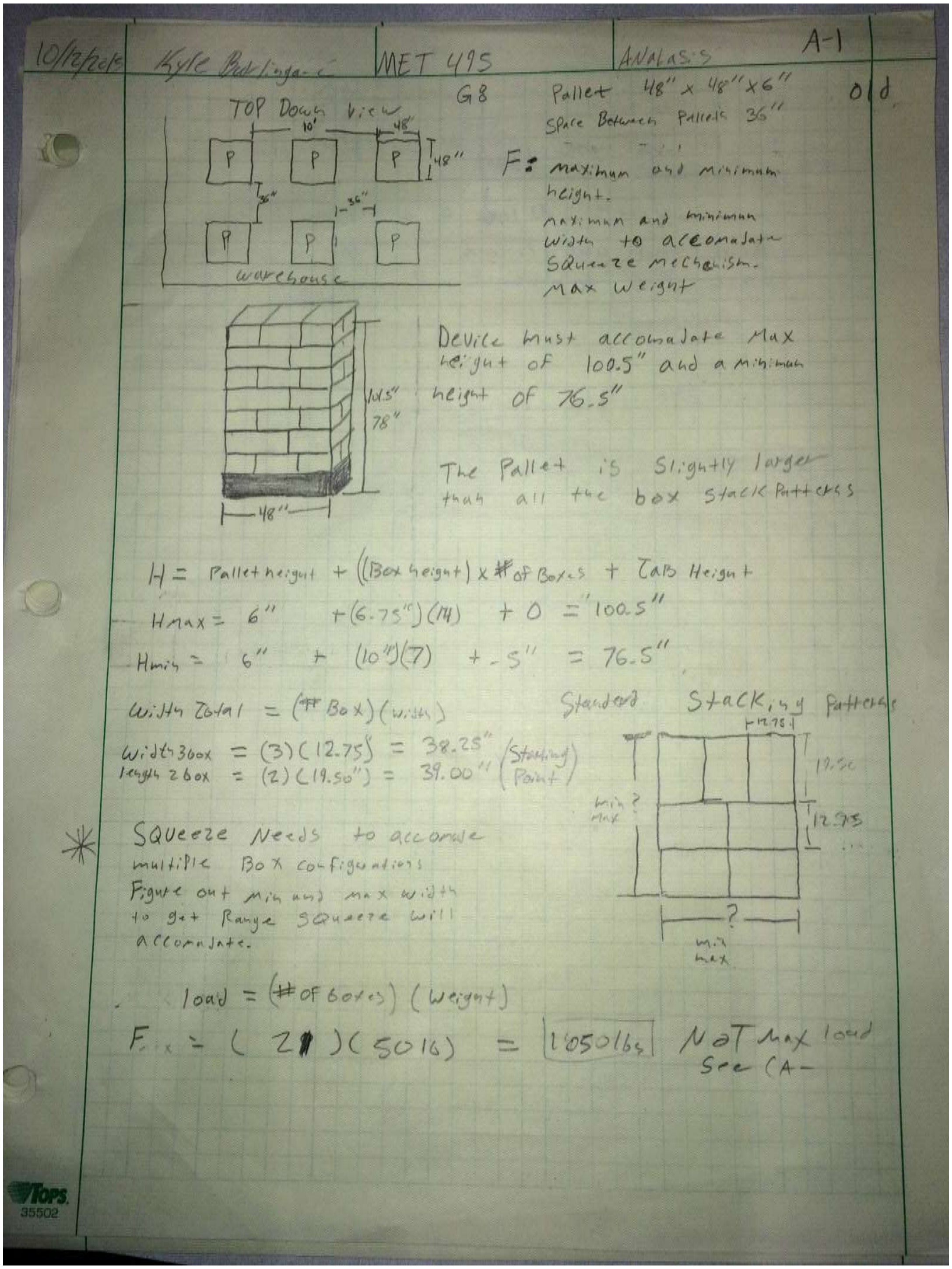
Ted Bramble has also been an important resource when discussing the manufacturing process of how some of the devices parts will be made.

Dr. Johnson and Professor Pringle have also been very helpful for providing feedback on the proposal of this device and the overall concept of this project.

Without the help of these seven individuals this project would not have been possible.

References:

Appendix A – Analyses



10/12/2015 Kyle Burlingame MET 495 ANALYSIS A-1

G8

Pallet 48" x 48" x 6"

Space Between Pallets 36"

old

TOP Down View

10' 48" 48" 36" 36"

P P P P P P

warehouse

F: maximum and minimum height.

maximum and minimum width to accomodate squeeze mechanism.

max weight

100.5" 78"

48"

Device must accomadate max height of 100.5" and a minimum height of 76.5"

The Pallet is Slightly larger than all the box stack Patterns

H = Pallet height + ((Box height) x # of Boxes + Cap Height

Hmax = 6" + (6.75")(14) + 0 = 100.5"

Hmin = 6" + (10")(7) + .5" = 76.5"

Width Total = (# Box)(width)

Width 3box = (3)(12.75) = 38.25"

length 2box = (2)(19.50") = 39.00" (Starting Point)

Standard Stacking Patterns

12.75

19.50

12.75

min? max

? min max

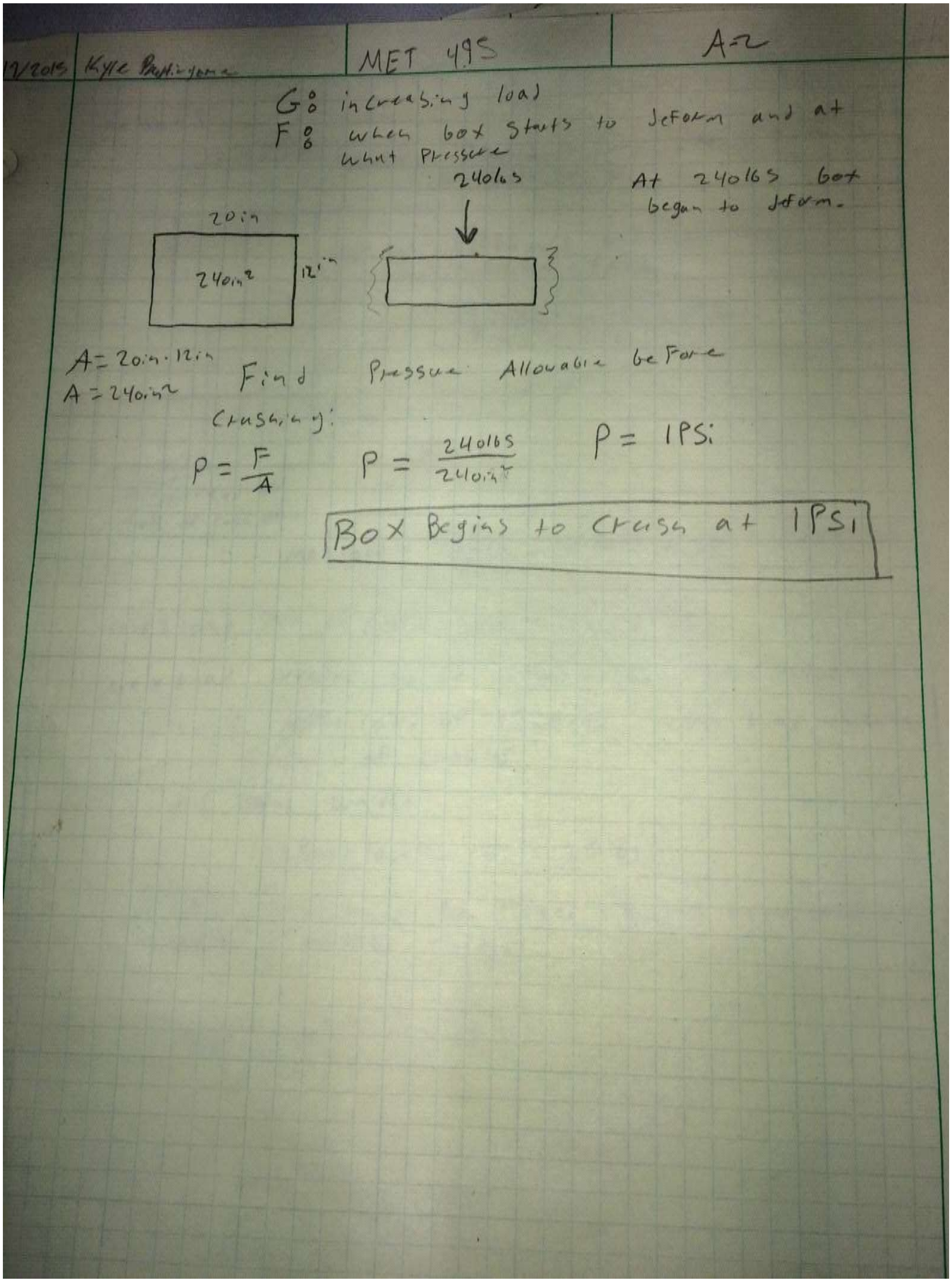
* Squeeze Needs to accomodate multiple Box configurations

Figure out min and max width to get Range Squeeze will accomodate.

load = (# of boxes)(weight)

F = (21)(50lb) = 1050lbs Not max load See (A-

A-1 General Analysis



[illegible]/2015 Kyle [illegible] | MET 495 | A-2

G: increasing load
F: when box starts to deform and at what pressure

240lbs

At 240lbs box began to deform.

$A = 20in \cdot 12in$
$A = 240in^2$

Find Pressure Allowable before crushing:

$P = \frac{F}{A}$ $P = \frac{240lbs}{240in^2}$ $P = 1PSi$

Box Begins to Crush at 1PSi

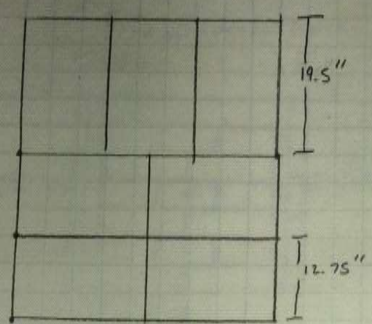
A-2 Pressure test on a cardboard box.

Kyle Burlingame | Maximum load. | A-3

Given:

Standerd Stack Pattern, 7 Boxes Per Row, Lift 7 Rows

W = 25lbs Per Box



7 rows stacked on top of each other

Find: max load that needs to be lifted.

So: Total weight = # Box's · wieght Per box

1-7

$$\text{Max load} = 7\,\frac{\text{boxs}}{\text{Row}} \cdot 7\ \text{Rows} \cdot \frac{25\,\text{lbs}}{\text{box}} = 1225\,\text{lbs}$$

Max load Due to Apple box = **1225lbs**

max load Needed to be lifted by linear Actuators

Given: Apple load of 1225lbs, over head machine weight of 1000lbs

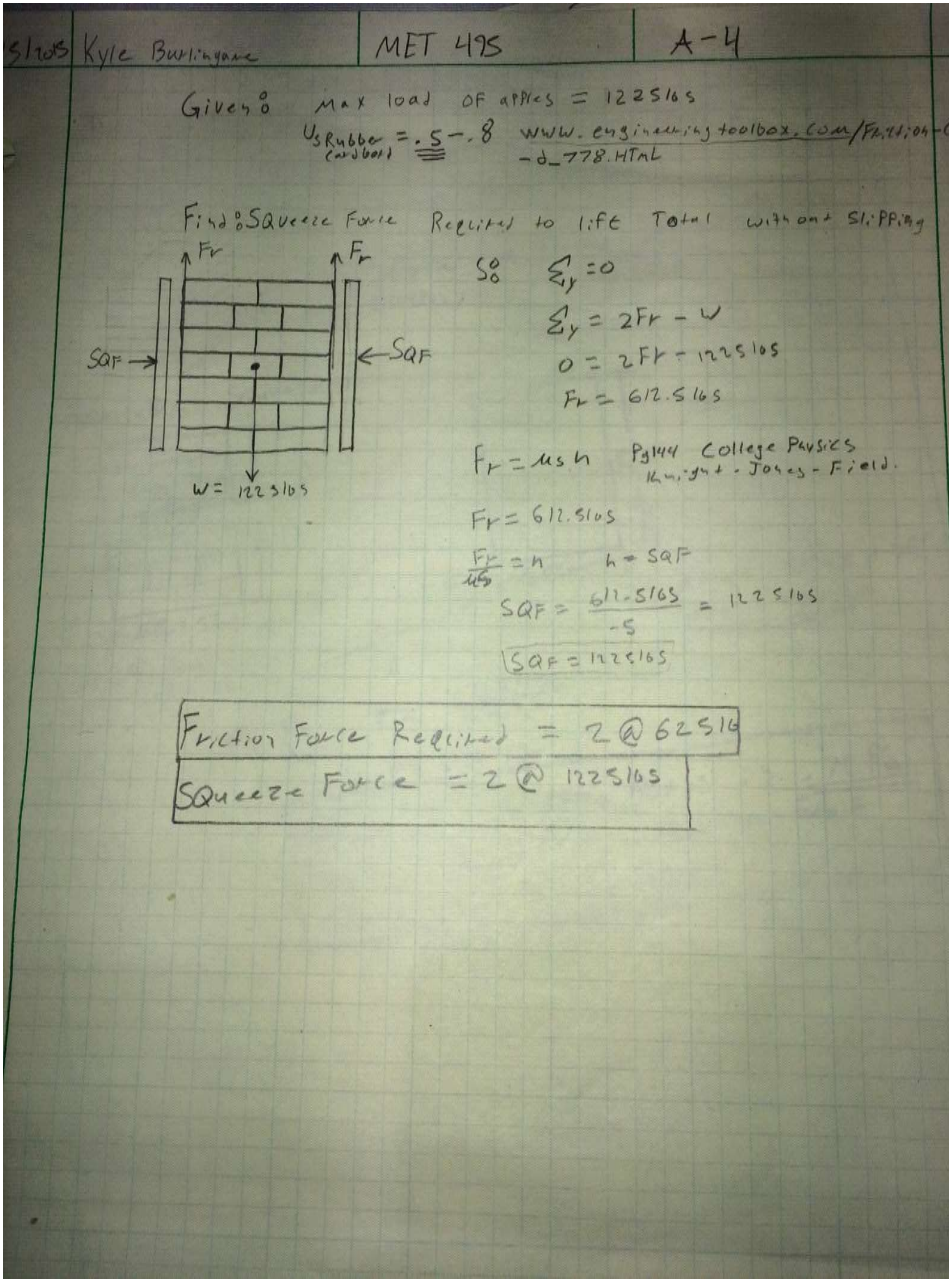
F: Total weight

1225lbs + 1000lbs = **2225lbs**

This load will be lifted by **2 linear actuators** apply **1500lbs each.**

$$SF = \frac{3000\,\text{lbs}}{2225} = \boxed{1.3}$$

A-3 Calculations to find the forces the linear actuators must supply.



5/2015 Kyle Burlingame | MET 495 | A-4

Given: Max load of apples = 1225 lbs

U_s Rubber (cardboard) = .5 - .8 www.engineeringtoolbox.com/Friction-c-d_778.HTML

Find: Squeeze Force Required to lift Total without Slipping

So: $\Sigma_y = 0$

$\Sigma_y = 2Fr - W$

$0 = 2Fr - 1225 \text{ lbs}$

$Fr = 612.5 \text{ lbs}$

$Fr = \mu_s n$ Pg144 College Physics Knight - Jones - Field.

$Fr = 612.5 \text{ lbs}$

$\frac{Fr}{\mu_s} = n$ n = SQF

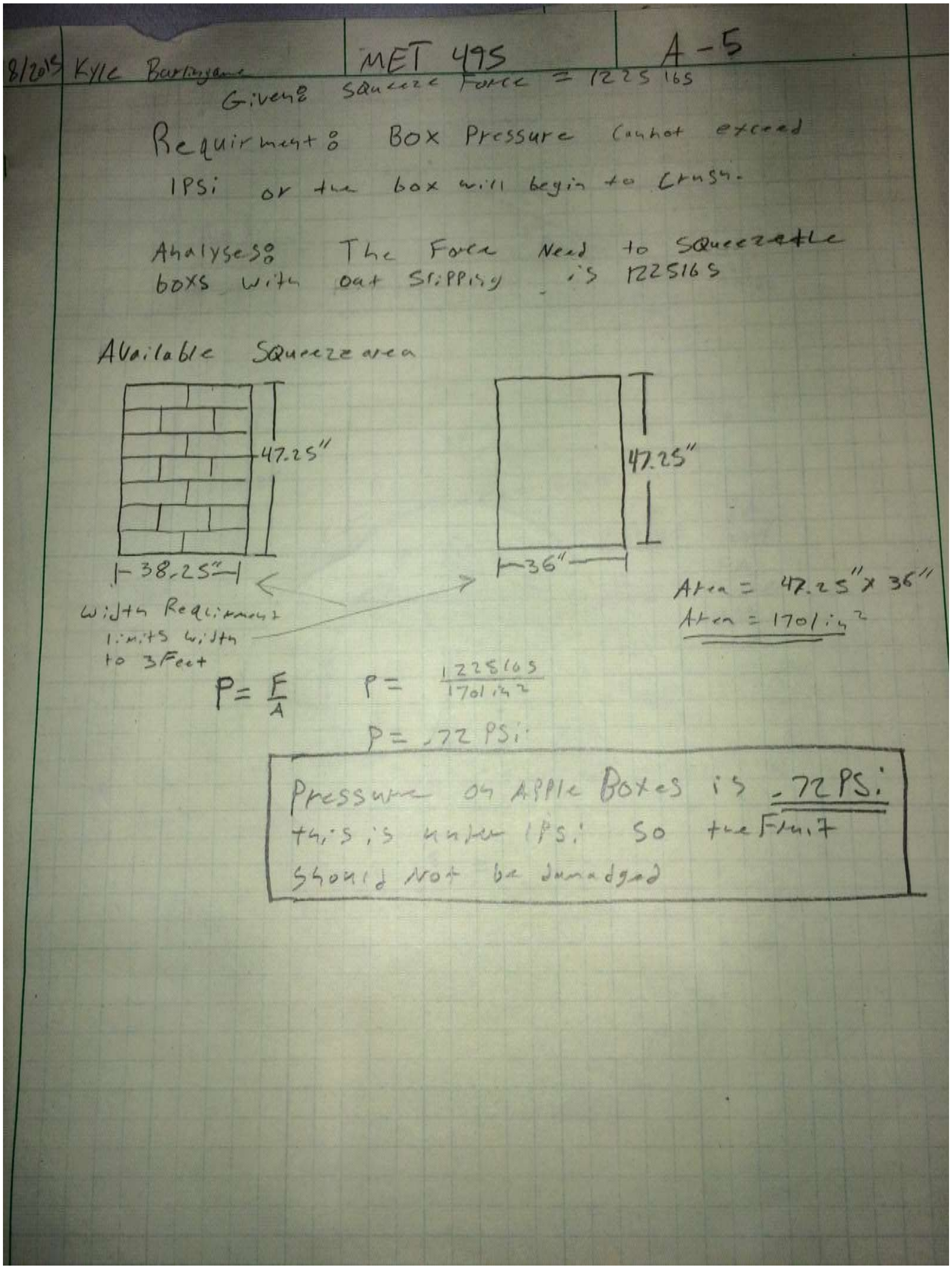
$SQF = \frac{612.5 \text{ lbs}}{.5} = 1225 \text{ lbs}$

SQF = 1225 lbs

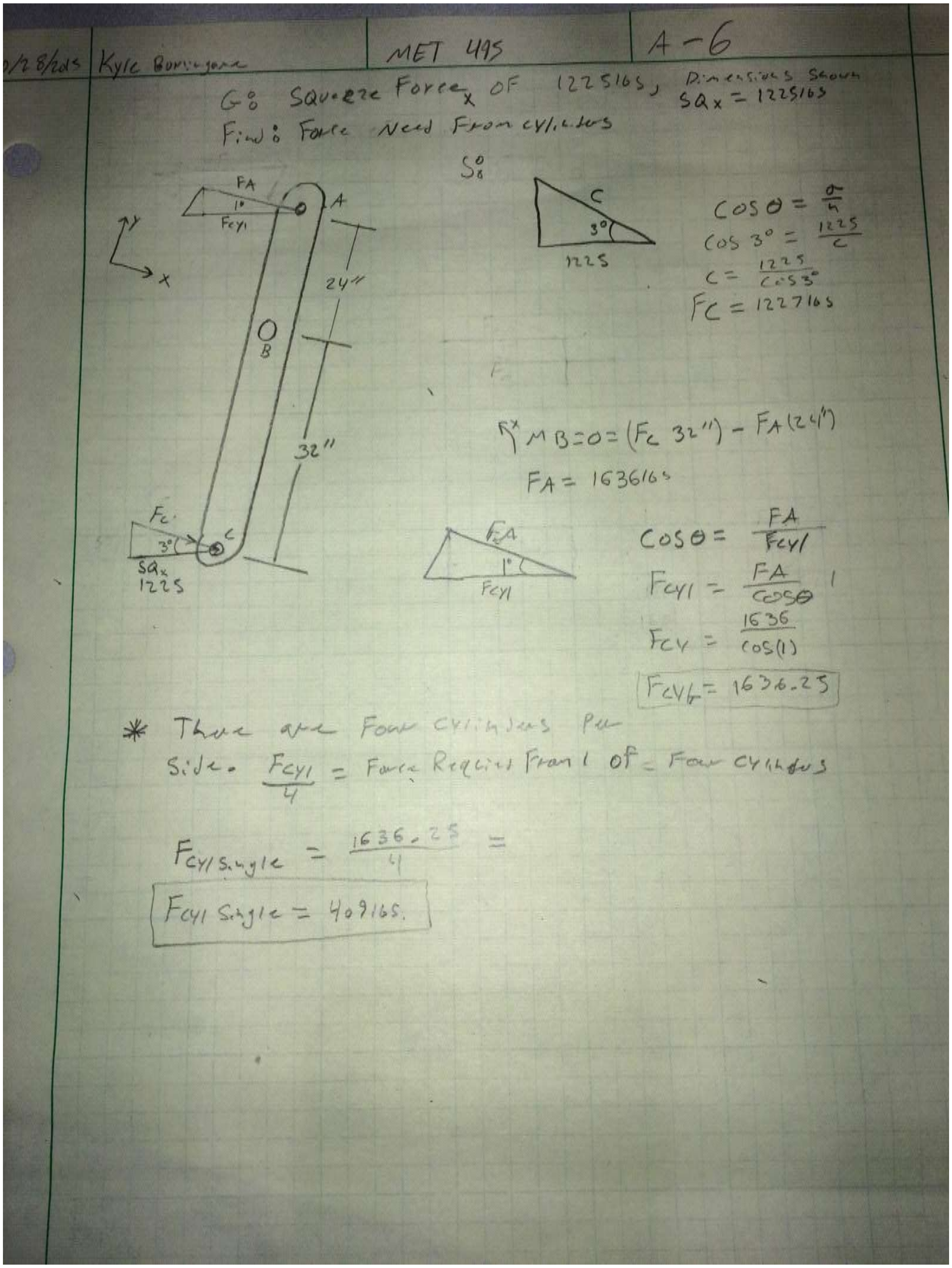
Friction Force Required = 2 @ 625 lb

Squeeze Force = 2 @ 1225 lbs

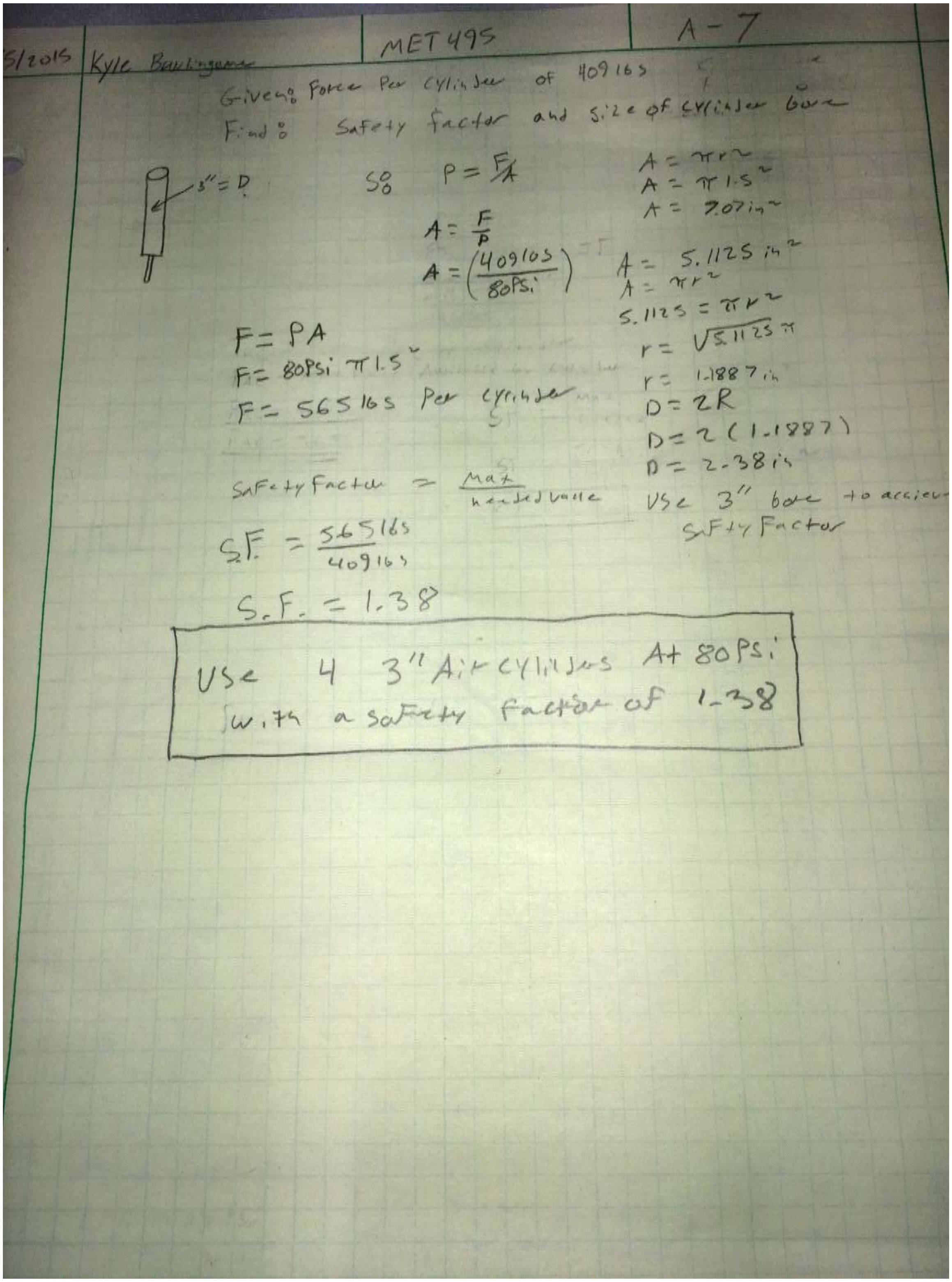
A-4 Calculations for the friction force and squeeze force needed to lift boxes without slipping.



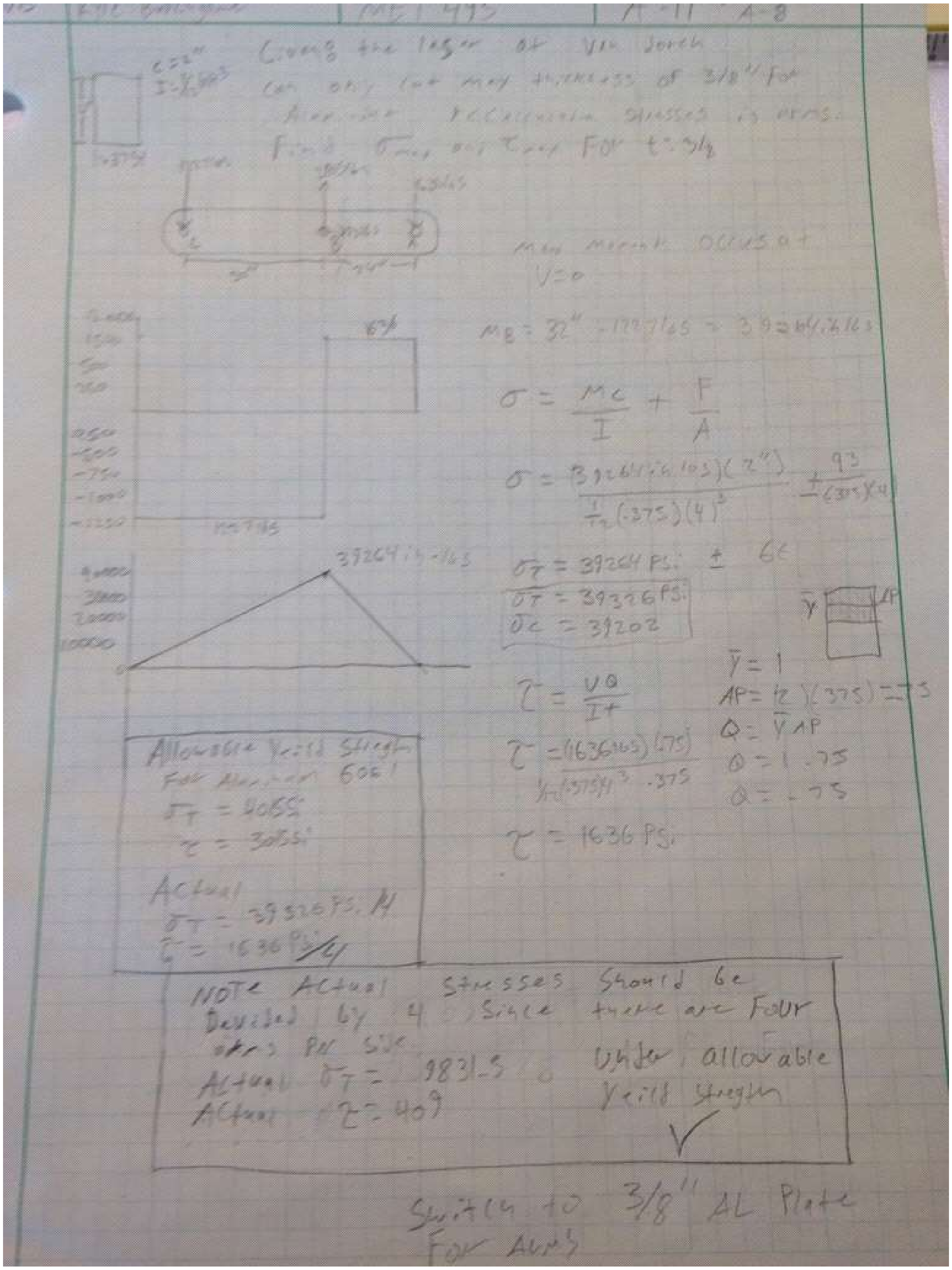
A-5 Calculations for the max pressure applied to the apple boxes when undergoing the max squeeze force.



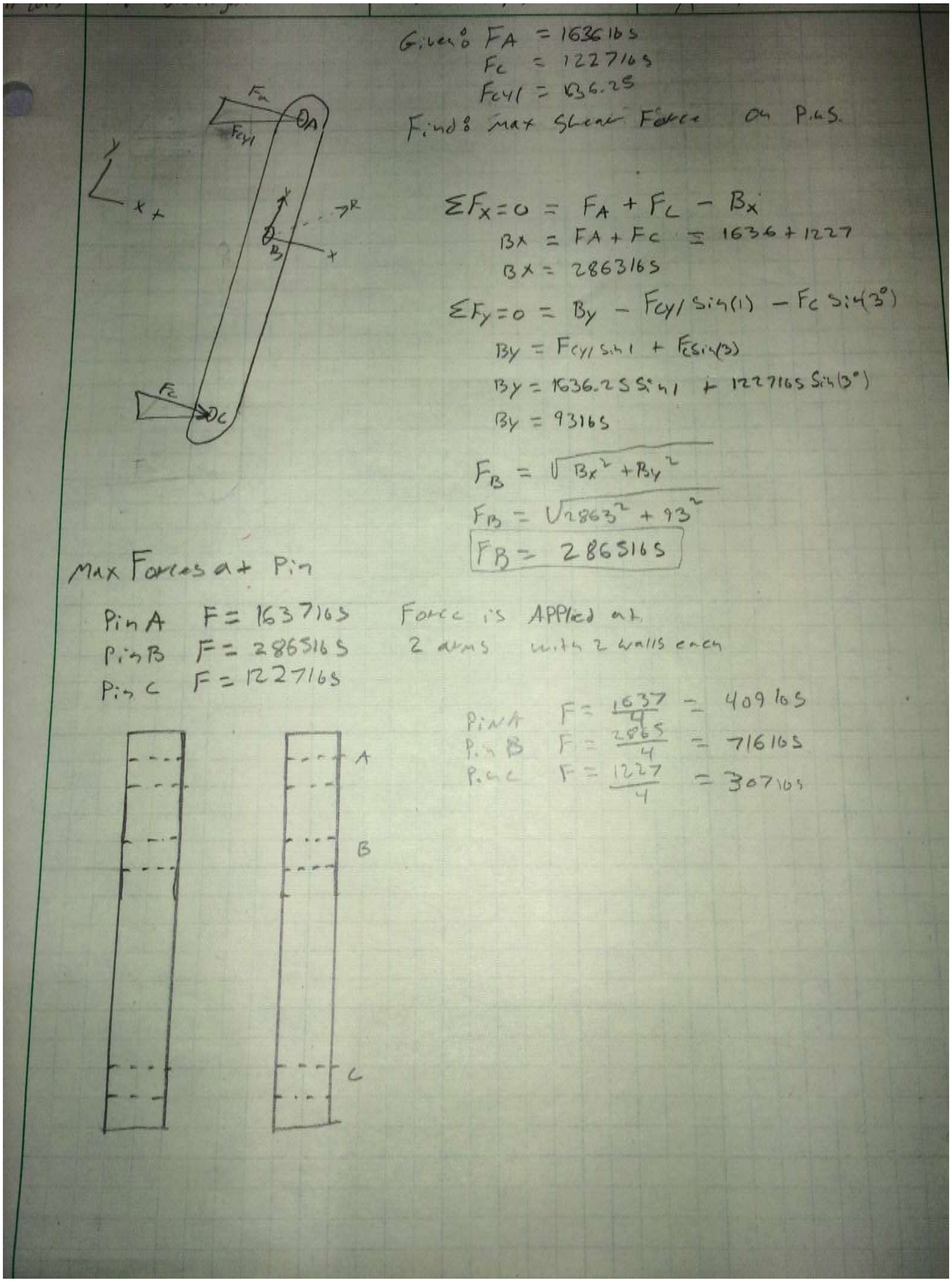
A-6 Calculations needed for the force of each of the four air cylinders that must be applied to the lever arms.



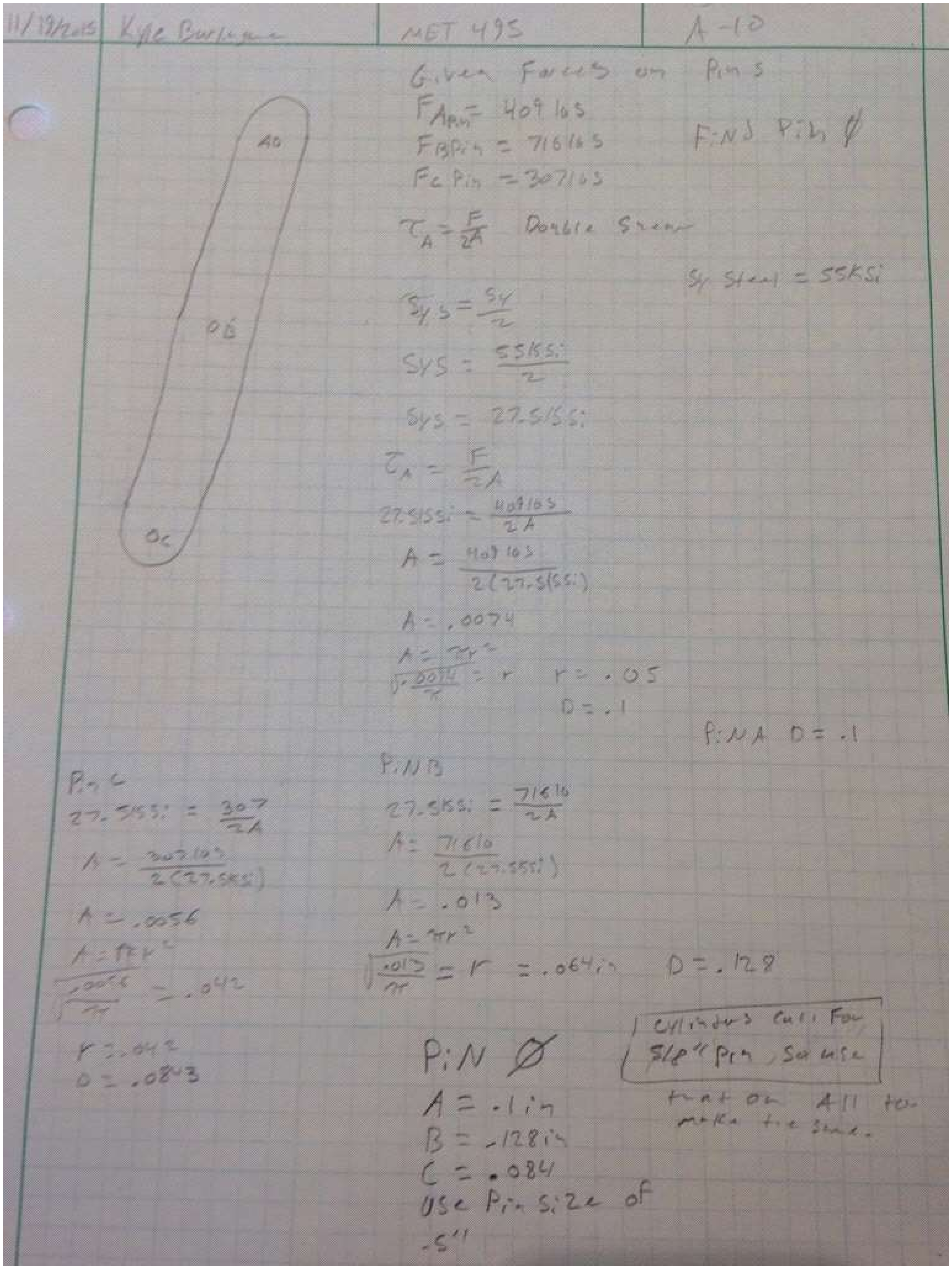
A-7 Air Cylinder Analysis



A-8 This sheet shows the max shear and moment on the lever arm. Max normal stress and shear stress have been calculated.



A-9 This shows the max force in each of the 3 pins.



11/19/2015 Kyle Burleyne — MET 495 — A-10

Given Forces on Pins

$F_{A\,Pin} = 409\ lbs$

$F_{B\,Pin} = 716\ lbs$

$F_{C\,Pin} = 307\ lbs$

Find Pin Ø

$\tau_A = \frac{F}{2A}$ Double Shear

Sy Steel = 55KSi

$S_{ys} = \frac{S_y}{2}$

$S_{YS} = \frac{55KSi}{2}$

$S_{ys} = 27.5KSi$

$\tau_A = \frac{F}{2A}$

$27.5KSi = \frac{409\ lbs}{2A}$

$A = \frac{409\ lbs}{2(27.5KSi)}$

$A = .0074$

$A = \pi r^2$

$\sqrt{\frac{.0074}{\pi}} = r \quad r = .05$

$D = .1$

Pin A D = .1

Pin C

$27.5KSi = \frac{307}{2A}$

$A = \frac{307\ lbs}{2(27.5KSi)}$

$A = .0056$

$A = \pi r^2$

$\sqrt{\frac{.0056}{\pi}} = .042$

$r = .042$

$D = .0843$

Pin B

$27.5KSi = \frac{716\ lb}{2A}$

$A = \frac{716\ lb}{2(27.5KSi)}$

$A = .013$

$A = \pi r^2$

$\sqrt{\frac{.013}{\pi}} = r = .064in \quad D = .128$

Pin Ø

A = .1in

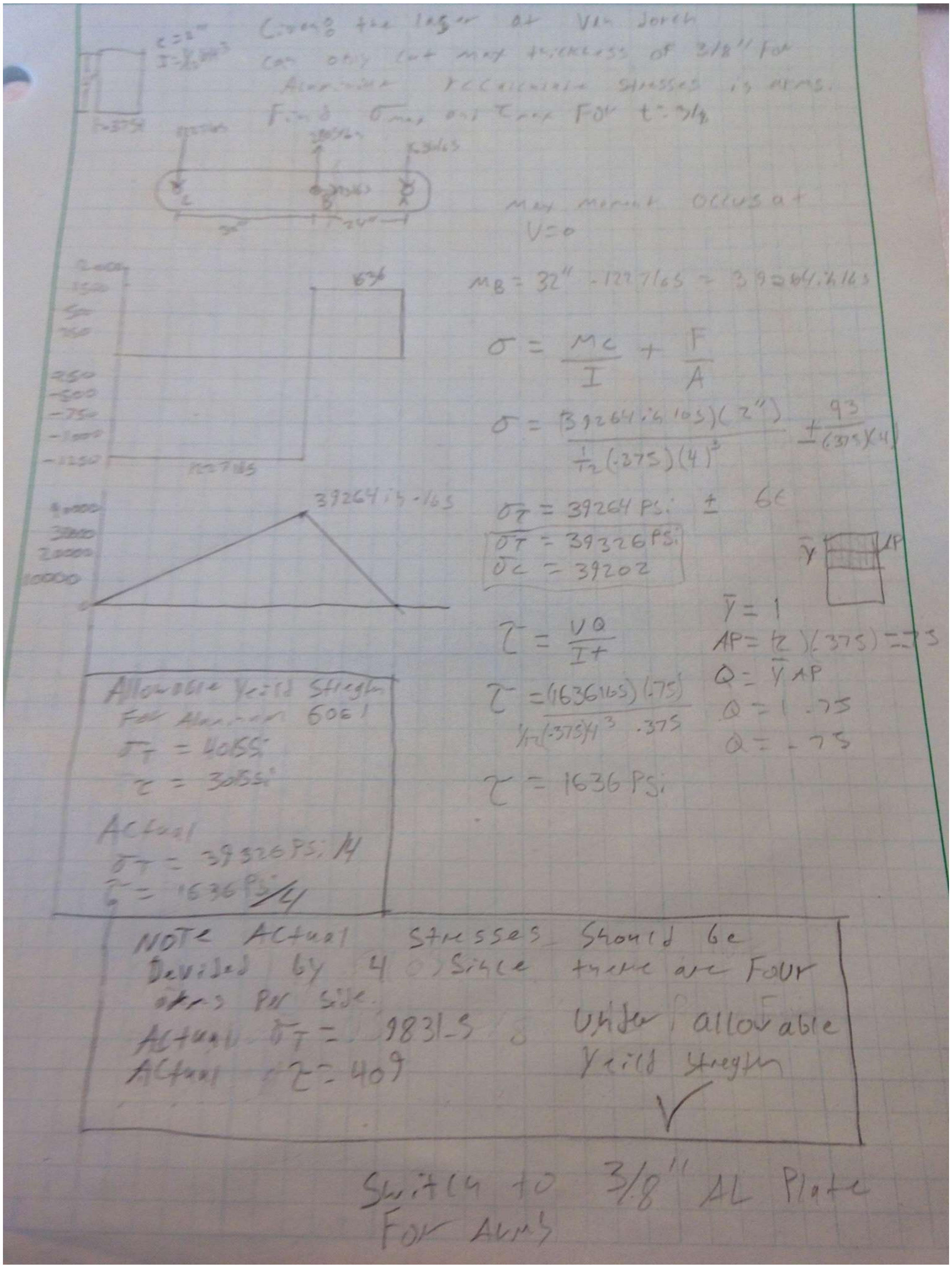
B = .128in

C = .084

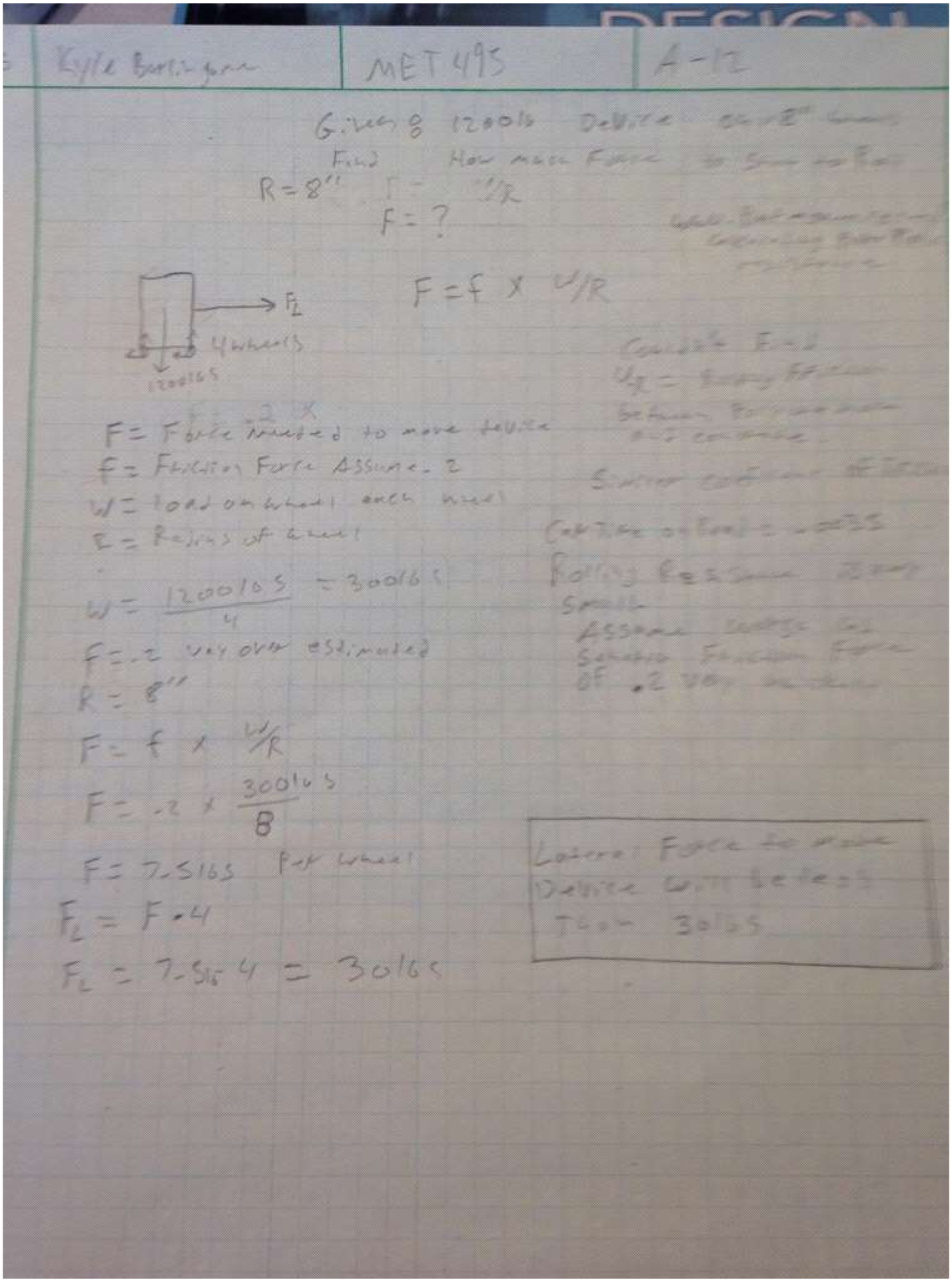
Use Pin size of .5"

Cylinders call for 5/8" Pin, so use that on all to make the same.

A-10 These are the calculations for determining the pin sizes. The company decided to go with 5/8" OD.



A-11 Calculation A-8 was recalculated because the thickness of the material was changed from ½”-3/8” to utilize Van Doren’s laser cutter.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Given: 1200lb Device [illegible]

Find: How much Force [illegible]

R = 8"

F = ?

F = f x W/R

F = Force needed to move device

f = Friction Force Assume .2

W = load on wheel each wheel

R = Radius of wheel

W = 1200lbs / 4 = 300lbs

f = .2 very over estimated

R = 8"

F = f x W/R

F = .2 x 300lbs / 8

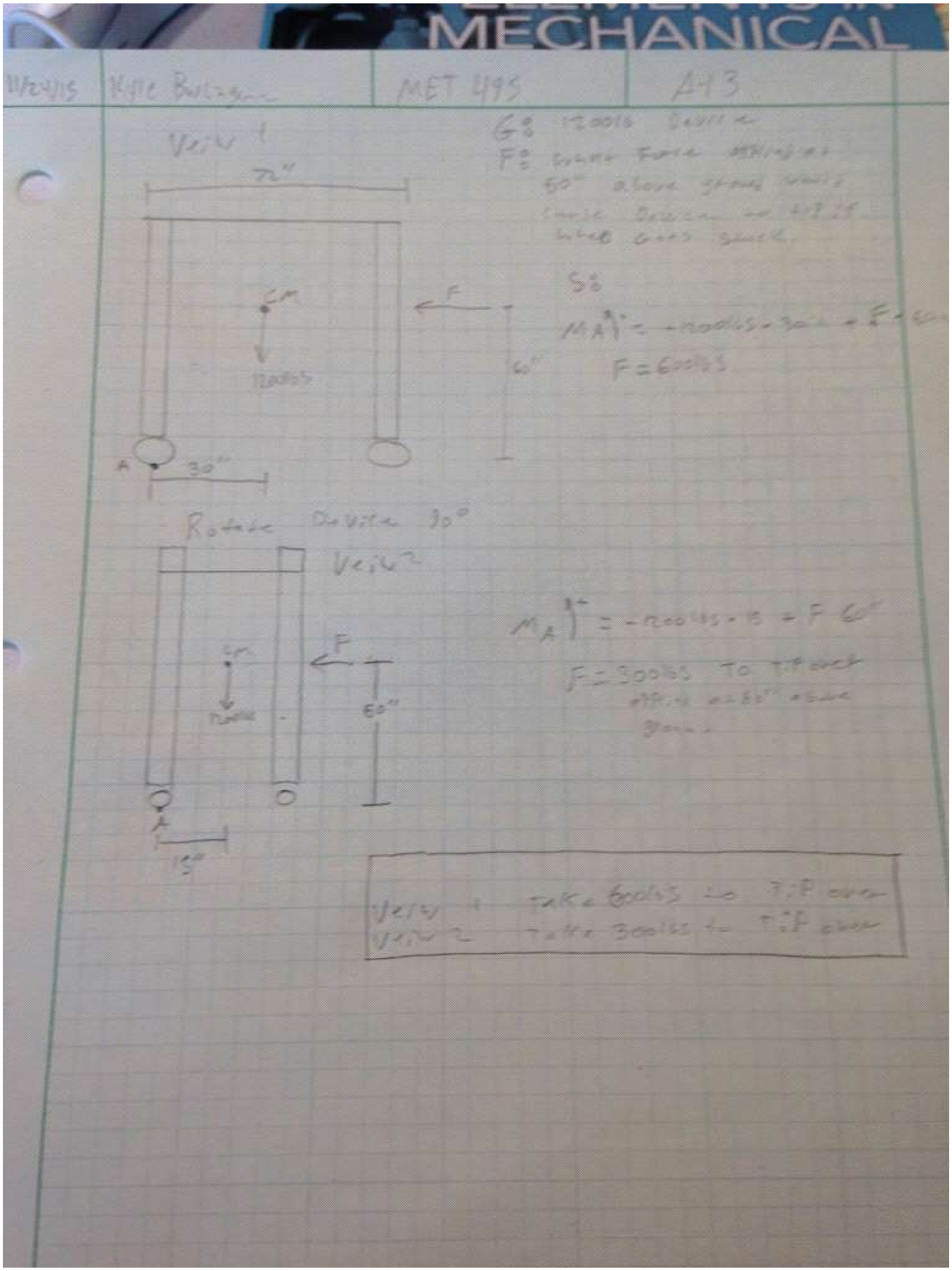
F = 7.5lbs per wheel

F_L = F · 4

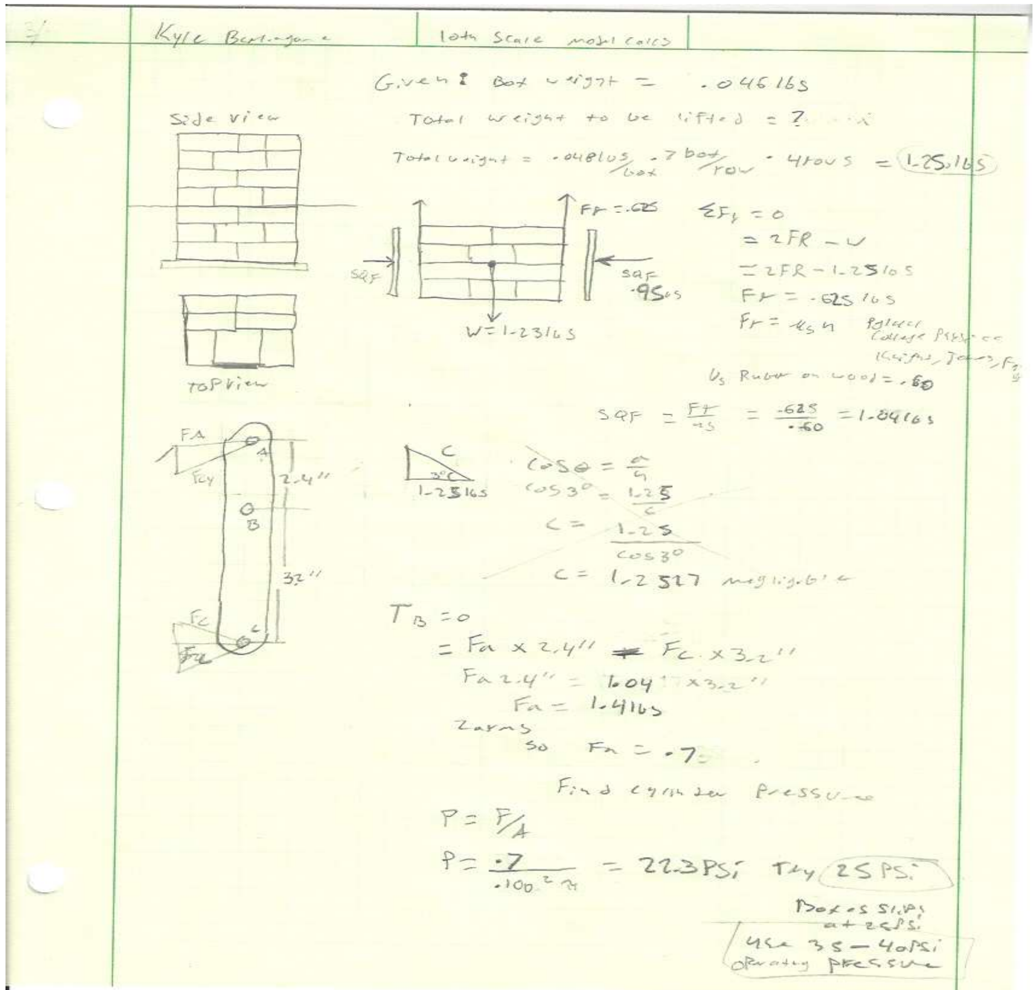
F_L = 7.5 · 4 = 30lbs

Lateral Force to move Device will be [illegible] 30lbs

A-12 This sheet shows the calculations for the required lateral force to move the device.



A-13 This sheet shows the amount of force required to tip the device over when applying forces to different sides.

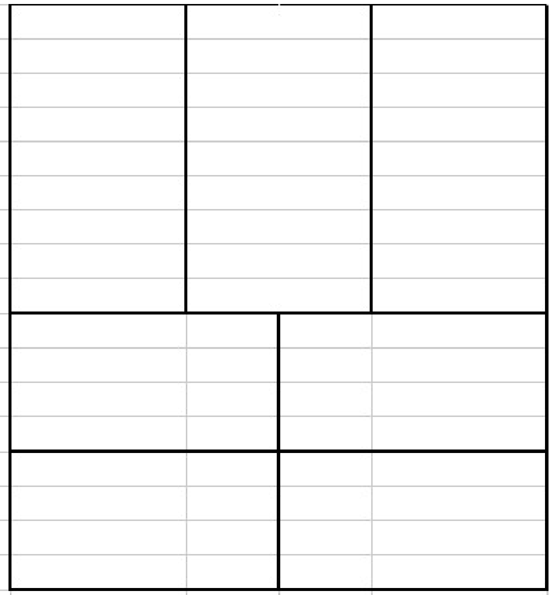


A-14 Scale Model Calculations.

Table A-1

Box force and pressure calcs		length	height	Area	lbs/box	box/row	row	load	Friction
Aldi Display	Euro	38.25	39	1491.8	29	5	6	870	
Pear carton	Standard	36.75	31.5	1157.6	45	7	3	945	
1/2 Carton Pear	Standard	36.75	37.5	1378.1	25	7	6	1050	
5.1 Euro	Euro	39	36	1404.0	29	5	6	870	
6.1 Euro	Euro	39	42	1638.0	29	5	6	870	
Costco Pear 1 Layer Display	Euro								
Display Carton	Euro	38.75	30	1162.5	45	5	3	675	
RPC 6419	Euro	38.75	38.75	1501.6	29	5	5	725	
Poly Bag Box	Euro	39.25	41	1609.3	43	5	4	860	
Apple box	Standard	38.25	36	1377.0	45	7	3	945	
HP Apple Box	Standard	38.25	38.25	1463.1	50	7	3	1050	
HP Apple Box	Standard	38.25	51	1950.8	50	7	4	1400	
1/2 Carton Apple	Standard	38.25	47.25	1807.3	25	7	7	1225	

Standard Stacking Pattern	**7**
Euro Stacking Pattern	**5**



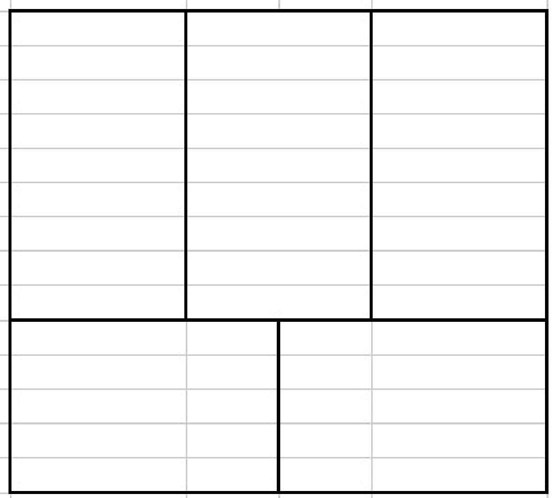
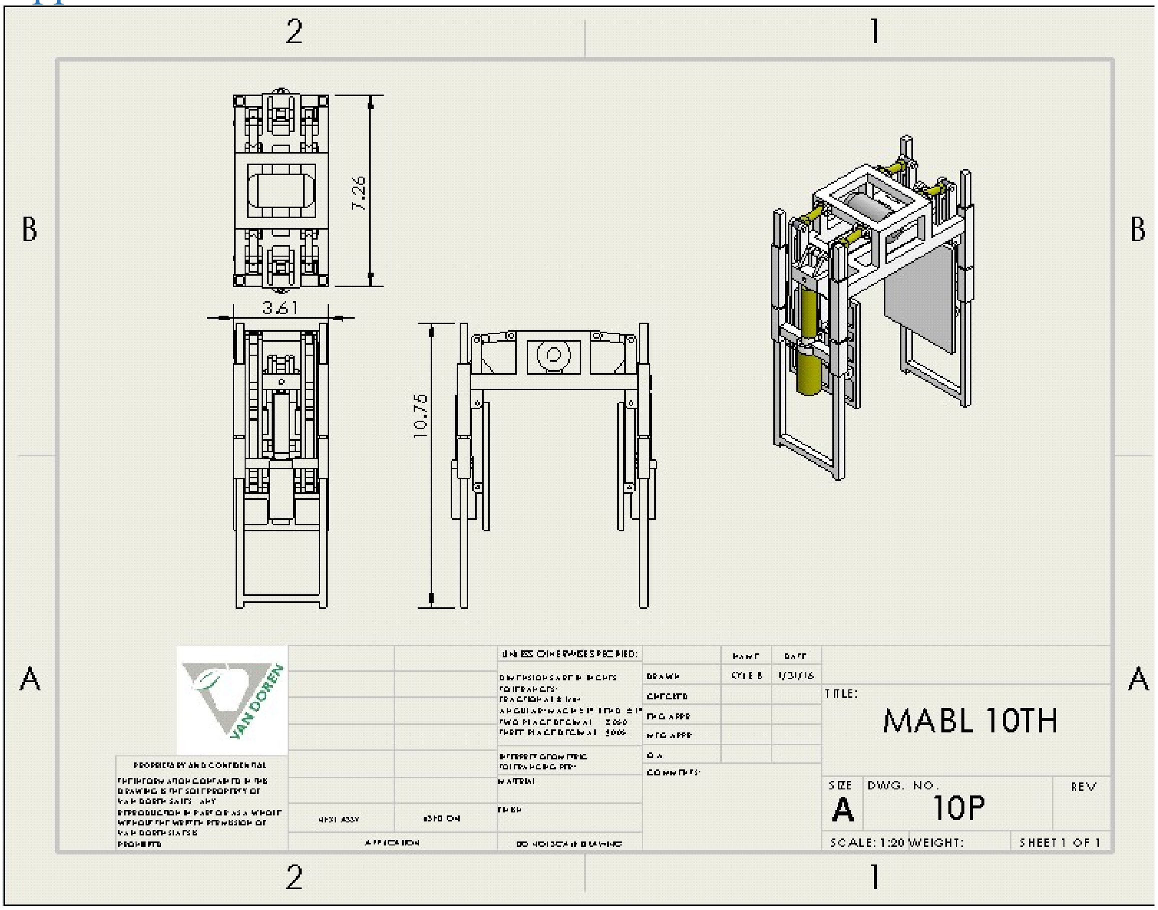


TABLE A-1 General stacking patterns for Chelan Fruit apples.

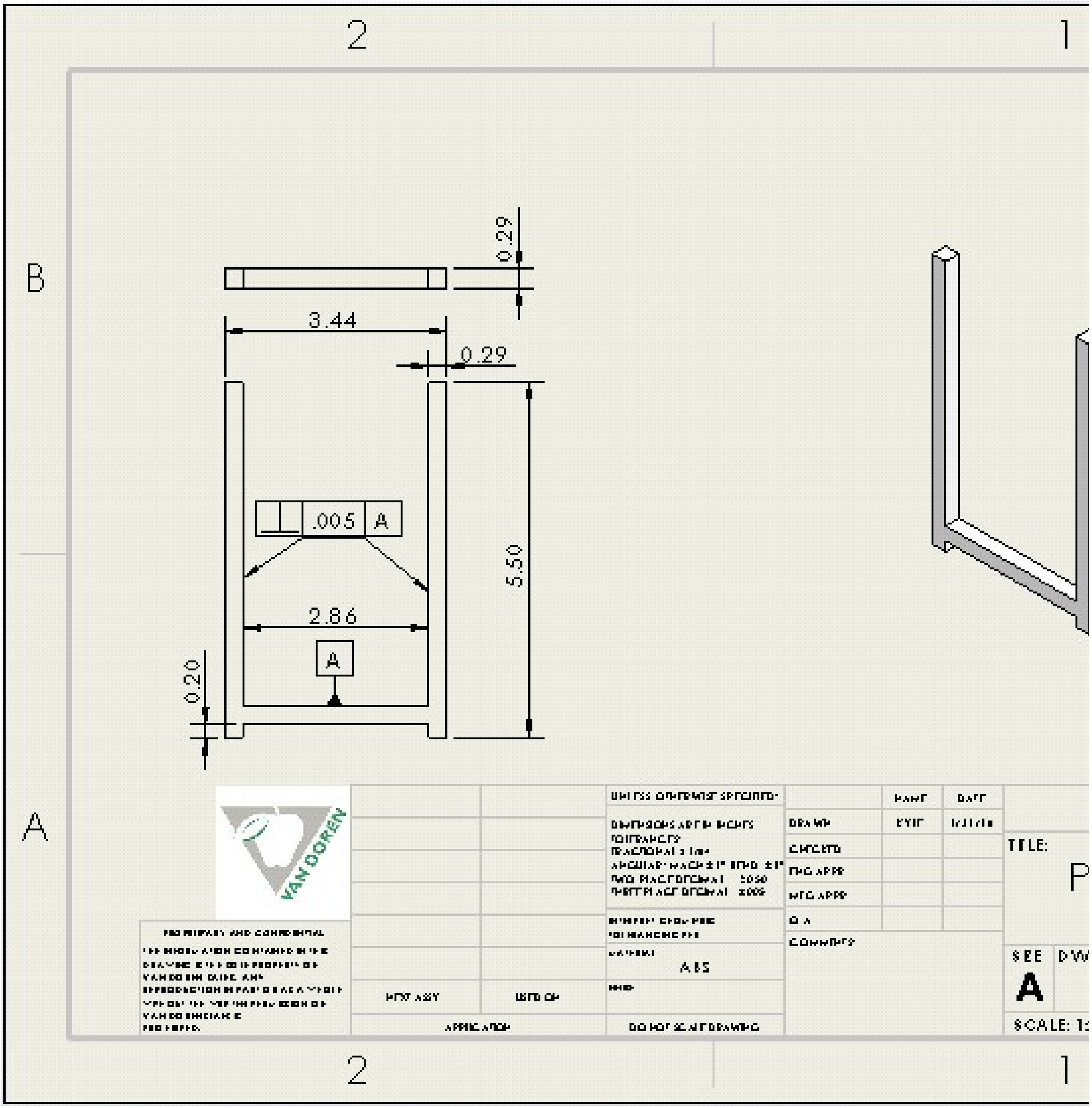
Appendix B – Drawings full sized model

Removed For Device Copyright Protection

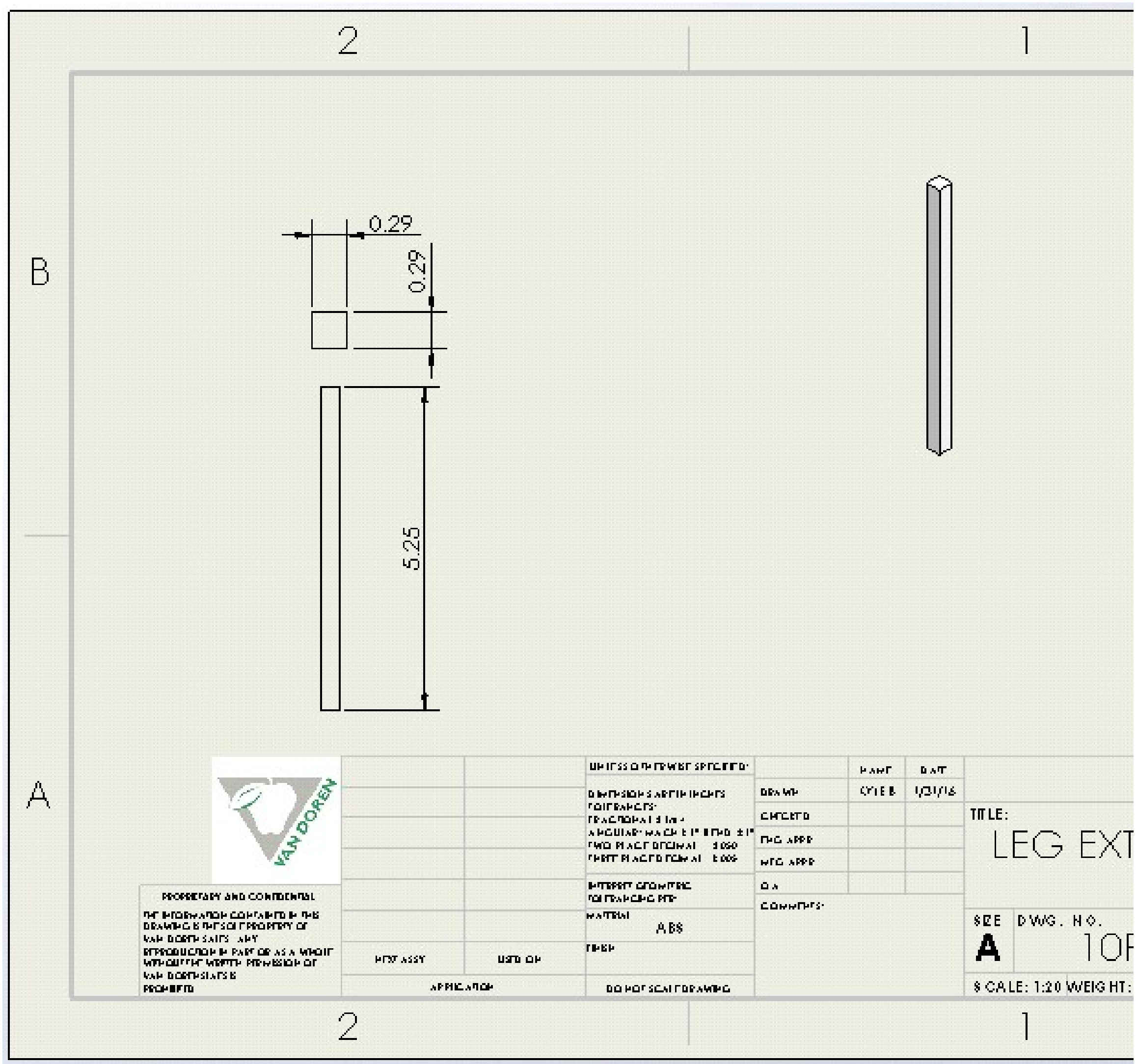
Appendix B2- 10th scale model



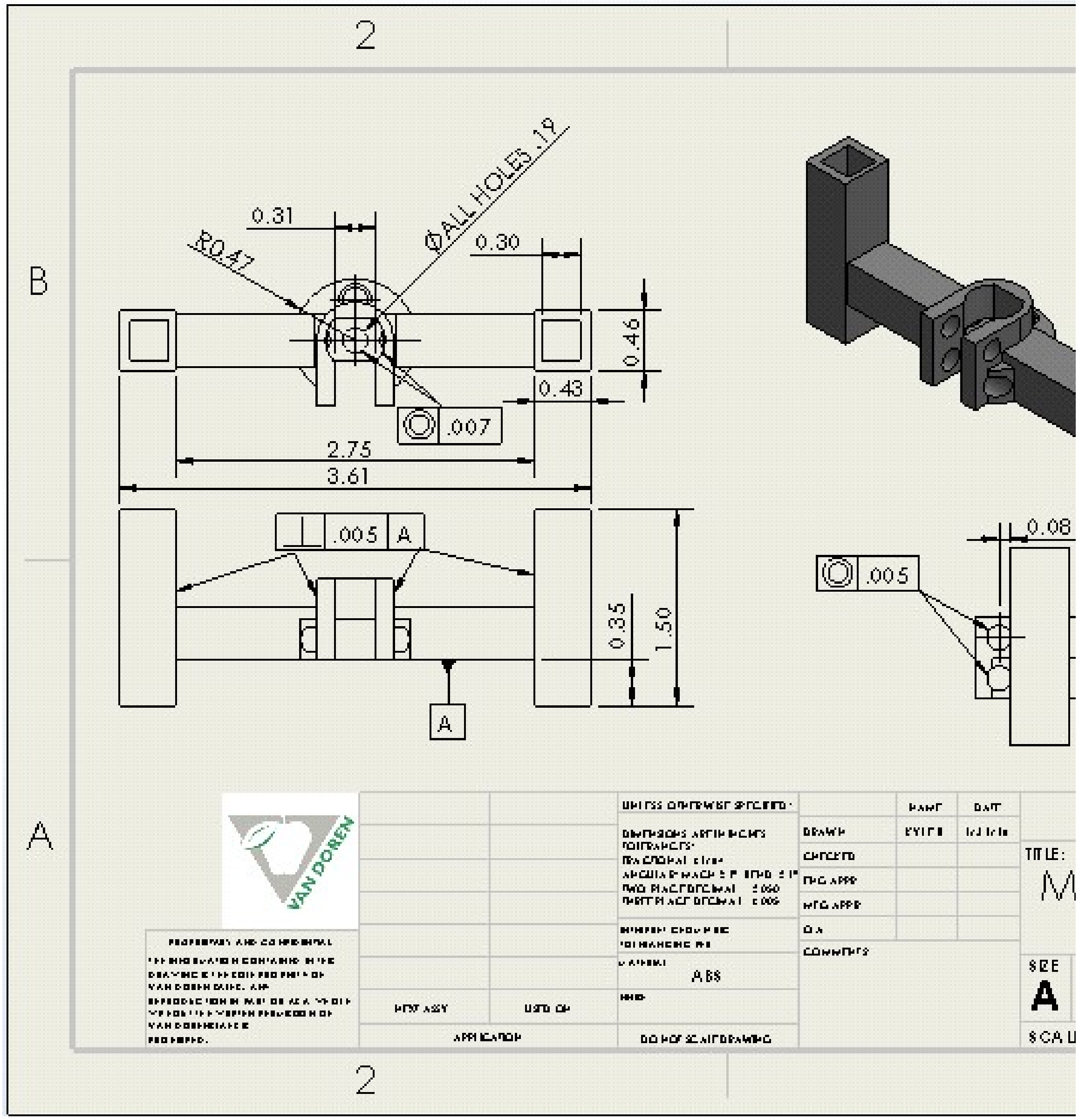
B1-10th Scale assembly



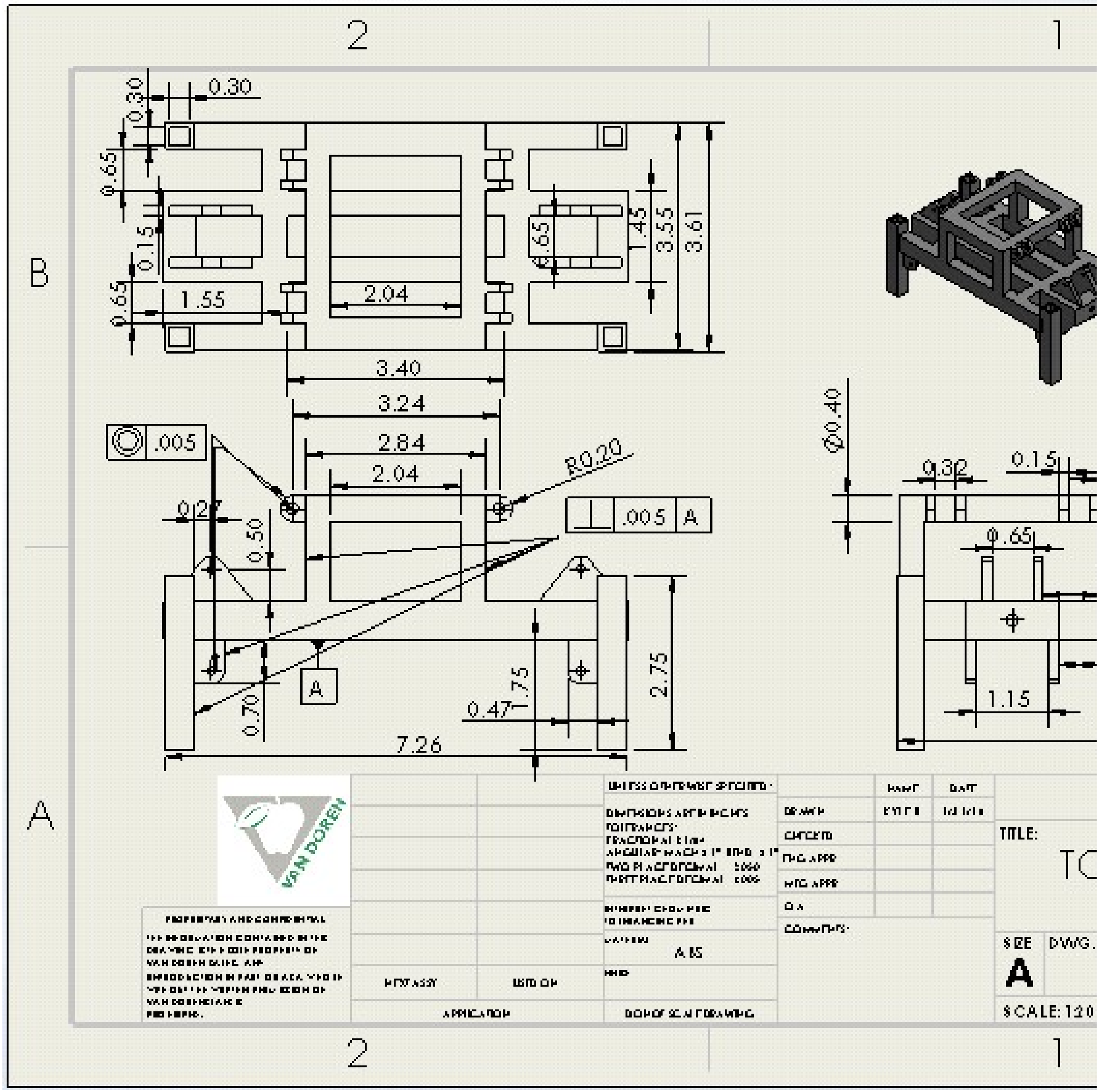
B1-1 Legs for 10th scale model



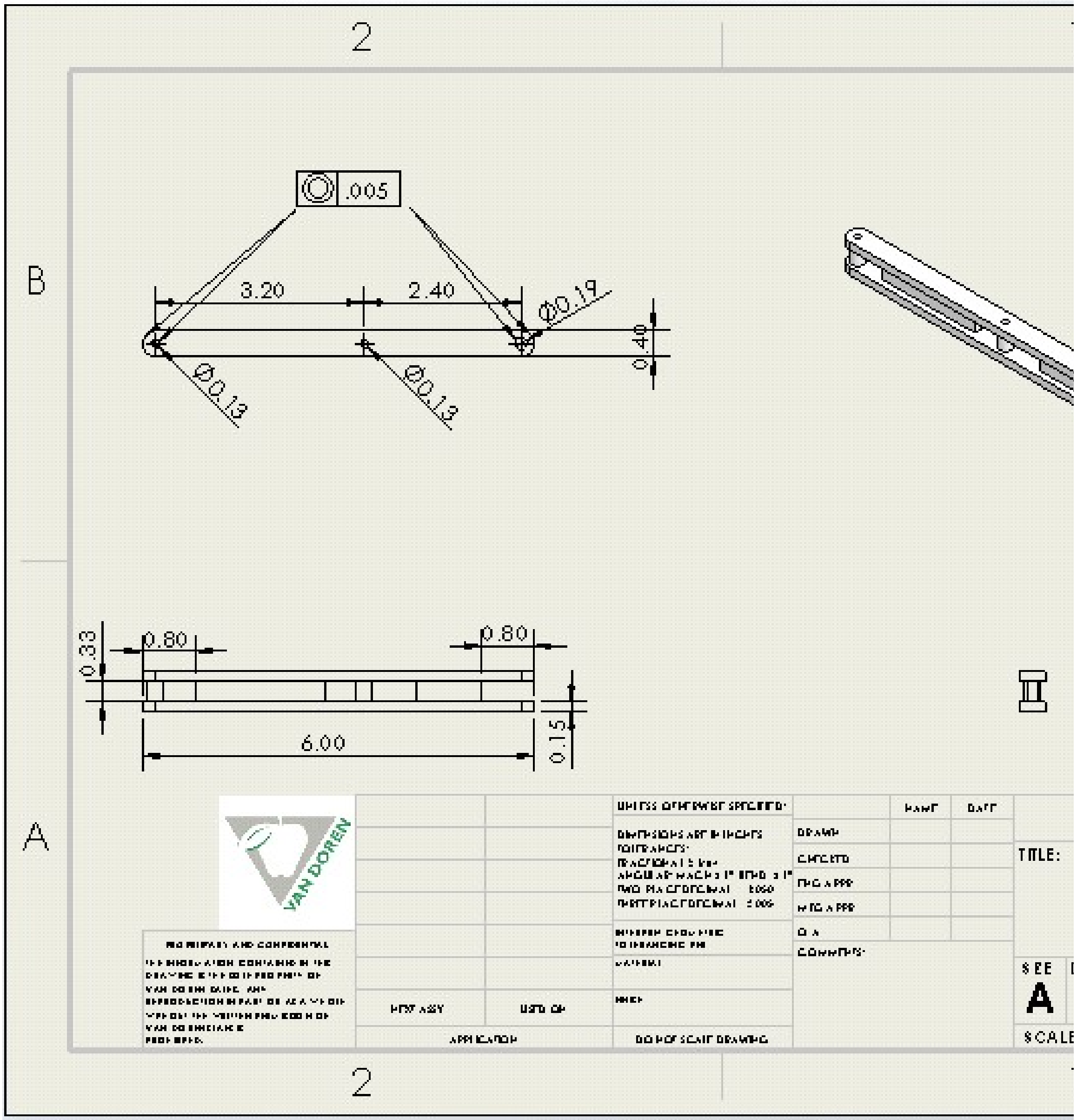
B1-1 Leg extensions for 10th scale model.



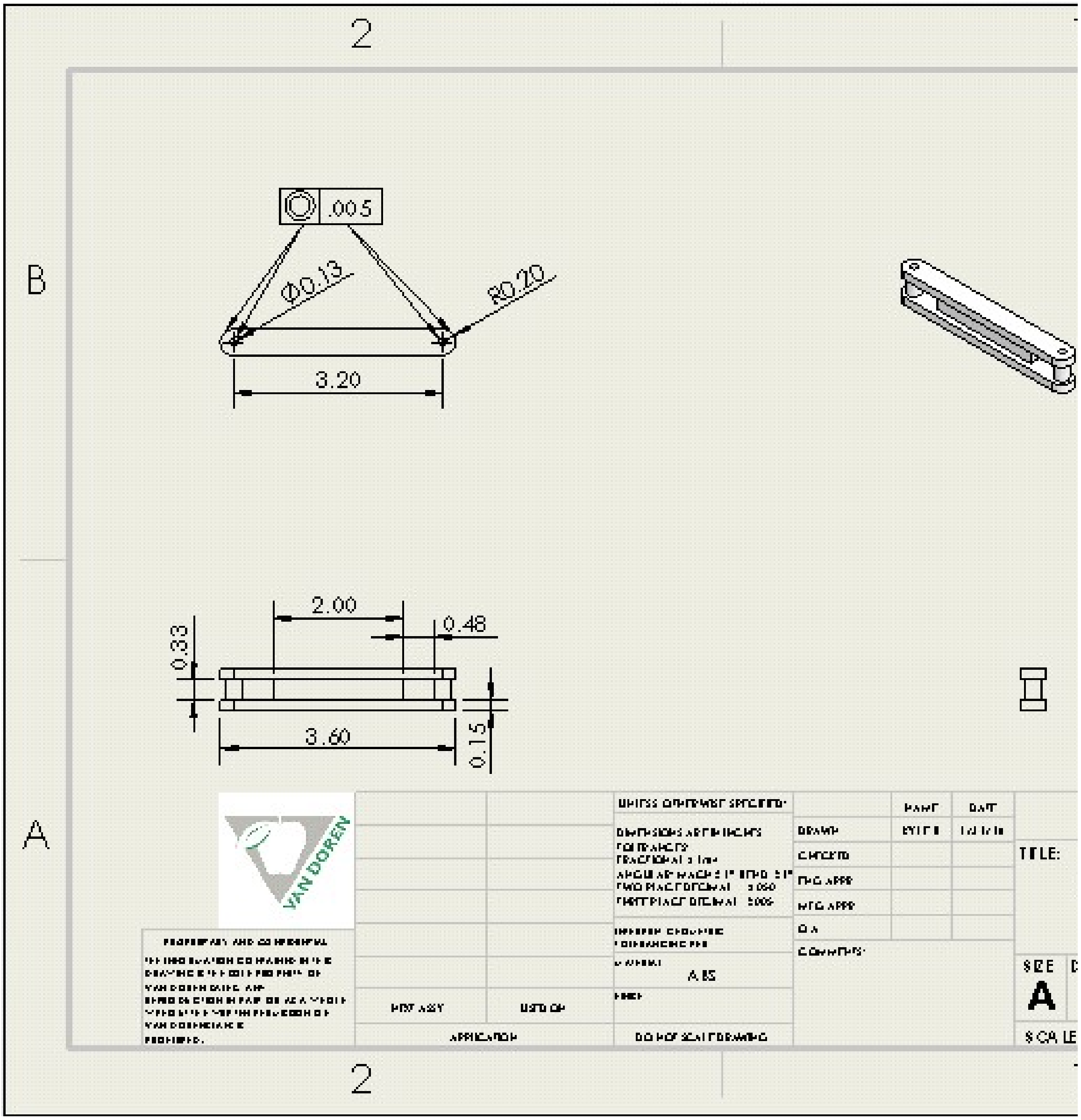
B1-4 Motor mount for 10th scale model.



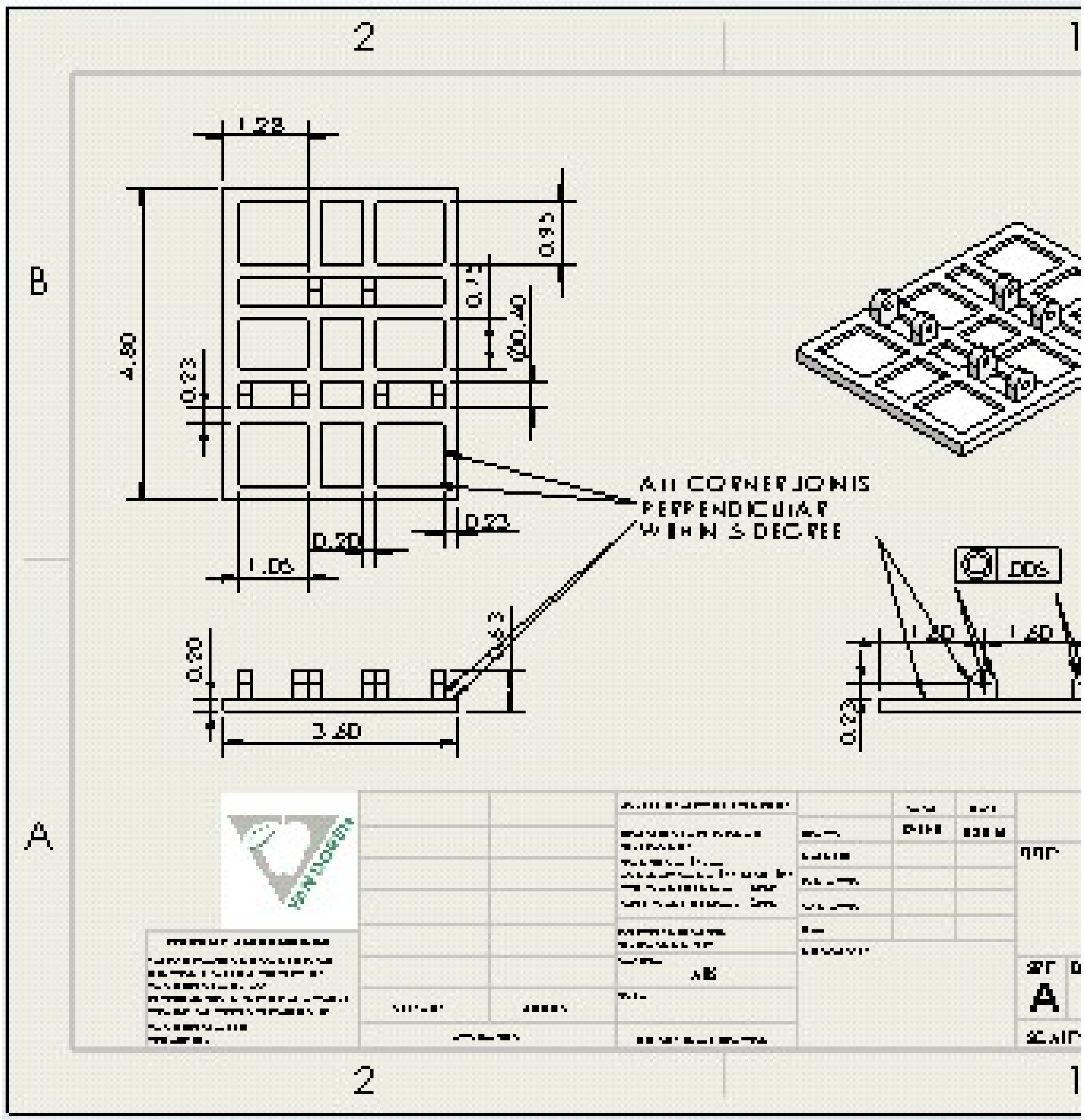
B1-5 Frame for 10th scale model.



B1-6 Large arms for 10th scale model.



B1-7 Small arms for 10th scale model.



B1-8 Plates for 10th scale model.

Appendix C – Parts List full sized model.

Parts List to Make 1 Multiple Apple Box Lift				
Part Number	Quantity	Material	Made From	Description
P1	2	Aluminum 6061	Assembly	Squeeze plate assembly
P1.1	2	Aluminum 6061	.25X3'X4' Plate	Plate
P1.2	4	Aluminum 6061	.25X1.75X28.75 Flat Bar	Flat Bar
P1.3	8	Aluminum 6061	.25X1.75X47.5 Flat Bar	Flat Bar
P1.4	8	Aluminum 6061	.25X1.75X6.625 Flat Bar	Flat Bar
P1.5	4	Aluminum 6061	.25X1.75X14.5 Flat Bar	Flat Bar
P1.6	12	Aluminum 6061	.375 PLATE	Flat Bar
BB1	12	Brass	Purchased Part 1"OD .625 ID	Brass Bushings .375 Thick
A1	4	Aluminum 6061	Assembly	Arm Assembly
A1.1	8	Aluminum 6061	.375 PLATE	Flat Bar
A1.2	4	Aluminum 6061	.5X5X10 Flat Bar	Flat Bar
A1.3	4	Aluminum 6061	.5X5X20 Flat Bar	Flat Bar
A1.4	8	Aluminum 6061	1.32"OD .96ID Pipe 5.75" long	Pipe
BB1	24	Brass	Purchased Part 1"OD .625 ID	Brass Bushings .375 Thick
AA1	2	Aluminum 6061	Assembly	Arm 2 Assembly
AA1.1	4	Aluminum 6061	.375 PLATE	Flat Bar
A1.3	2	Aluminum 6061	.5X5X20 Flat Bar	Flat Bar
A1.4	4	Aluminum 6061	1.32"OD .96ID Pipe 5.75" long	Pipe
BB1	8	Brass	Purchased Part 1"OD .625 ID	Brass Bushings .375 Thick
L1	2	Aluminum 6061	Assembly	Leg Assembly
L1.1	4	Aluminum 6061	.25X3X3X120 Square Tubing	Square Tubing
L1.2	2	Aluminum 6061	.25X3X3X28.5 Square Tubing	Square Tubing
L1.3	4	Aluminum 6061	.5X4.5X6.5	Flat Bar
L1.4	2	Aluminum 6061	.25X3X3X28.5/.5X5X6	Tubing and Plate welded Together
22655T52	4		Purchased Part	8" OD Wheel
F1	1	Aluminum 6061	Assembly	Frame Assembly
F1.1	2	Aluminum 6061	.25X4X4X35.5/.5X2X8	Square Tubing/ Flat Bar2x
F1.2	4	Aluminum 6061	.25X4X4X12 Square Tubing	Square Tubing
F1.3	4	Aluminum 6061	.25X4X4X40 Square Tubing	Square Tubing
F1.4	8	Aluminum 6061	.25X4X6X6.5 Rectangular Tubing	Rectangular Tubing
F1.5	2	Aluminum 6061	.25X4X6X72 Rectangular Tubing	Rectangular Tubing
F1.6	2	Aluminum 6061	.25X4X6X64 Rectangular Tubing	Rectangular Tubing
F1.7	2	Aluminum 6061	.25X4X4X15.5 Rectangular Tubing	Rectangular Tubing
F1.8	2	Aluminum 6061	.25X4X4X27.5 Rectangular Tubing	Rectangular Tubing/ Flat bar 5x4x.5
PB1	4	Aluminum 6061	.375" Plate	Plate
PB2	4	Aluminum 6061	.375" Plate	Plate
PB3	4	Aluminum 6061	.375" Plate	Plate
U1.1	8	UHMW	4X2 FLAT BAR 3'	Bushing
BB1	12	Brass	OD 1" ID .625" .375 Thick Bushing	Bushing
PP1	4	Stainless Steel	OD .625" 7.5" long Round Stock	Round Stock
PP2	6	Stainless Steel	OD .625" 9" long Round Stock	Round Stock
PP3	6	Stainless Steel	OD .625" 10" long Round Stock	Round Stock
Other Parts				
6498K697	8	Air Cylinder		Air Cylinder
4952K124	8	Mounting Bracket		Pin Mount
60645K371	8	Pivot attachment		Pin Connecters
U1.2	12	UHMW	1.375" OD .625 ID .875 Thick	Spacer
U1.3	12	UHMW	1.375" OD .625 ID .375 Thick	Spacer
U1.4	4	UHMW	1.375" OD .625 ID 3.125 Thick	Spacer
N1.1	32	Stainless Steel	1/4-20 Thread 1" Long	Hex Cap Screw for Top Frame
N1.2	8	Stainless Steel	1/2-13 Thread 1.5" Long	Socket Head Cap Screw for Top of Acuator
N1.3	4	Stainless Steel	1/2-13 Thread 3-3/4" Long	Hex Cap Screw for Bottom of Acuator
N1.4	16	Stainless Steel	1/2-13 Thread 1-3/4" Long	Hex Cap Screw for Wheel Bracket Connection
N1.5	20	Stainless Steel	1/2-13 Thread Hex Nuts	For Bottom of Acuator and Bottom of Wheel Bracket
N1.6	32	Stainless Steel	5/8-18 Thread Nylon Lock Nuts	For all Pins

Appendix C – Parts List 10th scale

Parts List 10th scale model				
Part Number	Quantity	Material	Made From	Description
10 P1	2	ABS Plastic	3D Printer	
10 P2	4	ABS Plastic	3D Printer	
10 P3	2	ABS Plastic	3D Printer	
10 P4	1	ABS Plastic	3D Printer	
10 P5	4	ABS Plastic	3D Printer	
10 P6	2	ABS Plastic	3D Printer	
10 P7	2	ABS Plastic	3D Printer	
Assembly 10 P	1	ABS Plastic	Assembly	
Lego Air Cylinders	4	Plastic	N/A	Bought Part
Lego Pump	1	Plastic	N/A	Bought Part
Lego Actuators	2	Plastic	N/A	Bought Part
Lego Tank	1	Plastic	N/A	Bought Part
Hose	3'	Rubber	N/A	Bought Part
Lego Wheels	4			Donated Part
Lego Swivels	4			Donated Part
Lego Motors	2			Donated Part
1/8" Pins X 1In	6	Silicon Bronze		Donated Part
3/16" Pins X 5/8"	8	Steel		Donated Part

Appendix D – Budget

Budget						
Description	Dimensions	Quantity	Material	Cost Each	Total	Supplier
Wheels	8" Diameter	4	Polyurethane	126.2	504.08	McMaster-Carr
.25X3X4 Plate		4'X8' Plate	Aluminum 6061		590.18	Metal Depot
.25X1.75 Flat Bar		60'	Aluminum 6061		150	Metal Depot
.375X4 Flat Bar		60'	Aluminum 6061		368.4	Metal Depot
.5X5 FLAT BAR		18'	Aluminum 6061		280	Metal Depot
1.32"OD .96ID Pipe		6'	Aluminum 6061		32.28	
.25X3X3 SQTUBE		52'	Aluminum 6061		772	Metal Depot
.25X4X4 SQ TUBE		32'	Aluminum 6061		740.72	Metal Depot
.25X4X6 RECT TUBE		30'	Aluminum 6061		938.24	Metal Depot
OD .625 ROUND		14'	Steel (Stainless)		56	Metal Depot
.5x2 flat bar		3'	Aluminum 6061		28.52	Metal Depot
OD 1" .625 ID .375 Thick		56	BRASS BUSHING			
1.375" OD .625 ID TUBE		3'	UHMW		30	McMaster-Carr
2"X4" FLAT BAR		3'	UHMW		126	McMaster-Carr
Air cylinder		8		188.8	1510.4	McMaster-Carr
Pin Mount		8		14.88	119.04	McMaster-Carr
Pin Connecters		8		9.64	77.12	McMaster-Carr
shelves		40 SQ'	UNSURE		400	
belt					200	
light					50	
compressor					155	
tank					50	
batteries					300	
Electronic Actuators		2		2929.04	5858.08	Joyce
Electronic Controls		1		500	500	
miscellaneous					1000	
				Total Cost	14836.06	

Appendix D2 – Budget 10^{th} scale model.

3/16" Pins X 5/8"	8	Steel		Donated Part	
Budget 10th scale model					
Part Number	Quantity	Material	Total Material	Cost Each	Total Cost
10 P1	2	ABS Plastic	2.5 IN^3		$30.00
10 P2	4	ABS Plastic	2 IN^3		$30.00
10 P3	2	ABS Plastic	2 IN^3		$30.00
10 P4	1	ABS Plastic	10 IN^3		$50.00
10 P5	4	ABS Plastic	3.5 IN^3		$30.00
10 P6	2	ABS Plastic	1.1 IN^3		$30.00
10 P7	2	ABS Plastic	5.4 IN^3		$30.00
Assembly 10 P	1	ABS Plastic	N/A		N/A
Lego Air Cylinders	4	Plastic		$9.74	$38.98
Lego Pump	1	Plastic		$9.45	$9.45
Lego Actuators	2	Plastic		$14.48	$28.96
Lego Tank	1	Plastic		$5.99	$5.99
Hose	3'	Rubber			$6.99
Lego Wheels	4				Donated
Lego Swivels	4				Donated
Lego Motors	2			$39.98	$79.96
1/8" Pins X 1"	6	Silicon Bronze			Donated
3/16" Pins X 5/8"	8	steel			Donated
					$400.33

Appendix E – Schedule

	KEY	
Shaded sections are when those tasks will be completed.		
	◊	
Diamonds are important deliverables that must be met.		

PROJECT TITLE: Multiple Apple Box Lift													
Engineering Technician.: Kyle Burlingame													
		Duration											
TASK:	Description	Est.	Actual	September	October	November	December	January	February	March	April	May	Jun
ID		(hrs)	(hrs)										
1	**Proposal****												
1a	Outline	0.5	3										
1b	Intro	1	2										
1c	Methods	2	5										
1d	Analysis	1	5										
1e	Discussion	1	2										
1f	Parts and Budget	1	10										
1h	Schedule	1	1										
1i	Summary & Appx	1	2										
1j	Turn in Final Proposal						◊						
	subtotal:	8.5	30										
2	**Analyses**												
2a	Layout Analysis	2	3										
2b	Stress and Force	3	10										
2c	Pressure	1	5										
2d	Deflection	1	2										
2e	Torsional	1	2										
	subtotal:	8	22										
3	**Documentation**												
3a	Plate Assembly drawing	0.5	4										
3b	P1.1 Drawing	0.5	2										
3c	P1.2 Drawing	0.5	2										
3d	P1.3 Drawing	0.5	2										
3e	P1.4 Drawing	0.5	2										
3f	P1.5 Drawing	0.5	2										
3g	P1.6 Drawing	0.5	2										
3h	Arm Assembly Drawing	1	3										
3i	A1.1 Drawing	1	1										
3j	A1.2 Drawing	1	1										
3k	A1.3 Drawing	1	1										
3l	A1.4 Drawing	1	2										
3m	Frame Assembly	1	8										
3n	F1.1 Drawing	0.5	2										
3o	F1.2 Drawing	0.5	1										
3p	F1.3 Drawing	0.5	1										
3q	F1.4 Drawing	0.5	1										
3r	Multiple Apple Box Assembly	2	25				◊						
3s	Pin Drawings	0.5	2										
3t	Small parts Modeling	2	8										
	subtotal:	16	72										
4	**Proposal Mods**												
4a	Project Schedule	1	4										
4b	Project Part Inv.	1	4										
4c	Critique and Design Review	1	10										

Figure C1: Fall Quarter Schedule

				September	October	November	December	January	February	March	April	May	Jun
7	Part/Assembly Construction												
7a	Buy All Materials	1	3										
7b	Update Website	1	1										
7c	Manufacture Plan	5	10										
7d	Make Part P1.1	3	Not built										
7e	Make Part P1.2	3	Not built										
7f	Make Part P1.3	3	Not built										
7g	Make Part P1.4	3	Not built										
7h	Make Part P1.5	3	Not built										
7i	Make Part P1.6	3	Not built										
7j	Make Plate Assembly (2x)	5	Not built										
7k	Make Part A1.1	4	Not built										
7l	Make Part A1.2	4	Not built										
7m	Make Part A1.3	4	Not built										
7n	Make Part A1.4	4	Not built										
7o	Make Arm Assembly	10	Not built										
7p	Make Part F1.1	3	Not built										
7q	Make Part F1.2	3	Not built										
7r	Make Part F1.3	3	Not built										
7s	Make Part F1.4	4	Not built										
7t	Make Frame Assembly	15	Not built										
7u	Multiple Apple Box Assembly	20	Not built										
7v	Take Device Pictures												
7w	Design Part 10 P1	2	2.5										
7x	Design Part 10 P2	2	2.5										
7y	Design Part 10 P3	2	2.5										
7z	Design Part 10 P4	2	2.5										
7aa	Design Part 10 P5	2	2.5										
7bb	Design Part 10 P6	2	2.5										
7cc	Design Part 10 P7	2	2.5										
7dd	Design Assembly 10 P	5	5										
7ee	Print Part 10 P1	10	7										
7ff	Print Part 10 P2	10	7										
7gg	Print Part 10 P3	10	7										
7hh	Print Part 10 P4	10	7										
7ii	Print Part 10 P5	10	7										
7jj	Print Part 10 P6	10	7										
7kk	Print Part 10 P7	10	7										
7ll	Build 10 P Assembly	5	9										
	subtotal:	201	112.5										

Figure C2: Winter Quarter Schedule

10				September	October	November	December	January	February	March	April	May	Jun
10a	Device Evaluation	3	1.5										
10b	List Parameters	3	1										
10c	Design Test Scope	3	0.5										
10d	Obtain resources	2	0.5										
10e	Make test sheets	1	0.5										
10f	Plan analyses	2	3										
10g	Test Plan*	1	3										
10h	Perform Evaluation	1	1										
10i	Take Testing Pics	1	0.5										
10j	Update Website	2	3										
10k	Abstract	1	8										
	subtotal:	20	22.5										
11													
11a	Test demo 1	5min	5min								4/11/2016		
11b	Test demo 2	5min	5min								4/25/2016		
11c	495 Deliverables	1											0
11d	Get Report Guide	2	0.5										
11e	Make Rep Outline	2	0.5										
11f	Write Report	10	2										
11g	Make Slide Outline	3	3										
11h	Create Presentation	3	3										
11i	Make CD Deliv. List	2	0										
11j	Write 495 CD parts	1	0										
11k	Update Website	1	3										
11l	Project CD*	10	12										
11m	poster	1	6										
	subtotal:	36	30										
	Total Est. Hours=	289.5	289	=Total Actual Hrs									

Figure C1: Spring Quarter Schedule

Appendix F - Expertise and Resources

The Van Doren Company has a full machine shop. In the machine shop the laser cutter will be used to cut several parts from aluminum plate. A lathe will be used to turn and part off the pins. Several other processes will take place in the machine shop at Van Doren's including milling, grinding and drilling. Also there are several welding units in the machine shop which will come in handy since most of the subassemblies need to be welded. Van Doren Sales also have fabricators available to run these machines. They will be utilized in making parts for this project.

Appendix G –Testing Data

Test Description	Predicted Value	Actual Value
Does the Device work	Yes	Yes
Weight of the Device	2lbs	1.43lbs
Force required to move the device	1lbs or less	N/A
Amount of load able to lift vertically	1.5625lbs	1.5625lbs
Squeeze load needed to lift	N/A	N/A

Maximum pressure applied to the boxes to lift without slipping	25psi	37psi
Time required for one cycle	2 min	1 Minute 23 Seconds

Appendix H – Evaluation Sheet

Appendix I – Testing Report

Introduction to Testing 1/10th scale

The testing of this device will consist of using the Multiple Apple Box Lift to lift 28 mini apple boxes. The testing of this device can take place at any location that has compressed air available and a flat surface. Most likely the testing will be done at the designer's home and Central Washington University.

Testing Requirements

The testing requirements for this project are as follows:

Parameters of Interest

- What is the optimal operating pressure for this device?
- At what operating pressure will the mini wood boxes begin to slide down the plates?
- How long will one cycle take?

Performance Predictions

- The mini boxes will begin to slide at an operating pressure of 25 psi.
- One cycle will take less than 5 minutes.
- The device will weigh 1.2 lbs. according to the Solid Works model.

Data Acquisition

The data that will be recorded is pressures, weights and cycle times. These will be recorded by using a scale, pressure regulator and stopwatch.

Schedule

There has been a lot of testing done on this device beginning in early March and there will continue to be more testing done through the beginning of May.

Important test dates can be found in the Gnatt chart located in the appendix.

Test demo one: Testing the device's concept and optimal pressure was completed on

April 11, 2016.

Test demo two: Testing the device's scale factor and weighing the device took place on April 25, 2016.

Method/Approach

Materials/Resources

- 1 1/10th scale Multiple Apple Box Lift
- 49 mini wooden boxes
- 1 mini pallet
- 1 air tank with 45+ psi of air
- 1 pressure regulator
- 1 scale
- 1 operator

Data Capture/Doc/Processing

- Test sheets will be used to keep track of all of the data see appendix for test sheet.
- Writing utensil
- Scale to weigh the device and the amount of weight the device will lift.
- Pressure regulator to record the pressure needed when lifting loads.
- USB to save the test sheet on with typed up data.

Test Procedure Overview

These are the methods used to test the deliverables and how they compare to the predicted values.

The weight of the device will be weighed on a scale and the actual weight will be compared to the prediction made from the solid works rendering.

The operating pressure and slipping pressure will be found from a pressure gauge that is attached to the system and compared to calculated values.

The load capacity will be tested by lifting a load that is greater than any load the customer will be lifting, with a safety factor of 1.25. The total weight of the mini apple boxes is 1.25 lbs. Therefore to insure a safety factor of 1.25, the device must be able to lift 1.5625 lbs. If the device can lift that weight without failure, this test will be a success.

The cycle time of the device will be measured with a stop watch. One cycle consists of squeezing the boxes, lifting the boxes, removing one box, replacing the box, lowering the boxes back down, and finally releasing the squeeze.

Operational Limitations

- Operating pressure shall not exceed 45 psi, because the hoses will burst or become disconnected.
- The load being lifted shall not exceed 1.5625 lbs

Precision and Accuracy

There are a lot of variables with this device that will affect the accuracy of the device. One is the plate placement. The plate height needs to be set to grab the entire face of the lowest box layer. Also, the plates need to be centered with the load. Establishing the same surface area contact is crucial for replicating the results. Another variable is making sure an even amount of force is applied to each side. This can be done by making sure both sides of the lever arms are at the same angle. The precision of this device is based on the pressure regulator being used which reads in increments of about 1psi.

Data Storage and Presentation

The data will be recorded on the test sheets provided on the last page of this document. The data will then be typed up in the data sheets for presentation comparing predicted values vs actual values. The files will be backed up to a USB drive.

Test Procedure

Weighing the Device:

Materials: Scale, Multiple Apple Box Lift
Procedure:

- Zero the scale.
- Gently lift the device up and place it on the scale.
- Record the weight on the test sheet.
- Remove the device from the scale

Lifting 28 Mini Boxes by squeeze and lift.

Materials: 49 mini boxes, 1 mini pallet, 1 Multiple Apple Box Lift, 1 air tank 2+ gallons that can handle 100psi, 1 pressure gauge, 1 pressure regulator, and a stop watch
Procedure:

- Fill up the air tank to about 100 psi. (Do not exceed pressure listed on the tank you are using).
- Attach the pressure regulator to the tank that will allow you to regulate the pressure between 0 and 45 psi. Set the pressure to 0 psi.

- Stack the mini boxes on the mini pallet using the stack pattern template on the test sheet. Rotate the pattern 180 degrees every layer.
- Using the quick connect on the pressure regulator connect the Multiple Apple Box Lift air lines.
- Set the three staged valve to the middle position. This blocks the flow of air.
- Start a stopwatch.
- Set the pressure regulator to 30 Psi.
- Listen for leaks, also make sure no movement of the device takes place. If no leaks or movement happens, proceed to the next step. If a leak occurs turn the pressure regulator back down to 0 psi and troubleshoot leaks and make sure the valve is set to the center position.
- Switch the valve direction to the lever pointing towards the black air line.
- Position the Multiple Apple Box Lift over the pallet of boxes so the top frame clears the top layer of boxes. The top frame may have to be raised so the device will clear the boxes. Use the up direction on the up and down control box to raise the top frame.
- Center the multiple apple box lift with the pallet, with this orientation see the picture.
- Next adjust the height of device so that the plates will fully grab the top four layers of the pallet stack. Do this with the up and down controls on the control box.
- Once the device is centered with the pallet stack and the height is set switch the valve position to the yellow air lines. The device should now be squeezing the boxes.
- Now lift the boxes by using the up direction on the control box. If the device does not successfully lift all the boxes lower the boxes back down open the plates and increase the pressure at 1 psi increments until the device lifts all of the intended boxes. Do not exceed 45 psi.
- Record the successful lifting pressure on the test sheet.
- Remove one center box from the row of boxes beneath the lifted load.
- Replace the center box.
- Lower the lifted stack of boxes back down on top of the boxes below using the down switch on the control box.
- Once the boxes are lowered switch the valve to the black air line position.
- Change the pressure on the regulator back to 0 psi and switch the valve back to the center position.
- Repeat steps 6-20 three times and record the cycle times on the test sheet.

Determining Slipping Pressure

- Repeat steps 1- 13 from the lifting 28 mini boxes procedure above.

- Then slowly reduce the pressure on the pressure regulator 1 psi at a time
- Record the pressure when the boxes start to slip from the plates on the test sheet.

Safety Factor Test

Materials: 1.5625 lbs. of weight, Multiple Apple Box Lift
Procedure:

- Double check that the pressure regulator is set to 0 psi and the pressure valve is set to the middle position.
- Increase the pressure on the regulator to 35 psi.
- Using your hand hold the weighted blocks in such a way the device will be able to squeeze and hold the blocks.
- Using the same pressure control valve as above squeeze the 1.75 lbs weighted block at 35 psi.
- Change the pressure control valve to the black air line this should make the device squeeze the weighted block.
- Once squeezed use the up and down control box to lift the weight up with the device.
- Record success or fail on the test sheet based on if the device was able to lift the block.

Deliverables

These are the deliverables that will be found from testing.

- Optimal squeezing pressure
- Slipping pressure
- 1.25 safety factor load test.
- Cycle time
- Weight of the device

Testing Results

	Predicted/calculated	Requirements	Actual Average Values
Weight of Device	1.2lbs	Less than 2lbs	1.43

Optimum operating pressure (recommend 3 trials)	>25psi	Less than 45psi	37 PSI Recommend 40 psi
Cycle time (recommend 3 trials)	5min	Less than 5 min	1:23
Slipping Pressure	25psi	Must not slip at operating Pressure	Pass
1.25lb SF load test	Pass	Must pass	Pass

Table 1: This table shows the key results from testing the Multiple Apple Box Lift.

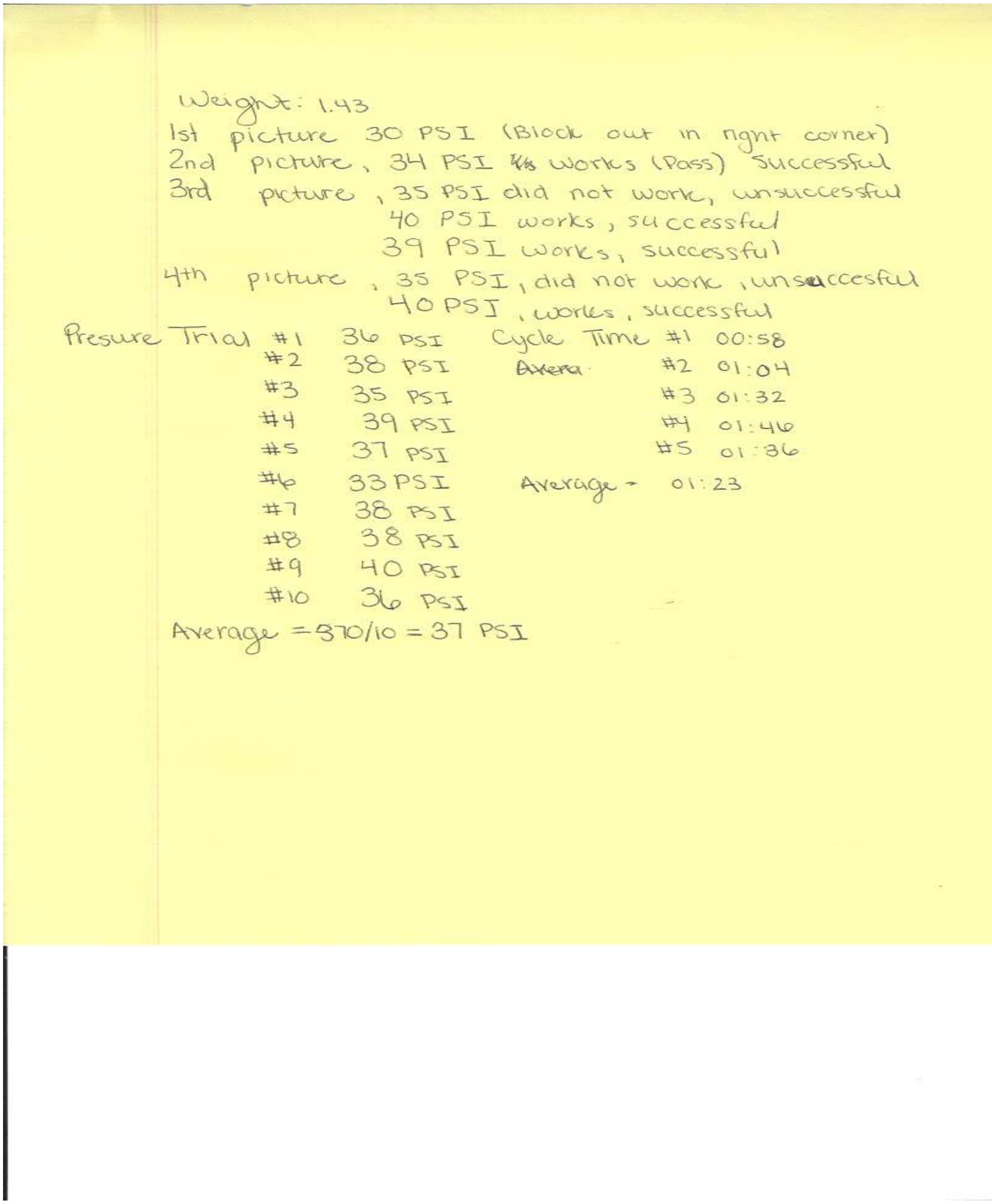
Success Criteria

The device passed all the requirements. Overall the project was a success. The average pressure to lift the mini boxes was 37 psi which meets the requirement however the device did not successfully lift the boxes every time at 37 psi. To insure the lifting of all the boxes without slippage, I would suggest an operating pressure of 40 psi. The cycle time was significantly less than what was predicted. The cycle time may be biased based on the operator, because the more times you do the test the faster you perform it.

Conclusion

The testing of the device was very successful. The device met all of the requirements. It would be an engineering solution to a common fruit company's problem. The problem of which is not being able to reach the center box of the stacked pallet of apple boxes for quality control purposes. The scale model was so successful that the presentation will be given to the owner of Van Doren Sales and the future of the device will be discussed. The company has already been talking about presenting the scale model to potential customers who might want to purchase a full scale model from the company.

Appendix



Weight: 1.43
1st picture 30 PSI (Block out in right corner)
2nd picture, 34 PSI works (Pass) Successful
3rd picture, 35 PSI did not work, unsuccessful
40 PSI works, successful
39 PSI works, successful
4th picture, 35 PSI, did not work, unsuccesful
40 PSI, works, successful

Presure Trial		Cycle Time	
#1	36 PSI	#1	00:58
#2	38 PSI	#2	01:04
#3	35 PSI	#3	01:32
#4	39 PSI	#4	01:46
#5	37 PSI	#5	01:36
#6	33 PSI	Average →	01:23
#7	38 PSI		
#8	38 PSI		
#9	40 PSI		
#10	36 PSI		

Average = 370/10 = 37 PSI

Figure 1: Test results data.

Test Images:

Image 1: This image shows the weighing of the device.

Image 2: This image shows the mini apple boxes lifted at a pressure of 40 psi.

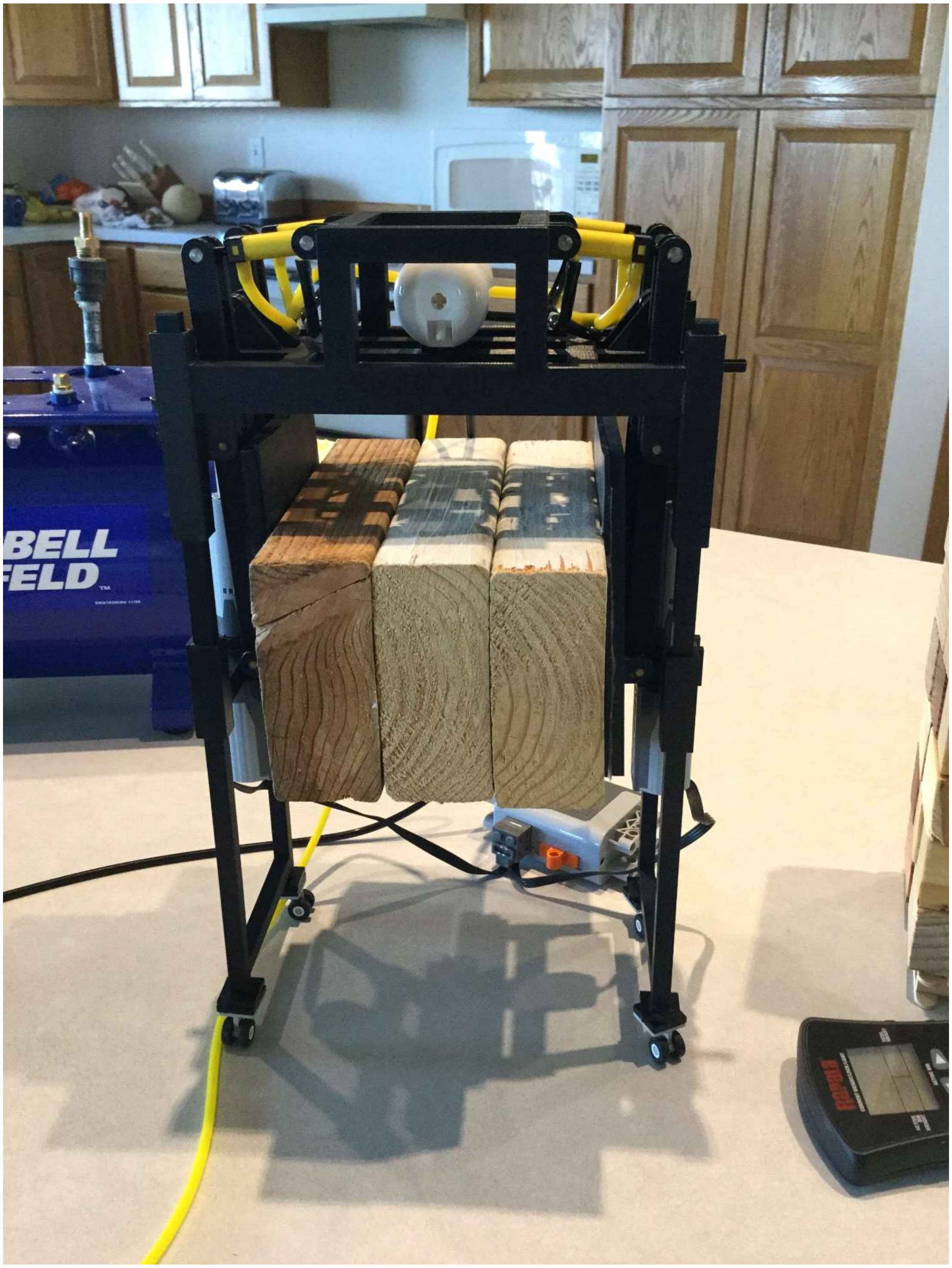


Image 3: This image shows the device lifting large blocks that proves the device has a safety factor of at least 1.25.

Multiple Apple Box Lift Test Sheet Table

	Predicted/calculated	Requirements	Actual Average Values
Weight of Device	1.2lbs	Less than 2lbs	
Optimum operating pressure (recommend 3 trials)	>25psi	Less than 45psi	
Cycle time (recommend 3 trials)	5min	Less than 5 min	
Slipping Pressure	25psi	Must not slip at operating Pressure	
1.25lb SF load test	Pass	Must pass	

Stack Pattern

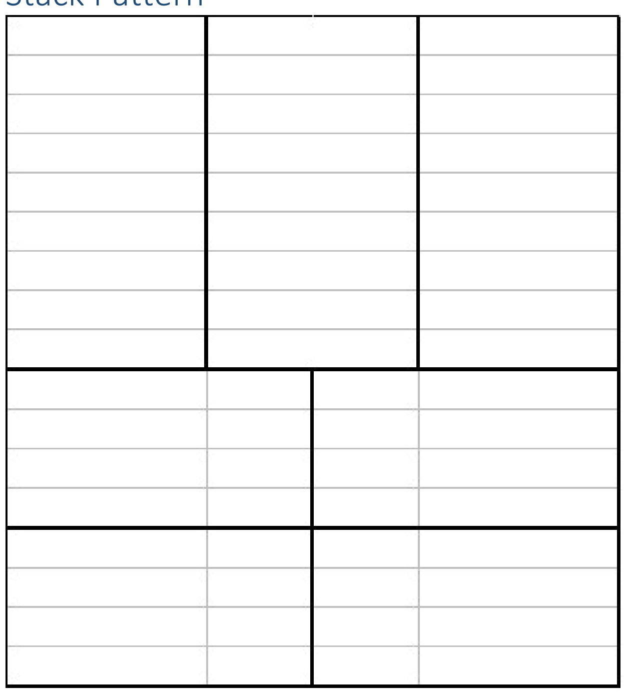


Figure 2: Stack pattern used, rotate 180 degrees each layer.

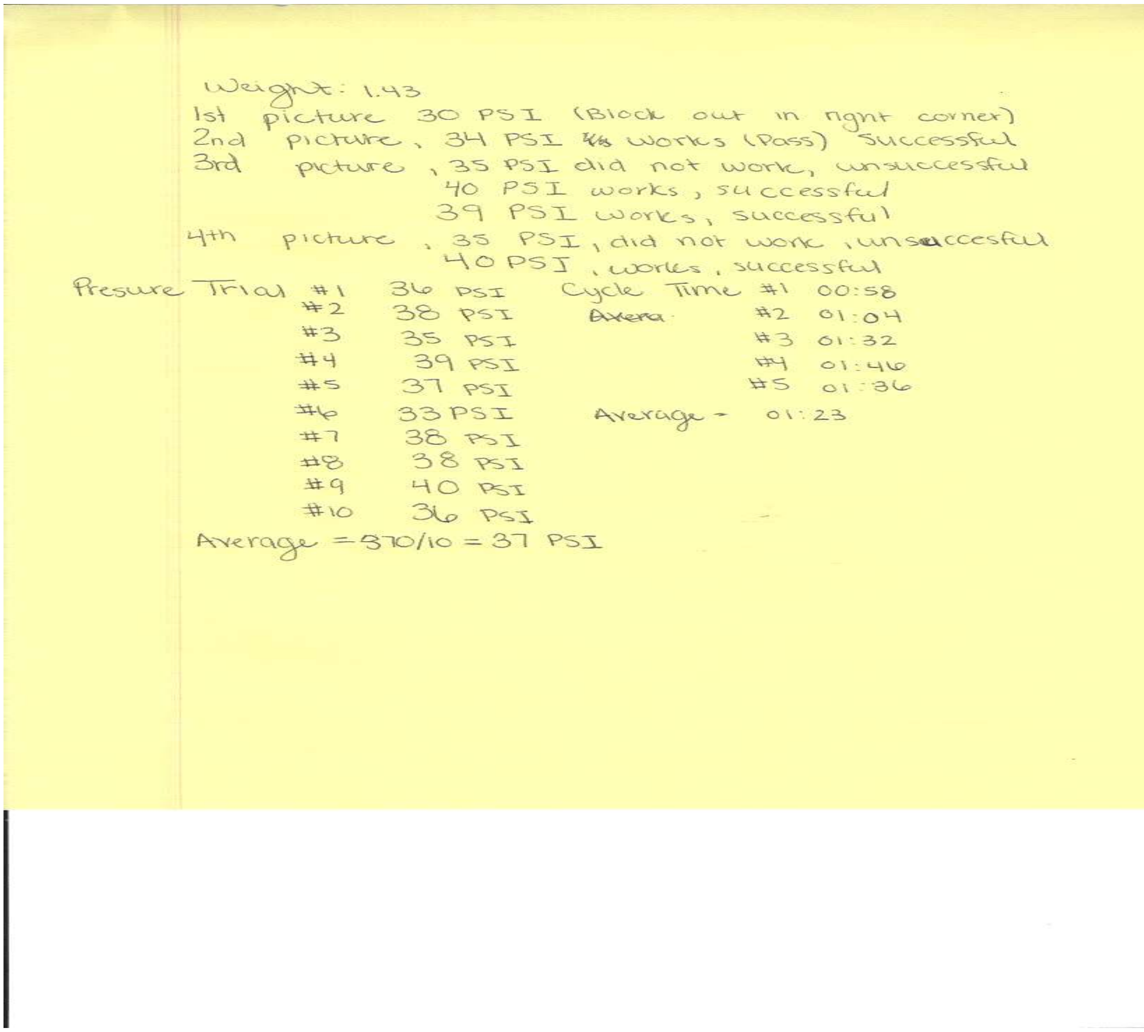
Schedule:

10				September	October	November	December	January	February	March	April	May	June
10a	Device Evaluation	3	1.5										
10b	List Parameters	3	1										
10c	Design Test Scope	3	0.5										
10d	Obtain resources	2											
10e	Make test sheets	1	0.5										
10f	Plan analyses	2	3										
10g	Test Plan*	1	2										
10h	Perform Evaluation	1	0.5										
10i	Take Testing Pics	1	0.5										
10j	Update Website	2	2										
10k	Abstract	1	8										
	subtotal:	20											
11													
11a	Test demo 1	5min	5min								4/11/2016		
11b	Test demo 2	5min	5min								4/25/2016		
11c	495 Deliverables	1											0
11d	Get Report Guide	2											
11e	Make Rep Outline	2											
11f	Write Report	10											
11g	Make Slide Outline	3											
11h	Create Presentation	3											
11i	Make CD Deliv. List	2											
11j	Write 495 CD parts	1											
11k	Update Website	1											
11l	Project CD*	25	0										
	subtotal:												
	Total Est. Hours=	178	223.5	=Total Actual Hrs									

Procedure Checklist.

- 1/10th Multiple Apple Box lift
- 49 mini apple boxes
- One mini pallet.
- Stopwatch
- Scale
- 10 Gallon air tank
- Safety glasses
- Access to 100psi Compressed air
- Pressure gauge/regulator
- Record all values in test sheet
- Back up test sheet to USB drive

Appendix



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Presure Trial	#1	36 PSI	Cycle Time #1	00:58
	#2	38 PSI	#2	01:04
	#3	35 PSI	#3	01:32
	#4	39 PSI	#4	01:46
	#5	37 PSI	#5	01:36
	#6	33 PSI	Average -	01:23
	#7	38 PSI		
	#8	38 PSI		
	#9	40 PSI		
	#10	36 PSI		

Average = 370/10 = 37 PSI

Figure 1: Test results data.

Appendix J – Full Scale Model Proposal.

Requirements

The requirements for this project are as follows:

- A device is required that can lift 1225 pounds of apple boxes. (A-3)
- The device must fit through a 3' aisle. (A-1)
- The device must fit around a 4'X4' pallet. (A-1)
- The device must be less than 15'tall when fully extended.
- The length of the device must be less than 10'.(A-1)
- The device must weigh less than 1250 pounds.

- The device must by moved by applying less than 30lbs of force. (A-12)
- The device must complete one lifting cycle in 5 minutes or less.
- The device must cost less than $15000 dollars, not including labor or design time to ensure a profitable product.
- The device must accommodate several different box dimensions and stacking patterns. (Table A-1)
- Each individual apple box cannot exceed a crushing pressure of 1 psi. (A-2)
- Each squeeze plate must apply at least 1225lbs of force. (A-4)
- The device must be driven by air cylinders that apply a pressure of at least 80 psi. (A-7)

Engineering Merit

This device will be lifting apples boxes. Engineering merit will take place in calculating loads and stresses on the structure as well as other parts of the project. Engineering merit will also take place in the lifting mechanism, stresses and loads will need to be calculated. This project will use air cylinders and electronic linear actuators to lift the apple boxes. Calculations dealing with pressure will need to be calculated to find the forces the air cylinders provide. Also, engineering merit will go into the overall design of the project.

Scope of Effort

This project will focus on the structure of the device and the squeeze/lift function that will be used to lift the top levels of boxes. Using some purchased parts that already have engineering specifications, for example the wheels, air cylinders and linear actuators.

Success Criteria

The goal of this project is to have a successful working device by the end of spring quarter. The device will be successful if it can lift the apple boxes and meets the customer's requirements. If the device meets the customer's requirements and they are satisfied with the product, there is a potential of making 18 more of these devices for them.

Approach: Proposed Solution

As stated above, a device is needed that can lift multiple apple boxes. There are several requirements dictating the design of this device. The requirements that have the most impact on this device are the size constraints and being able to lift the apple boxes without damaging the fruit or boxes. The first proposed design will consist of four linear columns of metal tubing that are on wheels. There will be some cross members to help support the structure which has to lift a heavy load. Attached to the structure there will be two plates used to squeeze and lift the top levels of apple boxes. The ultimate question is will this device be able to lift 1225lbs of apples using a squeeze technique? The answer to this question will be answered the following way: First, a compression test will be done to a variety of the cardboards to see what pressure the boxes can withstand before deformation. Using the pressure equation F/A. Once that number is determined, the plates will be designed to maximize the surface area for all the configurations. Then using a simple physics formula, $F=\mu N$ a friction force will be calculated to establish the normal force that is required by the plates to prevent the boxes from slipping. After the normal force is calculated then divide it by the surface area of the plate contacting the boxes. If the pressure is less than the allowable pressure this design should meet the requirement of not damaging the fruit or boxes.

After the first requirement is met the design will then have to fit the size constraints.

Once the size constraints are met, the analysis of the structure will need to be calculated to make sure the size of the device is still capable of lifting up to 1225lbs without failure. The analysis of the structure will be figured out by using strengths and materials and statics calculations. Maximum normal and shear stress will be calculated in the arms that transmit the squeezing force using the Equations $\sigma=Mc/I \pm F/A$ and $\tau=VQ/IT$. The maximum shear stress will also be calculated in the pins using the double shear formula $\tau=F/2A$. The calculated stress will be related to material properties to insure there will not be failure.

The lifting force will be provided by electronic linear actuators. The needed force of the actuators will be calculated using the $\Sigma Fy=0$. The Van Doren Sales electronics team will be helping tremendously in this section of the project.

The device needs to be mobile. Hence it needs to be on wheels so it can be pushed through the aisle easily. To meet this requirement the device will be built with the thought, the less it weighs the better. The rolling friction force equation $F=\digamma XW/r$ will be used to figure out the necessary force required to move the device after the design is completed.

The design needs to be built at the lowest cost possible. This goes hand in hand with weight because if the device cannot be moved easily by a human then it will have to be powered and that will increase the cost.

Performance Predictions

These are the following predictions made for the project and what they are based on.

- After completing a solid works rendering, the predicted mass will end up at about 1200lbs.
- After looking at the cost of parts and labor this is approximately a $15000 dollar project.
- Based on the amount of people at the company, and with all the different skills and knowledge, this device should be completed in five to eight weeks.

Description of Analyses

First of all the different stacking patterns will be collected. Next, determine how much each box configuration weighs and the surface area for lifting. All maximums and minimum values will be taken in to consideration for the calculations of the device. Key factors here are determining what surface area is available to squeeze and how much weight will be lifted. Once this is determined the plates of the design can be optimized to the correct size. After the plates are sized, the force required to squeeze the boxes without slipping can be calculated from the weight of each pattern and the respective surface area. From there the torque required from the lever arm can be calculated as well. The air cylinders have to make the needed force to apply this torque to the arm. Once the weight of the boxes is known the force needed to lift the boxes can be calculated. After these calculations are completed, the structure will need to be optimized to handle these forces and stresses without failure. Hopefully the forces and stressors are small enough to use a light weight material such as aluminum in order to meet the weight requirements and the ease of transportation. However, if this is not the case and a heavier material is needed the device may have to be redesigned to be a powered device.

Scope of Testing and Evaluation

The main thing that needs to be tested on this device is the allowable squeezing pressure that can be exerted on the boxes without damaging them. This is crucial to the success of the project because the fruit cannot be damaged. There are several individual pieces that need to be tested. One is the force applied by the air cylinders, next is the torque applied to the lever arm, and lastly the force exerted by the plates that causes the squeezing pressure. Another thing that needs to be tested is how much the electronic linear actuators can lift and how much force it takes to move this device. The cycle time can also be tested using a stopwatch.

After all these tests have been completed and meet the requirements the device will be used to do a test in an actual situation at Chelan Fruit.

Calculated Parameters

These are the calculated parameters for this project.

- Max lifting load of apple boxes is 1225lbs. (A-3)
- Max squeezing pressure of 1psi can be applied to the boxes without crushing. (A-2)
- Maximum needed squeezing pressure is .72 psi. (A-5)
- Max friction force needed to hold the boxes on both sides without slipping is 613lbs. (A-3)
- The device will take less than 30lbs of force to make it move on its wheels.(A-12)

Device Shape:

The device shape was dictated by the customer’s space requirements. The device needs to be no more than 36” wide so it can fit through the aisles between pallets. The height of the device is dependent upon the configurations of multiple pallet heights.

Device Assembly, Attachments

The device will be assembled the following way. The plates will be made from 3/8" aluminum plate. Cross members will be welded on the back side of the plates for additional support. Two attachments will then be welded to the plates so they can be attached to the lever arms via pins. The lever arms have a pivot point through the top frame, connected by pins. The top end of the lever arms will be connected to air cylinders. The air cylinders will be fixed to the top frame and lever arms via pins. The top frame will slide up and down on the leg system. The top frame will be lifted using 2 electric actuators. The structure will be made from aluminum square tubing as long as forces and stresses allow that material without failure. All the tubing will be welded together. The wheels will be attached to an aluminum plate that will be welded to the bottom of the square tubing on all four legs.

Tolerances, Kinematic, Ergonomic, etc.

Tolerance is important on this device. The holes drilled in the lever arm must be centered on both the x and y axis of the arm. They cannot be out of tolerance by more than .030in. Also the distance between the three holes needs to be within tolerance of .010in. That way when the distances are used to calculate forces and torque the values are precise. Also, when welding together the structure, all 90 degree connections cannot be out of tolerance by more than ½ a degree to insure even loading to the structure.

Operation Limits

There are some risks to evaluate with this device. The device will be top heavy so when moving one must be careful not to tip over the device. A force of 30lbs. is needed to move the device. In a situation where the device's wheels are not free rolling the device will tip over if more than 300 lbs. is applied to the device at 5 feet above the ground. (A-13) These calculations were done for a static situation assuming the device will not be moving at high speeds. For safety the device should be moved according to the directional sign to prevent tipping. Another risk is the apple boxes will be lifted ½ to 1 inch above the pallet to allow an employee to remove a box of apples from the middle of the pallet for quality control purposes. This is dangerous and some sort of safety will need to be incorporated here.

Methods and Construction

This device will be built at Van Doren Sales in Wenatchee, Washington. All the parts will be ordered to this location and be paid for by the company. Structural welded tubing will be ordered and cut to length on a band saw. The tubing will make up the structure of the device. The plates will be made from 3/8 in aluminum plate. Ribs will be added and welded on to the back side of plates for additional support. The arms of the device will be made from aluminum flat bar. The rounded pieces will be cut with a laser machine. The rectangular pieces will be cut to size with a band saw. After all 4 intermediate pieces have been made they will be welded together to make the arms. The pins will be made from 3/4 inch round stock. Then the pins will be turned down to the appropriate diameter, cut to length and chamfered. The brackets used to attach the wheels will be made from steel plate. These parts will be faced and drilled on the mill.

Description

The device is held together by structural tubing. Wheels are attached at the bottom of the two leg assemblies so the device can be mobile. The cross frame slides up and down on the steel tubing. Electronic linear actuators provide the force to do the lifting in the up and down direction. The actuators are connected to the bottom of the cross frame and the cross member holding the leg assemblies together. The arms are connected to the cross frame via pins. The arms also connected to air cylinders that are attached to the cross frame. This is where the squeezing force is generated. The arm is also attached to the plates via pins. The plates apply the squeezing force to the apple boxes. The device is powered by rechargeable batteries that power the linear actuators, portable air compressor and lights. Hoses and wires run along the device to make all the components work.

Drawing Tree, Drawing ID's

The first drawing tree shows the main sub-assembly and components that will make up the Multiple Apple Box Lift. The following drawing trees are the individual drawing tree for each sub-assembly. All the part drawings and assembly drawings can be referenced by the part number in Appendix B.

Manufacturing Issues

One of the manufacturing issues is that the engineer who designed this project lives in Yakima, WA. The building of this device will take place in Wenatchee, Washington. With the engineer going to school full time and living in Yakima it is going to be hard for him to make frequent trips to Wenatchee to oversee the manufacturing of the device and be available to answer questions. This is why it is crucial to have well drawn up drawings with needed dimensions and descriptions. The lead engineer on this project will have to try to be readily available by phone and email to keep the building of the device progressing.

Another manufacturing problem foreseen is that the lead engineer has designed his device based on using several purchased parts. However, some parts can only be ordered from certain suppliers. Therefore, the lead engineer may have to use similar parts and make modifications.

Discussion of assembly, sub-assemblies, parts, drawings

This device will built from 10 sub-assemblies/categories, they consist of wheels, brackets, plates, arms, legs, pins, bushings, frame, pneumatics and electronics. The best way to approach the building process is to first build all of the sub-assemblies. Once the sub-assemblies are built, weld the brackets to the bottom of the legs. Then fasten the wheels to the brackets. Next, assemble the arms to the frame with their corresponding pins and bushing components. Next, fasten the actuators to the legs and stand them upright. Then use a forklift to slide the frame on top of the leg and fasten the other side of the actuators to the frame. Then connect the plates to the arms. Lastly, run all necessary wires and hoses for the pneumatics and electronics.

Introduction

The testing of this device will take place at two locations. One of them is at Van Doren Sales in Wenatchee, Washington and the other is at Chelan Fruit. The first set of tests will take place at Van Doren sales. At this location the amount of force required to move the device will be tested as well as the amount of pressure the plates can exert. Also, the device will be tested for load lifting capabilities. At the second location Chelan Fruit, the device will be put to the true test. Can it lift and squeeze several rows of apple boxes without damaging the fruit?

Method/Approach

These are the methods used to test the deliverables and how they compare to the predicted values.

The weight of the device will be weighed on a scale and the actual weight will be compared to the prediction made from the solid works rendering.

The pressure on the plates will be measured by using a pressure gauge and the value will be compared to the calculated value and must be less than 1psi, so it does not crush the apples or apple boxes.

The load capacity will be tested by lifting a load that is greater than any load the customer will be lifting with a safety factor of 1.25. This number will be computed from the total weight of the apple boxes being lifted plus the portion of the device being lifted multiplied by 1.25. If the device can lift that weight without failure this test will be a success.

The lateral force to move the device will be tested by using a scale and then compared to the calculated value.

The cycle time of the device will be measured with a stopwatch.

Test Procedure

Weighing the Device:
Materials: Scale, multiple apple box lift
Procedure:

- Zero the scale.
- Use forklift to lift the device on the scale. (do not try to lift device manually)
- Make sure the device is stable on the scale and remove the forklift
- Record Weight
- After weight is recorded use a fork lift to lift the device off the scale

Making sure the device can lift the required load.
Materials: 2lbs of something inside of boxes, pallet, multiple apple box lift
Procedure:

- Stack boxes with weight inside them on a pallet in such a way the device can lift up the boxes.
- Apply enough squeezing force so the boxes don't slip and then lift the boxes up.

Recording the cycle time
Materials: Stopwatch, multiple apple box lift
Procedure:

- Place the multiple apple box lift in a location close to the pallet of apple boxes.
- Start stopwatch
- Record the total cycle time. 1 cycle consists of positioning the device; squeezing and lifting the apple boxes, having an employee remove an apple box from a middle row, complete their inspection of the apples in that box, replace the apple box, and then lower the boxes back on to the stack. Then the cycle time is complete.

Measuring the lateral force
Materials: Force measuring device, multiple apple box lift
Procedure:

- Attach the force measuring device to the multiple apple box lift.
- Pull on the force measuring device and record the amount of force it took for the device to start rolling.

Deliverables

These are the deliverables that will be found from testing.

- Squeezing pressure
- Load capacity
- Cycle time
- Required lateral force to move the device
- Weight of the device

Proposed Budget

Estimate total project cost

There are several costs factored into the total cost of this device. One is the materials. A list of the materials and their costs are listed in appendix C. The costs of the materials for this project are around $9500. Another cost of this project is fabrication time. Van Doreen Sales pays their welders $20 an hour and this project has a predicted weld time of 25 hours. That adds up to $400 in weld time. There will be additional fabrication time added to this project, but it will be done by volunteers in order to keep the total cost of the device down as the parts list is getting rather expensive. There will also be an additional $1000 dollars available for any unforeseen costs. With all this in mind the total cost of the project is estimated to be $11,000.

Funding source(s)

The funding for this project will be from Van Doren Sales. They hope to make their money back on this investment by selling this product to Chelan Fruit.

Proposed schedule

A complete schedule with specific tasks that must be completed by the end of each month is located in appendix E. Tasks are encouraged to be completed early so in the event of any setbacks or issues there will still be plenty of time to complete the project. It is very crucial that the schedule be followed. Van Doren Sales has many projects going on right now and if this project falls behind at any point, then the building of the project will not be completed on time. It will be the job of the engineer to make sure all tasks get done in a timely manner. The amount of time needed to complete each task will be recorded in the schedule.

Discussion

This project was a huge task to take on as a senior project. Even with the support of a well-established company with much knowledge and support this project has been difficult. The time spent on this project was far more than expected, many hours have been put into the design, analysis and proposal of this project. It was quite devastating to hear they would not be moving forward with the proposed design and would be cutting the funding to the project. However a lot was learned from this experience. Always try to be ahead of the game and make sure the right people are giving you the design requirement. Overall the 10^{th} scale redesign of this project has been a success, after several hours of redesigning and finding parts that would work for a 10^{th} scale model. The scale model should be able to prove the concept of how the device would have worked at full scale. This has been a huge setback because several hours had to go back into the proposal phase and planning phase.

Design Evolution / Performance Creep

The design evolution of this device is quite interesting. The basic movements of the device have been established from almost day 1. The device will squeeze and lift the boxes of apples. The part of the device that continues to be changed and redesigned is how the lift and squeeze technique will be performed. The first idea for this project was that the squeeze and lift would be driven by hydraulics. This quickly changed because the fruit company did not like the idea of hydraulic fluids being around the fruit. Also a hydraulic system was overkill for the amount of load the device needed to lift. The next idea was to move to pneumatics to drive the squeeze and lift force. This then came up for discussion because air is a compressible fluid. Before any lifting or squeezing occurs the device has to be able to be positioned so that the plates start at a certain height for that specific box configuration. Using air would make it hard to pin point certain heights for different box configurations since when adding air to a cylinder the movement is quite jerky. Also the layers of boxes have some glue between the layers so before the boxes could be lifted air would be compressing in the cylinders until the glue bond between layers was broken resulting in uncontrolled lift acceleration. This potentially could cause boxes to tip over. After all this was taken into account the company decided that pneumatics would be the best solution for the squeeze force of this device and that the lifting force would be provided by a linear electric actuator. The linear actuator provided precise, smooth movement. The only thing left to be determined on this device is it will need its own batteries and compressors to run the device. There will be a lot of help from the Van Doren Electric and pneumatic team for sizing batteries and compressors. Lastly the funding of the project was cut and now it is redesigned at a 10^{th} scale.

Project Risk Analysis

One of the greatest risks of this project is cost. The cost of this device keeps going up and up. My main concern is will this be a marketable product? There are 3 potential things that can happen based on the cost of this project. One is the device costs too much and the customer is not willing to pay for it, therefore this device is not manufactured. Two, the company keeps the cost down enough to make a profit and potentially sell many more units. And lastly, the company breaks even on the project and it’s up for redesign. In this case the customer did not accept the proposal and the device is up for redesign at a later time by the Van Doren Company.

Success

This project will be successful if the device allows access to a mid-level box in the pallet stack. The device must meet all the customers’ requirements and must not damage any of the fruit. Lastly, the device must be safe when used appropriately.

Next Phase

The next phase for this project is the manufacturing phase. All the drawings of the parts for this device have been completed. The part drawings will be sent to the Van Doren machine shop. Once all the parts are cut to size and made at the machine shop they will then be passed on to the welders. Once all the Sub-Assembly have been welded they will be put together to make the final assembly.

Appendix K – Resume/Vita

OBJECTIVE

Seeking a position as a full time engineer. Expected to graduate in June of 2016 with a bachelor's degree in Mechanical Engineering Technology. Current GPA is 3.7. Job interests include: mechanical engineer, manufacturing engineer, or a similar position.

EDUCATION

9/23/14 – current **Central Washington University** *Ellensburg WA*

CWU GPA 3.959

Honor roll Fall of 2015, Winter of 2015 Spring of 2015

Completed courses:

Metallurgy, Machining, Thermodynamics, Fluid dynamics, Advanced Machining, PLC's Solid Works Level 1 Certification, Computer Aided Manufacturing and Applied Strengths and Materials.

9/16/11 – 6/10/14 **Yakima Valley Community College** *Yakima WA*

Completed Associates of Arts and Science Direct Transfer Degree with honors December 2013.

YVCC GPA 3.595

Presidents List—Spring 2013, Spring 2014

Dean's List— Spring & Fall 2012, Fall 2014

Completed Related Courses:

Calculus based Physics series, Calculus 1 and 2, Statics, Dynamics, Strengths and Materials, Interpersonal Relationships (team building/communications course)

EXPERIENCE

3/30/2015 TO CURRENT **Van Doren Sales** *Yakima WA*

Engineering Intern

Van Doren Sales builds and designs fruit packaging equipment. What began as an internship has turned into a part time engineering job. An engineering intern helps with the Layout CAD Drawings of a Cherry Facility.

6/21/14 TO 9/17/2014 **Yakima County Public Services** *Yakima WA*

Survey Crew Member

A survey crew member learns how to acquire data for topography and upload it to AutoCAD. Also interns learn the process of laying out roads.

REFERENCES

Name	Phone Number	Email	Years Known	References	Title
Dr. Stephen Rodrigue		SRodrigue@yvcc.edu	2 Years	Instructor	Physics/Engineering
Kim & Connie Eisenzimmer			5 Years	Employer	Business Owners
Jason Rinehart		Jason.rinehart@co.yakima.wa.us	Summer Intern 2014	Employer	Professional Land Surveyor (Manager)
John Pickens		Jtpickens@triumphgroup.com	20 Years	Family Friend	Manufacturing Engineer