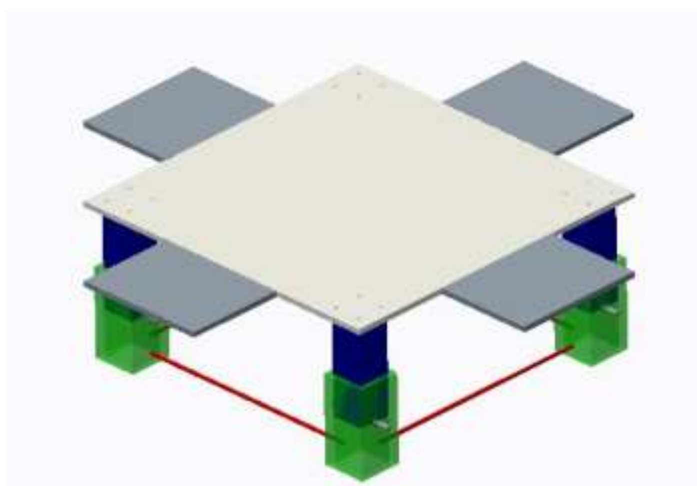
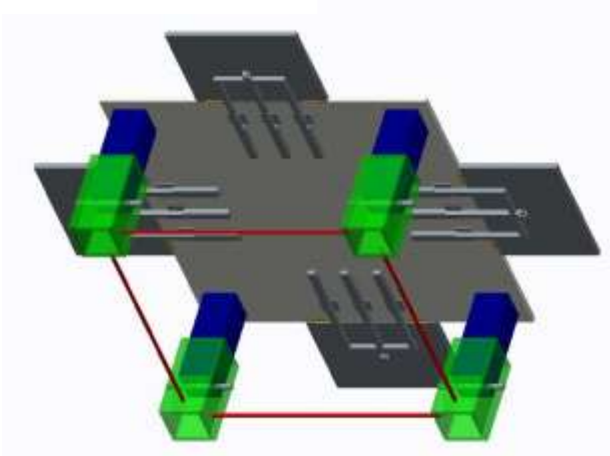
EZPong

Design and Analysis

Tyler Wei

ME 392
Dr. Roy McGrann





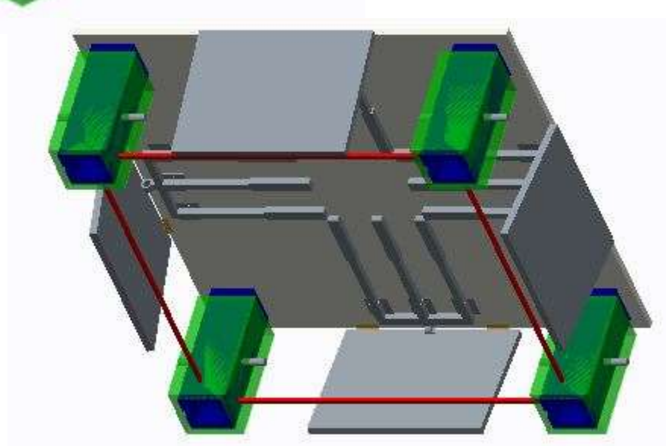


Table of Contents

Executive Summary

EZPong, as the name suggests, is a coffee table which can convert and deploy into the dimensions of two beer pong tables. For most university students, typically both versatility as well as feasibility is considered when purchasing furniture. This design allows for space conservation for both a coffee table for relaxed environments as well as a pong table for a more jovial situation. Through the use of PTC Creo Parametric, several design specifications and constraints were designed, modelled, assembled, and tested with Finite Element Analysis.

The tabletops and legs are composed of swamp white oak wood while the screws, hinges, pins, and beams are made from machined AISI 1040 CD steel. A standard HHKS75 hinge holds the leaves to the main tabletop and sliding AISI 1040 CD steel pull out bars can be pulled out from underneath the main tabletop to support the leaves. The entire table can also be lifted up and held in place with the leg pins, which fit into the hole on the side of the leg shell to support the inner legs. The connections of the legs and the pull out bars to their respective shells are Class RC7 H9/d8 Free-Running Clearance Fits. The hinges are held in place by 3/8" 6-40 UNF - 2B screws, and the pull out shells are held by 1/2" 1/4-20 UNC - 2B screws.

The table is subjected to several different loads, all chosen with ergonomic consideration. Since many of the users of this table may be intoxicated after several rounds of beer pong, safety is a main concern and thus, the design needs relatively high factors of safety. The main tabletop can support a load of 500 lbf, which in turn results in a maximum transverse shear stress of 3.89 ksi, a maximum deflection of 0.0243 in, and a factor of safety of 4.47. In the retracted position, the tabletop has a shearing force of 12 lbf from the screws attached to the hinges on the leaves to the tabletop screw holes. This results in a maximum stress of 0.133 ksi, and a factor of safety of 131. As from the pullout shells and bars, the tabletop has another shearing force of 225 lbf from a different screw hole resulting in 2.75 ksi and a 6.33 factor of safety. When the leaf is deployed, it can support 400 lbf, leading to a maximum stress of 2.38 ksi, a deflection of 0.0127 in and a value of 7.31 for the safety factor. Each of the leg pins supporting the upper table can undergo 415 lbf resulting in a maximum transverse shear stress of 2.62 ksi, a deflection of 0.0000485 in, and a factor of safety value of 27.1. The pull out bars, which support the leaves, can each support 400 lbf, which leads to a maximum stress of 26 ksi. The result of this shows a factor of safety of 2.73. The inner legs and leg shells underwent a force of 255 lbf and 295 lbf correspondingly, and resulted in stresses and factors of safety of 0.179 ksi at 97.2 and 0.218 at 79.8, respectively.

The table is also subjected to fatigue log life tests to see how many cycles this can undergo. It was determined that the pull out bar has the fatigue log life of $10^{6.007}$ and the leg pin of $10^{16.82}$. Typically, a minimum of 1 million cycles is desired. By these results, it is evident that the design of the EZPong is one that not only accomplishes the goal of space-conservation as well as a multifunctional piece of furniture, but also of structural soundness.

To: Prof. Roy McGrann
From: Tyler Wei
Subject: EZPong Report
Due Date: 4/27/2015

Introduction

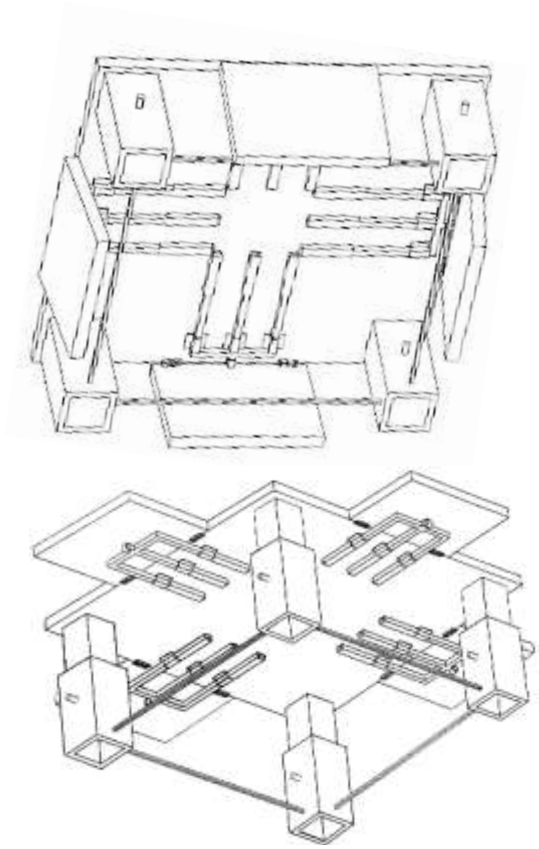


Figure 1: Design 1 Retracted (Top) Deployed (Bottom)

As young men and women experience their collegiate life, versatility and multi-functionality often play a huge role in furniture shopping and interior design. Likewise, most students in their collegiate/university years tend to enjoy two other activities aside from going to classes and studying: drinking games (namely beer pong) and lounging about with other students. The problem that this mechanical engineering design project will attempt to resolve is space conservation with both a beer pong table and a coffee table together in a space confined room.

Most university students tend to be frugal with their spending budget, thus versatility is sought during furniture acquisition. However, a pong table is typically used exclusively for beer pong due to the unique dimensions and thus is pretty much impractical on other occasions. With regard to tackling this problem effectively and efficiently, the constraints and requirements had to be taken into account. Typically, coffee tables have a height of between 15 inches and 20 inches; tabletops do not have specified dimensions, however, for the purpose of this project, the tabletop will be a 60 inches by 60 inches. According to the World Series of Beer Pong (WSOPB), regulation beer pong tables have a tabletop dimension of 24 inches by 96 inches and a height of 27.5 inches. Also, the proposed solution needs to be able to conserve space.

Design Description

As stated in the EDP as well as the Progress Report, the attached design of EZPong in Figure 1 aims to resolve the problem of conserving space with both a beer pong table as well as a coffee table for young men and women during their collegiate years. In essence, the design iteration is a coffee table which can be deployed into a beer pong table with leg height adjustment as well as leaves placement. As delineated in Figure 1, the design utilizes hinges to support the additions of leaves to the main tabletop. This design offers both the ease in rapid deployment and retraction as well as support for dual game capability.

EZPong has a unique design which offers both space conservation as well as multi-functionality. In its retracted position, EZPong can be used as a coffee table for the typical college student to lounge about with other colleagues. In this position, each of the four leg shells almost completely cover the inner legs of the upper portion of the table, the pull out bar is pushed completely underneath the bottom of the table top, and the leaves fold downwards and rest beside the sides of the table.

In its deployed position, the upper portion of the table is lifted up and held in place via leg pins. This allows for the users to adjust the height of the tabletop from typical coffee table heights to the height of official competition beer pong tables. Another important feature of the table is that due to the hinge connection of the leaves to the tabletop. This allows for the leaves to be raised up extending the length of the table to the appropriate length for beer pong and is held in position by the pull out bars, which slide from underneath the table through a series of shells.

Features and Mechanisms

The key to the table’s versatility and ability to save space lies within the unique applications of its mechanisms. The first and foremost feature of EZPong is the ability to change the size and shape of the tabletop. The design calls for the table leaves attached to the main tabletop by steel hinges. The pull out bar then holds up and supports the leaves, aligning both of the top surfaces. The pull out shells are screwed to the bottom of the tabletop around the pull out bar.

The next feature is the ability for the table to change in height. As described earlier, the inner legs of the upper table slide up and down the leg shells and are held in place via cylindrical pins. Fits between the leg pins and the hole in the leg shell as well as the fits between the inner leg and the leg shell will be addressed. Only clearance fits apply to these parts and they both call for Class RC7 H9/d8 free running fits.

Requirements

In order to properly design and assemble this mechanism, certain constraints as well as requirements had to be identified, referenced, checked for feasibility, and applied. According to WSOBP, official competition beer pong tables have the dimensions of 96 inches, 24 inches, and 27.5 inches for length, width, and height, respectively. In the deployed position, the leg pins supporting both the inner and outer leg shells must have the capability to support 500 lbf. This value was determined from the weight of the entire table above the pin divived by four and then the addition of the weights of two beer pong partners who have decided to stand atop the table for a drunken victor revelry. Both the pull out bar as well as the leaves shall have the capability of supporting the same weight of 500 lbf. As for the EZPong in the retracted position, the table has a much greater stability and can take even more weight due to the fact that the leg pins will no longer be in place and the leaves will not be a part of the table top. In the aforementioned position, the table is a coffee table thus it has the typical height of one, between 15-20 inches and has a square tabletop with the side length of 60 inches.

Assembly

The final assembly was put together through PTC Creo Parametric (referred to as Creo from now on). For this, only the leg assembly on the table was constraint to be rigid due to the assumption of it being fixed to the ground, the tabletop was assembled with slider connections in Figure 2 to the leg assembly as was the pull out mechanism to support the leaves. Steel pins put into circular cut holes are also utilized to support the inner legs of the tabletop. The hinge parts were

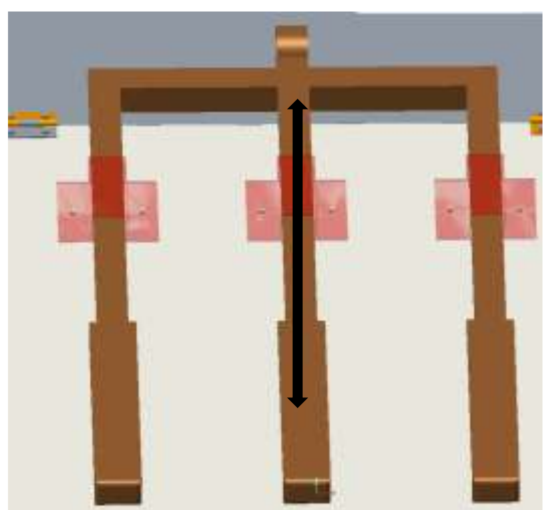


Figure 2: Slider connection for the pullout bar (brown) and its shell (red)

constrained to each other via “pinning” as shown in Figure 3, as was how the screws were assembled. For the materials in this design, the majority of this table consists of Swamp White Oak wood due to its moderate price, a high modulus of rupture of 17.4 ksi, rot and decay resistance, and typical usage in furniture, cabinetry, and boat building. The pins, hinges, screws, pull out mechanism (bar and shell), and the support beams were made of machined AISI 1040 CD Steel. After assembling all parts with no global interferences and with the ability to retract and deploy in the desired motion, projected forces were then applied to the load in the Finite Element Analysis.

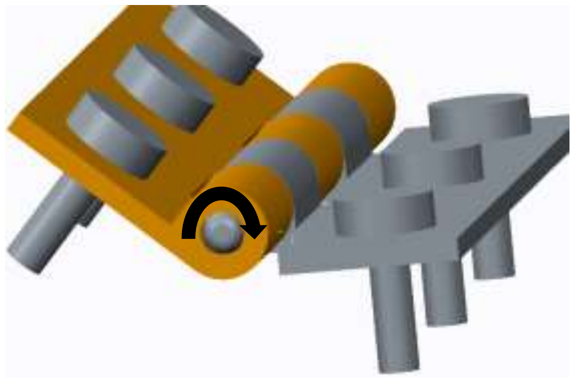


Figure 3: Pinning Mechanism in hinge assembly

Analysis

A series of analyses were initiated and started to ensure both the stability and the feasibility of this design. For the Finite Element Analysis (FEA), each study for a different portion of the table was performed at the 9^{th} polynomial edge order and is set to a convergence percentage of 1 percent to yield results as accurate as possible. In each of these analyses, both the constraints and the maximum applied forces needed to be identified.

The maximum expected forces for each of component was analyzed and applied to Creo’s FEA. This analysis yields the appropriate von Mises stress, deflection, or fatigue life fringe diagram as well as a strain energy convergence plot. The maximum stress on the fringe diagram which is noted in red, is then used to calculate the Factor of Safety for each of the components. The results are tabulated in the next section titled *Results*. A fatigue life analysis was run on the steel parts. This study observes the number of repeated loading it would take for the corresponding part to fail; typically the minimum desired number of cycles is 10^6. For this design, most of the table was made from Swamp White Oak wood, which has a modulus of rupture of 17.4 ksi with pins, screws, and bars made of AISI 1040 CD Steel which has a yield strength of 71 ksi. This means that in all likelihood, rather than the pins breaking from loads exerted on the table, the table parts made of wood which hold the pins would break first.

Results

Part	Material	Maximum Force (lbf)	Maximum Stress (ksi)	Yield Stress (ksi)	Factor of Safety
Tabletop	Swamp White Oak	500	3.89	17.4	4.47
Tabletop (Force from Hinges)	Swamp White Oak	12	0.133	17.4	131
Tabletop (Force from Pullout Shells)	Swamp White Oak	225	2.75	17.4	6.33
Leaf (Deployed)	Swamp White Oak	400	2.38	17.4	7.31
Leaf (Retracted, Force from Hinges)	Swamp White Oak	12	0.402	17.4	43.3
Leg Pin	AISI 1040 CD Steel	415	2.62	71.0	27.1
Pull Out Bar	AISI 1040 CD Steel	400	26.0	71.0	2.73
Inner Leg	Swamp White Oak	255	0.179	17.4	97.2
Leg Shell	Swamp White Oak	295	0.218	17.4	79.8

Table 1. Results of von Mises Stress FEA.

Part	Material	Maximum Force (lbf)	Maximum Stress (ksi)	Maximum Displacement (in)
Tabletop	Swamp White Oak	500	3.89	0.0243
Leaf (Deployed)	Swamp White Oak	400	2.38	0.0127
Leg Pin	AISI 1040 CD Steel	415	2.62	0.0000485
Pull Out Bar	AISI 1040 CD Steel	400	26.0	0.0264

Table 2. Results of Displacement FEA

Part	Material	Fatigue Log Life (10^N Cycles)
Pull Out Bar	AISI 1040 CD Steel	6.007
Leg Pin	AISI 1040 CD Steel	16.82

Table 3. Results of Fatigue Log Life FEA (Desired minimum of 10^6 is desired).

Discussion

PTC Creo Parametric's Finite Element Analysis results validate the integrity as well as the stability of the EZPong design. The table has the capability to withstand a repeated load for a minimum of $10^{6.007}$ cycles. As stated earlier, due to the material composition of table parts, rather than the steel pins or screws breaking from an external force, the wooden parts would break first due to wood having a rupture modulus smaller than the yield stress of steel.

Typically, so long as a design's factor of safety is above 1, the design has the structural stability to withstand. However, for the purposes of this design needing to support several inebriated university students as well as their belongings on them, the factor of safety should be well above 1.0 in order to ensure a design where the users can stay safe. For the FEA, the weight of the typical college aged student was assumed to be 175 pounds. The tabletop in the retracted coffee table position is able to withstand two people with a full keg and have a factor of safety of 4.47. In the deployed position, the main tabletop can still support the same weight since there is no mechanical difference between the two forms; however, there is the addition of the leaves. For this FEA, the weight of a bored college student drunk texting his or her friend while sitting on the leaves with several beers, was implemented. For the entire leaf and pull out bar system, it is clearly shown in the results that it can support this weight, however, the pull out bar has a lower factor of safety of 2.73 compared to that of the leaf, 7.31.

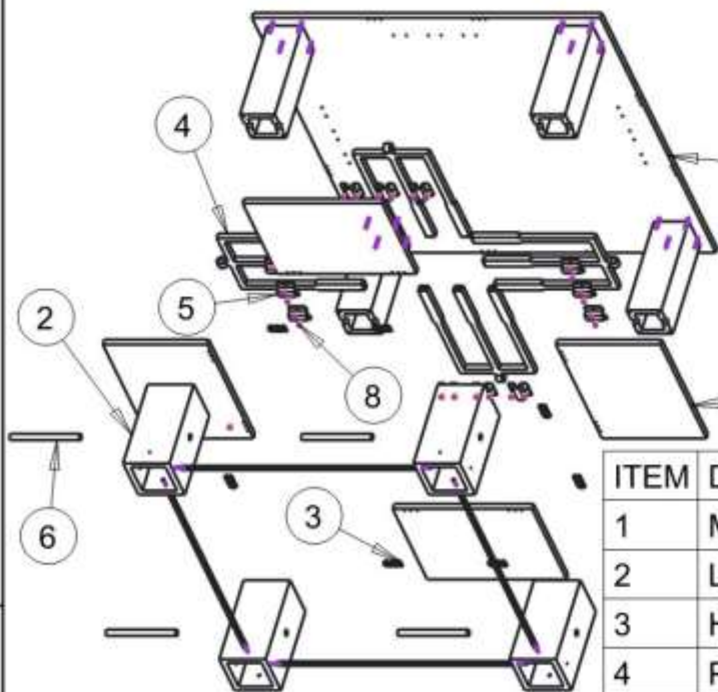
Conclusion

Through the use of ergonomic analysis and innovation, many mechanical design ideas have arisen for industrial, academic, and entertainment purposes. The EZPong aims to help collegiate aged students to conserve space for a table used for lounging about in relaxing environment as well as for a beer pong table in a more lively and festive atmosphere.

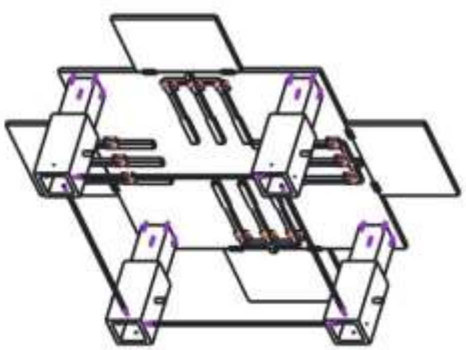
Despite the fact that this table in the retracted form as a coffee table has its leaves blocking the sides of the table, thereby preventing placements of objects underneath it, the distinctive design of EZPong allows for versatility, multi-functionality, as well as simultaneous support for more than one game of pong. The design allows for tabletop area and shape extension as well as a height raise. The table top in the retracted form is a square coffee tabletop, however, when all leaves are deployed, it has the shape of two pong tables crossed over each other. This allows for efficiency in space conservation.

In conclusion, this design has passed all FEA requirements with relatively high factors of safety. Due to the fact that most users who operate the mechanisms are most likely inebriated, in order for injury prevention, the lowest factor of safety was 2.73. The values of the loads implemented on the table were determined by the weights of the typical college student and the table has proven to be able to withstand the respective forces as well as being able to go past the anticipated minimum of 10^6 loading cycles. EZPong is an efficient and effective design which when applicable, allows for an economic approach for flexibility, dual game support, and entertainment within the room of a university student.

Appendix I: Assembly Drawings



ITEM	DESCRIPTION	QTY	MATERIAL
1	MAIN TABLE TOP ASSEMBLY	1	VARIOUS
2	LEG ASSEMBLY	1	VARIOUS
3	HINGE ASSEMBLY	8	AISI 1040 CD STEEL
4	PULL OUT BAR	4	AISI 1040 CD STEEL
5	PULL OUT SHELL	9	AISI 1040 CD STEEL
6	LEG PIN	4	AISI 1040 CD STEEL
7	LEAF	4	SWAMP WHITE OAK
8	1/2" - 1/4-20 UNC - 2B PHILLIPS-HEAD SCREW	24	AISI 1040 CD STEEL



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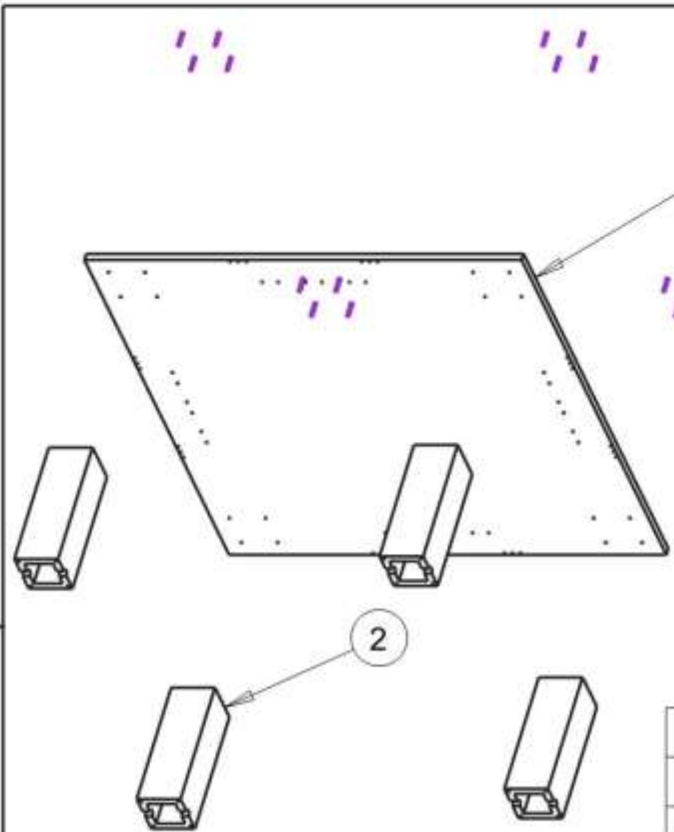
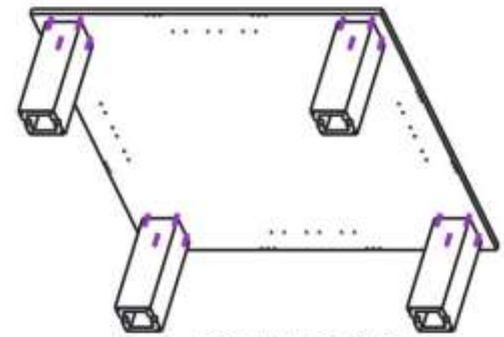
All dimensions inches	DRWN by:	Tyler Wei	Date: 5/11/2015





SCALE 0.040

ITEM	DESCRIPTION	QTY	MATERIAL
1	TABLETOP	1	SWAMP WHITE OAK
2	INNER LEG	2	SWAMP WHITE OAK
3	2" - 1/4-20 UNC - 2B PHILLIPS-HEAD SCREW	16	AISI 1040 CD STEEL

Unless otherwise shown: All tolerances ±0.001 of last decimal given.	Binghamton University Mechanical Engineering Department MAIN TABLETOP ASSEMBLY	
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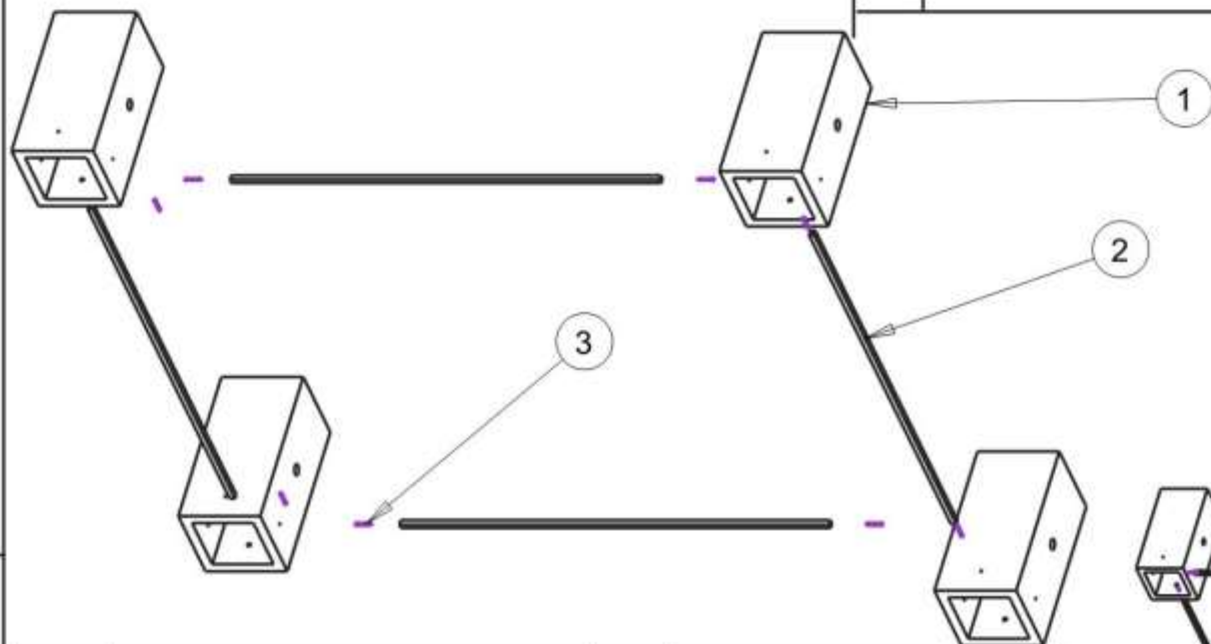

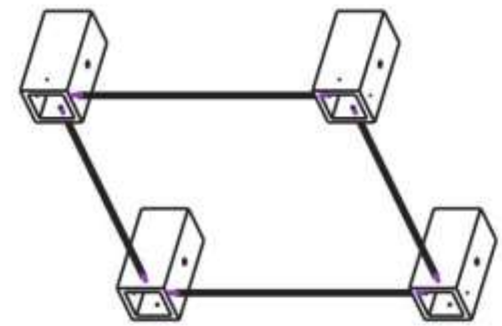

SCALE 0.040

ITEM	DESCRIPTION	QTY	MATERIAL
1	LEG SHELL	4	SWAMP WHITE OAK
2	LEG BEAM	4	SWAMP WHITE OAK
3	1 1/2" - 8-32 UNC - 2B PHILLIPS-HEAD SCREW	8	AISI 1040 CD STEEL

Unless otherwise shown: All tolerances ±0.001 of last decimal given.	Binghamton University Mechanical Engineering Department		
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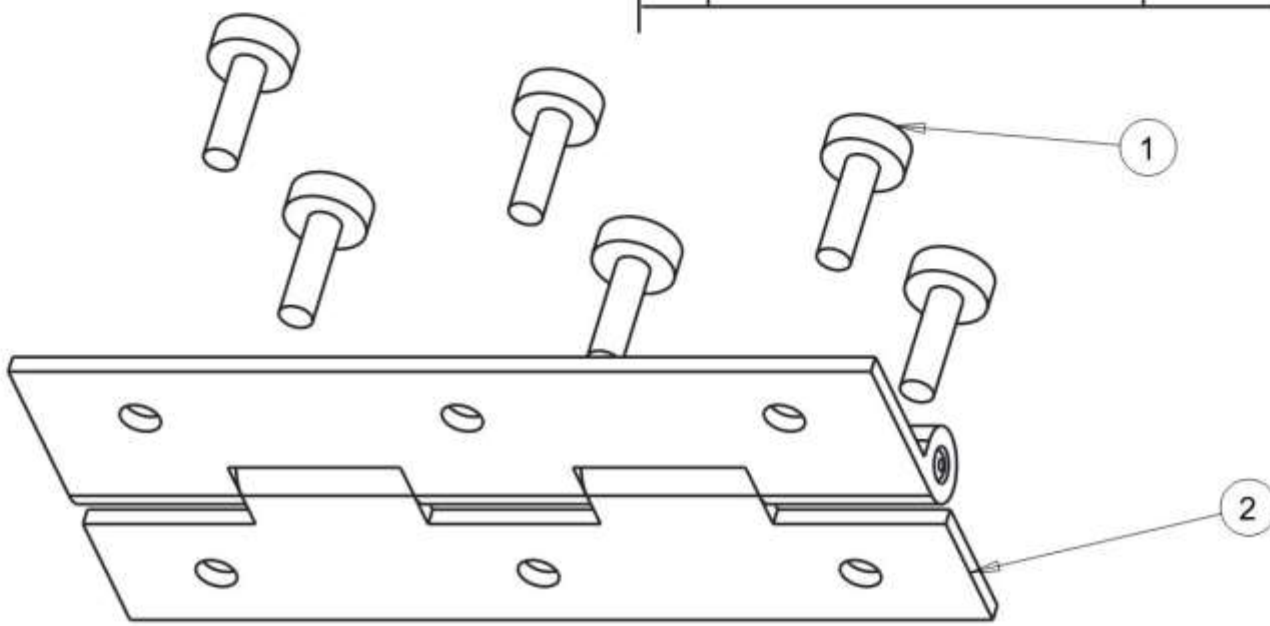
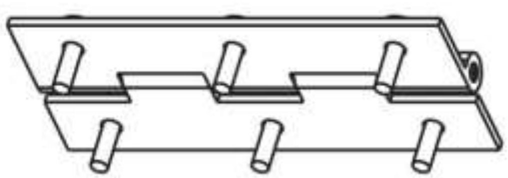
All dimensions inches	DRWN by: Tyler Wei		Date: 5/11/2015



ITEM	DESCRIPTION	QTY	MATERIAL
1	3/8" - 6-40 UNF - 2B PHILLIPS-HEAD SCREW	6	AISI 1040 CD STEEL
2	HHKS75 HINGE	1	AISI 1040 CD STEEL



SCALE 1.000

Unless otherwise shown:
All tolerances $\pm$0.001 of last decimal given.

Binghamton University
Mechanical Engineering Department

HINGE ASSEMBLY

SCALE 2.000

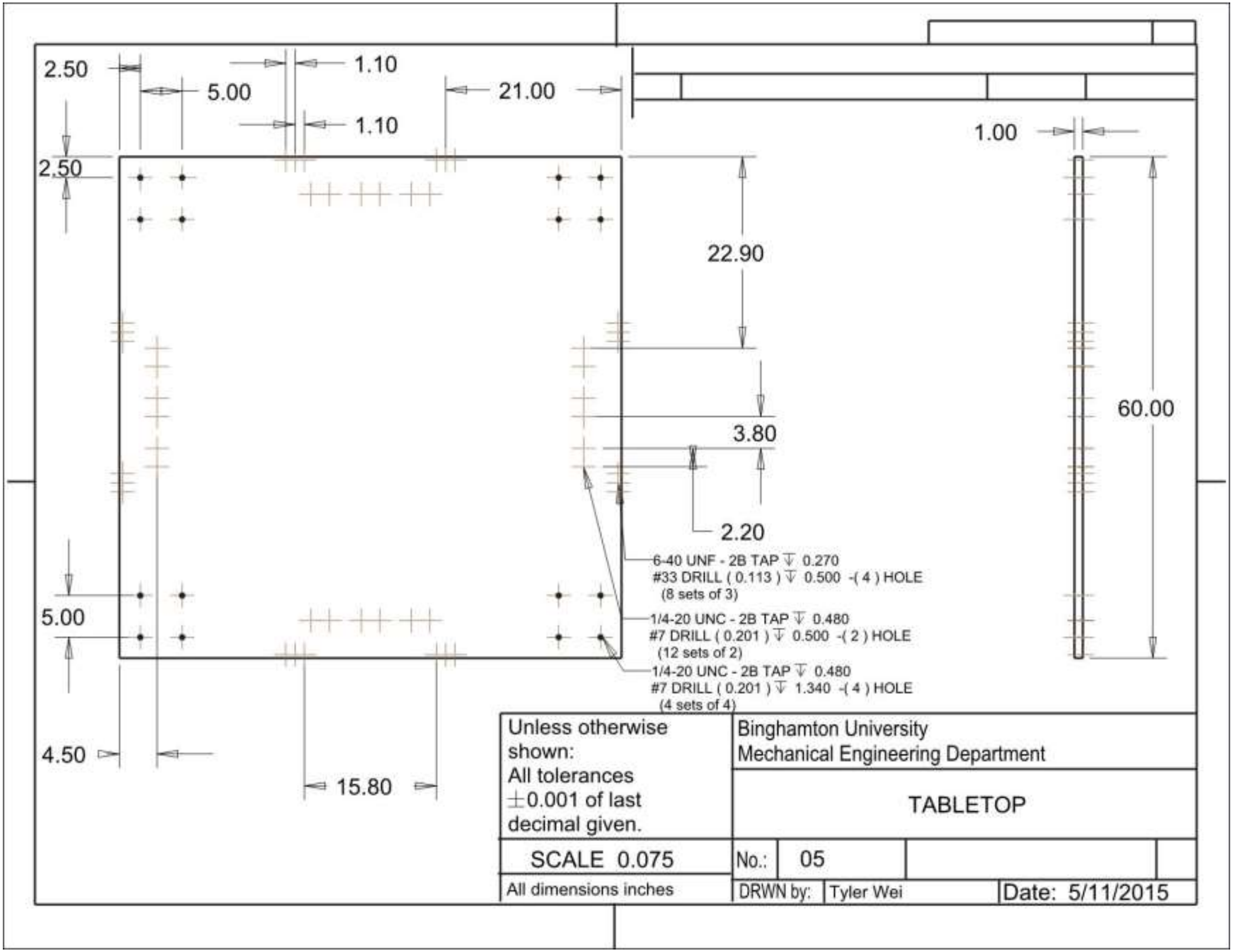
No.: 04

All dimensions inches

DRWN by: Tyler Wei

Date: 5/11/2015

Appendix II: Detailed Drawings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2.20
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(8 sets of 3)
1/4-20 UNC - 2B TAP ↧ 0.480
#7 DRILL (0.201) ↧ 0.500 -(2) HOLE
(12 sets of 2)
1/4-20 UNC - 2B TAP ↧ 0.480
#7 DRILL (0.201) ↧ 1.340 -(4) HOLE
(4 sets of 4)
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4.50
15.80
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All tolerances ±0.001 of last decimal given.
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Mechanical Engineering Department
TABLETOP
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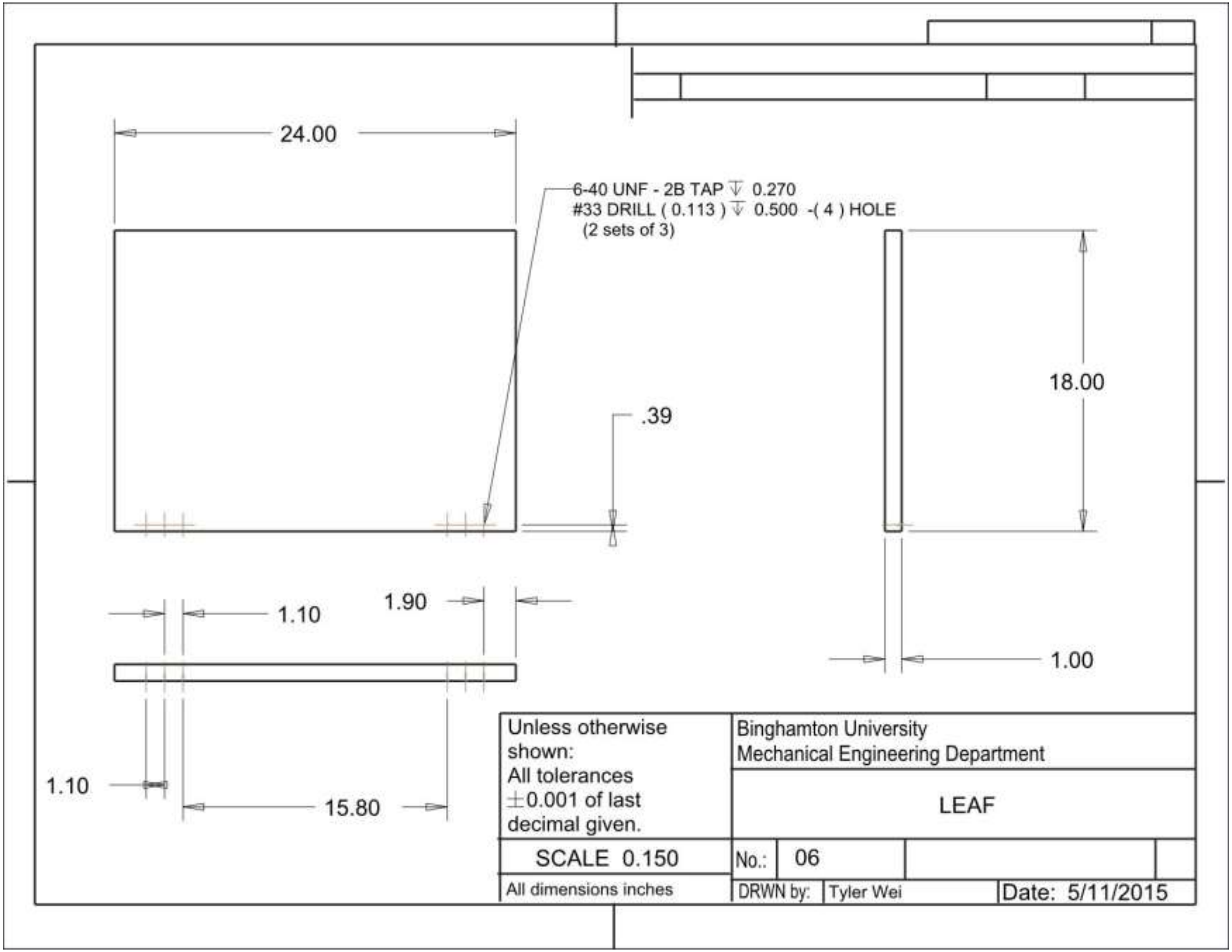
DRWN by: Tyler Wei
Date: 5/11/2015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6-40 UNF - 2B TAP ↧ 0.270
#33 DRILL (0.113) ↧ 0.500 -(4) HOLE
(2 sets of 3)
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.39
1.10
1.90
1.00
1.10
15.80
Unless otherwise shown:
All tolerances ±0.001 of last decimal given.
Binghamton University
Mechanical Engineering Department
LEAF
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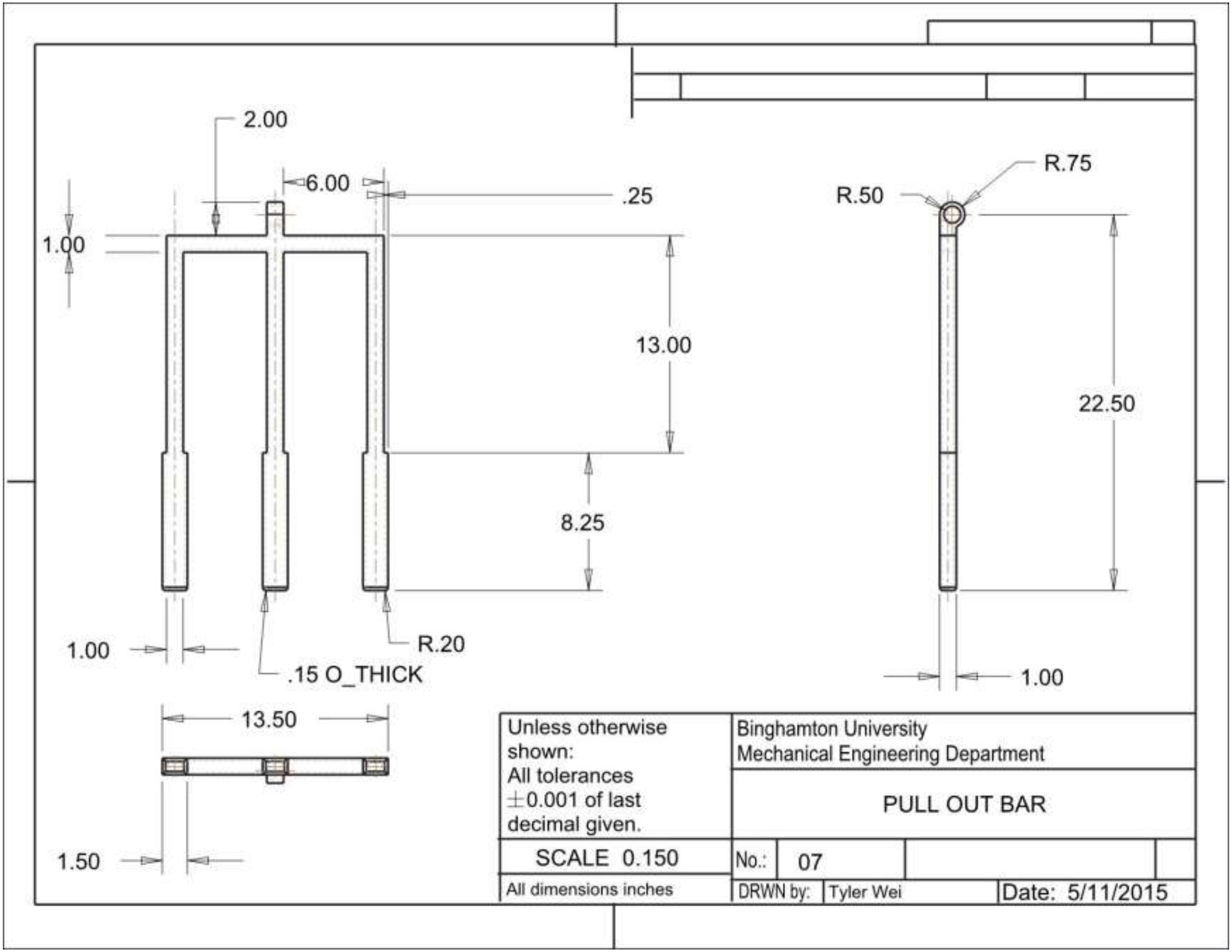
All dimensions inches
DRWN by: Tyler Wei
Date: 5/11/2015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1.00
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R.20
.15 O_THICK
13.50
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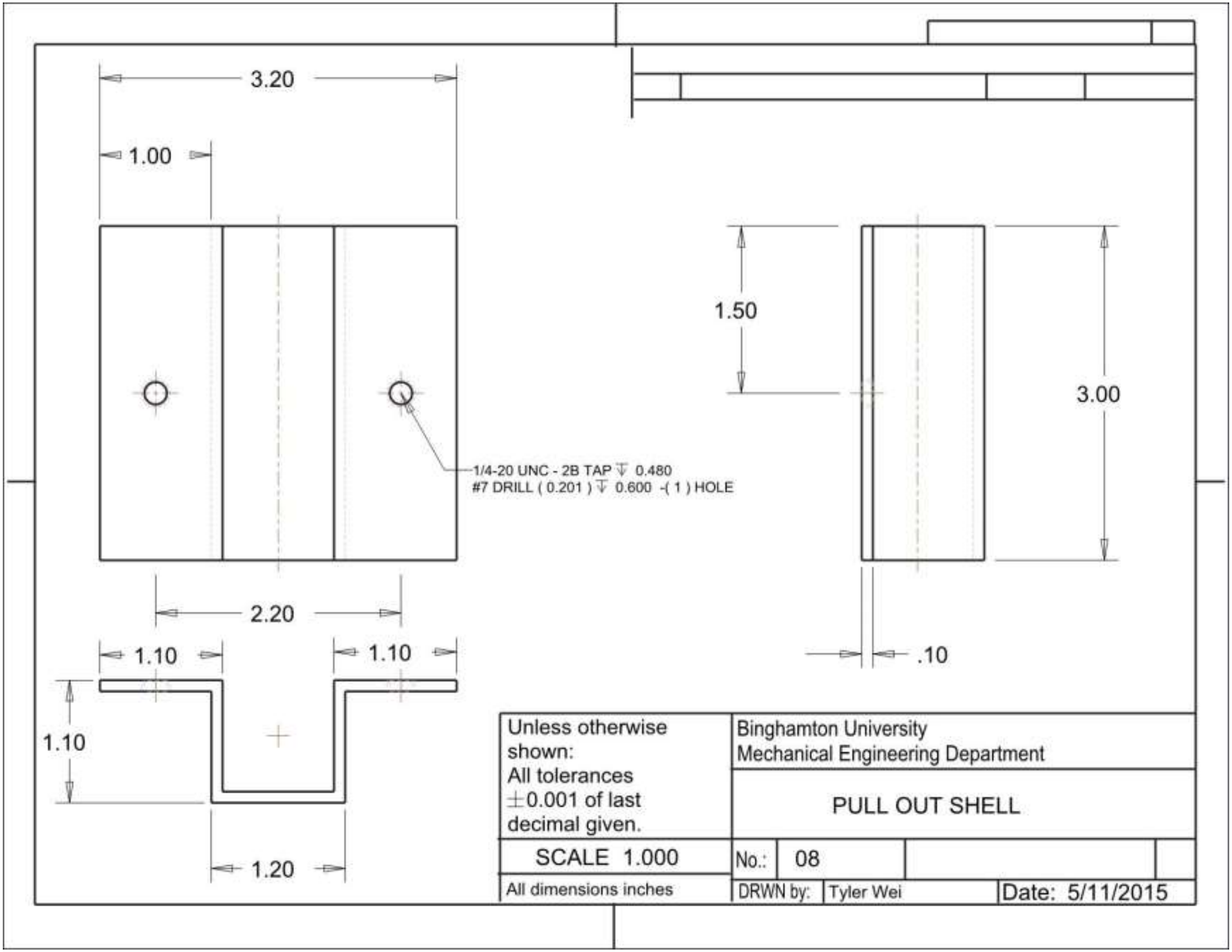
R.75
R.50
22.50
1.00
Unless otherwise shown:
All tolerances ±0.001 of last decimal given.
SCALE 0.150
All dimensions inches
Binghamton University
Mechanical Engineering Department
PULL OUT BAR
No.: 07
DRWN by: Tyler Wei
Date: 5/11/2015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1.00
1.50
3.00
1/4-20 UNC - 2B TAP ↧ 0.480
#7 DRILL (0.201) ↧ 0.600 -(1) HOLE
2.20
1.10
1.10
.10
1.10
1.20
Unless otherwise shown:
All tolerances ±0.001 of last decimal given.
SCALE 1.000
All dimensions inches
Binghamton University
Mechanical Engineering Department
PULL OUT SHELL
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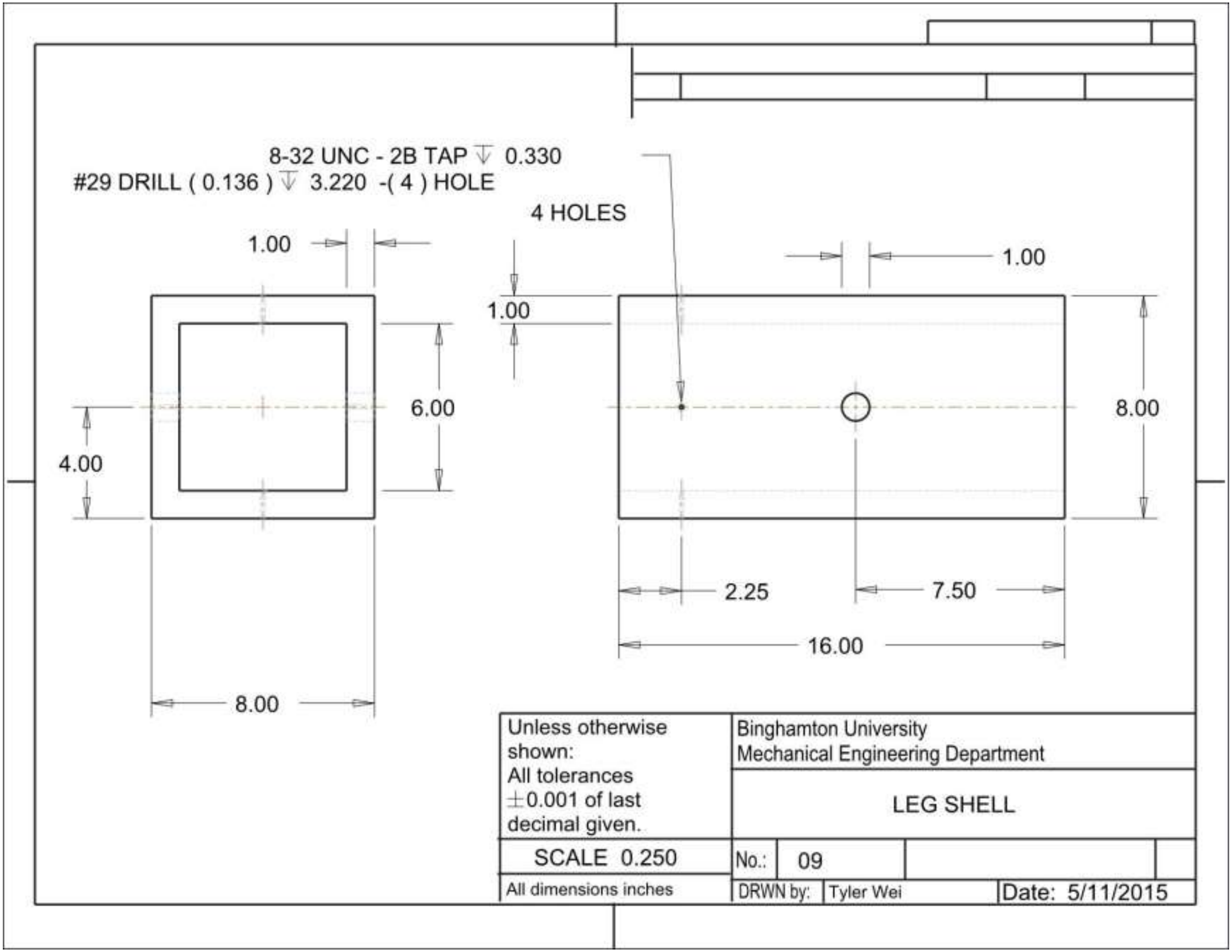
DRWN by: Tyler Wei
Date: 5/11/2015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4.00
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7.50
16.00
Unless otherwise shown:
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All dimensions inches
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Mechanical Engineering Department
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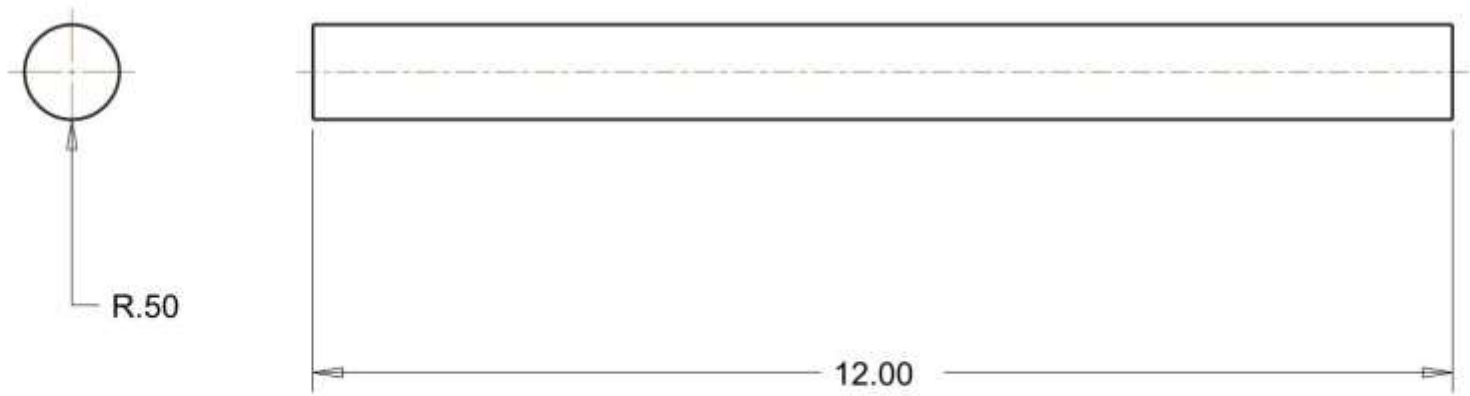
DRWN by: Tyler Wei
Date: 5/11/2015



Unless otherwise shown: All tolerances ±0.001 of last decimal given.	Binghamton University Mechanical Engineering Department		
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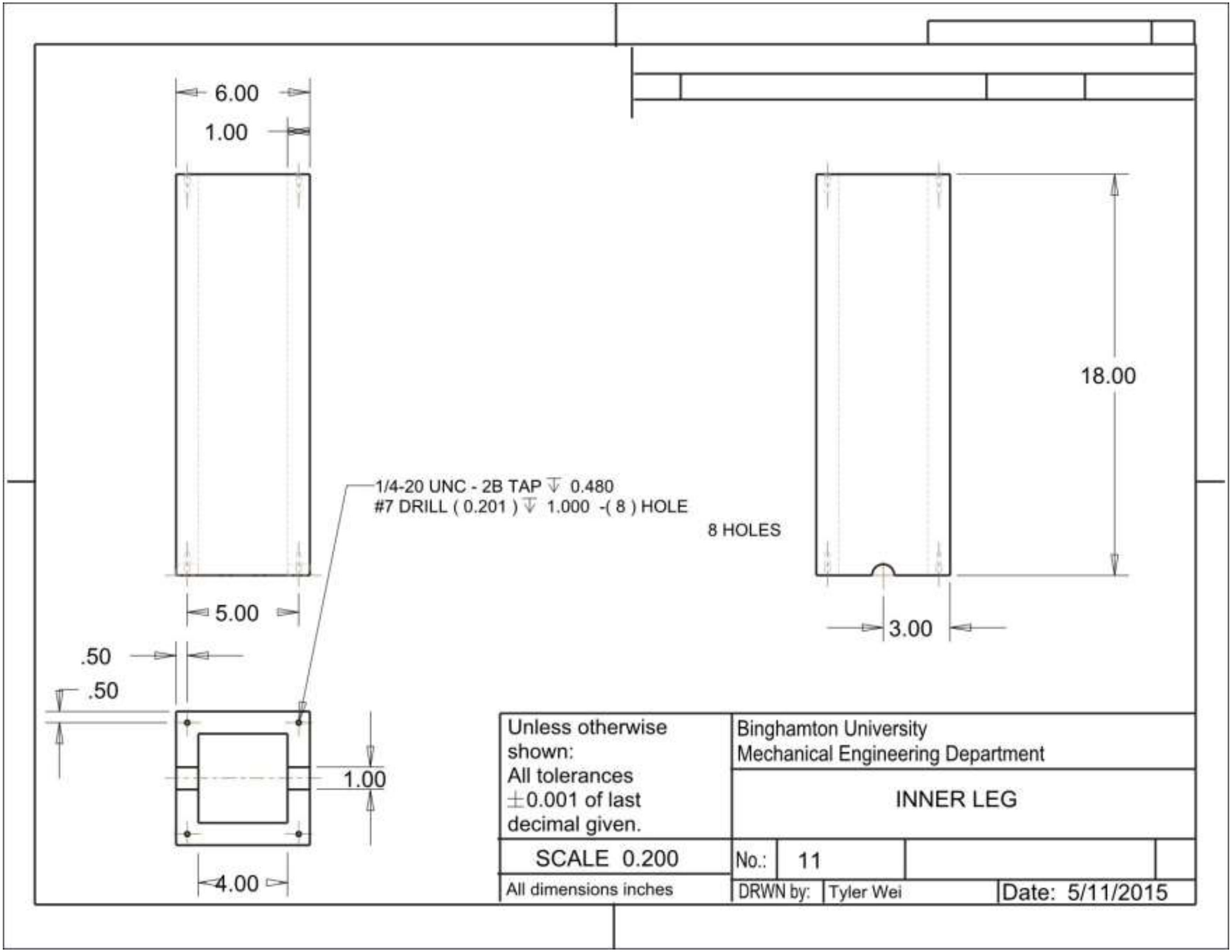
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18.00
3.00
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Binghamton University
Mechanical Engineering Department
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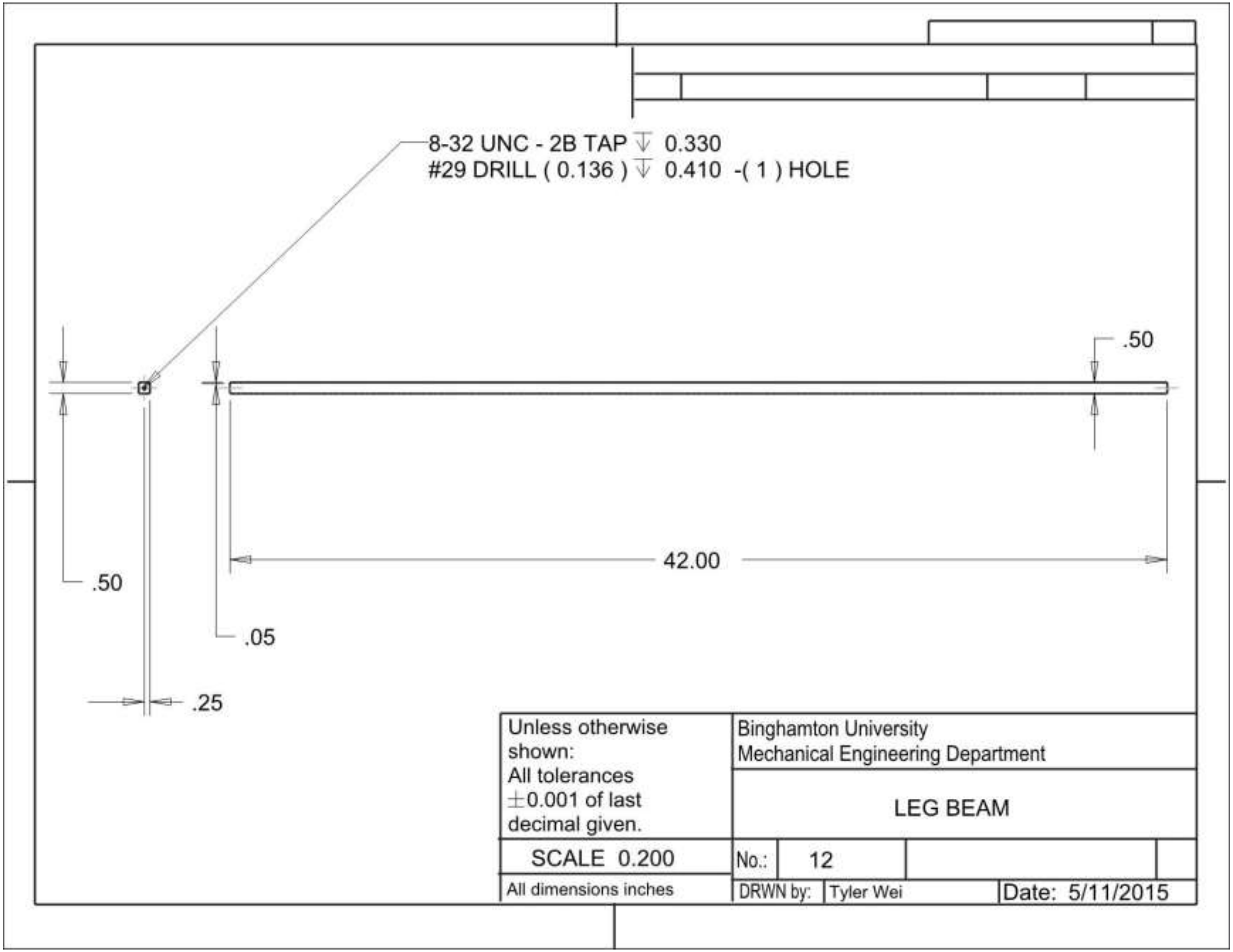
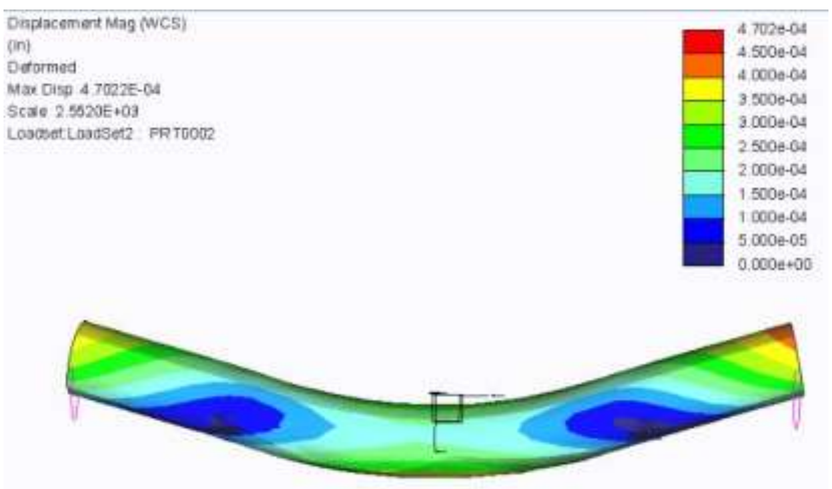
Date: 5/11/2015


8-32 UNC - 2B TAP ↧ 0.330
#29 DRILL (0.136) ↧ 0.410 -(1) HOLE
.50
.50
42.00
.05
.25
Unless otherwise shown:
All tolerances ±0.001 of last decimal given.
SCALE 0.200
All dimensions inches
Binghamton University
Mechanical Engineering Department
LEG BEAM
No.: 12
DRWN by: Tyler Wei
Date: 5/11/2015

Appendix III: Calculations

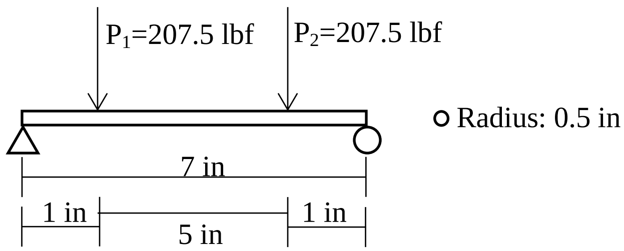
Verification

Despite the fact that Creo's FEA tool is a great way to determine the results of von Mises stress and deflection, ultimately it is a script which can simply spew numerical value. In order to verify and test the accuracy of the program, a sample hand calculation was performed and compared to the experimental value as shown below. A deflection analysis was performed on the steel leg pin used to support the upper table leg to the leg shell. For this, the distributed loads and reaction forces were approximated as point loads and reactions. The two external loads were 207.5 lbf each and based on the theory of superposition, the maximum deflection calculated was 0.000499 in. As shown in the Figure 4, the maximum displacement value was 0.00047 in, thus producing a percent error of 5.77% between Creo's FEA value and the hand calculated theoretical value.



Deflection for Leg Pin

Maximum Transverse Shear Stress



$$\tau = \frac{VQ}{It}$$

$$V = 207.5\ lbf$$

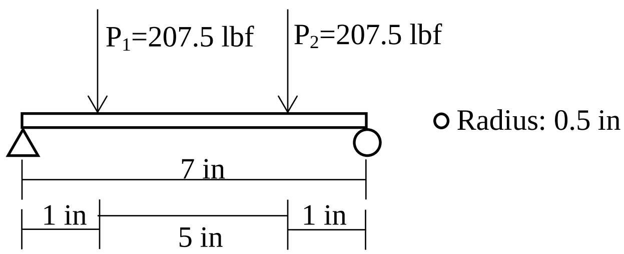
$$\tau_{avg} = \frac{207.5\ lbf}{(0.5\ in)^2} 12 = 12700\ psi$$

$$\tau_{max} = \frac{4}{3}\tau_{avg} = 16900\ psi = \mathbf{16.9\ ksi}$$

$$Creo\ FEA\ Value = 18654\ psi = \mathbf{18.7\ ksi}$$

$$\%\ Error = \left|\frac{theoretical - experimental}{theoretical}\right| \times 100 = \left|\frac{16.9\ in - 18.7\ in}{16.9\ in}\right| \times 100 = \mathbf{10.65}\ \%$$

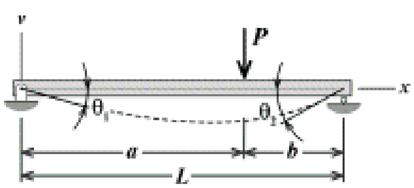
Beam Deflection



$$E = 29 \times 10^6 \; psi$$

$$I = \frac{\pi r^4}{4}$$

Method of Superposition:



$$v_{max} = \frac{-Pba}{6EIL}(L^2 - b^2 - a^2)$$

$$v_1 = \frac{-P_1 ba}{6EIL}(L^2 - b^2 - a^2) = \frac{-(-207.5 \; lbf)(6 \; in)(1 \; in)}{6(29 \times 10^6 \; psi)\left(\frac{\pi(0.5 \; in)^4}{4}\right)(7 \; in)}((7 \; in)^2 - (6 \; in)^2 - (1 \; in)^2) = 0.000249881 \; in$$

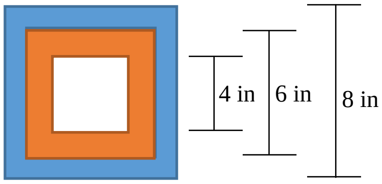
$$v_2 = \frac{-P_2 ba}{6EIL}(L^2 - b^2 - a^2) = \frac{-(-207.5 \; lbf)(1 \; in)(6 \; in)}{6(29 \times 10^6 \; psi)\left(\frac{\pi(0.5 \; in)^4}{4}\right)(7 \; in)}((7 \; in)^2 - (1 \; in)^2 - (6 \; in)^2) = 0.000249881 \; in$$

$$v_{max} = v_1 + v_2 = 0.000249881 \; in + 0.000249881 \; in = \mathbf{0.000499 \; in}$$

$$Creo \; FEA \; Value = \mathbf{0.0004702 \; in}$$

$$\% \; Error = \left|\frac{theoretical - experimental}{theoretical}\right| \times 100 = \left|\frac{0.000499 \; in - 0.0004702 \; in}{0.000499 \; in}\right| \times 100 = \mathbf{5.77} \; \%$$

Clearance Fit (Inner Leg to Leg Shell)



Class RC7 H9/d8 Free-Running Clearance Fit

Let d, d_i, and d_o represent middle square diagonal, inner square diagonal, and outer square diagonal respectively.

$$d_i = \sqrt{2(4in)^2} = 5.66\ in$$

$$d = D = \sqrt{2(6in)^2} = 8.49\ in$$

$$d_o = \sqrt{2(8in)^2} = 11.31\ in$$

$$\Delta_D = 0.0045\ in$$

$$\delta_d = -0.007\ in$$

$$\Delta_d = 0.0098\ in$$

Leg Shell (Sleeve)

$$D_{max} = D + \Delta_D = 8.49\ in + 0.0045\ in = \mathbf{8.4945\ in}$$

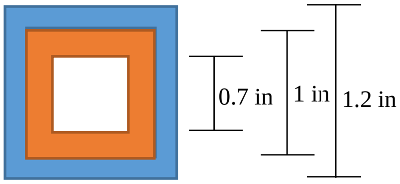
$$D_{min} = D = \mathbf{8.49\ in}$$

Inner Leg (Bushing)

$$d_{min} = d - \Delta_d = 8.49\ in - 0.0098\ in = \mathbf{8.4802\ in}$$

$$d_{max} = d + \delta_d = 8.49\ in - 0.007\ in = \mathbf{8.483\ in}$$

Clearance Fit (Pull Out Bar to Pull Out Shell)



Class RC7 H9/d8 Free-Running Clearance Fit

Let d, d_i, and d_o represent middle square diagonal, inner square diagonal, and outer square diagonal respectively.

$$d_i = \sqrt{2(0.7\ in)^2} = 0.990\ in$$

$$d = D = \sqrt{2(1\ in)^2} = 1.41\ in$$

$$d_o = \sqrt{2(1.2\ in)^2} = 1.70\ in$$

$$\Delta_D = 0.0025\ in$$

$$\delta_d = -0.003\ in$$

$$\Delta_d = 0.0046\ in$$

Leg Shell (Sleeve)

$$D_{max} = D + \Delta_D = 1.41\ in + 0.0025\ in = \mathbf{1.4125\ in}$$

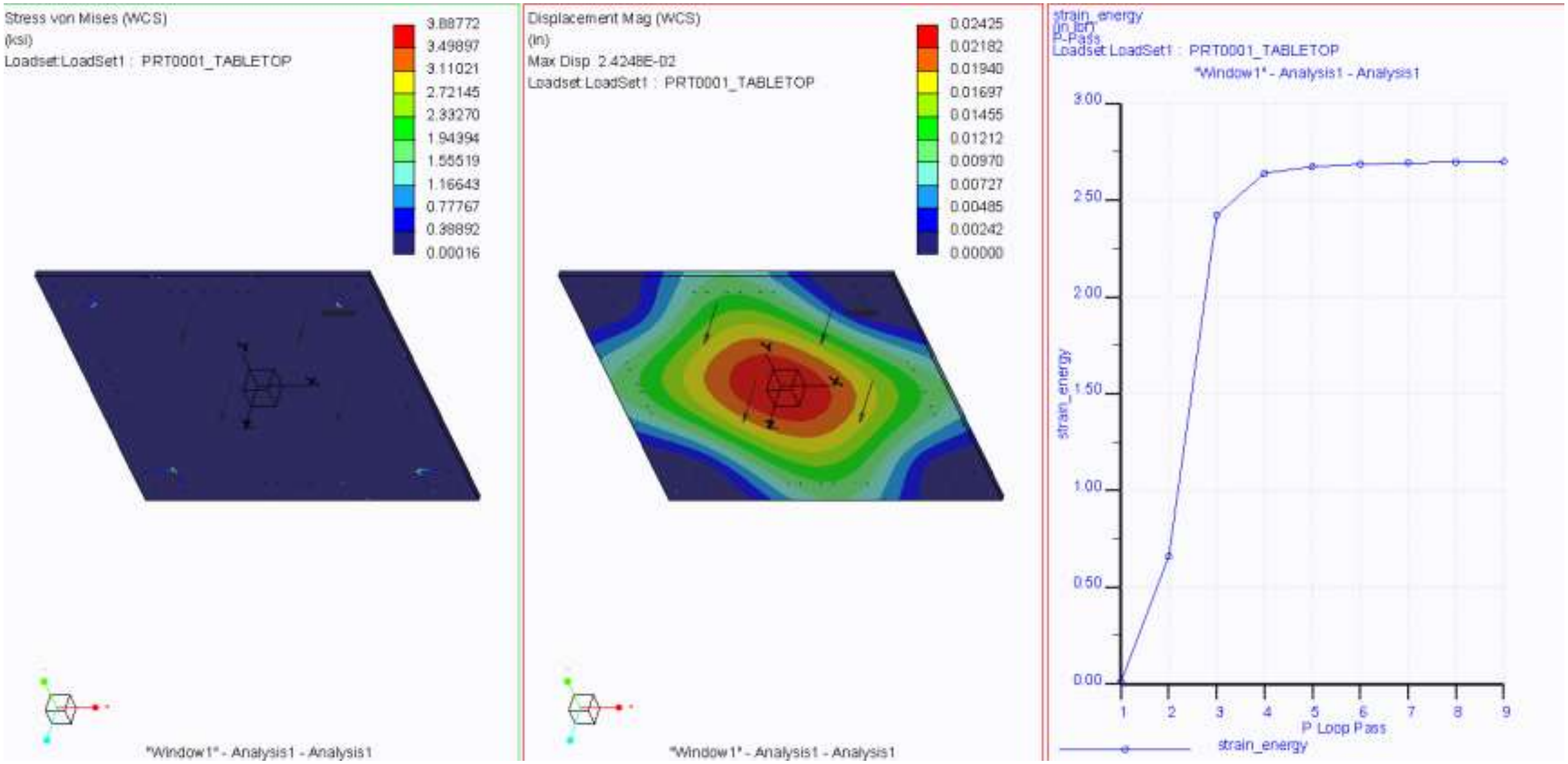
$$D_{min} = D = \mathbf{1.41\ in}$$

Inner Leg (Bushing)

$$d_{min} = d - \Delta_d = 1.41\ in - 0.0046\ in = \mathbf{1.4054\ in}$$

$$d_{max} = d + \delta_d = 1.41\ in - 0.003\ in = \mathbf{1.407\ in}$$

Appendix IV: Finite Element Analysis

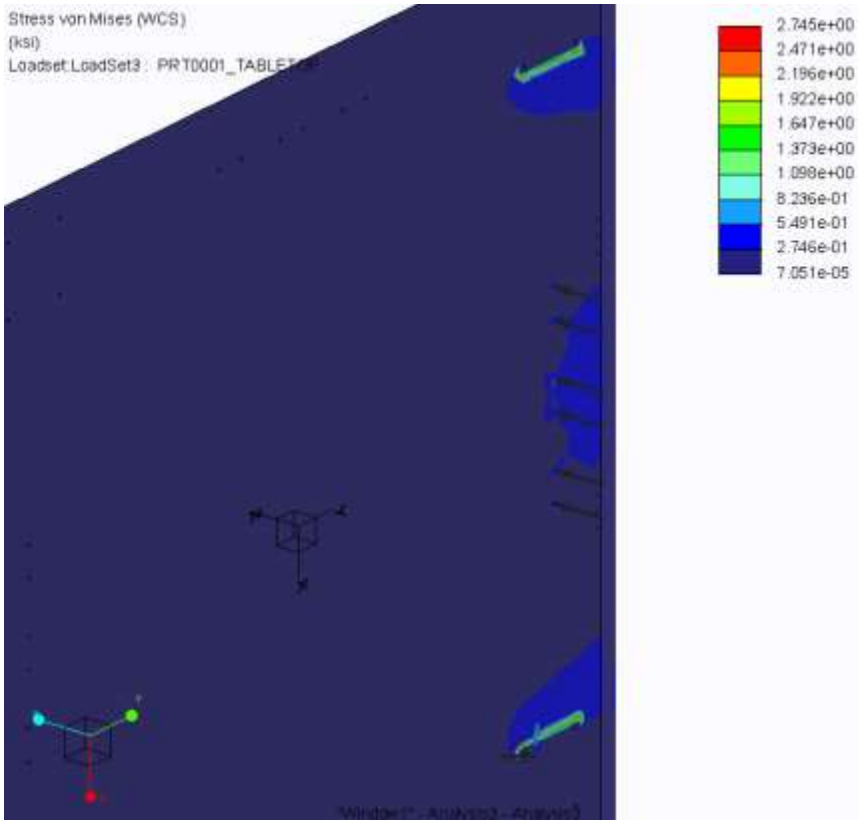


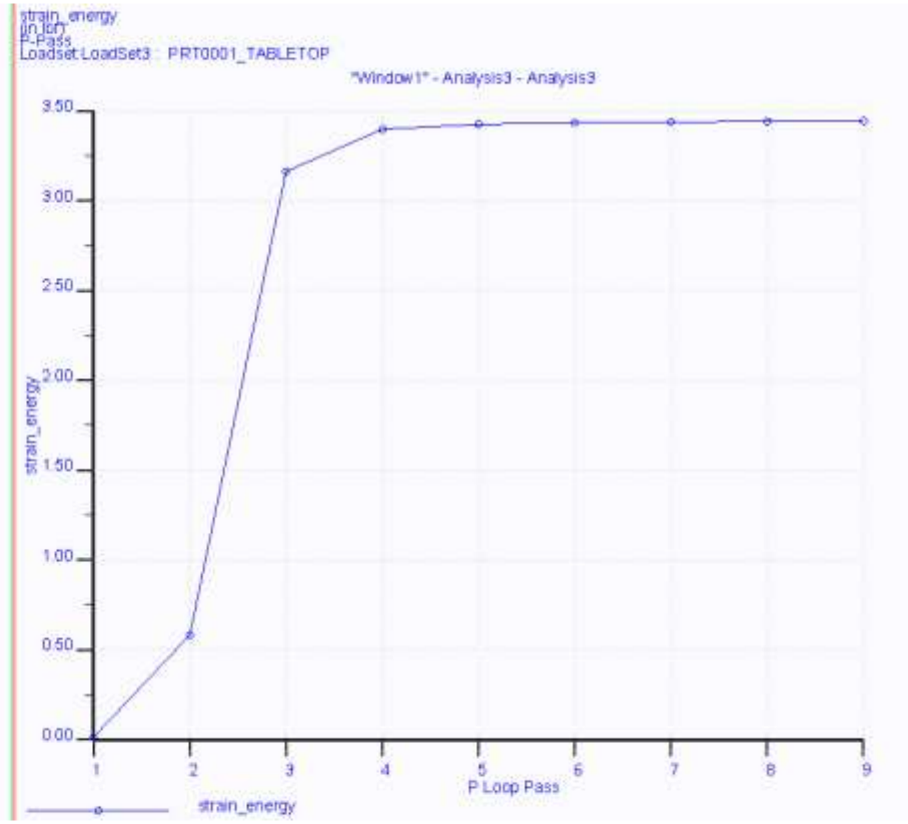
External Load: 500 lbf

Right: von Mises Stress Fringe Plot

Center: Displacement Fringe Plot

Left: Convergence Plot

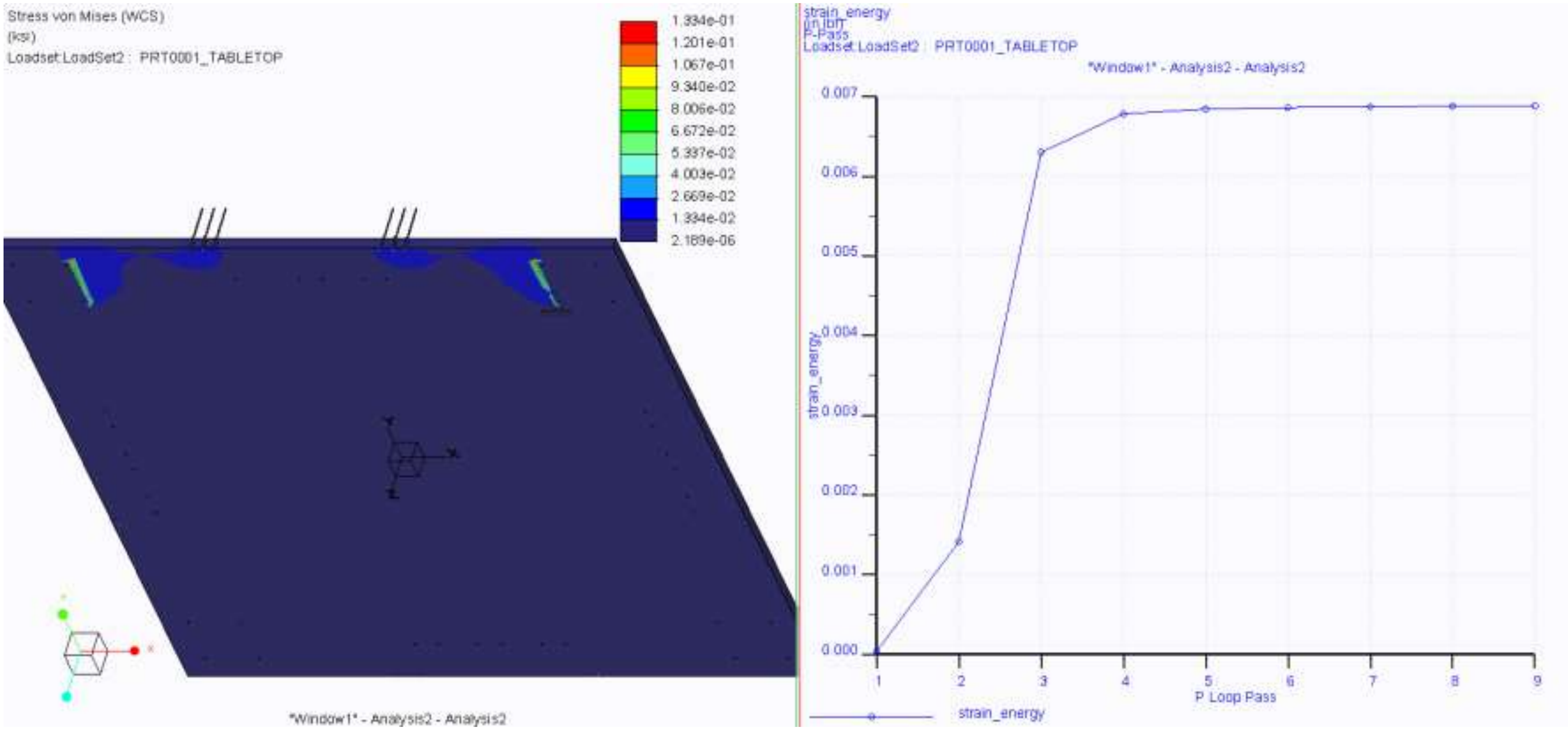




Shearing Force from Pull Out Shell Screws: 225 lbf

Right: von Mises Stress Fringe Plot

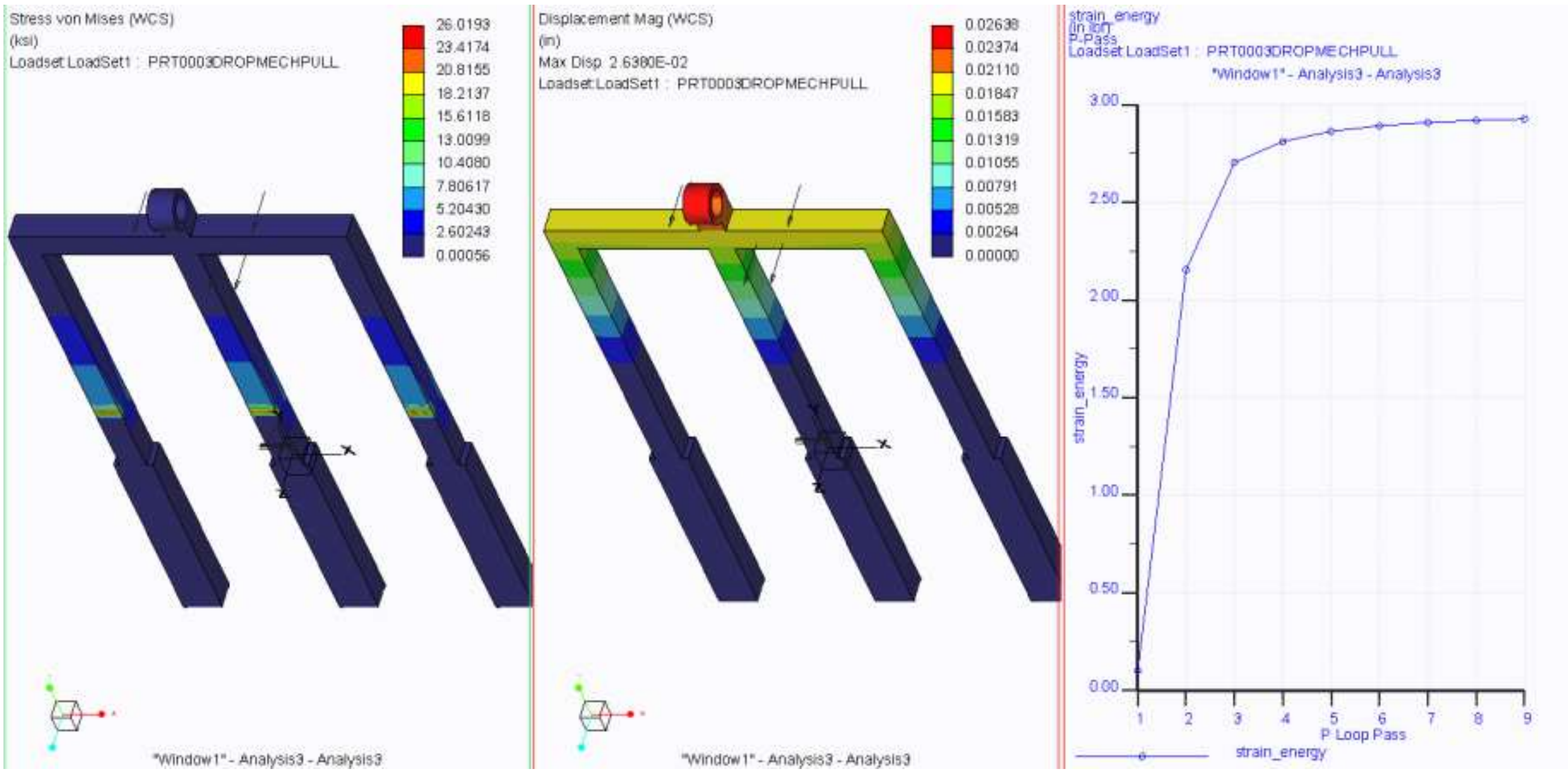
Left: Convergence Plot



Shearing Force from Hinge Screws: 12 lbf

Right: von Mises Stress Fringe Plot

Left: Convergence Plot

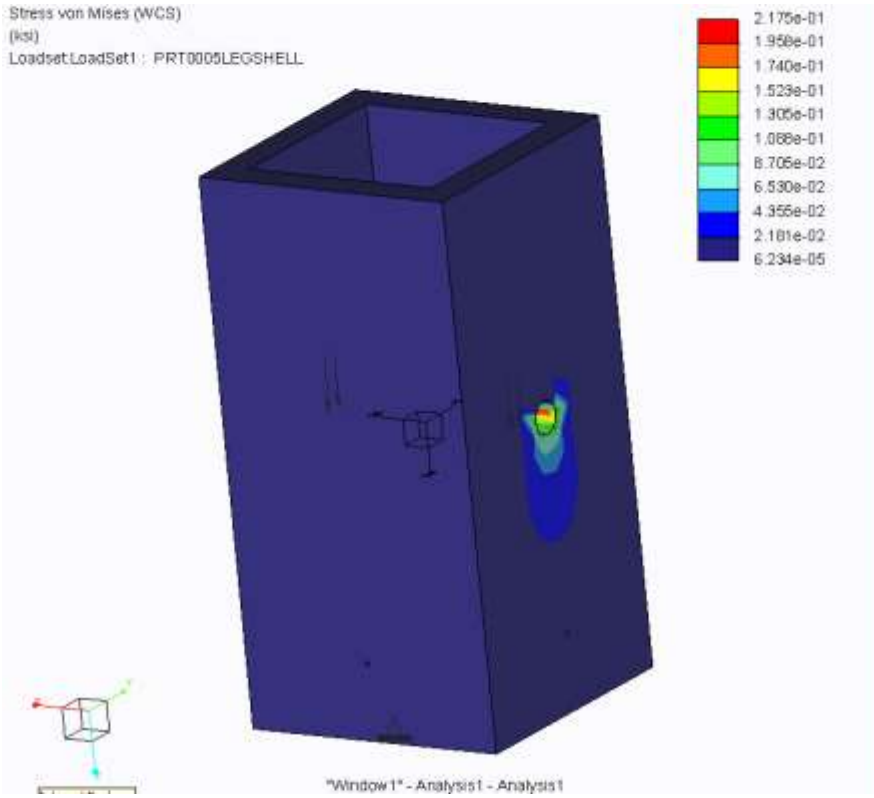


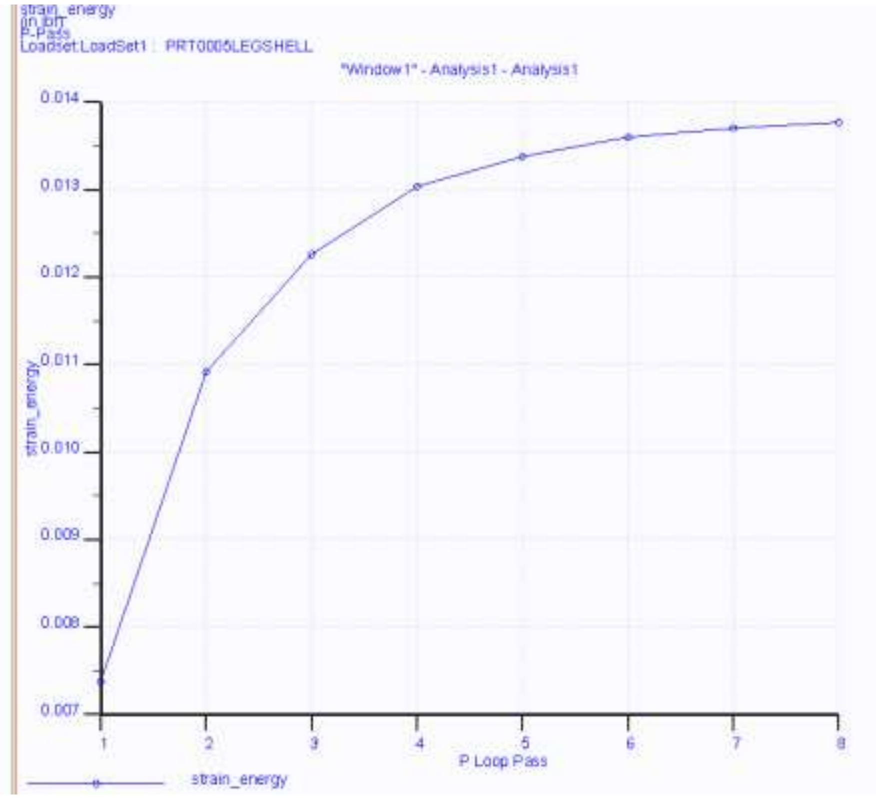
Load: 400 lbf

Right: von Mises Stress Fringe Plot

Center: Displacement Fringe Plot

Left: Convergence Plot

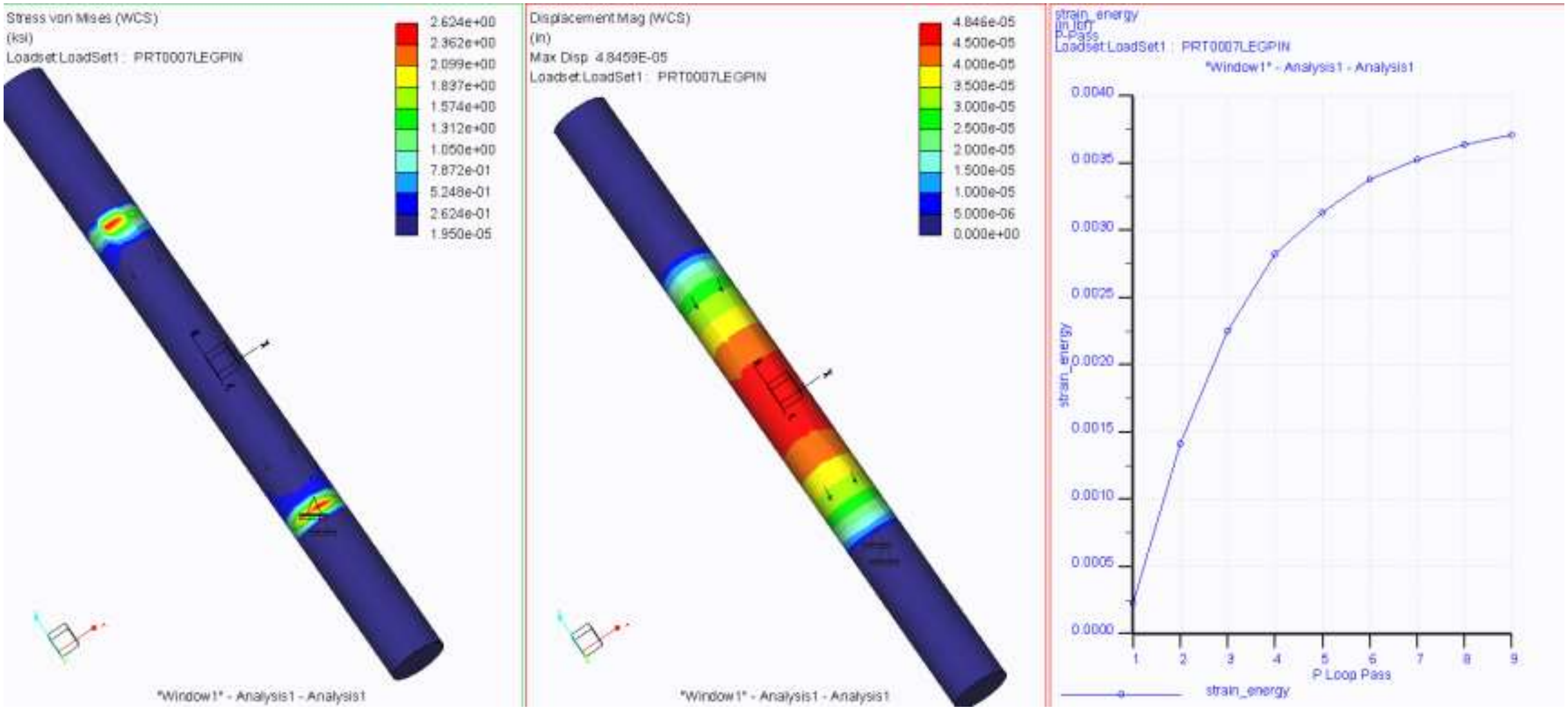




Load: 295 lbf

Right: von Mises Stress Fringe Plot

Left: Convergence Plot

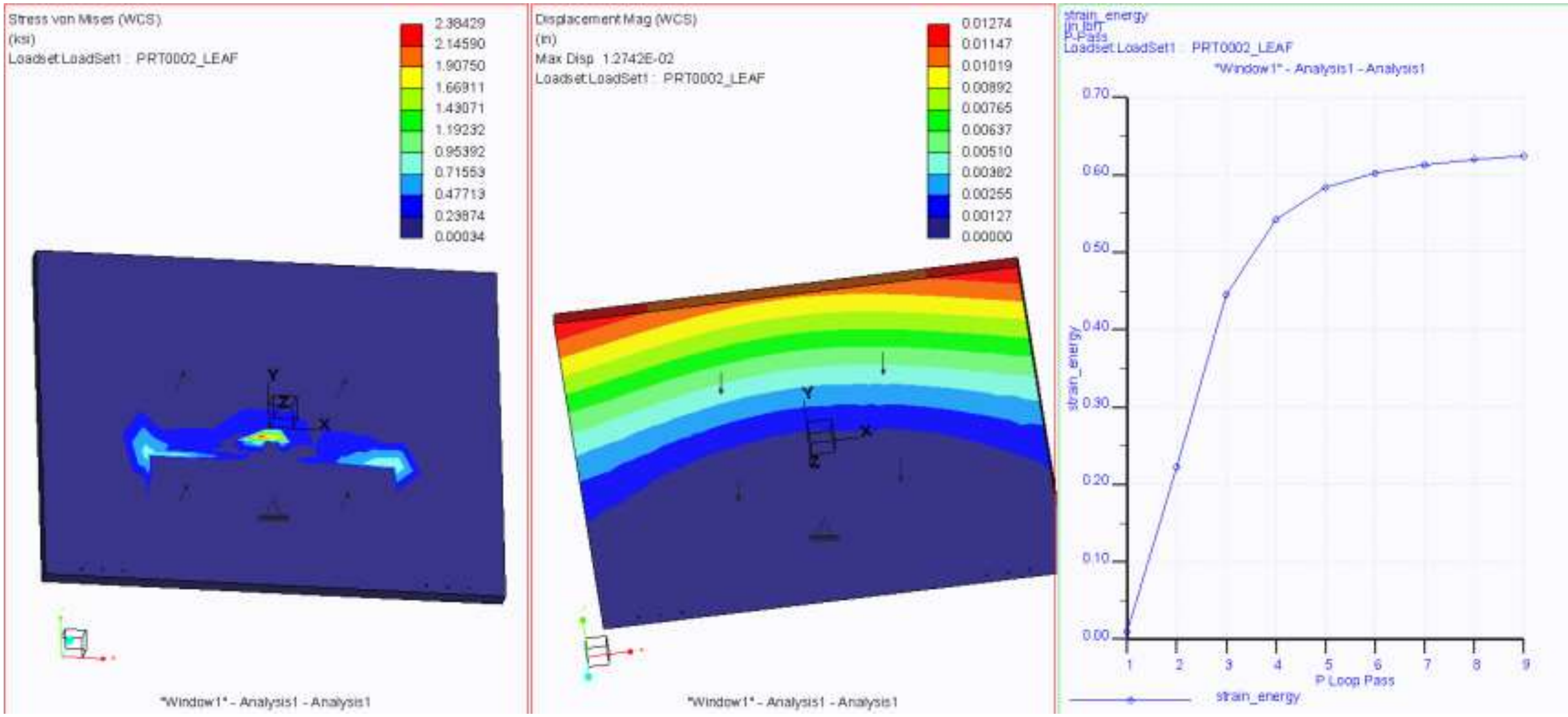


Load: 415 lbf

Right: von Mises Stress Fringe Plot

Center: Displacement Fringe Plot

Left: Convergence Plot

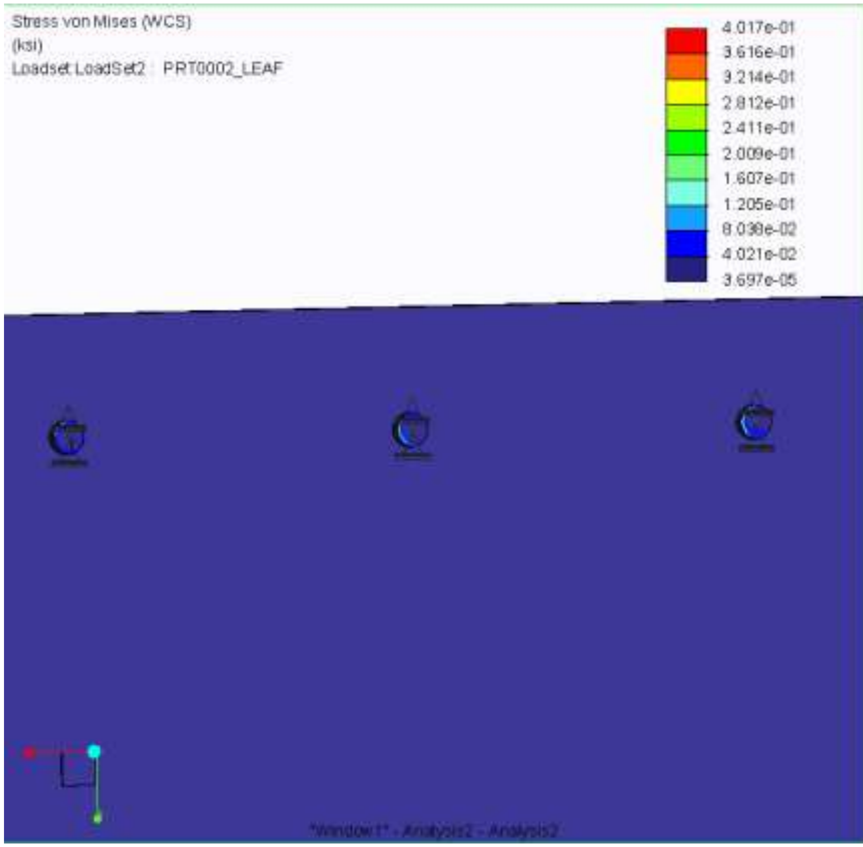


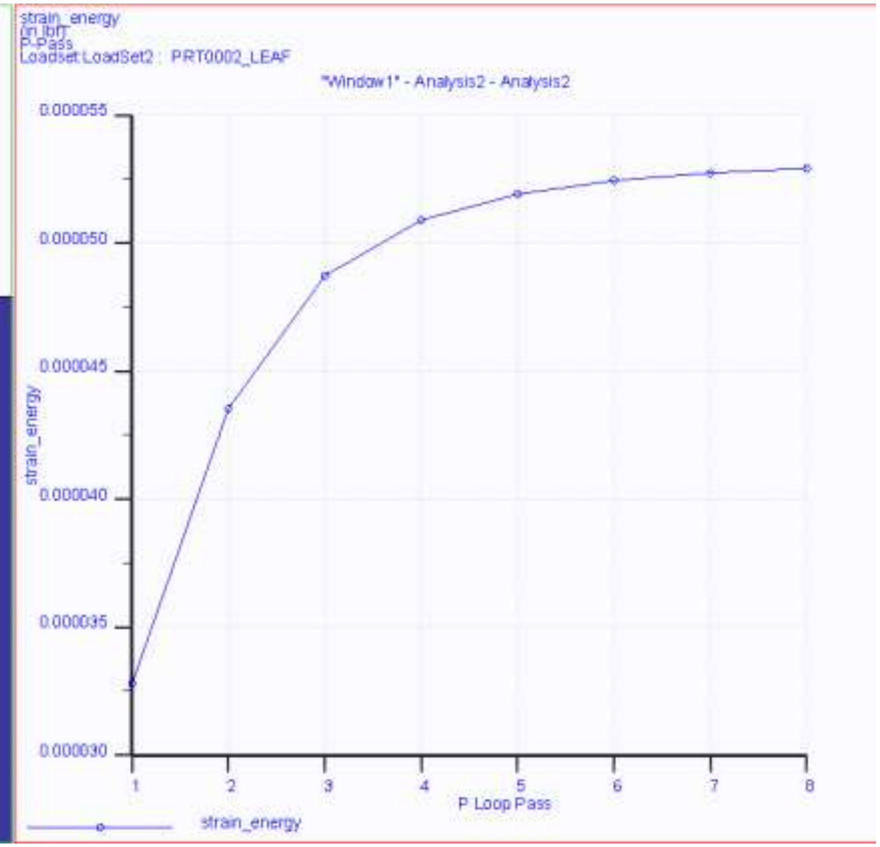
Load: 400 lbf

Right: von Mises Stress Fringe Plot

Center: Displacement Fringe Plot

Left: Convergence Plot

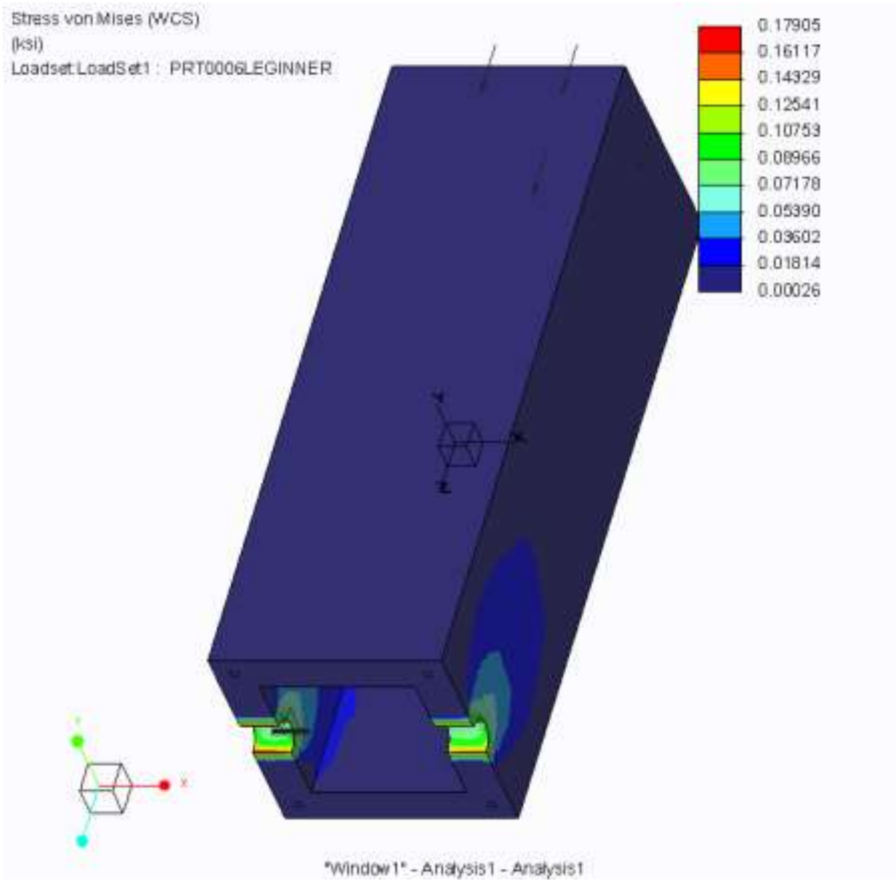


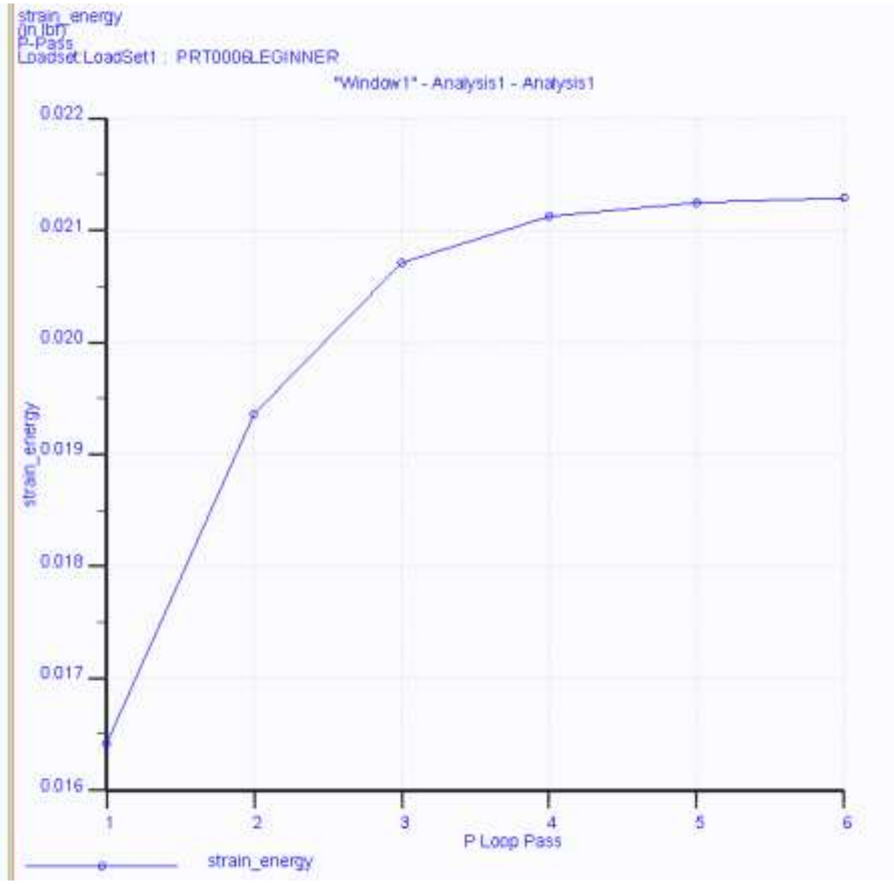


Shearing Force from Hinge Screws: 12 lbf

Right: von Mises Stress Fringe Plot

Left: Convergence Plot





Load: 255 lbf

Right: von Mises Stress Fringe Plot

Left: Convergence Plot