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Emulsion Pump Pressure Relief

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MET Senior Project

Emulsion Pump Pressure Relief

By:

Aaron Greear

Abstract

Over time the harsh outdoor environment wears away at asphalt surfaces. Asphalt emulsion is sprayed onto the surface to act as a sacrificial barrier. To pump this asphalt emulsion for spray application an effective pressure relief device must be incorporated. High pressure is needed to achieve the desired spray pattern, but this same pressure can cause components to fail in the presence of a pressure spike. Hydraulically driven positive displacement pumps are used to pump the emulsion, so a pinched hoses or a clog in the system results in a severe pressure spike. Due to the emulsions viscosity and abrasive additives a direct relief device is not suitable for long term service. A remote activated pressure relief device is needed to allow adequate spray pressure and prevent system failure. The device is manufactured with off the shelf hydraulic and pneumatic parts bolted to a steel base plate. A pilot pressure is taken from the emulsion circuit and feeds a pneumatic cylinder that pulls a linearly actuated hydraulic valve, in turn diverting the hydraulic flow to the reservoir instead of driving the pump. The pull of the cylinder is balanced by an adjustable spring to allow for different pressure settings. After installing the pressure relief device pressure was be measured at different locations throughout the system. The emulsion pressure relief device performed an as engineered and the pressure remained between 50 and 90 psi.

Table of Contents:

INTRODUCTION

Motivation:

This project stems from the need for an effective pressure relief system bridging two fluid circuits. One circuit is an asphalt emulsion pump system, and the other is the hydraulic power system. One of the thing my job requires is to build and maintain equipment. The company is Central Sealcoat, and the device I'm building will be for the emulsion pump on a truck. In its original design the pump requires 2 people to operate, 1 controlling the pump and 1 operating the dispensing hose. With an effective pressure relief system the pump could be turned on and operated by a single person. The emulsion consists of asphalt, emulsified with water by use of detergents. Sand, clay, and fiber are then added to the emulsion to add strength once dried. The emulsion is a difficult material to pump as it varies in viscosity dependent on water concentration, the sand additive is abrasive, and solids settle out of suspension causing clogs. The pump used to pump the emulsion is a Bowie brand, positive displacement gear pump driven by a hydraulic motor. Due to the nature of the emulsion material a direct pressure relief device is not commercially available or practical. In its original design the pump system requires 2 people to operate, one controlling the hydraulic motor driving the pump and one operating the dispensing hose. With a pressure relief system the pump could actuated, and operated safely and efficiently by a single person.

Function Statement:

The pressure relief system must receive a pilot pressure from the pressure side of the emulsion pump. This pilot pressure will be used to operate a hydraulic relief valve to slow/stop the emulsion pump through the driving motor's hydraulic circuit once set pressure is reached.

Requirements:

The system must conform to these requirements.

- Maintain consist pressure +/- 5 psi across varying hydraulic and emulsion viscosities
- Maintain a minimum of 50 psi at end of discharge hose
- Relief pressure must adjust +/- 20 psi from target of 50psi
- Completely separate emulsion from pressure relief device
- Continue to operate for 3 months without maintenance
- Cannot hinder existing systems ability to operate independently
- Allow pump to maintain and flow rate of 10 GPM

Success Criteria

When the pump is activated and emulsion discharge is closed, the hydraulic motor will slow or shut off to maintain 50 psi in the emulsion circuit. When the discharge is open the emulsion pump must reactivate and run at full volume until the discharge is closed agian.

Scope:

The main focus of this project will be the device that uses the pilot pressure from the emulsion circuit to control a hydraulic valve. The pressure column, valve bracket, and plumbing will be the main objects being engineered and constructed. Component's such as the pneumatic cylinder, hydraulic valve, hoses, and return springs will be purchased based of calculated specifications.

DESIGN & ANALYSIS

Approach:

The pilot pressure signal could be transmitted through fluid, air, or electronically. Through fluid would be the easiest, electronically would be the simplest, but pneumatically seems to pose the least overwhelming design obstacles. Most fluids would be soluble with the emulsion because the emulsion consists of both water and oil. A piston apparatus could be used to separate the two fluids but the sand would wear at the seals and bore over time. An electronic system would not be compatible with the existing hydraulic components, resulting in a costly system remake, taking more time and resources. By using air as the media of transfer there will be no contamination with the emulsion. A simple column will be used to keep the two media separated. Gravity will keep the fluid at the bottom, and because it's a closed system, it will hold pressure and stop the emulsion from filling the column. Using a pneumatic system has a unique advantage as a surge control device. The added air will compress with raising pressures, buffering the pump surges.

Description:

Since the emulsion and air are in direct contact, the air pressure delivered to the cylinder will directly reflect the pressure in the emulsion system. This pressure will be fed to a pneumatic cylinder that pulls a linearly actuated hydraulic valve, in turn diverting the hydraulic flow to the reservoir instead of driving the pump. Because of the difficulty involved in finding the perfectly matched pneumatic cylinder for the desired pressure, an adjustment spring will be used to resist the cylinder (schematic 1 Appendix B). The spring will be tensioned using the threads of a bolt to move it linearly through a stationary nut.

Due to the emulsions high viscosity there will be a considerable loss of pressure through the 50 foot length of 1" hose. The target pressure to shut the pump off must account for the loss of pressure do to viscosity.

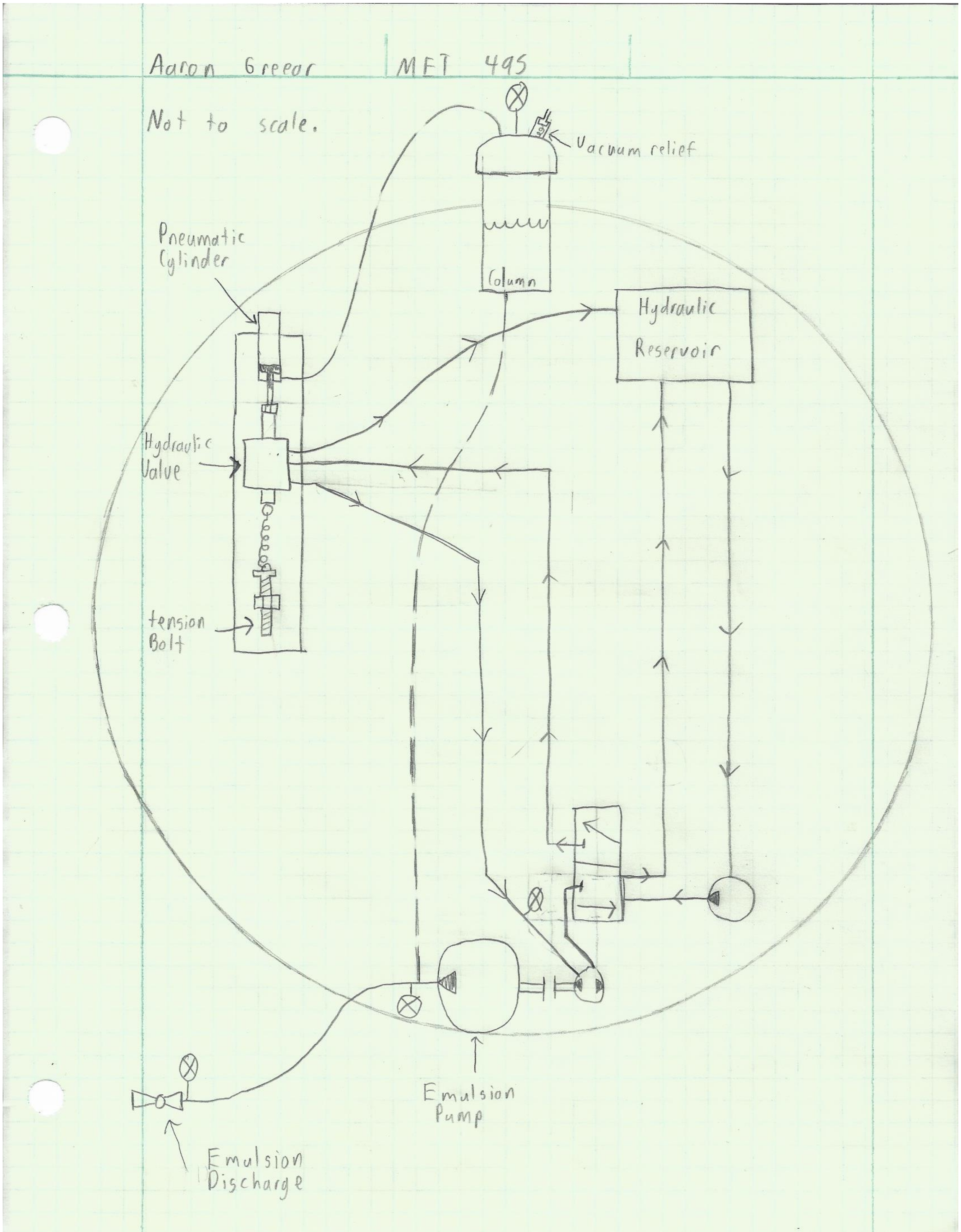


Figure 1 (schematic of emulsion, hydraulic, and pneumatic systems)

Benchmark:

The goal is to have the emulsion pumping system work as good, or better than others in the industry. Most pump systems in the emulsion industry use diaphragm pumps. Diaphragm pumps are ideal for the application because the pneumatic pressure applied to the diaphragm is easily controlled and the pressures are directly correlated. Pressure air in = pressure emulsion out. The downside is a large surge created that diaphragm pumps cause with each stroke. They also have a very low displacement and corresponding flow rate. A Bowie pump, like the one for this system, has a high volume output and a smooth flow. A Bowie pump with the consistent pressure of a diaphragm pump would be ideal and is the benchmark for this design.

Performance Predictions:

Once complete the pressure relief device will be tested. The device should slow or disable the hydraulic pump driving the emulsion pump once the emulsion has reached a pressure of 99 psi (Appendix A, 6).

Engineering Merit:

A large part of this system involves different local pressures throughout the system. With the calculated using $P=\frac{F}{A}$ equations. A pressure drop calculation $\Delta P = f * \frac{L}{D} * \frac{\rho V^2}{2}$ [1] for the loss in the discharge hose and two 90º fittings. To do the pessure drop equations kinematic viscosity must be found using dynamic viscosity and density with $V= \frac{\mu}{\rho}$. Hooke's law, F=kX, will be used when optimizing the spring rate to counteract the cylinder. A simplified version of the ideal gas law will be used to determine the size of the air column. Start and finish pressures are known as well as minimum end volume. Using PV=PV the required initial volume can be found (Appendix A, 5)

Optimization:

In regards to the proposed pneumatic system design most components being constructed will be done with a safety factor of 2. This ensures the system will function and adjustments can be made once operation is insured.

Once the system is operationally components can be downsized and the safety factor can be lowered.

The pressure relief device will be operational for a set amount of time based on the rate at which air leaks from the system. The size of the column will be adjusted to accommodate the loss of air through leaks. After testing, it was found that none of the individual component leak a measurable amount in a 10 minute span, which is the max time the pump should remain on. Once the pump is shut off a vacuum relief valve in the top of the column will allow the emulsion level in the column to lower, resetting the system.

If there is an issue with excessive leakage from the pneumatic cylinder, a higher viscosity oil should be used to better seal the piston. An issue could also arise concerning system oscillation, where the pressure spikes and drops due to static friction on the system delaying valve actuation. This would call for a dampening system or a different hydraulic valve that will meter flow more effectively.

The hydraulic selector valve is designed to function in and on off fashion. A type of metering valve is desired, but nothing is commercially available that has a linear actuation. A flow control valve would idea, but it's 90 degree radial actuation would need to be adapted to the pneumatic cylinders linear actuation.

During testing if the Bowie pump is unable to create sufficient pressure shims must be removed to tighten up the tolerances in the pump, allowing less pump leakage and higher overall efficiency. This can be done to a point where internal friction seizes the pump.

Analysis:

The required pressure of 50 psi for the emulsion pump is measured at the end of the discharge hose. This pressure is required when the fluid is flowing, so there is a pressure drop between the pump and the end of the discharge hose that must be accounted for. The pressure drop attributed to fluid friction will be approximately 46 psi (Appendix A, 4). The pressure drop is considered approximate because is based on the manufacturer spec for the fluid viscosity which can change with water concentration [4]. The pressure drop from 60 feet of hose and two 90º bends is added to 50 psi to get 96 psi required at the pump output. This value is used to determine the amount of spring tension resisting the pneumatic cylinder. The static pressure of 3.15 psi from the emulsion in the tank will be used as well (Appendix A, 2). The fluid column will be located at the top of the tank so the static pressure will be counteracting the pilot pressure whenever the tank is anything but full. In order to maintain a minimum of 50 psi at the discharge hose there must be 99.15 psi at the emulsion pump output.

In order to keep the emulsion from ever getting into the air system the max compression of the gas in the system must be found. If the emulsion tank is full, the air column must have a certain volume above the emulsion tank so that it will not completely fill with emulsion once the system is pressurized. The volume above the emulsion tank must be proportional to the volume of air occupying the pneumatic lines plus the volume inside the pneumatic cylinder. The volume required with a safety factor of 2 is 53.8 in^3. This equates to a 17.1" tall 2" diameter column, or a 7.6" tall 3" diameter column (Appendix A, 5). Due to the existing height of the truck and emulsion tank a 3" column diameter will be used to keep overall truck height to a minimum. The 7.6" is height above the emulsion tank required. An overall length of 16" will be used so it can be secured on the part below the top of the tank.

Failure Analysis:

The device can fail in two main ways. First it could jam in the relief position, not allowing the pump to turn on. This failure is a setback, but in no way a serious risk to the system or its operators. The second is if the system were to jam in the power position causing the pressure to rise to the pumps limit. The first thing to fail in the pump pressure circuit will be the 1” flex hose at its rated burst pressure of 130 psi [3]. This is dangerous

Methods and Construction:

Description:

Most of the project will be designed and constructed at Central Sealcoat’s shop. Some of the machine work on the valve bracket will be done at the CWU machine shop. There is no set budget, but smaller and cheaper would be in the company’s interest. First the column will be built, followed by the valve assembly, then the final assembly will be constructed.

Parts List:

The full list of parts is located in appendix E. Most components were already acquired before the conception of this project due to their generality and other uses inside the company. The remaining parts were purchase from the Surplus Center, McMaster-Carr, and Irrigation Sales.

Drawing Tree:

The drawing tree is a visual representation of how the system will be constructed and can be found in appendix C. At the bottom in red boxes are the components and raw material I will start with. As you go up sub assembly are created and at the very top is the final assembly.

Process:

Pressure column construction

- 3” Schedule 40 PVC pipe will be used due to its high pressure rating and thick walls that allow it to be easily drilled and tapped for pipe thread. Cast Iron could be used, but would be more expensive and harder to drill/tap. Copper is another possibility, but would be even more expensive and would require soldering threaded bungs in place. Schedule 40 PVC is rated at 240 psi and the system should never reach a pressure higher than 150.
- The column will have a 1” NPT port on the bottom that will plumed to the output of the emulsion pump using PVC flex line and barb fittings. There is already a 1” line on the emulsion tank that can be directly connected to the column.
- On the top of the column there will be a cap has 2 holes drilled and tapped to 1/4“ NPT. One will have a vacuum relief valve and the other a push fitting for the pneumatic pilot pressure.

- The column will be mounted at the top of the emulsion tank using zip ties to secure it to existing structure.

Adapting hydraulic valve

- One end of shaft will get a ¼-28 nut welded on it to accommodate the threads on the pneumatic cylinder shaft
- Opposing end of shaft will have a 3/8-16 nut welded on where an I-bolt will be inserted for connecting the tension spring.

Valve Bracket construction

- The three components, cylinder/valve/spring will be mounted linearly on a base plate of 1”x3” tube.
- A PVC sleeve will be used to secure the cylinder in relation to the valve. This minimizes the possible side loading that could occur from hard mounting the cylinder in a misaligned state.
- Holes will be drilled in the base plate to match the ones in the valve. ¼” bolts will secure the valve to the base and will be countersunk so the base plate can be flush mounted.
- A ½” x 20 nut will be welded to the baseplate for tensioning bolt
- Tensioning bolt will have a hook welded on its head for the spring to attach.

Assembly:

The valve bracket will be mounded on the back cap of the emulsion tank so that is easily visible and accessible. The pneumatic cylinder will be connected to the top of the pressure column with ¼” polyethylene tubing. The hydraulic valve will be spliced into the pressure line for the hydraulic motor and hydraulic system reservoir. Lastly the column will be connected to the pressurized emulsion circuit. With all connections tight and leak free testing can begin.

Testing Method

Introduction:

The pressure relief system was tested with water being pumped instead of emulsion. Water is a much cleaner and more consistent media to test the relief system. However, water is less viscous than the emulsion so overall pressure will be lower. A target of 40 psi minimum will be used for the water. Testing begins with pressure analysis. Pressure gauges are placed at the output of the Bowie pump, top of the air column, end of the transfer hose, and in the hydraulic motor circuit. These pressure gauge readings serve as a basis for optimization. Testing went as scheduled Longevity and performance testing will be performed in the summer of 2015.

Method:

First the emulsion tank is filled with 500 gallons of water. The gauge at the top of the column, output of the pump, and end of the hose are redundant for the static system, but should read different once fluid is flowing and dynamic pressure is being measured. Because water is a different viscosity the values will have to be adjusted. The precision of these pressure readings is good with the style pressure gauges I am using. Accuracy could be slightly off, but all the gauges were tested relative to each other to ensure accuracy. It is important to analyze the hydraulic system pressure when the fluid is cold and hot because the pressure relief system should operate steadily over these ranges.

Test Procedure:

The device will be tested as follows. Pressure readings will be taken as an average over a 30 second duration. Test will be conducted in my field.

1. With motor and pump off, take pressure readings from all 4 gauges to calibrate zero
2. Turn on hydraulic pump and take cold hydraulic pressure readings
3. Activate bowie pump with discharge open and record pressures
4. Shut discharge hose valve and record pressures
5. Tension spring to raise pressure or loosen it to lower pressure to reach target pressure
6. Repeat steps 2-6 until target pressure is reached
7. Repeat steps 2-6 for warm hydraulic fluid pressure readings

Deliverables:

The test gave a maximum pressure of 75 psi and minimum pressure of 30 psi. The goal for the device was a minimum of 50 psi, which is easily within reach once emulsion is being pumped.

Budget/Schedule/Project Management

Cost:

A comprehensive budget can be found in appendix D. Most of the system components used have multiple applications throughout the company. Parts like ½” hydraulic hoses, pressure gauges, and PVC pipe are readily available through the company. The other parts are being purchase from outlets like Surpluscenter and Mcmaster-Carr. These sources were chosen due to their comparatively low cost and the specifications for the parts listed online. To calculate the cost of some items a relative equivalent was found on the market and used for cost analysis. Parts that have been purchase for the first design add up to $178.18. Roughly half the budget comes solely from the hydraulic valve and hoses.

Schedule:

The comprehensive schedule can be found in appendix F. A Gantt chart was used was used to provide an extensive visual display of how the project will progress. The green squares represent the planned time on task. A planed total of 127.6 hours was estimated to complete the project. So far 83.9 hours have been spent, which is slightly more than planned to get this far in the project. The project search began on 9/22/14 and a project was decided upon on 9/25/14. The Proposal was completed on 12/1/14. Device must be fully constructed by 3/17/15. The project will end on 6/15/15 following the completion of a final report and presentation including final data on project testing.

Project Management:

One person will be in charge the entirety of this project and will see it to completion. Material resources are readily available through the sponsoring company as well as financial backing. A comprehensive budget assures that the final device will cost around 180 dollars, well below the 500 initially estimated.

Risk:

The conception of this design was to lower the risk involved with the emulsion pump. With pressures in the pump circuit approaching 100 psi a blowout could occur spraying asphalt emulsion at high pressure onto surrounding occupants. With this pressure relief system it will be assumed a blowout will not occur whilst the system is operating correctly. That being staid the system must always operate correctly and not add any risk to the existing system.

Discussion

The first time the valve assembly was constructed there were many deviations from the initial design. First of all the 2” base plate that was designated in the initial drawing was too small to adequately support the valve. A wider support was needed. A 1x3 piece of rectangular tubing was substituted because it was wider and allowed the bolts securing the valve to be countersunk enough for flush surface mounting. Secondly the height of the tensioning bolt did not correspond to the height of the valve shaft. The bolt needed to be raised in order to pull on the same axis of the valve shaft. To accomplish this, a second bolt was added to adjust the tension nut vertically. The tension spring can now be moved in axis. Lastly the wrong surface area was used during calculations to find the pulling force for the cylinder. The surface area of .31 was used instead of the 1.62 for the cylinder. The force required to counter act the cylinder would have been much greater and would cause the valve to shut off at a much lower pressure. During initial pressure testing the valve actuated at 20 psi and shut off at 25 psi. A smaller cylinder is being subsided to remedy this mistake. A stiffer spring could have been used, but that would have added more force and a higher chance of component failure. The initial calculations were for a 5/8 diameter cylinder, and after further consideration a ¾” bore will be used. This was choosing based off a balance between keeping a lower spring tension and still having enough force to overcome the valves resistance.

Conclusion

The emulsion pressure relief device was a relative success because it did not allow the pressure to exceed the max for the system. When pumping water through the circuit the max pressure could be adjusted between 50-70 psi with a minimum pressure between 25-50 psi. During testing operations the column was able to keep the emulsion circuit and pneumatic circuit from cross contaminating. The pressure also remained steady across varying hydraulic fluid temperatures and consistencies.

The only criteria the device did not reach was being able to hold a consistent minimum pressure. This is due to an innate flaw in the hydraulic valve I use. There comes a state of hydraulic deadlock where the valve will bind in the middle. This leaves the emulsion pump at a pressure of 30-50 psi. After further investigation this same binding occurs in the flow control valve as well as the motor spool valve, preventing me from using the same cylinder/spring concept on one of those valves.

Acknowledgments

Thanks to Central Sealcoat the problem that started this project and for financial backing. If it wasn't for them this project would not exist. Thanks also to the CWU staff, especially Ted Bramble, Roger Beardsley, and Patrick Hanson for sharing his knowledge of hydraulic and pneumatic systems.

References

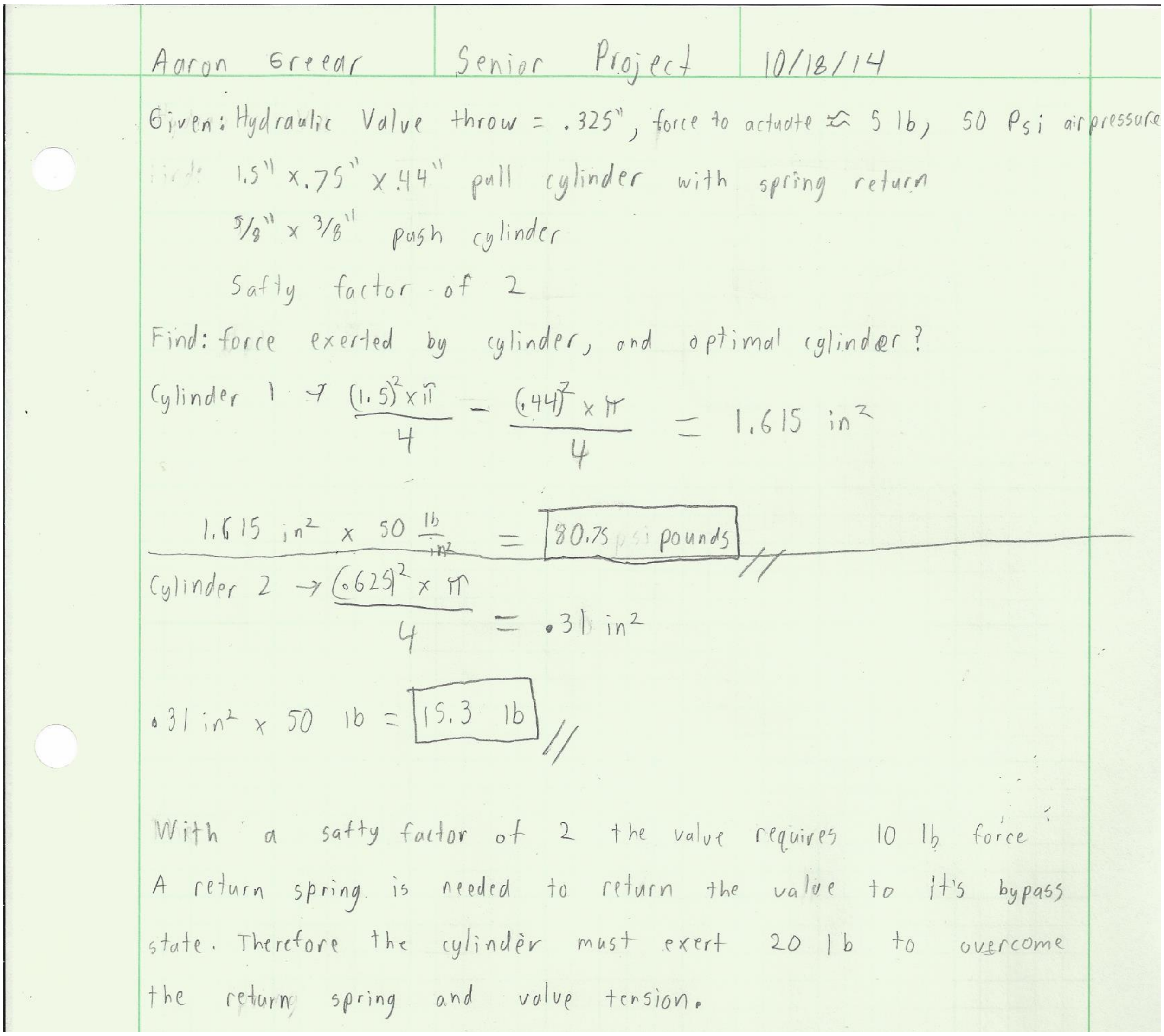
[1] Esposito, Anthony. *Fluid Power with Applications*. 7th ed. 11th Nov 2014

[2] "Ideal Gas Law." Wikipedia. Wikimedia Foundation, n.d. Web. 03 Feb. 2015.

[3] "Nylobrade® Braid Reinforced Clear PVC Tubing - NSF Certified Clear PVC Hose - NSF 51 Hose and NSF 61 Hose - DEHP Free." Nylobrade® Braid Reinforced Clear PVC Tubing - NSF Certified Clear PVC Hose - NSF 51 Hose and NSF 61 Hose - DEHP Free. N.p., n.d. Web. 09 Feb. 2015.

[4] Jensen, Chris. 3 Dec. 2014. Cascade Asphalt

APPENDIX A – Analysis



Aaron Greear | Senior Project | 10/18/14

Given: Hydraulic Valve throw = .325", force to actuate ≈ 5 lb, 50 Psi air pressure
1.5" x .75" x .44" pull cylinder with spring return
5/8" x 3/8" push cylinder
Safty factor of 2

Find: force exerted by cylinder, and optimal cylinder?

Cylinder 1 → $\frac{(1.5)^2 \times \pi}{4} - \frac{(.44)^2 \times \pi}{4} = 1.615 \text{ in}^2$

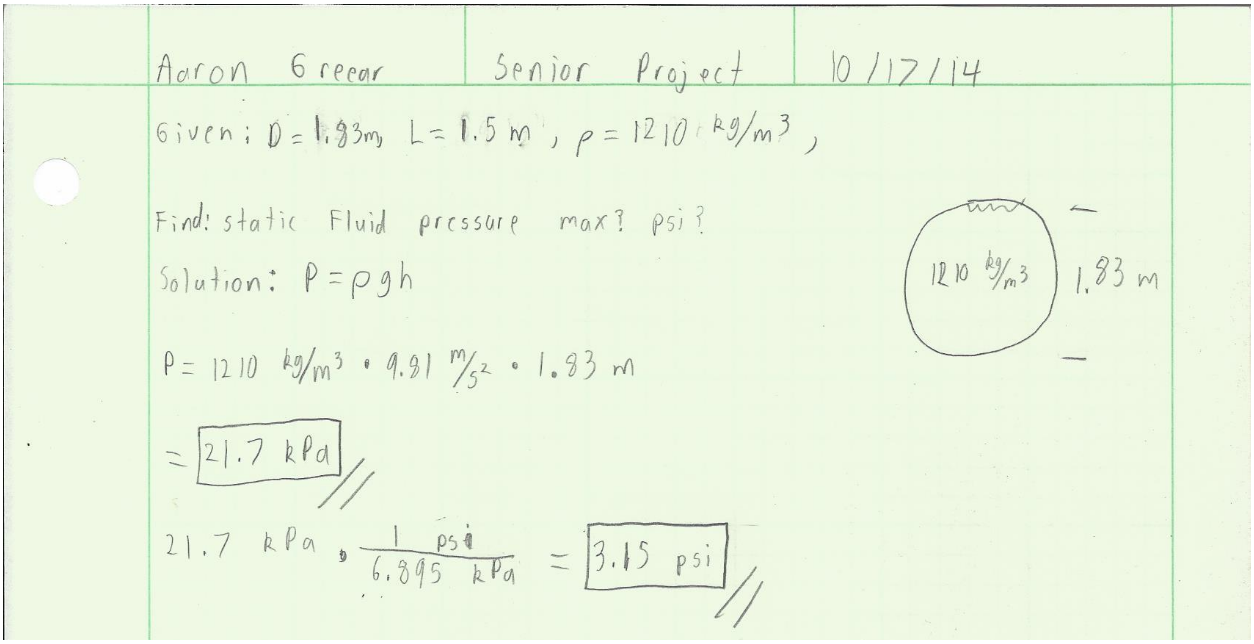
$1.615 \text{ in}^2 \times 50 \frac{\text{lb}}{\text{in}^2} = \boxed{80.75 \text{ pounds}}$ //

Cylinder 2 → $\frac{(.625)^2 \times \pi}{4} = .31 \text{ in}^2$

$.31 \text{ in}^2 \times 50 \text{ lb} = \boxed{15.3 \text{ lb}}$ //

With a safty factor of 2 the value requires 10 lb force A return spring is needed to return the value to it's bypass state. Therefore the cylinder must exert 20 lb to overcome the return spring and value tension.

1



Aaron Greear | Senior Project | 10/17/14

Given: $D = 1.83\,m$, $L = 1.5\,m$, $\rho = 1210\ kg/m^3$,

Find: static Fluid pressure max? psi?

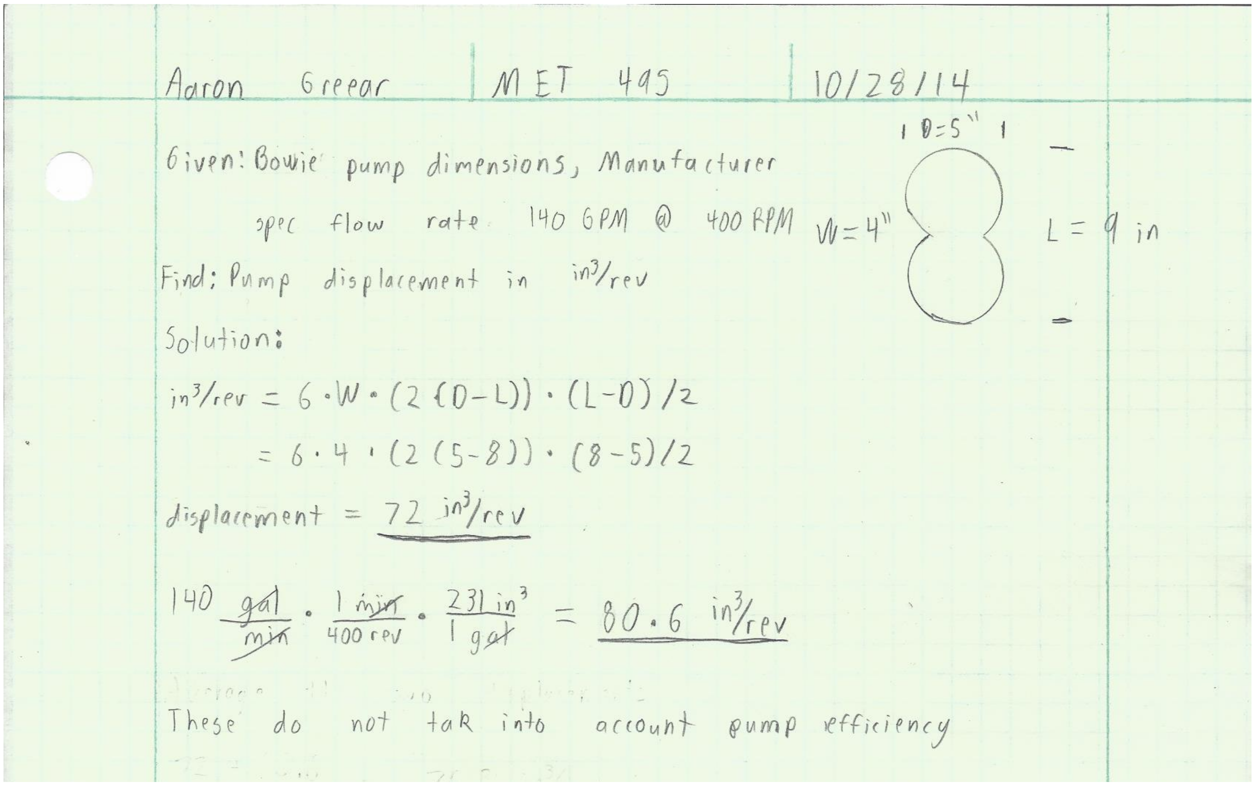
Solution: $P = \rho g h$

$P = 1210\ kg/m^3 \cdot 9.81\ m/s^2 \cdot 1.83\ m$

$= \boxed{21.7\ kPa}$ //

$21.7\ kPa \cdot \frac{1\ psi}{6.895\ kPa} = \boxed{3.15\ psi}$ //

2



Aaron Greear | MET 495 | 10/28/14

Given: Bowie pump dimensions, Manufacturer spec flow rate 140 GPM @ 400 RPM

Find: Pump displacement in in^3/rev

Solution:

$in^3/rev = 6 \cdot W \cdot (2(D-L)) \cdot (L-D)/2$

$= 6 \cdot 4 \cdot (2(5-8)) \cdot (8-5)/2$

displacement = $\underline{72\ in^3/rev}$

$140\ \frac{\cancel{gal}}{\cancel{min}} \cdot \frac{1\ \cancel{min}}{400\ rev} \cdot \frac{231\ in^3}{1\ \cancel{gal}} = \underline{80.6\ in^3/rev}$

These do not tak into account pump efficiency

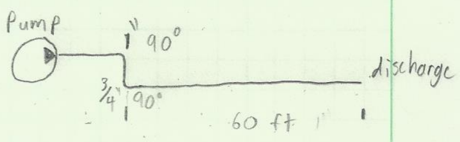
3

Aaron Greear | MET 495a | 11/1/14

Given: 10 gal/min discharge @ 50 psi, 60 ft plastic hose,
1" 90° elbow, 3/4" 90° elbow, $\nu = 380$ cS, $\rho = 75.57\ \text{lb/ft}^3$

Find: Required pump output pressure?

(4-6) Solution: $H_L = f \cdot \frac{L}{D}\left(\frac{v^2}{2g}\right)$



$v = 10\ \frac{\cancel{gal}}{\cancel{min}} \cdot \frac{231\ in^3}{1\ \cancel{gal}} \cdot \frac{1\ \cancel{min}}{60\ sec} \div \frac{\pi 1^2}{4} in^2 \cdot \frac{1\ ft}{12\ in}$

$v = 2.52\ ft/sec$

(4-3) $N_R = \frac{7740\ (v) \times D}{\nu} = \frac{7740 \cdot (2.52) \cdot (1)}{380} = 51.3$

(4-5) $f = 64/N_R = 64/51.3 = 1.25$

$\Delta P = 1.25 \cdot \frac{60\ ft}{1/12\ ft} \cdot \frac{(2.52\ ft/sec)^2}{2\ (32.2\ ft/s^2)} = \boxed{88.7\ ft}$

(4-8) H_L in ellbows: $H_L = K\left(\frac{v^2}{2g}\right)$ $K = .75$ (Figure 4-11)

1": $H_L = .75\left(\frac{(2.52\ ft/s)^2}{64.4}\right) = \boxed{.074\ ft}$

3/4": $v = 10\ \frac{gal}{min} \cdot \frac{231\ in^3}{gal} \cdot \frac{1\ min}{60\ sec} \div \frac{\pi (.75)^2}{4} in^2 \cdot \frac{1\ ft}{12\ in} = 7.26\ ft/sec$

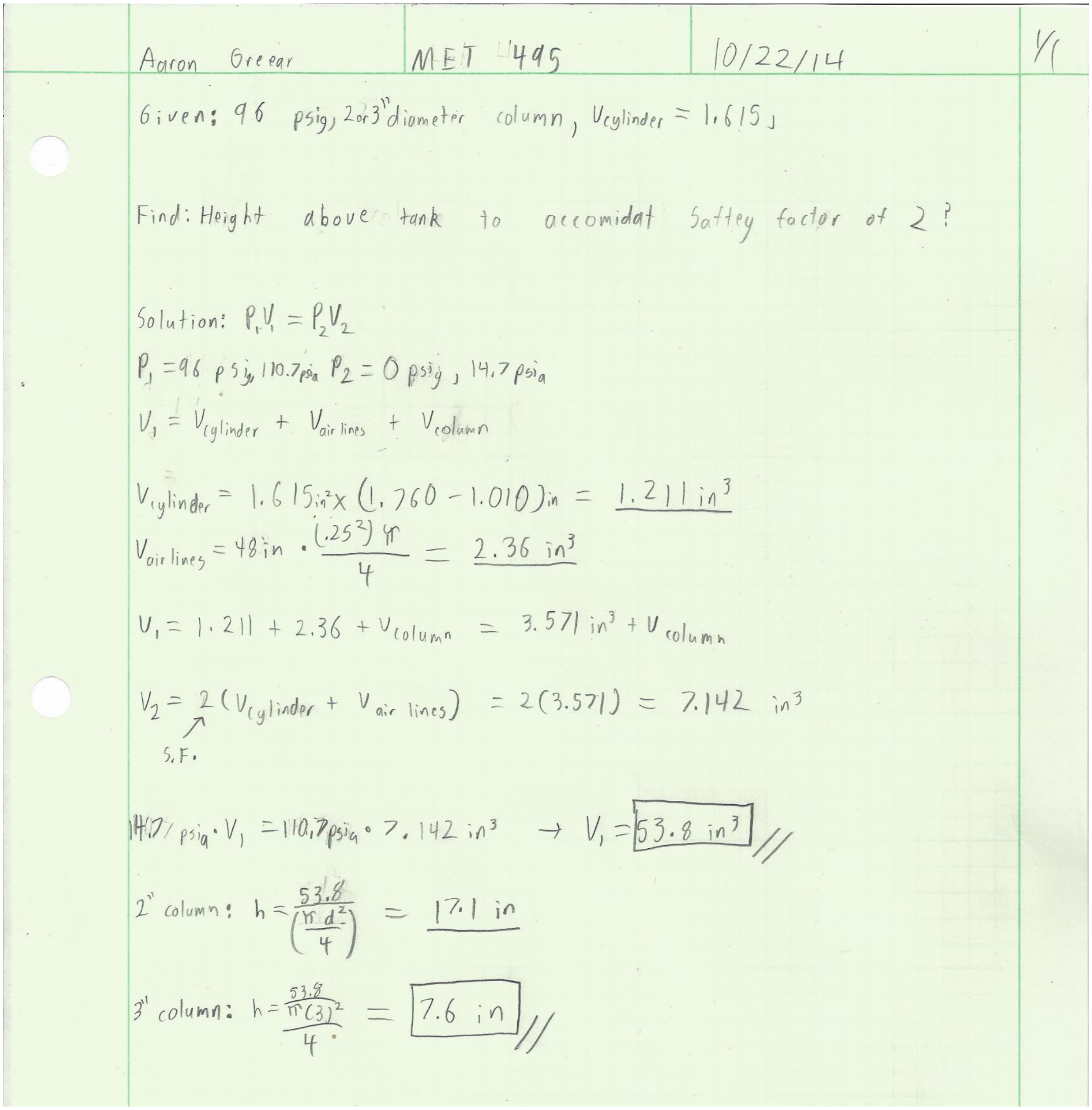
$H_L = .75\left(\frac{(7.26\ ft/s)^2}{64.4}\right) = \boxed{.614\ ft}$

$H_L = 88.7 + .074 + .614 = \boxed{89.4\ ft}$

$\Delta P = SG \cdot .0361 \cdot 12 \cdot H_L$

$SG = \frac{75.57}{62.4} = 1.21$

$\Delta P = 1.21 \cdot .0361 \cdot 12 \cdot 89.4 = \boxed{46.9\ psi}$ // $46.9\ psi + 50\ psi = \boxed{96.9\ psi}$ //



Aaron Greear | MET 495 | 10/22/14 | 1/1

Given: 96 psig, 2 or 3" diameter column, $V_{cylinder} = 1.615$,

Find: Height above tank to accomidat Saftey factor of 2?

Solution: $P_1V_1 = P_2V_2$

$P_1 = 96$ psig, 110.7 psia $P_2 = 0$ psig, 14.7 psia

$V_1 = V_{cylinder} + V_{air\ lines} + V_{column}$

$V_{cylinder} = 1.615\,in^2 \times (1.760 - 1.010)\,in = \underline{1.211\ in^3}$

$V_{air\ lines} = 48\,in \cdot \frac{(.25^2)\pi}{4} = \underline{2.36\ in^3}$

$V_1 = 1.211 + 2.36 + V_{column} = 3.571\ in^3 + V_{column}$

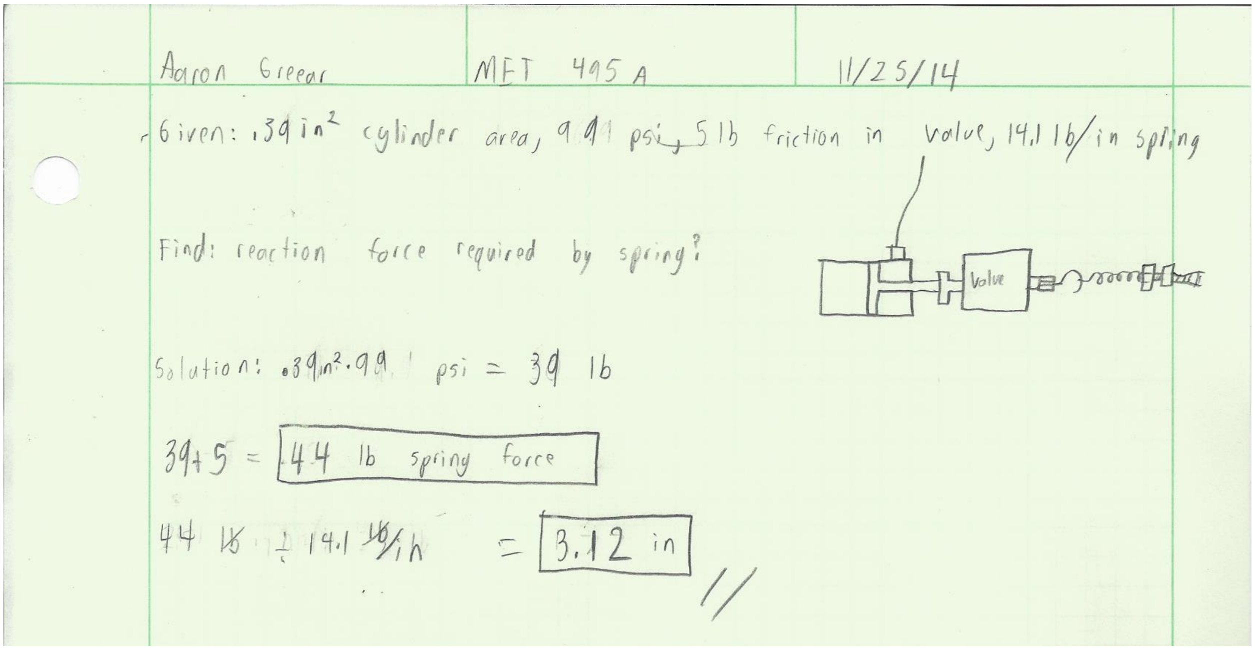
$V_2 = \underset{\text{S.F.}}{2}(V_{cylinder} + V_{air\ lines}) = 2(3.571) = 7.142\ in^3$

$14.7\ psia \cdot V_1 = 110.7\ psia \cdot 7.142\ in^3 \rightarrow V_1 = \boxed{53.8\ in^3}$ //

$2''$ column: $h = \frac{53.8}{\left(\frac{\pi d^2}{4}\right)} = \underline{17.1\ in}$

$3''$ column: $h = \frac{53.8}{\frac{\pi(3)^2}{4}} = \boxed{7.6\ in}$ //

5



Aaron Greear | MET 495 A | 11/25/14

Given: .39 in² cylinder area, 99 psi, 5 lb friction in valve, 14.1 lb/in spring

Find: reaction force required by spring?

Solution: $.39\,in^2 \cdot 99\,psi = 39\,lb$

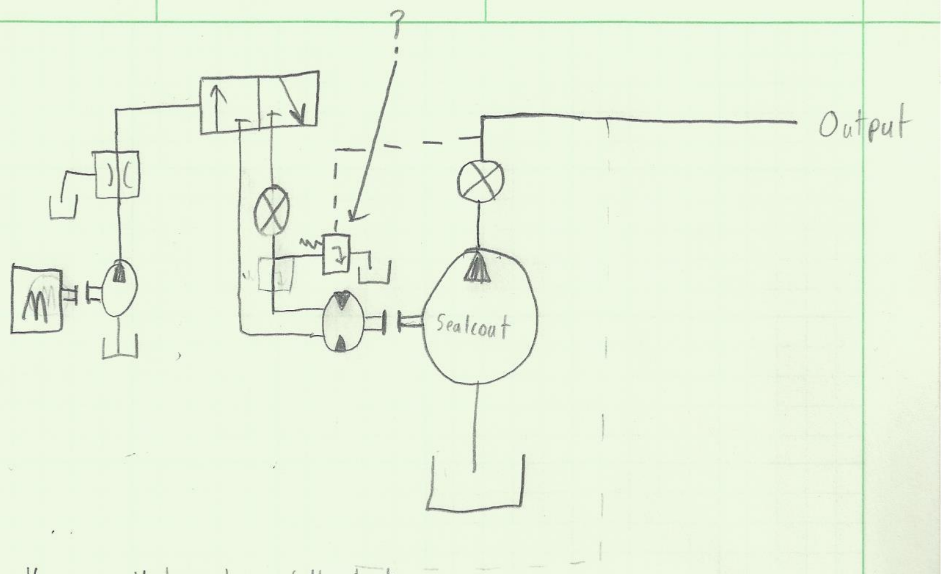
$39 + 5 = \boxed{44\ lb\ spring\ force}$

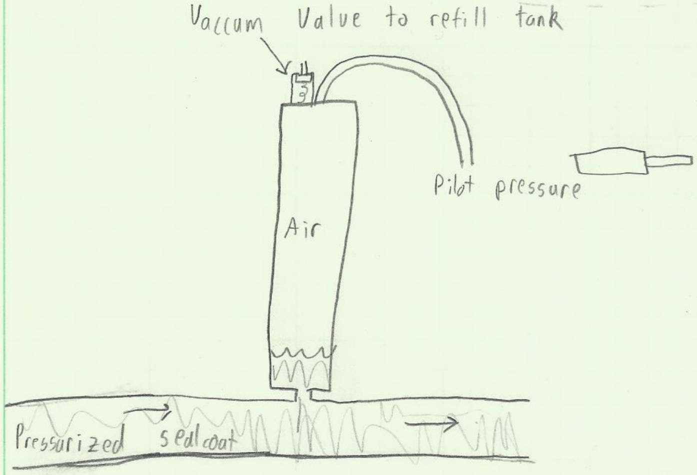
$44\ \cancel{lb} \div 14.1\ \cancel{lb}/in = \boxed{3.12\ in}$

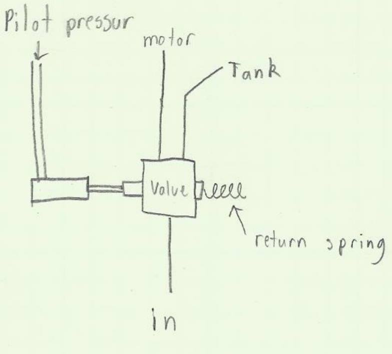
//

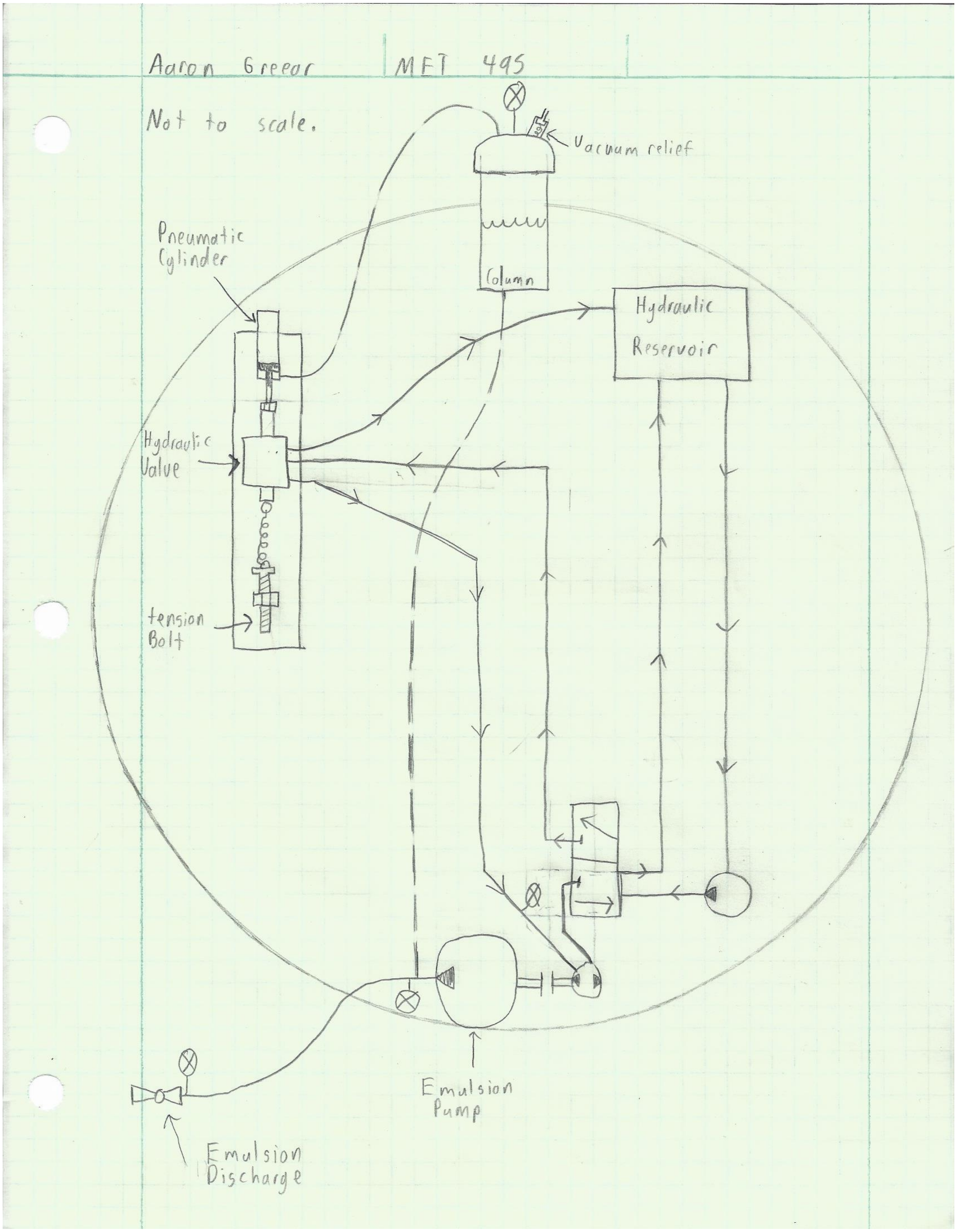
6

APPENDIX B – Schematics

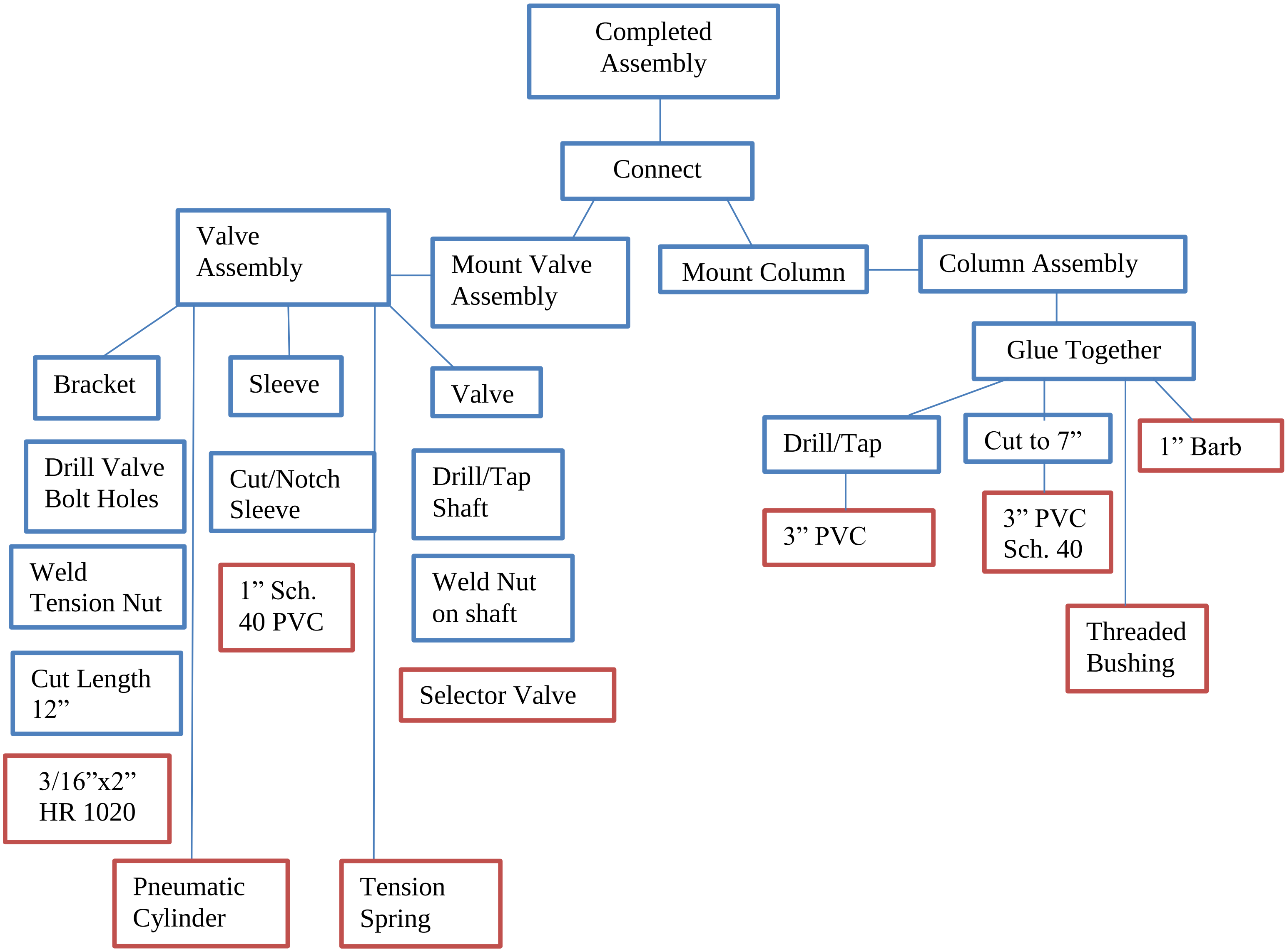




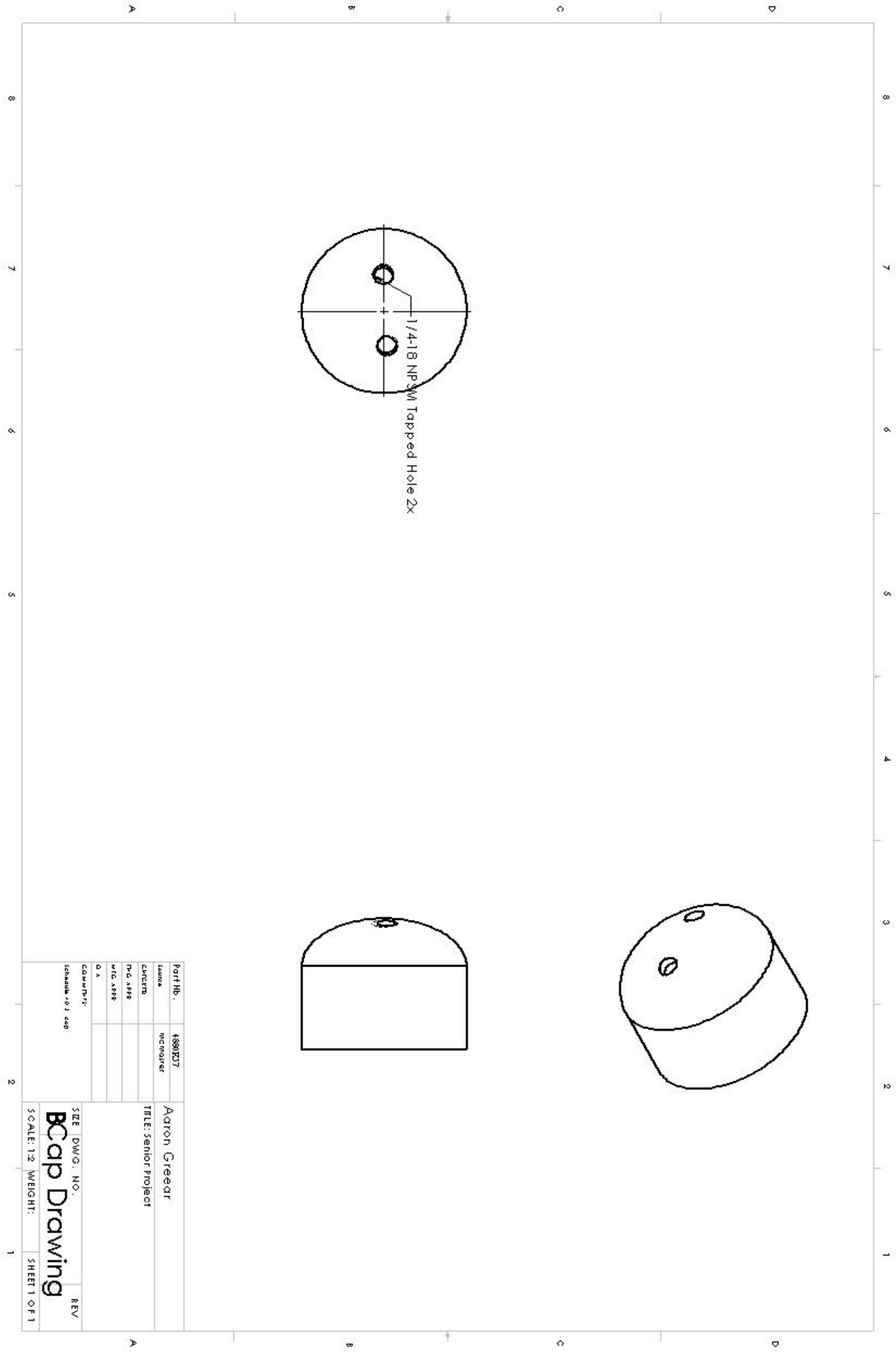



Aaron Greear
MET 495
Not to scale.
Vacuum relief
Column
Pneumatic Cylinder
Hydraulic Reservoir
Hydraulic Valve
tension Bolt
Emulsion Pump
Emulsion Discharge

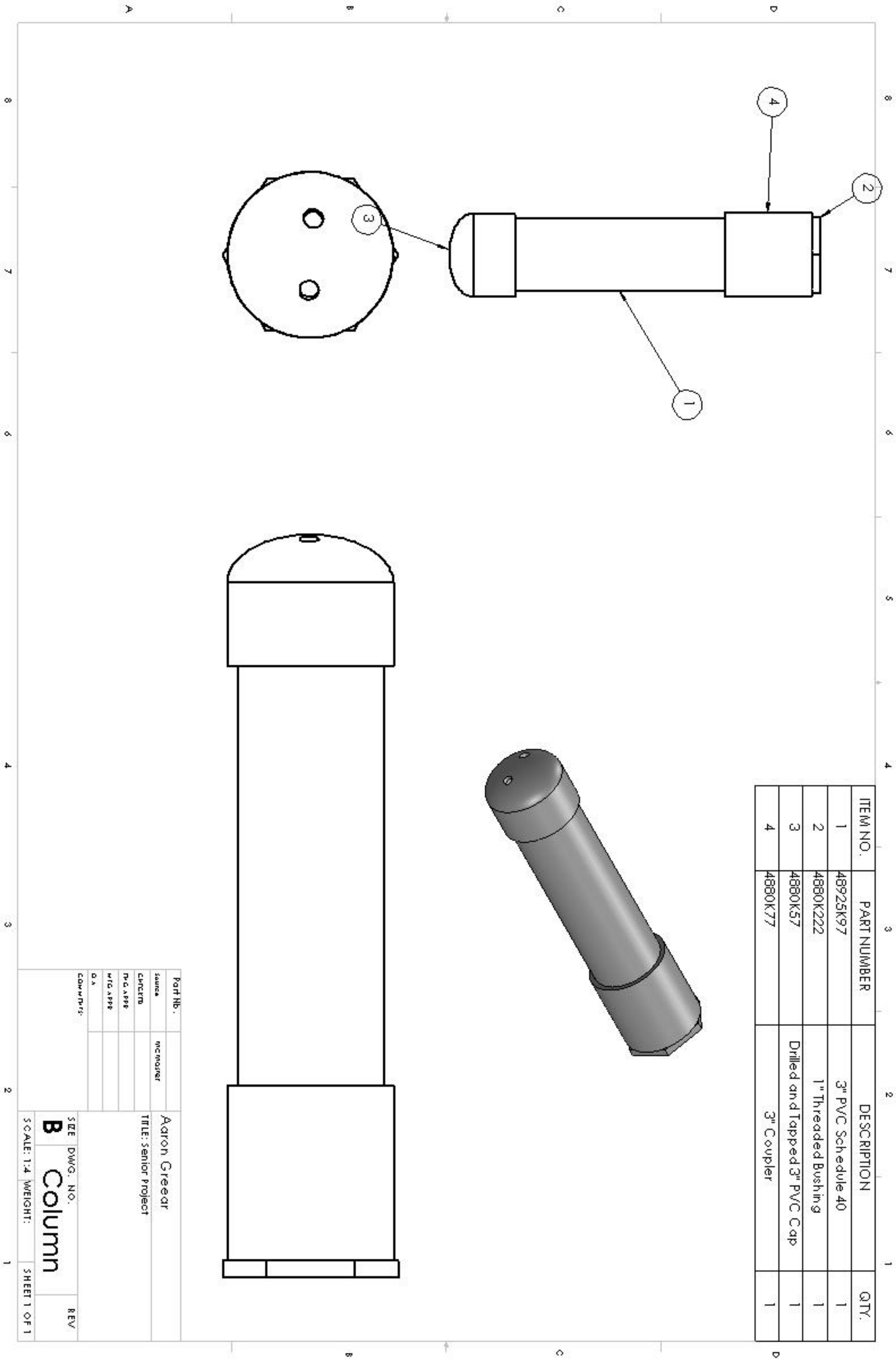
APPENDIX C – Drawing Tree



APPENDIX D – Drawings

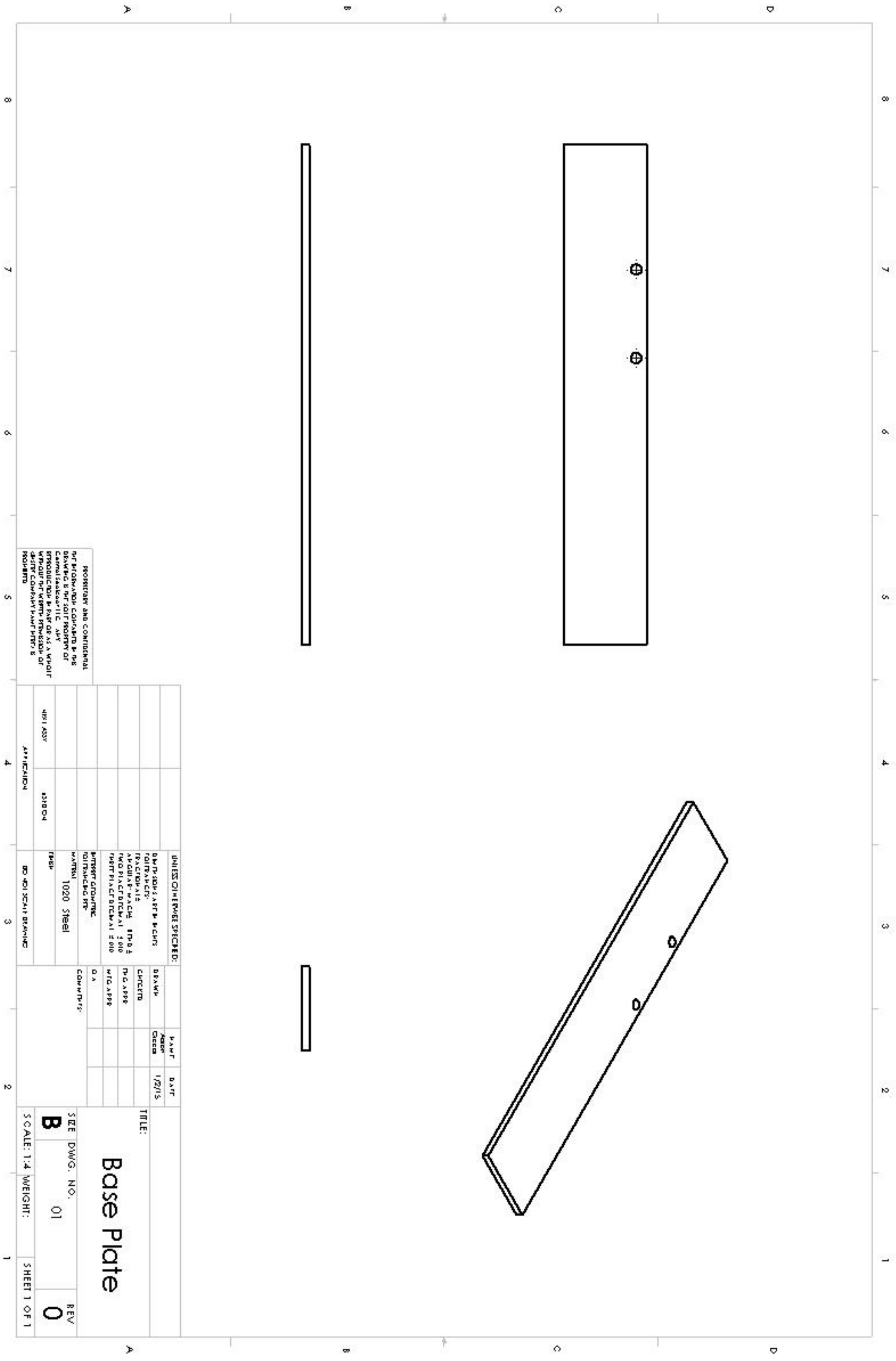


Drawing 1

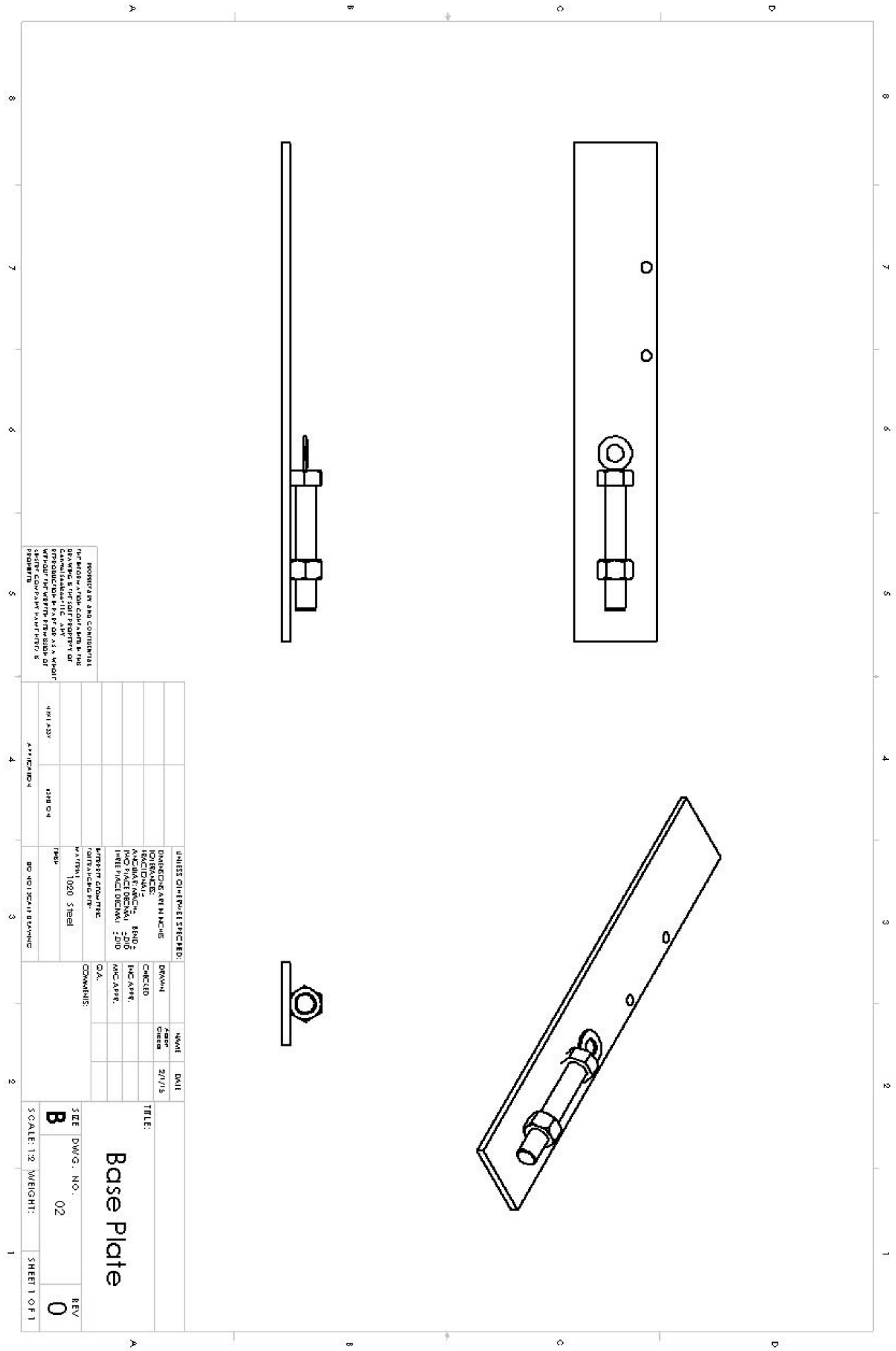


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	48925K97	3" PVC Schedule 40	1
2	4880K222	1" Threaded Bushing	1
3	4880K57	Drilled and Tapped 3" PVC Cap	1
4	4880K77	3" Coupler	1

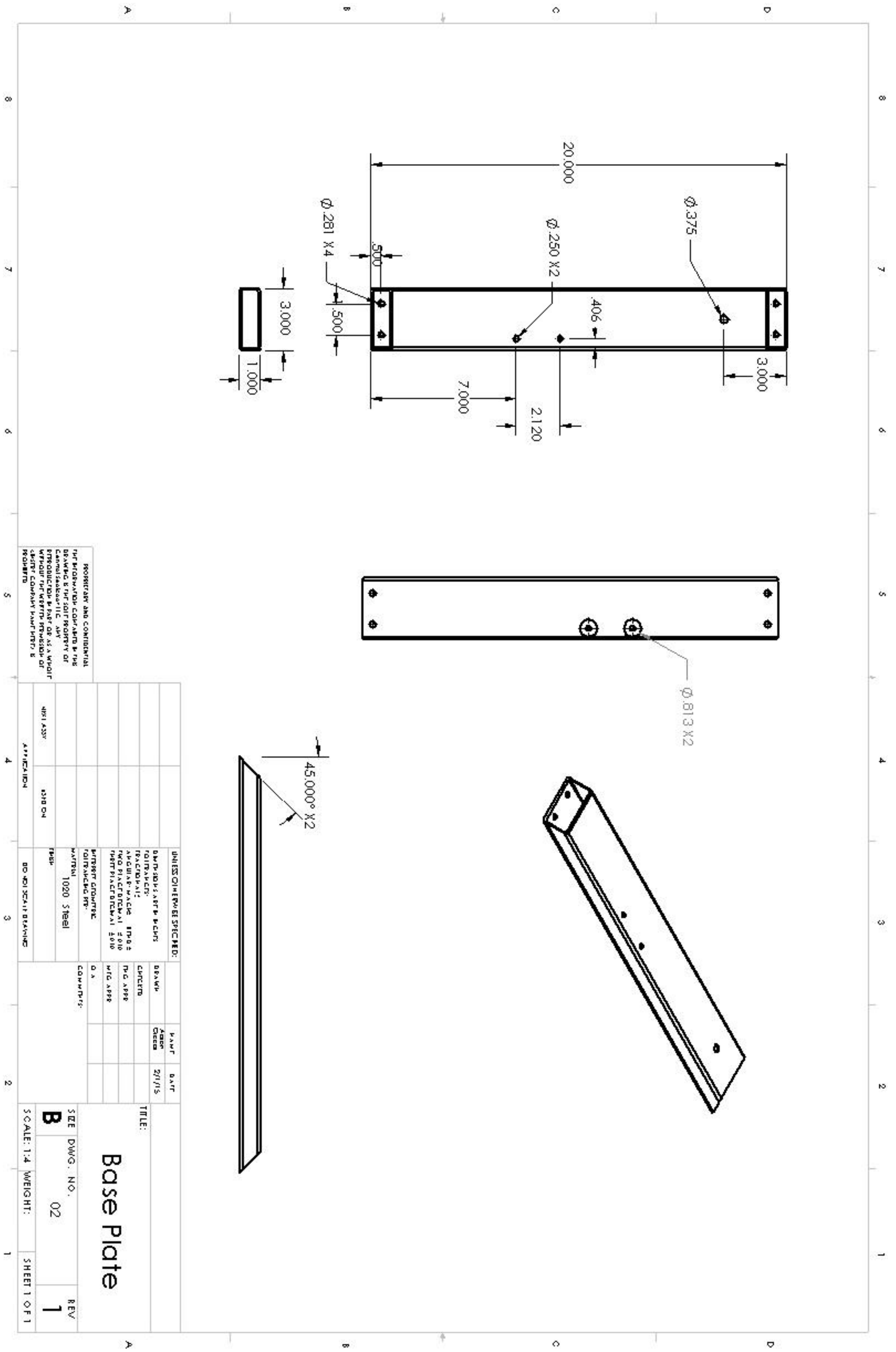
Drawing 2


UNLESS OTHERWISE SPECIFIED:
MATERIAL
1020 Steel
FINISH
DO NOT SCALE DRAWING
DRAWN
CHECKED
COMMENTS:
NAME
DATE
1/2/15
TITLE:
Base Plate
SIZE
B
DWG. NO.
01
REV
0
SCALE: 1:4
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
APPLICATION

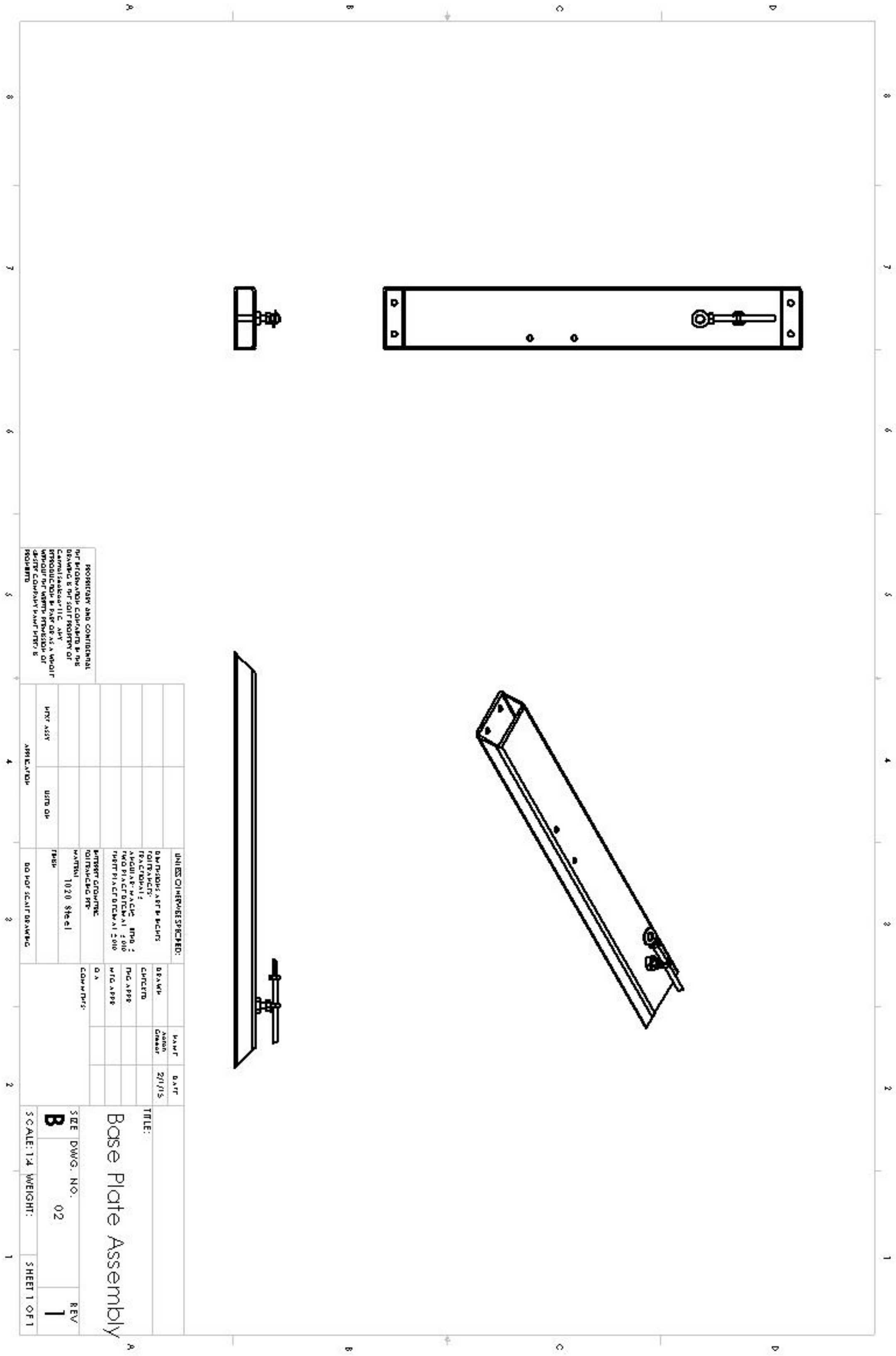
Drawing 3


UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±.010
THREE PLACE DECIMAL ±.010
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
1020 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
2/1/15
TITLE:
Base Plate
SIZE
B
DWG. NO.
02
REV
0
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
A
B
C
D
1
2
3
4
5
6
7
8

Drawing 4


20.000
Ø.375
Ø.250 X2
Ø.281 X4
.500
.500
3.000
1.000
.406
3.000
7.000
2.120
Ø.813 X2
45.000° X2
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
MATERIAL
1020 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
2/1/15
TITLE:
Base Plate
SIZE
B
DWG. NO.
02
REV
1
SCALE: 1:4
WEIGHT:
SHEET 1 OF 1
A
B
C
D
1
2
3
4
5
6
7
8

Drawing 5


UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
MATERIAL
1020 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
2/1/15
TITLE:
Base Plate Assembly
SIZE
B
DWG. NO.
02
REV
1
SCALE: 1:4
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
A
B
C
D
1
2
3
4
5
6
7
8

Drawing 6

APPENDIX E – Parts List/Budget

Part	Description	Part Number	Qty.	Source	Price/Qty.	Total
1" hose	Price per ft.	1531100100	5	Maxx Flex	0.6	3
1/2"x36" Hydraulic hose	Male ends	917-2236	3	Surplus Center	11.95	35.85
Selector Valve	1/2" NPT Ports	9-6134	1	Surplus Center	61.95	61.95
Pressure Guage	0-125 PSI	21-1729	4	Surplus Center	3.99	15.96
Pneumatic Cylinder	1.5" bore Pull	4-1762-b	1	Surplus Center	6.95	6.95
Vacuum Relief	1/4 NPT	VR25-100	1	Control Devices	7.5	7.5
Air line	Price per ft.	C604-50	20	Power Products	0.5	10
Push fittings	1/4" OD air line	B009ITF6QC	3	Amico	0.51	1.53
3" pipe	Sch. 40		2	Irrigation Sales	3.65	7.3
3" Cap	Sch. 40		1	Irrigation Sales	4	4
3" threaded adapter	Sch. 40		1	Irrigation Sales	6	6
Hose Clamps	1-1.5"		2	Irrigation Sales	0.25	0.5
1" Barb			2	Irrigation Sales	3.5	7
1" Pvc Pipe	Sch. 40		1	Irrigation Sales	1	1
3/16" steel plate	H.R. 2" wide		1	Haskins Steel	0.4	0.4
1/4" Bolt	Grade 5		2	Fastenal	0.08	0.16
1/4" Nut	nyloc		2	Fastenal	0.04	0.08
Tension Spring	14.1 Lb/in	9432K118	1	Mcmaster	4	4
						Total: 173.18

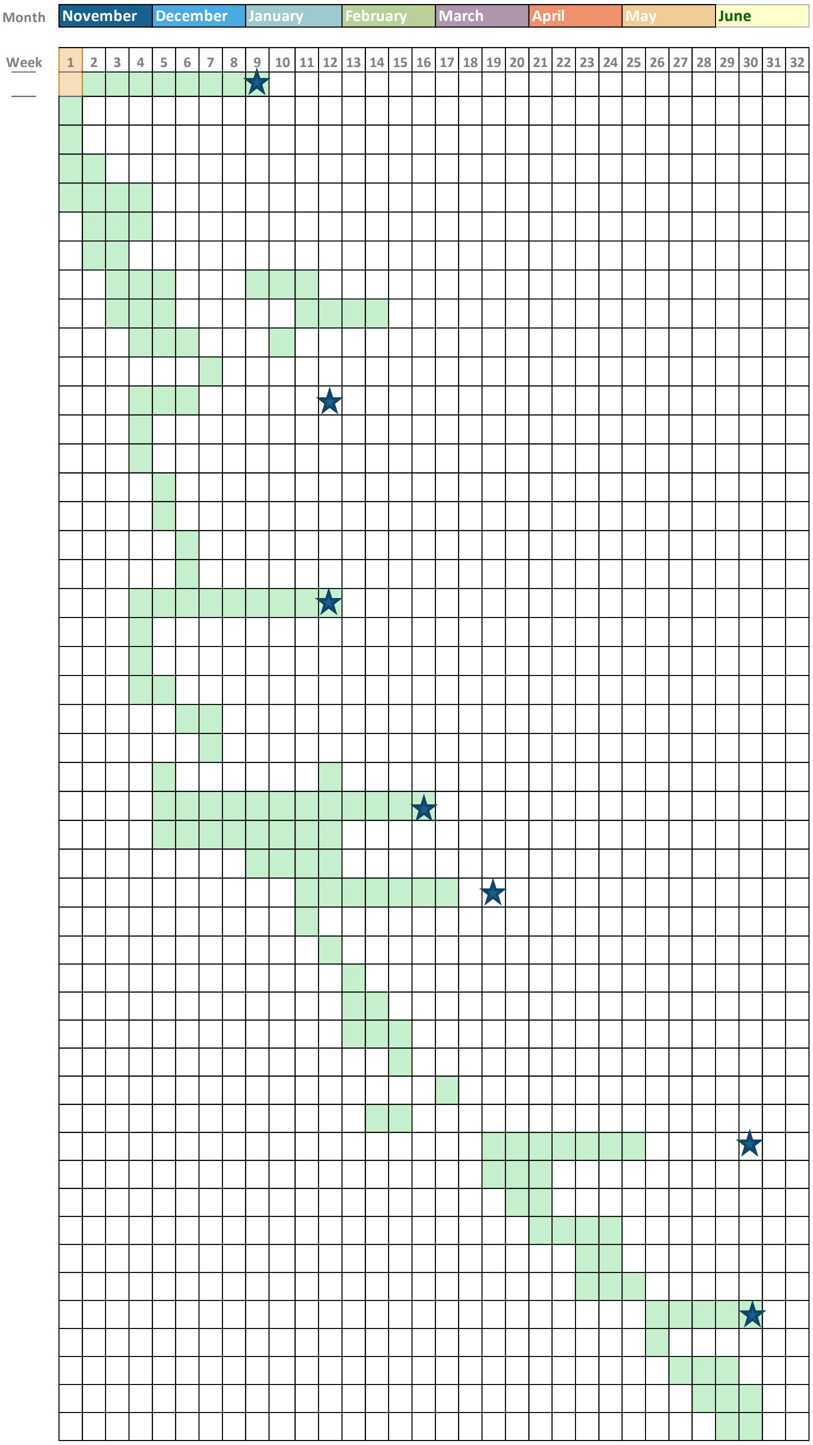
- # APPENDIX F – Schedule

Emulsion Pump Pressure Relief

By: Aaron Greea 1

★ = Milestone

Task	PLAN DURATION	ACTUAL DURATION
Proposal		
Outline	1	0.9
Intro	0.5	0.7
Scope	2	2.2
Design	6.5	6.8
Analysis	2	3.5
Discussion	3	2.4
Parts/Budget	3.5	2.6
Drawings	2	5.8
Schedule	2	4.5
Summary	0.5	0.8
Analyses		
Static Pressure	1	1.8
Cylinder Force	1.5	2
Flow Rate	3.5	1
Pressure Drop	3	4.5
Column Size	2	2.4
Spring Rate	3	1.3
Documentation		
Column Cap	2	2.1
Column Assembly	6	4.6
Bracket	1	0.3
Spring	5	3.5
Cylinder	3	3.8
Bracket Assembly	7	5.3
Proposal Mods		
Changes	4	8.5
Optimization	5	12.6
Construction		
Column Cap	2	0.8
Coulmn Assembly	3	1.8
Compression Sleeve	1	0.6
Base plate	3	2.6
Base plate Assembly	4	5.4
Vavle Nut	0.5	2
Hydraulic Plumb	2	1.2
Valve Eye	3	1.3
Evaluation		
Pressure Testing	4	6.4
Analysis	6	3
Optimization	3	...
Final Testing	2	
Documentation	4	
Final Documentation		
Website	6	
Report	6	
Presentation	7	
Conclusion	1.1	
Total:	127.6	109



APPENDIX G – Evaluation Sheet

Evaluation Sheet				
	Pump Output	Air Column	Hose Discharge	Hydraulic Circuit
Zero Reading	psi	psi	psi	psi
Cold pressure Reading	psi	psi	psi	psi
Warm Pressure reading	psi	psi	psi	psi
Opperating Pressures				
Max	psi			
Min	psi			

APPENDIX H – Procedure Checklist

Test Procedure Checklist

Check 1. With motor and pump off, take pressure readings from all 4 gauges to calibrate zero.
Check 2. Turn on hydraulic pump and take cold hydraulic pressure readings
Check 3. Activate bowie pump with discharge open and record pressures
Check 4. Shut discharge hose valve and record pressures
Check 5. Tension spring to raise pressure or loosen it to lower pressure to reach target pressure
Check 6. Repeat steps 2-6 until target pressure is reached
Check 7. Repeat steps 2-6 for warm hydraulic fluid pressure readings

APPENDIX I – Testing Data

Evaluation Sheet				
Fluid: Water				
	Pump Output	Air Column	Hose Discharge	Hydraulic Circuit
Zero Reading	0 psi	0 psi	psi	psi
Cold pressure min	32 psi	30psi	psi	psi
Cold pressure max	75 psi	73psi	psi	psi
Warm pressure min	30 psi	30psi	psi	psi
Warm Pressure max	74 psi	74psi	psi	psi
Opperating Pressures				
min	30 psi			
max	75 psi			

APPENDIX J – Resume

Aaron Greear
Agreear6@gmail.com
509-929-3980

Education

Central Washington University
- Bachelor Science in Mechanical Engineering Technology
- Minor in Mathematics

Work Experience

Central Emulsion, Operations Manager 2012-Present

Duties included sales, customer relations, product research, employee management, and equipment design/fabrication/maintenance.

Ellensburg Solar, Installation Technician 2010-2012

Installed solar hot water and photovoltaic systems, work involved plumbing, electrical wiring, and brackety construction.

College Park Apartments, Maintenance 2008-2010

Cleaning, Painting, Household Repairs, Snow Removal,

Skills

- Metal Fabrication
- Machining
- AutoCAD
- SolidWorks
- Automotive Repair
- Home construction
- Carpentry
- Asphalt Repair
- Small Equipment Operation
- Fluid Power