Hydraulic Sprayer Boom Upgrade

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Hydraulic Agriculture Sprayer Boom Upgrade

By
Chad Omlin
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INTRODUCTION

Motivation:

This project was motivated by a time dependent job that could use hydraulic power to make the job more efficient. It can be more efficient if the operator does not have to get out of the tractor to set up the sprayer, and also allows the operator to not come in contact with the chemicals.

Function:

A device is needed that will allow the operator to control the booms of the sprayer from the cab of the tractor.

Requirements:

The design requirements of this project will determine the specs of what the owner and operator are interested in. Thus, the requirements are listed below.

• Hydraulics must lift 10-foot booms.
• Booms must weigh less than 50 lbs.
• The booms must be able to be controlled separately from two hydraulic remotes.
• Hydraulic drive must reduce the setup time by 75% vs. manual setup.
• Cost must stay under $600.
• Booms must fold up vertically past 90 degrees and be no wider than eight feet when folded up and no higher than ten feet from center of the base frame.
• Hydraulic rams must not require more than 2600 psi to lift the booms.

Engineering Merit:

Some equations that will be used in the analysis of this design will be:

• \( F = PA \)  \hspace{1cm} \text{(Force=Pressure*area)}
  
  This equation will be used to determine the size of the hydraulic cylinder needed to raise the boom.

• \( \sum M_d = 0 \)
  
  This equation will be used to determine the force required to lift the boom.

Success Criteria:

The success of this design will be presented through a timed video of the operation of the manual mode set up, then demonstrated using the new hydraulic setup. This will show the improvement of the design to the end user.
Scope of this effort:

The scope of the project focuses on the booms being strong enough to withstand the use of agriculture terrain, while being light enough for the hydraulics to operate.

DESIGN & ANALYSIS

Approach:

The design is a hydraulic assembly using supplied hydraulic pressure from the tractor to activate the hydraulic rams mounted from the sprayer frame to the sprayer boom.

The driving requirement in this design is to have the booms fold up vertically and be no wider then eight feet and no taller than 10 feet from center. This is difficult due to the geometry of how and where the hydraulic cylinders mount.

The next requirement that one must focus on is to design a boom that weighs less then 50 Lbs. with a length of 10 feet. This is crucial so that the hydraulic ram can be spec’d out properly.

Design Description:

The new design was conceived by using the original sprayer design, while adding appropriate tabs and hydraulics to allow correct movement of the arms. The new booms will also be one foot longer than the original. It is important to have the geometry right to allow the hydraulics to operate correct while folding the booms in and out.
Figure 1 shows the initial design of the sprayer boom. From the figure you can see the hydraulic tab attached to the main boom. The boom is attached to the sprayer unit using a pin and bushing.

There were a few design choices on how the booms would fold. One being vertically or x-fold and the other being a front fold.

The benefit to front fold would be you could run longer booms and have a height restriction. The geometry for this setup would be much simpler also. The downfall to this design is that the booms fold along the tractor in transport mode creating it hard for the operator to get access to the cab. The other restriction in this setup is the operator does not have vertical control over the booms and cannot raise the booms due to obstacles or terrain changes which will result in damage.

The benefits of the vertical fold design outweigh the benefits of the front fold. This is due to the versatility of the vertical motion. The operator can adjust heights of the booms to avoid obstacles and terrain changes. Once the booms are folded into transport mode it allows clear passage for the operator to fill the tank with fluids and have access to the cab.

**Benchmark:**

The benchmark for this project is the original sprayer. It has nine-foot booms that are manually operated. The design is also weak due to its structure. The goal of this project is to increase the setup time from transport mode to field mode by at least 75%. It takes 45 seconds to setup the sprayer manually and the new design would reduce the time to 15 seconds or less.

**Performance Predictions:**

Expectations of this design are based off of the requirements. The booms must weigh less than 50 lbs. After drawing up an assembly in solid works, the software calculated a weight of 41.078 lbs. As stated above the setup time will be reduced by at least 75% resulting in 11.25 seconds or less to go from transport mode to field mode. The design was to be no taller than 10 feet from center of base frame and the calculated height was right at 118.4 inches.

**Description of Analyses:**

In order to analyze and spec out appropriate parts for the design you must start with the force needed to lift the boom. This depends on the weight of the boom and location of where the hydraulic ram is mounted. Using a free body diagram you can isolate where the forces and moments are acting. Figure A-1 in appendix A shows the
analyses of the force required to lift the boom. The outcome of this will then allow one to calculate the required size of hydraulic cylinder needed.

Figure A-2 analyses the size of the hydraulic piston needed. This is based off of the force required and the supplied hydraulic pressure from the tractor. One can then determine the diameter of the piston.

**Scope of Testing and Evaluation:**

To test the force required to lift the boom, a load gauge will be used along with a lever. The lever will be used to achieve the force needed to raise the boom. Then, to test the hydraulic ram, one will attach the hydraulic ram provided to the assembly and determine if the ram is suitable.

**Analyses:**

To approach the analyses of the force required, design the boom in a 3D software to get correct geometry. This is important so that you have correct angles and distances when doing calculations. Once the design complete, create a free body diagram showing the forces and distances. Figure A-2 in appendix A demonstrates this. In this problem there is moment created at the Pin labeled A. This is due to the force being applied at B. We can now determine the moment equation.

\[ \sum M_a = 0 \ W(d_w)-(F_x)(d_y)+(F_x)(d_z)=0 \]
Now the forces in the x and y directions are unknown causing us to have one equation with two unknowns. Another equation is found by using the resultant vector \( F_{Hy} \).

- \( \cos \theta = F_x/F_{Hy} \quad F_x = \cos \theta(F_{Hy}) \)
- \( \sin \theta = F_y/F_{Hy} \quad F_y = \sin \theta(F_{Hy}) \)

Now that we have our unknowns solved for we can substitute them back into the original equation.

\[ \sum M_a = 0 \ W(d_w)-(\cos \theta(F_{Hy}))(d_y)+(\sin \theta(F_{Hy}))(d_z)=0 \]
Now we have one equation and one unknown, which we can now solve for. Now that we have solved for the force of the hydraulic we can now determine the size of the hydraulic piston.

- \( F=PA \) or \( F_{Hy}=\text{Pressure}\times\text{Area} \)
Now solve for area.
- \( A=F/P \)
Now that you have solved for area of the piston solve for the diameter.
- \( D=\sqrt{(4(A))/\pi} \)
Now that you have the diameter of the piston, you can now determine which size is appropriate.

In this design it only requires a \( \frac{1}{2} \) inch diameter piston to run this device, although a safety factor would be applied to that to ensure proper reliability. In this project a 3 inch diameter piston will be used due to the donation of the hydraulic cylinders.
Figure A-3 shows the analyses of the pins used to hold the hydraulic cylinders in place. Due to a low load force the shear force is also quite small. This allows a wide range of materials to be used. For this project we will use a steel pin sourced from mcmaster-carr.com.

To compute the design factor for the hydraulic cylinder, you must first determine the force required to extend the boom. Figure A-4 shows the analyses for these calculations. It is very similar to that of the calculations to find the retract force. The force required to extend the boom from the folded position is very small at 5.6 lbs.

Now using both the extend and retract forces you can calculate the design factor for the cylinder. Figure A-5 shows the steps and calculations for this. A safety factor of 82 was calculated. This is extremely high, which is not a bad thing. This will ensure that the hydraulics should never be over worked. If one were to be sourcing a cylinder at cost a smaller, cheaper cylinder with a 1” piston will work.

The last thing needed to be determined is if the design will reduce setup time by 75%. In the standard manual mode it takes approximately 45 seconds to setup. With this design being hydraulically operated through the hydraulics of the tractor, the max flow is 20.1 GPM. Figure A-6 shows the calculations of the speed at which the hydraulics would operate at maximum flow. With the 3 inch diameter piston the extend speed 10.94 inches per second. The retract speed is 13.25 inches per second. With a 10 inch stroke this gives a maximum extend time of .91 seconds and the maximum retract speed of .8 seconds. Although the tractor will not be run at maximum flow for this design, it will reduce the setup time by far more than 75%. To achieve a 75% quicker set up time the pump must run at least 2 GPM.

Figure A-7 is an initial design with the hydraulic mount placed five inches away from the hinge. This design did not work because it did not allow the booms to fold past 90 degrees.

To find the placement of the hydraulic ram mount on the frame side some simple calculations are used. The Pythagorean theorem is great method to use to get quick results. The extended length of the hydraulic ram from center of the clevis on the rod end, to the center of the clevis on the tube end is 30.25 inches. The height from the hole on the boom bracket to the hole on the frame bracket is a difference of 1.5 inches. This gives you a simple right triangle. $A^2+B^2=C^2$ where $A=1.5$ and $C=30.25$, solving for $B$ you get 30.21 inches. These calculations are presented in figure A-8.

Figure A-9 and A-10 are the calculated values for the welds. All material is ¼ inch thick. In both analyses the weld sizes are quite small due to the low loads on the material. Due to the size of the material used which was ¼ inch the minimum weld that will be used will be 3/8 inch according to the Robert L. Mott in Machine Elements in Mechanical Design.

Figure A-11 is discussed later in the methods and construction portion of the report.
Device: Parts, Shapes, and Conformation:

The design of the boom influenced by the customer wanting it to look like the booms were originally designed for the sprayer. The brackets were designed by myself for both look and functionality. The wide opening allows easy installment of the hydraulic rams.

Device Assembly and Attachments:

This device will attach to the existing main frame on the sprayer. There will be new tabs welded to the main frame to accommodate the hydraulic cylinders. The boom will then assemble to the main frame and the hydraulic ram will assemble to both the new boom and the existing frame. Figure B-1 shows the boom, which includes the hydraulic ram mounting bracket. Figure B-2 shows the boom assembled to the main frame and the hydraulic rams attached.

Technical Risk Analysis, Failure Mode Analyses, Safety Factors, Operation Limits:

A failure analyses that one may encounter in this design is the weight of boom may change slightly due to fluids running through tubes along the boom. This will be delt with by adding a larger hydraulic cylinder than needed to raise the bare boom. With this as the fix, you can assure there will be no modes of failure in this design.

METHODS & CONSTRUCTION

This project was conceived, analyzed, and tested at Steve Omlin Farms Inc. The design of the project was conducted at Central Washington University. SOF will fund the parts, although some of the parts may be made at the CWU machine/shop facility. These parts may include hydraulic ram mounting tabs and others parts required to be CNC cut.

Construction of the device:

The device itself will be built at SOF. The booms will be retrofitted to an existing 3-point sprayer unit. All but the hydraulic rams will be manufactured in house. This project is made of two hydraulic rams and two 10-foot boom assemblies. The first part that will be constructed will be the booms. Each boom will consist of two 10-foot, 1 ¼” X 1 ¼” square tubing braced down the center. This will require the use to a horizontal band saw to ensure good straight cuts. The hydraulic brackets and the hinges will be cut at the CWU fabrication facility with the plasma table. Once these are cut they will be attached to the boom assembly at SOF. The booms, hinges and brackets will require to be
welded which will also be done at the SOF shop. Figure A-11 in appendix A demonstrates some decision making on how the brackets would be fabricated. The options that were to be determined were whether the part should be fully welded or bent first then welded. For this case where only this one project will be built it is best to go with the fully welded method. This is due to the cost to purchase a jig large enough to handle \( \frac{\text{\textfrac{1}{4}}}{\text{inch}} \) plates. The cost to bend the part would come to a total of $341.50. This is due to the initial cost of the jig. The more parts one would produce the return payout would be much lower. Although the welding method would take nine more minutes to produce than the bending method, the cost to fabricate the part is much lower at $7.50. Labor and cost to cut and purchase the material was neglected due to the fact that the material is the same and that the project is donated.

**Drawing Tree:**

The design is made up of seven parts. The initial parts are the hydraulic bracket for the boom side, the hydraulic bracket for the frame side, and the hinges for both the boom side and frame side. These parts will be laser cut with the plasma table at CWU. They will then be welded together.

Once they are welded together they will then be welded to the frame and the boom. Once this is complete the hydraulic rams will be installed. They will be installed using clevis pins. This will complete the installation of the system.
Appendix B illustrates the design and assemblies needed to complete the project.

Figure B-2 shows the mounting tab assembly that will be welded onto the boom. This is ¼ inch plate with a one inch mounting hole to house a durable pin. Figure 3 illustrates the pivot point assembly. This is also made out of ¼ inch steel plate with a 1-¼ inch steel tubing.
Figure B-18 illustrates the boom. This is where the hydraulic brackets, and the pivot point of the system will be welded. This is made out of 1/8 inch steel tubing. Steel was chosen for the material due to the ease of maintenance for the customer later down the road.

The cylinder assembly is modeled in figure 5. The customer provided this cylinder. It has a three-inch diameter piston with a stroke length of 10 inches. This cylinder is well over the required size needed for this design.

Figure B-17 illustrates the entire assembly. In this photo the original mainframe boom is also featured. The main frame will not be manufactured, as it will be reused. Figure B-22 shows an exploded view of the model with the parts labeled.

**Device Operation:**
The operation of this design is quite simple. The hydraulic rams will each be connected to individual hydraulic remotes coming off the tractor. When the remote in the cab is activated the tractor will send hydraulic fluid to the ram which will activate the booms causing the ram to either retract or extend which will cause the booms to fold or unfold.

**Manufacturing Issues:**
Some manufacturing issues that could become a reality would be the use of the plasma table provided by the university. The mounting tabs for the hydraulic cylinders and the joints will need to be CNC cut. Lack of experience with this machine could cause an issue. To solve this problem, a staff technician will aid in the manufacturing of these parts.

The use of the plasma cutter may cause some issues later in manufacturing due to the precision of the machine. Although it makes straight lines, the size of the part is affected during the cutting due to the arc of the plasma. This will be investigated more once the brackets and hinges are in the welding state.

During the manufacturing of the device, the issues that were projected did come into affect. The major issue was the holes on the brackets. These holes although programmed for one inch, they were cut slightly larger. This became an issue during the final assembly once the bolts were inserted. The extra clearance created some un-wanted movement during operation. To fix this problem, the holes should be offset roughly .030 inch inside the hole. This would allow for the arc blowout during the cutting process.

To fix the issue on this specific device, slightly larger bolts, bolted in the hinges and brackets will be used rather than pins. This will reduce some of the clearance and keep the booms and cylinders tight in the brackets.
BUDGET

The budget on this project is no more than $500. This was a specified price by the customer. This design does not require many different parts but many of the same due to the symmetry that it requires. The first expense will be the boom frame tubing. It will require 40 feet of tubing to get the correct length. Within the boom frame there are six braces one inch long. This comes to total of 41 feet of tubing. The tubing will be approximately 1x1x.125 inch. AISI 1020 steel at these parameters calculates to 61.94 pounds. After doing some research I found the best place to get steel was Moses Lake Steel Supply. Their price per pound on this size of steel was .7354 cents. Calculating this out gives a total cost of $45.55. The flat bar and round tubing will also be sourced from Moses Lake Steel Supply and the prices are listed below in appendix B. Most of the remaining parts such as the clevis pins, cotter pins, and grease zerks will be sourced from mcmaster-Carr.com. This project will require two grease zerks, four clevis pins, four cotter pins and eight spacers. The hydraulic hose and fittings will be sourced locally from Basset Repair. The last parts required for the project are the two hydraulic rams. These will be sourced from the customer at no charge. This brings the total of the project to $394.19. This is lower than the projected cost, but due to the hydraulic rams being supplied at no cost this lowered the cost by roughly $200.

SCHEDULE

The schedule for the project begins on the 23rd of September and ends the 10th of December. This is just the proposal section of the project, which includes writing the proposal, budgeting the project, and designing and drawing the prototype. The most time consuming parts of the project will be the design, analysis, and the drawings. These parts will each consume 14 days worth of the project and totaling an estimated 24 hours. The least amount of hours projected to be spent on one item will be no less than two hours. It is suspected that the building and testing will require 50+ hours. View appendix E for more detail on the schedule of the project.

DISCUSSION

Throughout the design of this project, the major issue I had with designing the system was where to locate the hydraulic cylinder to get maximum folding distance. When first designed for the lifting force, the hydraulic mounted farther away from the pivot point. Although this allowed for a smaller moment created at the pivot, it did not allow the booms to fold past 90 degrees. This was one of my requirements that must be met. It also caused the booms to be taller than 10 feet from the center of the main frame.

The issue was fixed by moving the hydraulic ram closer to the pivot point, a total of 6 inches closer. This allowed the boom to fold up into 102 degrees from horizontal. This also made the boom height right under ten feet at 118.4 inches.
Another design that was changed during the process was the length of the booms. Originally the design was for 12-foot booms. Once the rendering was created for this length the folded height length was very large and was not appealing to the customer. At the request of the customer the length of the booms were lowered to 10 feet. With the boom lengths at this and the main frame having a length of 7 feet it gives a total length of 27.375 feet including the hinges.

The other interesting part about this design is the use of such a large hydraulic cylinder. Although the design only requires a ½ inch piston, the customer supplied a hydraulic having a piston size of three inches. If one were to build this without already having the cylinders supplied one would want to use a smaller cylinder such as a 1” diameter piston to cut down on cost.

**CONCLUSION**

This design will improve the efficiency of the machine. It will cut operation time down which will decrease cost which will then increase profit. It will make it simpler for the operator to run, which will allow more confidence in the operator and in the owner. With this design the operator will not have to come in contact with the chemicals being applied, resulting in a more safe environment.

This project will succeed because the analyses has been completed and checked. The design has been checked for structural integrity and performance. The people involved are trained and qualified to perform the tasks required to complete the project. The other advantage is that the cost of the machine came in under budget and will be completed on task.

**ACKNOWLEDGMENTS**

I would like to thank SOF farms for the funding and opportunity to be apart of the project and to use it as my senior project for the MET program at CWU University. I would also like to thank the mentors professor Pringle and Professor Johnson for the guidance during this ongoing project. Last I would like to thank the University for the use of their resources such as the plasma table in the fabrication shop. Without the help of these people and companies this project would not be a success.
Appendix A

Given:
- Boom pinned at A
- Hydraulic ram pinned at B
- Weight of boom = 41.64 lb at C
- Length of boom = 121.25" from A
- \( \Theta = 28.7^\circ \)

End:
Determine the force the hydraulic ram must exert to lift the boom.

\[
\sum M_A = 0 \quad \text{Vertical force equilibrium:} \quad F_y - W = 0
\]

\[
\cos \Theta = \frac{F_{x}}{F_{yd}} \quad \sin \Theta = \frac{F_{y}}{F_{yd}}
\]

\[
2M_A = 0 \quad 41.64 \times (46.18 \times 12) - F_x (39.98^\circ) + F_y (5.78^\circ) = 0
\]

\[
41.64 \times 126.98 = F_x \cos(28.7^\circ) \times 39.98 + F_y \sin(28.7^\circ) \times 5.78
\]

\[
F_{yd}(3.681) = 1922.94 \text{ lb}
\]

\[
F_x = 531.5 \text{ lb}
\]

\[
F_y = 531.5 \text{ lb} + \cdots
\]

Figure A-1
Chad Omlin  MET 495a piston  10/24/15

Given
- Force = 531.5 lb
- Supplied Psi = 2,600 psi

Find
- Determine Piston Size
- of Hydraulic Ram

Solu

\[ F = PA_p \]
\[ 531.5 \text{ lb} = 2,600 \text{ Psi} (A) \]
\[ A_p = \frac{531.5 \text{ lb}}{2,600 \text{ psi}} \]
\[ A_p = 0.2 \text{ in}^2 \]

\[ D_p = \sqrt{\frac{4(A_p)}{\pi}} \approx 1.12 \text{ in} \]
\[ D_p = 0.5 \text{ requires at least } 0.5'' \text{ piston.} \]
Given
The pin @ A is supported by two fixed "sides" the pin has.
Two shearing surfaces between the cylinder and the "sides."
The force of the cylinder acting on the pin is 531.5 lb.
Pin φ = 1.00".

Find
Determine the average shear stress in the pin and specify an appropriate material.

Solution
\[ V = \frac{F}{2} = \frac{531.5 \text{ lb}}{2} = 265.8 \text{ lb} \]

\[ \tau = \frac{V}{A} = \frac{265.8 \text{ lb}}{\frac{\pi}{4} (1.00 \text{ in})^2} = 338.4 \text{ psi} \]

Due to low shear stress many materials may be used. Steel will be used.
Given

Boom weight = 91.078 lb
Center of mass @ x= 3.340 inches
y= 47.951 inches

Find
Determine force required to extend boom from folded position.

Solution

\[ \sum \tau_{A}=0 \]

\[ -41.078 \text{lb} \times 3.34 \text{ in} = F_x (24.38 \text{ in}) + F_y (2.5 \text{ in}) = 0 \]

\[ F_x \cos(8.75^\circ) \times 24.38 \text{ in} + F_x \sin(8.75^\circ) \times 2.5 \text{ in} = 137.2 \text{ lb in} \]

\[ F_x (24.38 \text{ in}) + F_y (2.5 \text{ in}) = 137.2 \text{ lb in} \]

\[ F_x (24.38 \text{ in}) = 137.2 \text{ lb in} \]

\[ F_x = \frac{137.2 \text{ lb in}}{24.38 \text{ in}} = 5.616 \text{ lb} \]

\[ F_x = 5.616 \text{ lb} \]

\[ \cos \theta = \frac{F_x}{F_{\text{net}}} \]

\[ F_{\text{net}} = F_x \cos \theta + F_y \sin \theta \]

Figure A-4
Given
A hydraulic cylinder pushes a boom outward placing a compressive load of 5.6 lb in the piston rod. During the return stroke the rod pulls the boom with a force of 531.5 lb. SAE 1045 chrome plated

Find
Compute the resulting design factor for the 1.25 in. diameter rod.

Soln
SAE 1045 chrome plated $S_u = 97,900$ psi, $S_m = 49,000$ psi

$A = \frac{\pi}{4} (0.75^2) \rightarrow \frac{\pi}{4} (1.25)^2 = 1.23 \text{ in}^2$

$F_{\text{max}} = 531.5 \text{ lb}$
$F_{\text{min}} = 5.6 \text{ lb}$

$F_m = 531.6 - 5.6 \frac{1}{2} = 263 \text{ lb}$

$F_a = 531.6 - 263 = 268.6 \text{ lb}$

$S_m = \frac{F_m}{A} \rightarrow \frac{263}{1.23} = 213.8 \text{ psi}$

$S_a = \frac{F_a}{A} \rightarrow \frac{268.6}{1.23} = 218.4 \text{ psi}$

$c_8 = (1.25/1.3)^{-11/65}$

$S_n = 26.989 \text{ psi}$

$\frac{1}{N} = \frac{S_m + k_t S_a}{S_n} \rightarrow \frac{1}{N} = \frac{213.8}{97,900} + \frac{1(268.6)}{26.989} \rightarrow N = 82$

* $N=82$ is very high but customer requested cylinders.

Figure A-5
Given
- Hydraulic Cylinder
- Bore $\varnothing = 3''$
- Piston Rod $\varnothing = 1.25''$
- Stroke $= 10''$
- GPM: 20.1

Find
- Determine Max Speed for Hydraulic Extend and Contract.

S/ln

Extend Speed

\[ \frac{2.31 \text{ (GPM)}}{60 \text{ (sec/min)}} / \left( \frac{60 \text{ sec}}{1 \text{ min}} \right) \left( \frac{\pi}{4} (3^2) \right) = 10.94 \frac{\text{in}}{\text{sec}} \]

Retract Speed

\[ \frac{2.31 \text{ (GPM)}}{60 \text{ (sec/min)}} \left( \frac{\pi}{4} (1.25^2) \right) = 1.28 \frac{\text{in}}{\text{sec}} \]

Extend Time

\[ 10.94 \frac{\text{in}}{\text{sec}} \cdot \frac{1}{10} \text{ in} = \frac{1}{100} \text{ sec} \Rightarrow \frac{1}{100} \text{ sec} = .01 \text{ seconds} \]

Retract Time

\[ 1.28 \frac{\text{in}}{\text{sec}} \cdot \frac{1}{10} \text{ in} = \frac{1}{1325} \text{ sec} \Rightarrow \frac{1}{1325} \text{ sec} = .0009 \text{ seconds} \]

Figure A-6
Chad Omlin  BOOM DESIGN 10/12/15

Given
- Strays Boom pinned @ A
- Hydraulic Ram pinned @ B
- Weight of Boom W = 45.16 lbs
- Length of Boom L = 12 feet
- 2,600 PSI Hydraulic Pressure

Find
Determine the Force the hydraulic ram must exert to lift the Boom.

Solve
FBD

\[ F = \frac{P}{A} \]

\[ P = 2,600 \text{ PSI} \]

\[ \frac{F_x}{W + F_{\text{hyd}}} = 0 \]

\[ \frac{F_y}{F_{\text{hyd}} \sin \theta} = 0 \]

\[ \frac{F_{\text{hyd}}}{F_{\text{hyd}} + \sin \theta} = 0 \]

\[ F_{\text{hyd}} = \frac{F_{\text{hyd}}}{F_{\text{hyd}} \sin \theta} \]
Chad Omlin  MET 495a  12/1/15

Given
Right triangle shown

Find
Determine length of x to placement hydraulic cylinder on the main frame?

Solve

\[ A^2 + B^2 = C^2 \]
\[ B^2 = C^2 - A^2 \]
\[ B^2 = 30.25^2 - 1.5^2 \]
\[ B^2 = 915.0625 - 2.25 \]
\[ B^2 = 912.8125 \text{ in} \]
\[ B = 30.21 \text{ inches} \]

Figure A-8
Chad Omkin  MET 485a  12/2/15

Given
1/4" plate
Fillet weld
4" long

Find
Determine the weld size for the bracket joint.

Solution

\[ A_w = L^2 \times 2 = 4^2 = 16 \text{ in}^2 \]

\[ P_w = 5 \times E = 5 \times (120,000 \text{ psi}) = 600,000 \text{ psi} \]

\[ t_e = t/\sqrt{A_w} \]

\[ t_e = 3/16 \text{ in} \]

\[ t = t_e/5 = 0.0381 \text{ in} \]

\[ L = 1.4141 (t) \]

\[ L = 0.22 \]

According to Robert L. Mott, minimum size for 1/4" plate = 3/16".

Figure A-9
Given
Cross section shown @ right
1.25" diameter,.25" wall
.25" plate

Find
Determine the weld size required for the hinge tube.

Solution
\[ A_w = \pi \left( \frac{d}{2} \right)^2 \]
\[ = \pi \left( \frac{1.25}{2} \right)^2 \]
\[ = \pi \left( 0.625 \right)^2 \]
\[ = 1.185 \text{ in}^2 \]
\[ J_w = \pi \left( \frac{d}{2} \right)^4 \]
\[ = \pi \left( 0.625 \right)^4 \]
\[ = 0.785 \]
\[ V = P = 41 \text{ lb} \]
\[ F_s = \frac{P}{A_w} = \frac{41}{1.185} = 34 \text{ lb/in} \]
\[ w = \frac{F_s \mu}{\theta} = \frac{34 \times 10}{7000} = 0.004 \text{ in} \]

Use \( \frac{7}{8} \)" weld due to material

Figure A-10
### Bend hydraulic brackets

<table>
<thead>
<tr>
<th>Action</th>
<th>time spent</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut out one bracket three sided bracket</td>
<td>2 minutes</td>
<td>-</td>
</tr>
<tr>
<td>Purchase bending jig</td>
<td>10 minutes</td>
<td>$339</td>
</tr>
<tr>
<td>Bend hydraulic brackets</td>
<td>5 minutes</td>
<td>-</td>
</tr>
<tr>
<td>Weld on remaining pieces</td>
<td>10 minutes</td>
<td>$2.50</td>
</tr>
</tbody>
</table>

**Total time**: 27 minutes  
**Total cost**: $341.5

*.25 cents per minute welding cost

### Weld hydraulic brackets

<table>
<thead>
<tr>
<th>Action</th>
<th>time spent</th>
<th>cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut three separate pieces</td>
<td>6 minutes</td>
<td>-</td>
</tr>
<tr>
<td>Weld three pieces together</td>
<td>20 minutes</td>
<td>$5</td>
</tr>
<tr>
<td>Weld on remaining pieces</td>
<td>10 minutes</td>
<td>$2.50</td>
</tr>
</tbody>
</table>

**Total time**: 36 minutes  
**Total cost**: $7.50

*.25 cents per minute welding cost

---

Figure A-11
Figure B-1: Drawing 1
Figure B-3: Drawing 2.1
Figure B-4: Drawing 2.2
Figure B-5.1: Drawing 2.4
Figure B-6: Drawing 3
Figure B-7: Drawing 3.1
Figure B-8: Drawing 3.2
Figure B-9: Drawing 3.3
Figure B-10: Drawing 4
Figure B-11: Drawing 4.1
Figure B-12: Drawing 4.2
Figure B-13: Drawing 4.3
Figure B-14: Drawing 5
Figure B-16: Drawing 5.2
Figure B-18: Drawing 6.2
Figure B-20: Drawing 6.4
## Parts/Budget Sheet

### Steel

<table>
<thead>
<tr>
<th>Part</th>
<th>Part Description</th>
<th>Source</th>
<th>Part number</th>
<th>Price ($/lb)</th>
<th>Quantity (lb)</th>
<th>Total price ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square tubing</td>
<td>1x1x.125 inch</td>
<td>Moses Lake Steel Supply</td>
<td>-</td>
<td>0.7354</td>
<td>61.94</td>
<td>45.55</td>
</tr>
<tr>
<td>Flat bar</td>
<td>.25x6 inch</td>
<td>Moses Lake Steel Supply</td>
<td>-</td>
<td>0.627</td>
<td>24.96</td>
<td>15.65</td>
</tr>
<tr>
<td>Round tubing</td>
<td>1.25x.125 inch</td>
<td>Moses Lake Steel Supply</td>
<td>-</td>
<td>0.7354</td>
<td>0.57</td>
<td>0.42</td>
</tr>
</tbody>
</table>

### Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Description</th>
<th>Source</th>
<th>Part Number</th>
<th>Price ($)</th>
<th>Quantity</th>
<th>Total price ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>grease zerk</td>
<td>45* 1/8 inch NPT</td>
<td>McMaster-Carr</td>
<td>1095K23</td>
<td>0.9</td>
<td>2</td>
<td>1.8</td>
</tr>
<tr>
<td>Hydraulic ram</td>
<td>3&quot; piston ram</td>
<td>SOF Farms</td>
<td>-</td>
<td>Donated</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>welding wire</td>
<td>.030&quot; All Purpose (ER70S-6)</td>
<td>Moses Lake Steel Supply</td>
<td>-</td>
<td>35.25</td>
<td>1</td>
<td>35.25</td>
</tr>
<tr>
<td>Clevis Pin</td>
<td>1&quot; diameter x 4&quot; long</td>
<td>McMaster-Carr</td>
<td>97245A521</td>
<td>6.7</td>
<td>4</td>
<td>26.8</td>
</tr>
<tr>
<td>Cotter pin</td>
<td>Clevis pin 7/8&quot;-1&quot;</td>
<td>McMaster-Carr</td>
<td>92375A363</td>
<td>3.61</td>
<td>4</td>
<td>14.44</td>
</tr>
<tr>
<td>Hydraulic hose</td>
<td>10 ft 1/2 inch hose with fittings</td>
<td>Basset Repair</td>
<td>-</td>
<td>74.82</td>
<td>2</td>
<td>149.64</td>
</tr>
<tr>
<td>Spacers</td>
<td>1 1/2&quot; OD, 1&quot; ID</td>
<td>McMaster-Carr</td>
<td>92415A172</td>
<td>13.08</td>
<td>8</td>
<td>104.64</td>
</tr>
</tbody>
</table>

| Total        |                              |                            |             |            |          | 394.19          |

---

**Appendix C**
# Appendix D

## Parts/Budget Sheet

### Steel

<table>
<thead>
<tr>
<th>Part</th>
<th>Part Description</th>
<th>Source</th>
<th>Part number</th>
<th>Price ($/lb)</th>
<th>Quantity (lb)</th>
<th>Total price ($)</th>
</tr>
</thead>
<tbody>
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<td>15.65</td>
</tr>
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<td>Moses Lake Steel Supply</td>
<td>-</td>
<td>0.7354</td>
<td>0.57</td>
<td>0.42</td>
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</tbody>
</table>

### Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Description</th>
<th>Source</th>
<th>Part Number</th>
<th>Price ($)</th>
<th>Quantity</th>
<th>Total price ($)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1095K23</td>
<td>0.9</td>
<td>2</td>
<td>1.8</td>
</tr>
<tr>
<td>Hydraulic ram</td>
<td>3&quot; piston ram</td>
<td>SOF farms</td>
<td>-</td>
<td>Donated</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>welding wire</td>
<td>.030&quot; All Purpose (ER70S-6)</td>
<td>Moses lake Steel Supply</td>
<td>-</td>
<td>35.25</td>
<td>1</td>
<td>35.25</td>
</tr>
<tr>
<td>Clevis Pin</td>
<td>1&quot; diameter x 4&quot; long</td>
<td>McMaster-carr</td>
<td>97245A521</td>
<td>6.7</td>
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<td>26.8</td>
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<td>-</td>
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<td>2</td>
<td>149.64</td>
</tr>
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<td>1 1/2&quot; OD, 1&quot; ID</td>
<td>McMaster-carr</td>
<td>92415A172</td>
<td>13.08</td>
<td>8</td>
<td>104.64</td>
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**Total** | **394.19**
**Fall Quarter Gantt Chart**

<table>
<thead>
<tr>
<th>Task</th>
<th>Start date</th>
<th>Duration</th>
<th>End date</th>
<th>Hours projected</th>
<th>Hours Spent</th>
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<tbody>
<tr>
<td>Fall Quarter</td>
<td>23-Sep</td>
<td>78</td>
<td>9-Dec</td>
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<td>-</td>
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<tr>
<td>Function statement</td>
<td>24-Sep</td>
<td>7</td>
<td>30-Sep</td>
<td>2 hours</td>
<td>2.5 hours</td>
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<tr>
<td>Required statement</td>
<td>1-Oct</td>
<td>7</td>
<td>7-Oct</td>
<td>2 hours</td>
<td>2 hours</td>
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<tr>
<td>Design</td>
<td>8-Oct</td>
<td>14</td>
<td>21-Oct</td>
<td>10 hours</td>
<td>12 hours</td>
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<tr>
<td>Analysis</td>
<td>22-Oct</td>
<td>14</td>
<td>4-Nov</td>
<td>4 hours</td>
<td>3 hours</td>
</tr>
<tr>
<td>Budget</td>
<td>5-Nov</td>
<td>7</td>
<td>12-Nov</td>
<td>2 hours</td>
<td>1 hour</td>
</tr>
<tr>
<td>Drawings</td>
<td>13-Nov</td>
<td>14</td>
<td>26-Nov</td>
<td>10 hours</td>
<td>15 hours</td>
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<tr>
<td>Presentation</td>
<td>27-Nov</td>
<td>7</td>
<td>2-Dec</td>
<td>2 hours</td>
<td>-</td>
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<tr>
<td>Completed proposal</td>
<td>3-Dec</td>
<td>7</td>
<td>9-Dec</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Winter Quarter Gantt Chart

- Winter Quarter
- Submit updated proposal
- Purchase Steel/materials
- Cut booms to length
- Weld boom braces in cut hinge plates on CNC table
- Weld Hinges
- Cut Hydraulic mount
- Assemble boom to frame
- Promo Video
- Completed product

<table>
<thead>
<tr>
<th>Start Date</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-Mar</td>
<td>15</td>
</tr>
<tr>
<td>25-Feb</td>
<td>7</td>
</tr>
<tr>
<td>19-Feb</td>
<td>3</td>
</tr>
<tr>
<td>1-Feb</td>
<td>2</td>
</tr>
<tr>
<td>2-Feb</td>
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</tr>
<tr>
<td>5-Feb</td>
<td>3</td>
</tr>
<tr>
<td>29-Jan</td>
<td>3</td>
</tr>
<tr>
<td>22-Jan</td>
<td>2</td>
</tr>
<tr>
<td>21-Jan</td>
<td>1</td>
</tr>
<tr>
<td>12-Jan</td>
<td>9</td>
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<td>5-Jan</td>
<td>7</td>
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<td>5-Jan</td>
<td>73</td>
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<tr>
<td>Task</td>
<td>Start date</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Winter Quarter</td>
<td>5-Jan</td>
</tr>
<tr>
<td>submit updated proposal</td>
<td>5-Jan</td>
</tr>
<tr>
<td>Purchase Steel/materials</td>
<td>12-Jan</td>
</tr>
<tr>
<td>Cut booms to length</td>
<td>21-Jan</td>
</tr>
<tr>
<td>weld boom braces in</td>
<td>22-Jan</td>
</tr>
<tr>
<td>cut hinge plates on CNC table</td>
<td>25-Jan</td>
</tr>
<tr>
<td>Weld Hinges</td>
<td>29-Jan</td>
</tr>
<tr>
<td>Cut Hydraulic mount Brackets on CNC Table</td>
<td>3-Feb</td>
</tr>
<tr>
<td>Weld Hydraulic Bracket Assembly’s</td>
<td>5-Feb</td>
</tr>
<tr>
<td>Weld Hinges to frame and Boom</td>
<td>12-Feb</td>
</tr>
<tr>
<td>Weld Hydraulic brackets to frame and Boom</td>
<td>13-Feb</td>
</tr>
<tr>
<td>Assemble boom to frame and attach hydraulics</td>
<td>19-Feb</td>
</tr>
<tr>
<td>Promo Video</td>
<td>25-Feb</td>
</tr>
<tr>
<td>Completed product</td>
<td>3-Mar</td>
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<tr>
<td>Task</td>
<td>Start Date</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------</td>
</tr>
<tr>
<td>Spring Quarter</td>
<td>29-Mar</td>
</tr>
<tr>
<td>Test 1</td>
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<td>19-Apr</td>
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<td>Test 2</td>
<td>29-Apr</td>
</tr>
<tr>
<td>Source</td>
<td>23-May</td>
</tr>
</tbody>
</table>

Appendix J
Objective

Seeking position in mechanical engineering field. I am driven and eager to learn. This is a great opportunity to help your business be successful and grow.

Experience

Agriculture business/management 2010-Present

- Over the years I have moved up from farm hand to small farm owner. I know how to move up in a business and be successful.
- Experience on how to run a company financially, physically, and mentally.
- Experience working and managing with others, which has intern created great people skills.

Education

Big bend Community College 2011-2013

- Associates in Arts and Sciences degree

Central Washington University 2013-Present

- Currently a student in the mechanical engineering tech program.

Skills

- Mechanical Design
- Fabrication and manufacturing
- Work well with teams
- Driven and committed to my work