Residents on the Zuni Native American Reservation in New Mexico currently use wood to heat their homes. Heat provided from burning wood is adequate, but the lumber supply in this region is diminishing. Jim Kuiper, our contact for the project and a teacher at the Zuni Christian Reformed Mission School, had seen an alternative style of home construction that involves the use of discarded tires filled with soil as the home’s exterior walls. The challenge in building these homes is that filling the tires with soil is done using sledgehammers and shovels which requires large amounts of heavy labor. This labor cost deters potential homebuilders and also accounts for 30% of the overall building cost. Our team plans to provide an easier, more cost effective method of packing tires. To realize this goal a machine has been conceptualized that can fill a tire with soil and compact the soil to the required density automatically. The proposed machine is roughly 3’x 4’, uses hydraulic components to compress the soil and is electrically controlled and operated through the use of selector switches.
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Introduction:

A new type of energy efficient house being built in New Mexico that uses discarded tires filled with soil as the main exterior walls. A home built with these thick walls has much better insulation than a traditionally constructed home. The main difficulty with building these houses is that tires have to be packed using a sledgehammer and shovel, about 1200 tires are required to build a three bedroom home. This part of the construction is the most time consuming and labor intensive causing this portion of construction to be extremely expensive. The contact for the project Jim Kuiper, had requested that a machine be build to aid in the process of filling the tires with soil. Mr. Kuiper desires to build and promote construction of this alternative type of home on the Zuni Native American Reservation where he lives and works as a elementary school teacher. There are two specific reasons that Jim Kuiper desires to build this type of home. First, Native Americans living in the community use wood to heat there homes. The availability of wood resources continue to deplete with the growing population in the region, this type of home would allow the local community to need less wood to heat their homes. Second, he would like to build homes for church sponsored volunteers that come to help in the area. The main objective for this project is to build a machine that will fill discarded tires with soil at a faster rate than traditional methods as well was requiring less strenuous effort for the machine operator.

Project Challenges:

- **Scope of Project**

  There are three stipulations that define the project’s scope and give to STP’s. First, no more than two people will be needed to operate the device; this is to avoid increasing the required number of workers and labor requirements. Second, the machine should be able to fit in the back of a standard pickup truck, and be light enough that two people can lift it from the back of the truck so that the machine is easier to move from one place to another. The target weight of the machine is between 150-300 lbs. Though the contact person in the target area it was learned that standard pickup trucks are one of the common transportation vehicles for the people who will be using the device. The target operation time for the machine is 30 minutes or less.
The target time of 30 minutes was given to us by our team contact Jim Kuiper. The current time that it takes to fill a tire by traditional techniques is approximately 40 minutes.

- **Christian Perspective**
  As Christians there is a responsibility to God’s creation. As engineers this can be shown by how the design process is approached. The descriptions below show the design norms and how they apply to this project.

**Cultural Appropriateness – The design ought to fit the culture into which it is introduced**
Cultural appropriateness is an important consideration for this project because it will be used on the Zuni Native American Reservation, where the cultural setting is different from that in Grand Rapids, MI. The device is a machine and so to be cultural appropriateness it must be built in such a way that the target community can understand and operate it. One example of this in the project is in the size requirements so that the people using the device will be able to transport it to the construction site where the home is being built. As part of the machine design it will be able to fit in the back of the average pickup truck because, common transportation for larger equipment may not be accessible for our customers in the New Mexico desert.

**Transparency – The design should be open, understandable, predictable, and intuitive**
The transparency of the design will manifest in its simplicity. Unlike a computer program, the user of the device can easily see the components used to build the device. To clearly communicate the function of the design, operating instructions were created in a style that the people using the machine will be able to easily understand.

**Stewardship – The design should carefully use environmental, economic, and human resources**
Economic and environmental stewardship are two integral parts of the project. Economic stewardship was an issue that forced the design to optimize the materials used so that the materials would meet the design requirements, yet, be at a cost that is low enough to stay within the given budget. The environmental stewardship part of the project is that homes being built by the machine are extremely energy efficient, which will reduce the amount of wood used in heating the homes of the community. One way in which this machine could violate the stewardship norm is if people started building these homes without suitable preparation. If too much soil is take from the landscape it could cause damage to the local topography, causing other unexpected results to the local ecosystem.
Integrity - The design should promote human values and relationships

Integrity is very important in today’s society. It would be easy for an engineer to design something to be self-serving in their motivations. This machine is intended to make life easier for Native Americans and church workers living on the reservation, because, it will allow them to lower the cost of building homes and reduce the cost of annual heating expenses.

Justice – Design ought to respect the rights of all persons

Justice has been incorporated into this project in that the machine can be operated with a feeling of comfort and safety by the operator. Another way that this machine approaches justice is though the use of sound reducing components, extremely loud machinery may not respect the rights of other people in the community.

Caring – Design ought to show due care for persons; physically, socially, and psychologically

The machine will show care for persons in that it is going to decrease the costs of build alternative style homes for community. By reducing the required labor costs and annual heating costs the community could increase its standard of living.

Trust – Design should be trustworthy, dependable, and reliable

The trustworthiness of the machines is such that the prototype will be tested before being delivered to the target operator to make sure that it is safe. Safety for the user when operating the machine is extremely important, safety labels and other warnings will be implemented to make the operator aware of possible hazards.

- Project Economics

The economic goal of this project was to have a cost effective solution. This entailed finding financial support and material donations in order to meet the financial limitations. The operating budget of this device was to be $300, provided by the Calvin Engineering Department. Due to the nature of the equipment used the machine has to be flexible in order to use non-ideal components. Small components were purchased from local companies while major components were purchased or donated from suppliers.
Final Challenge Solution:

- **Approach**

To approach the challenge a variety of questions were addressed about the conditions that the machine would be operated in. One of the first questions that were addressed was “What constitutes a full tire?” A full tire is packed when the soil causes the sidewall of the tire to expand 2 inches larger the original width shown in Figure 1.

![Figure 1: Packed Tire on Left Unpacked Tire on Right Showing Change in Size](image)

Another issue addressed was “Who would be using the machine?” Due to the variety of users it was determined that the machine would be transparent and easily operated anyone with limited technical background. The next question addressed was “How will the device be powered?” Upon consulting with the project recipient it was found that a standard generator will be present at the job site as the main source of electrical power. “How much force will we need to pack a tire?” was the next question addressed. This question was addressed by attempting to reproduce traditional methods for compacting a tire using the force and motion of a sledgehammer, hand calculates were used to estimate these forces, see Appendix 1. The final question addressed was “How transportable will the device need to be?” The long term goal of the project recipient is to create multiple tire filled homes requiring that the machine is transportable by standard pickup truck.
• **Final Design**

Once the primary design concerns were addressed, it was determined that the final design would take the form of a pressing machine powered by a hydraulic system that would be responsible for compacting the soil in multiple areas of the tire, an electrical system that would control the operation and timing of the hydraulic system and, finally a structural component that will support and combine all systems together.

• **Structural Design**

Once the basic form of the device was determined, the structural components were designed. It was decided that the tire being packed would be raised off the ground, so that after the tire is packed a cart could be used to relocate the tire. By constructing a raised base structure the hydraulic components can also be concealed to prevent tampering or injury. The structural design of the tire packing device is based on a rectangular frame to which a cantilevered beam is mounted, all components used to control and compress the soil are attached to the main frame structure.

![Figure 2: Main Structural Design](image)

The base frame structure is composed of both one inch and two inch square tubing. Added structural support was incorporated under the area where the tire is placed. The cantilevered
beam is composed of two inch square tubing, with one inch square tubing used as cross bracing for added support. The need for added supports on both the base frame structure and the compressing arm was to allow for unanticipated loading situations so that there would be limited risk that the structure would fail and possibly injure the user. To hold the hydraulic cylinders two hinged brackets were created from quarter inch steel plate and one and a half inch square tubing. With the used of hydraulic cylinders large amounts of force are being generated in the compacting area, by allowing the forces to be located near vertical members and along bracing members the machine is able to experience large forces with little to no deflection in the base frame. All joints were welded together on all available edges. Welding was chosen to provide rigidity and a more cost effective joint than bolts with bracing. To validate the proposed design stress and deflection calculations were carried our. To verify that the frame design was robust enough to hold the expected loads, stress and bending calculations were carried out in the form of hand calculations found in Appendix 1 and FEA analysis found in Appendix 2. These calculations show that there is an expected deflection of .36 inches in the compacting arm, with a stress concentration located at the joint were the arm is attached to the frame. For the base frame the areas of deflection are located at the connection of the compacting arm as well as on the two horizontal support members in the front of the frame, the maximum deflection calculated was .02 inches. The analysis on the hydraulic brackets showed a stress concentration at the rear mounting position of the compacting cylinder.

The cost to produce the prototype frame was all covered by donations. The scrap material supply in the Calvin Metal shop had all necessary materials to produce the frame. If material was purchased there would have been an overall cost of $230.00. The estimated cost to purchase the steel tubing for the frame construction was based on a cost of five dollars per foot for the one inch square tubing and nine dollars per foot of two inch square tubing.

The labor required to recreate the base frame design and compacting arm would be about two or three days for a relatively experienced fabricator. Requiring roughly four hours to cut all pieces from bar stock, an hour or two to prepare the material for welding, four to five hours required to weld all joints, and another hour required for weld polishing and repair. To paint the frame a full day or more is required depending on paint used and number of coats applied.

In the schedule set for construction of the frame for the prototype, design revisions delayed construction for two months. This delay did not interfere with project completion as
sequential parts required modification to incorporate the design changes. Design changes limited the full testing procedure planned earlier in the semester.

The structural components were made from the square steel tubing based upon availability and ease for construction. The choice to construct the frame from steel oppose to aluminum was based on the construction techniques that were available to Team 4 and anticipated capabilities of the workers on the reservation in New Mexico. If there happens to be some accidental damage to the frame structure during operation there is a greater chance that the construction site in New Mexico will have a welder capable of welding steel over aluminum. Other construction materials were not used or considered in an effort to reduce final cost of the prototype and reproductions of the prototype.

- **Hydraulic System**

  The mechanical movements of this prototype are driven by a hydraulic oil system. This system includes one (1) hydraulic power unit consisting of a 1750 RPM – ¾ HP electric motor, ¼ GPM at 1750 RPM gear-pump, and a two gallon reservoir tank; two (2) four-way, two-position solenoid valves; one (1) two-way, two-position solenoid valve; two (2) 1-1/8” bore, 5” stroke cylinders; one (1) 0.196 in3/rev hydraulic drive; two (2) cross-style manifold fittings; and several #4 JIC hydraulic line and fittings.

  In an effort to determine a method to imitate the packing force of a sledgehammer several options were proposed but hydraulic power was chosen. A hydraulics system was chosen due to the large mechanical advantage achievable but more importantly because most of the components listed above were acquired in previous years and available free of charge in the Calvin Engineering storage room. The parts not available from previous design projects were generously donated.

- **Electrical System**

  The initial electrical system was very transparent during the development stages of the project however the final load requirements were not. The initial concept proposed a distributed load of around 15 amps at 120V 1Ø phase plus overload protection, this required a 2130 Watt power system. The load requirement was based from a proposed system requiring 2 electric motors. The electrical system would also include motor controls and safety switches to ensure the operator’s safety during the tire compacting process. A control panel would also be created to initiate user control and have safety switches for preventing any accidents to the operator.
The final design encompassed the initial concept of using a control panel which included motor control and a safety system. However, a larger load requirement of 21.44 amps at 120V 1Ø phase plus overload protection was required to operate our hydraulic pump, (2) cylinders, and (1) hydraulic motor system.

The final design required a load which exceeded the capacity of a typical 20A outlet, an alternate system design was needed. Two alternate systems were proposed based on the wiring capabilities of the hydraulic pump system - 30A 120V 1Ø phase system or 20A 240V 1Ø phase system. Both systems require a special outlet connection. Typically, on a new construction site temporary power is required to power tools and equipment until the building can be connected to the power grid. A typical portable generator is used for this purpose. These generators typically have 240V receptacle(s) and have a large enough load capacity to operate construction equipment. An example would be large power tools such as power saws, welders and concrete mixers. The project recipient confirmed a portable generator with 20A 240V 1Ø capability would be available to the workers at the construction site. The decision was made to design the system to operate from a 20A 240V 1Ø phase system.

The hydraulic pump is fed directly from the 240V 1Ø supply and the control components are fed downstream of a 0.275kVA control transformer at 120V 1Ø. The control components include (2) 22W solenoid valves for cylinder control, (1) 42W solenoid valve for the tire rotation hydraulic motor and (1) Pico controller for automation timing. The in-depth power distribution analysis and power schematic, one-line diagrams are provided in Appendix 3 and Appendix 4 respectively.

The Pico control system was included in the design to provide the user with an automatic packing cycle. The automation system provides the user with the ability to operate the machine by themselves, not requiring a second worker to operate controls while soil is being added. Automatic and manual ladder logic diagrams, timing sequence blocks, input and output controls, and machine operation manuals provided for the Pico controller can be found in Appendix 5. The panel parts list can be found in Appendix 6.

- **Budget**

To produce the proposed prototype $300 was provided by the Calvin College Engineering Department. Due to the large cost of some components used in the final proposed design the overall cost of the prototype exceeded the available budge. To construct the prototype
spare hydraulic components were used. These components were found in the engineering storage room and consisted of the main hydraulic pump assembly, both hydraulic cylinders and hydraulic tubing. The electrical components were all donated from local companies, listed in the acknowledgements section.

The projected cost to reproduce the proposed design is roughly $3000, detailed pricing is found in Appendix 7. Approximate pricing for the main three systems was $500 for structural and mounting components, $900 for electrical components and, $1700 for hydraulic components. Of the estimated $3000 the most costly components are the hydraulic cylinders, the hydraulic pump, and the Pico controller. To reduce the costs of the controller an alternative controller called the “Alpha Controller” made by Mitsubishi can be used and is one third of the price of the Pico controller, however, does not provide as much versatility. The hydraulic components do not have any cost saving alternatives; however, cylinders that require less pressure could be used but, 3000 psi is considered to be a small cylinder.

- **Schedule**

A project a project schedule was created at the beginning of the project and can be found in Appendix 8. Approximately half-way through the completion of the project the schedule was being met and followed, however, during the second half of the project major design changes not accounted for in the original project schedule limited the team’s ability to continue adhering to the original project timeline. Design modifications hindered the team’s ability to follow the schedule, weekly and monthly schedules in the form of to-do lists were created and maintained to keep the project on track and completed by the original deadline. An example of these task lists can be found in Appendix 8. In creating shorter task lists the focus was to use “the 80% design rule,” start building prototypes when 80% of the original goals are met, to make up for being behind in the original schedule.

**Conclusion:**

The original scope of the project was to fill and compact a tire in 10 minutes through the use of a mechanically assisted machine, with comparable density than done through traditional means. Through the design process it became imperative to adjust the scope. Changes to the scope included that the machine would no longer come in three separate pieces, but instead one
piece that could be transported by three people. The original scope also said that the amount of
time to pack a tire would be less than 10 minutes, in revised goal pack a tire in 30 minutes. The
main explanation of this change was the needed a larger hydraulic pump to move the ram fast.
The final solution consisted of three main systems, a structural component that utilized steel
square tubing and a cantilever beam to support the hydraulic cylinders which are used to
compact the soil and are controlled by the electrical system that utilizes a Pico control unit to
time all motions. This device has been able to compress soil to a comparable density with
traditional techniques while meeting all required, deadlines and, financial limitations.

**Recommendation:**

In further development of this project there are several recommendations that would
improve the overall design. First, if hydraulic flow rate was increased the hydraulic ram would
move faster. Flow rate can be increased by replacing the hydraulic pump or exchanging the
drive gears in the pump that we are currently using (if the gears are changed it will move the ram
faster but decrease the pressure). Second, there is no flow control on the hydraulic motor that is
used to rotate the tire. If flow controls were added the user would be able to more accurately
index the tire. Next, if independent pressure control for the drive and cylinders were used the
user would be able to more efficiently distribute the capabilities of the hydraulic fluid. A greater
proportion of the pressure would go to the hydraulic motor which requires more pressure than
the hydraulic cylinders. Finally, a spring loaded hydraulic drive mount would allow the user to
easily adjust the machine for different sized tires.
Acknowledgements:

We would like to give a special thanks to the following people for their guidance, mentoring and helping hand.

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Extol Inc. – For allowing us to use their equipment for some of our prototype fabrication.

Thank you!
Dave, Jeremy, Josh and Chris
Appendixes

Appendix 1: Hand Calculations
Appendix 2: ALGOR-FEA Analysis
Appendix 3: Distributed Power Analysis
Appendix 4: Electrical Schematics
Appendix 5: Control System Operation
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Appendix 7: Budget
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Appendix 9: Drawing Prints
Appendix 10: Operation Manuals and Instructions
Appendix 1: Hand Calculations

Ram Force Calculations

Handle length := 3-ft

Time swing := .15-sec

\[ V_{swing} := \left( \frac{\text{Handle length} \pi}{2 \times \text{Time}_{swing}} \right) \]

\[ \text{Acceleration}_{swing} := \frac{V_{swing}}{\text{Time}_{swing}} \]

\[ \text{mass}_{sledge} := 8\text{-lb} \]

\[ \text{Force}_{sledge} := \text{mass}_{sledge} \times \text{Acceleration}_{swing} \]

\[ \text{Force}_{sledge} = 52.077\text{lbf} \]

Straight Swing

\[ \text{Length}_{swing} := 2\text{-ft} \]

\[ \text{Swing}_{time} := .15\text{-sec} \]

\[ \text{Swing}_{Velocity} := \frac{\text{Length}_{swing}}{\text{Swing}_{time}} \]

\[ \text{Swing}_{Acceleration} := \frac{\text{Swing}_{Velocity}}{\text{Swing}_{time}} \]

\[ \text{Swing}_{Force} := \text{mass}_{sledge} \times \text{Swing}_{Acceleration} \]

\[ \text{Swing}_{Force} = 22.102\text{lbf} \]

Impulse Calculation

\[ \delta_m := 0.5\text{in} \]

\[ h := 20\text{ft} \]

\[ F_e := \text{mass}_{sledge} \times \left[ 1 + \sqrt{1 + 2 \times \frac{h}{\delta_m}} \right] \]

\[ F_e = 256\text{lb} \]
Deflection in center  (Calculated with no Supports under structure)

\[
\text{Load} := 1075 \text{lbf} \\
\text{Length} := 33 \text{ in} \\
E := 30 \times 10^6 \text{psi} \\
I := \frac{(1\text{-in})(1\text{-in})^3}{12} - \frac{.75\text{-in}(.75\text{-in})^3}{12} \\
\delta_{\text{max}} := \frac{\text{Load} \cdot \text{Length}^3}{192E \cdot I} \\
\delta_{\text{max}} = 0.118\text{in}
\]

Deflection with angular Loading  (Calculated with no Supports under structure)

\[
\text{Load}_2 := 575 \text{lbf} \\
\text{Length}_2 := 33 \text{ in} \\
\delta_{\text{max}2} := \frac{\text{Load}_2 \cdot \text{Length}_2^3}{192E \cdot I} \\
\delta_{\text{max}2} = 0.063\text{in}
\]
Stress of Center Member

\[ \text{Moment} := \text{Load} \cdot \frac{\text{Length}}{2} \]

\[ c := \text{.5-in} \]

\[ \sigma_{\text{vertical}} := \frac{\text{Moment} \cdot c}{I} \]

\[ \sigma_{\text{vertical}} = 1.557 \times 10^5 \text{ psi} \]

Stress for Angular Loading

\[ \text{Moment} := \text{Load} \cdot \frac{\text{Length}}{2} \]

\[ c := \text{.5-in} \]

\[ \sigma_{\text{vertical}} := \frac{\text{Moment} \cdot c}{I} \]

\[ \sigma_{\text{vertical}} = 8.327 \times 10^4 \text{ psi} \]

Arm Deflection and Stress

\[ B := 2\text{-in} \quad H := 2\text{-in} \quad L := 27\text{ in} \quad E := 300000000\text{psi} \]

\[ I := \left[ \frac{B \cdot H^3}{12} - \frac{(B - .25\text{ in})(H - .25\text{ in})^3}{12} \right] \cdot 2 \]

\[ \text{Force} := 1000\text{lbf} \]

\[ \text{hinge}_\text{length} := 5\text{-in} \]

\[ M := \text{Force} \cdot \text{hinge}_\text{length} \]

\[ \text{Deflection}_\text{moment} := \frac{M \cdot L^2}{2 \cdot E \cdot I} \]

\[ \text{Deflection}_\text{moment} = 0.055\text{in} \quad \text{(down)} \]

\[ P := 5\text{lbf} \]

\[ \text{Deflection}_\text{weight} := \frac{P \cdot L^3}{3 \cdot E \cdot I} \]

\[ \text{Deflection}_\text{weight} = 9.909 \times 10^{-4}\text{ in} \quad \text{(down)} \]
Arm Mount Calculations

\( \alpha := 30 \text{ deg} \quad \beta := 20 \text{ deg} \quad \gamma := 90 \text{ deg} \)

Compressing force := 2000 lb

\[
F_b := \frac{\text{Compressing force} \sin \gamma}{\sin \alpha + \cos \alpha \sin \beta}
\]

\[
F_f := \frac{F_b \cos \alpha + \text{Compressing force} \cos \gamma}{\cos \beta}
\]

\( w := 2 \text{ in} \)

\( d := .5 \text{ in} \)

\[ r := \frac{d}{w} \quad r = 0.25 \]

\( K_t := 2.3' \)

\[
K_g := K_t \left( \frac{w}{w - d} \right)
\]

\( \sigma_b := \frac{1}{2} \cdot K_g \cdot \frac{F_b}{.5 \cdot 1.5} \)

\( \sigma_f := \frac{1}{2} \cdot K_g \cdot \frac{F_f}{.25 \cdot 1.5} \)

Turn Table Support

\[
\frac{350 \text{ lbf}}{\frac{33 \text{ in}}{2}} = 0.409 \text{ psi} \quad \text{(Load From Tire)}
\]

\( E := 70 \cdot 10^9 \cdot \text{Psi} \)

\( L := 3 \text{ in} \)

\( I := .197 \text{ in}^4 \)

\[
y_{\text{max}} := \frac{-(.409 \cdot 1.5) \frac{\text{lbft}}{\text{in}} \cdot \frac{4}{\text{in}}}{8 \cdot E \cdot I}
\]

\[
y_{\text{max}} = -7.889 \times 10^{-8} \text{ m}
\]
Direct Shear Loading for all Bolted Joints and Pins

\( \text{ksi} := 1000 \text{psi} \)

**Diameters and Areas of (4) pins and (1) bolt pattern**

\[
\begin{align*}
\text{Pin}_\text{ram} & := 0.5 \text{in} \\
\text{Pin}_\text{endrod} & := 0.5 \text{in} \\
\text{Pin}_\text{pivot} & := 0.625 \text{in} \\
\text{Pin}_\text{roller} & := 0.25 \text{in}
\end{align*}
\]

\[
\begin{align*}
\text{Bolt}_\text{cylinder} & := 0.25 \text{in}
\end{align*}
\]

\[
\begin{align*}
A_{\text{ram}} & := \pi \cdot \frac{\text{Pin}_{\text{ram}}}{4}^2 \\
A_{\text{endrod}} & := \pi \cdot \frac{\text{Pin}_{\text{endrod}}}{4}^2 \\
A_{\text{pivot}} & := \pi \cdot \frac{\text{Pin}_{\text{pivot}}}{4}^2 \\
A_{\text{roller}} & := \pi \cdot \frac{\text{Pin}_{\text{roller}}}{4}^2 \\
A_{\text{cylinder}} & := \pi \cdot \frac{\text{Bolt}_{\text{cylinder}}}{4}^2
\end{align*}
\]

**Maximum Forces Experienced by Members**

\[
\begin{align*}
F_{\text{ram}} & := 3000 \text{lb}f \\
F_{\text{endrod}} & := 3000 \text{lb}f \\
F_{\text{pivot}} & := 3000 \text{lb}f \\
F_{\text{roller}} & := 500 \text{lb}f \\
F_{\text{cylinder}} & := 3000 \text{lb}f
\end{align*}
\]

**Shear Calculations of Pin Members: All Members are SAE Grade 8 with Yield Strength of 120 ksi**

\[
\begin{align*}
\tau_{\text{ram}} & := \frac{F_{\text{ram}}}{A_{\text{ram}}^2} \\
\tau_{\text{endrod}} & := \frac{F_{\text{endrod}}}{A_{\text{endrod}}^2} \\
\tau_{\text{pivot}} & := \frac{F_{\text{pivot}}}{A_{\text{ram}}^2} \\
\tau_{\text{roller}} & := \frac{F_{\text{roller}}}{A_{\text{roller}}^2}
\end{align*}
\]

\[
\begin{align*}
\tau_{\text{cylinder}} & := \frac{F_{\text{cylinder}}}{A_{\text{cylinder}}^4}
\end{align*}
\]

\[
\begin{align*}
\tau_{\text{ram}} & = 7.639 \text{ksi} \\
\tau_{\text{endrod}} & = 7.639 \text{ksi} \\
\tau_{\text{pivot}} & = 7.639 \text{ksi} \\
\tau_{\text{roller}} & = 5.093 \text{ksi}
\end{align*}
\]

\[
\tau_{\text{cylinder}} = 15.279 \text{ksi}
\]
**Gear Connection**

$$\text{rpm} := \frac{2}{\text{min}}$$  
(Motor Speed)

$$\omega_2 := \text{rpm} \left( \frac{60}{2\pi} \right)$$  
(Converted Motor Speed)

$$N_1 := 6$$  
(Number of teeth on meshing gear)

$$N_2 := 4$$  
(Number of teeth on motor gear)

$$\frac{N_1}{N_2} = 1.333$$  
(Gear Ratio)

$$\omega_{\text{operating}} = \left( \frac{N_1}{N_2} \right) \omega_2$$  
(Operating Speed of ram)

$$\omega_{\text{operating}} = 0.424 \text{Hz}$$  

$$\text{Torque}_{\text{motor}} := 115 \text{ in.-lbf}$$  
(Torque Available from Motor)

$$\text{Torque}_{\text{operating}} = \left( \frac{N_2}{N_1} \right) \cdot \text{Torque}_{\text{motor}}$$  
(Torque applied to meshing gear)

$$\text{Torque}_{\text{operating}} = 9.745 \text{ J}$$  

**Tire Speed**

$$\text{Motor}_{\text{speed}} := \frac{10}{\text{min}}$$  

$$\text{speed}_{\text{rev per min}} = \text{Motor}_{\text{speed}} \left( \frac{60}{2\pi} \right)$$

$$\text{Tire}_{\text{radius}} := 16$$

$$\text{Tire}_{\text{radius}} := 3$$

$$\text{Tire}_{\text{rotating speed}} = \frac{\text{Tire}_{\text{radius}}}{\text{speed}_{\text{rev per min}}}$$

$$\text{Tire}_{\text{rotating speed}} = 0.298 \text{ Hz}$$

$$\text{Tire}_{\text{rotating speed rpm}} = \frac{\text{Tire}_{\text{rotating speed}} 2\pi}{60}$$

$$\text{Tire}_{\text{rotating speed rpm}} = 0.031 \text{ Hz}$$
Hydraulic Motor Calculations

\[ \text{rev} := 2\pi \text{rad} \]

\[ \text{PumpFlow} := 0.25 \frac{\text{gal}}{\text{min}} \]

\[ \text{Drive}_{\text{displacement}} := 0.194 \frac{\text{in}^3}{\text{rev}} \]

\[ \text{TireSpeed} := 20 \frac{\text{rev}}{\text{min}} \]

\[ \text{Drive}_{\text{speed}} := \frac{\text{PumpFlow}}{\text{Drive}_{\text{displacement}}} \]

\[ \text{Drive}_{\text{speed}} = 297.68 \frac{\text{rev}}{\text{min}} \]

\[ \text{R}_{\text{tire}} := 16.5 \text{in} \]

\[ \text{R}_{\text{gear}} := \frac{\text{R}_{\text{tire}} \cdot \text{TireSpeed}}{\text{Drive}_{\text{speed}}} \]

\[ \text{R}_{\text{gear}} = 1.109 \text{in} \]

\[ \text{TireSpeed} = 0.333 \frac{\text{rev}}{\text{sec}} \]
Appendix 2: ALGOR-FEA Analysis

Load Case: 1 of 1
Maximum Value: 0 in
Minimum Value: 0 in

Load Case: 1 of 1
Maximum Value: 72338.8 lb (in)
Minimum Value: 0 lb (in)
Appendix 3: Distributed Power Analysis

Distributed Power analysis and overload protection

Load calculations for (1) motor, (3) solenoid valve system, (1) controller

\[ V_{s120} = 115V \quad V_{s230} = 230V \quad \theta = 1\text{phase} \quad f_{\text{req}} = 60\text{Hz} \]
\[ \text{Poles} = 4 \quad \text{HP} = 0.75 \quad f_{\text{max}} = 60 \quad \text{Eff} = 54 \quad \text{Pf} = 58 \]

Hydraulic Pump System Load Calculations

\[ I_{\text{meas\_motor}} = 19\text{A} \quad P_{\text{pump}} := I_{\text{meas\_motor}} \cdot V_{s120} \quad P_{\text{pump}} = 2.185 \times 10^3 \text{W} \]

Speed of Induction Motor

\[ S_{\text{rpm}} = \frac{230 \text{Hz}}{\text{Poles}} \quad I_{230} = 10\text{A} \quad S_{\text{rpm}} = 3.45 \times 10^3 \text{ rpm} \]

Calculating Breaking/Full Torque

\[ \tau = \frac{5250 \cdot \text{HP}}{S_{\text{rpm}}} \quad T = 1.14\text{ lb-ft} \]

Calculating Horse Power

\[ \text{HP} := \frac{V_{s230} \cdot I_{\text{meas\_motor}} \cdot \text{Eff} \cdot \text{Pf}}{746} \quad \text{HP} = 1.825\text{W} \]

\[ I := \frac{\text{HP} \cdot 746}{V_{s230} \cdot \text{Eff} \cdot \text{Pf}} \quad I = 19\text{A} \quad \text{checking measured values} \]

Start-up inrush and operation loads

Pivot Solenoid

\[ P_{\text{sol1}} = 22\text{W} \quad I_{\text{sol1}} = \frac{P_{\text{sol1}}}{V_{s120}} \quad I_{\text{sol1}} = 0.191\text{A} \]
\[ I_{\text{sov1}} := I_{\text{sol1}} \cdot 1.25 \quad I_{\text{sov1}} = 0.239\text{A} \]

Ram Solenoid

\[ P_{\text{sol2}} = 22\text{W} \quad I_{\text{sol2}} = \frac{P_{\text{sol2}}}{V_{s120}} \quad I_{\text{sol2}} = 0.191\text{A} \]
\[ I_{\text{sov2}} := I_{\text{sol2}} \cdot 1.25 \quad I_{\text{sov2}} = 0.239\text{A} \]
Hydraulic Motor Solenoid

\[ P_{\text{sol3}} = 42\text{W} \quad I_{\text{sol3}} = \frac{P_{\text{sol3}}}{V_{s120}} \quad I_{\text{sol3}} = 0.365\text{A} \]

Combined solenoid load

\[ I_{\text{tsolv}} = I_{\text{sol1}} + I_{\text{sol2}} + I_{\text{sol3}} \quad I_{\text{tsolv}} = 0.935\text{A} \]

\[ P_{\text{tsolv}} = P_{\text{sol1}} + P_{\text{sol2}} + P_{\text{sol3}} \quad P_{\text{tsolv}} = 86\text{W} \]

Pico Controller Load Calculations

\[ I_{\text{input}} = 5\text{mA} \quad I_{e} = 70\text{mA} \quad I_{\text{total.input}} = 6 \cdot I_{\text{input}} \quad I_{\text{total.input}} = 3 \times 10^{-3}\text{A} \]

\[ I_{\text{pico.run}} = I_{e} + I_{\text{total.input}} \quad I_{\text{pico.run}} = 0.073\text{A} \]

\[ I_{\text{pico.inrush}} = 1.5\text{A} \quad I_{\text{pico.operate}} = I_{\text{pico.inrush}} + 4\text{mA} \quad I_{\text{pico.operate}} = 1.504\text{A} \]

\[ P_{\text{pico.inrush}} = I_{\text{pico.inrush}}V_{s120} \quad P_{\text{pico.inrush}} = 172.5\text{W} \]

\[ P_{\text{pico.operate}} = I_{\text{pico.operate}}V_{s120} \quad P_{\text{pico.operate}} = 172.96\text{W} \]

Combined 120V 1PH System Load

\[ P_{\text{system}} = P_{\text{pump}} + P_{\text{pico.operate}} + P_{\text{tsolv}} \quad P_{\text{system}} = 2.444 \times 10^{3}\text{W} \]

\[ I_{120\text{system}} = I_{\text{pico.operate}} + I_{\text{mech}\text{-motor}} + I_{\text{tsolv}} \quad I_{120\text{system}} = 21.439\text{A} \]

\[ I_{120\text{system.overload}} = I_{120\text{system}} \times 1.25 \quad I_{120\text{system.overload}} = 26.792\text{A} \]

\[ KVA_{120} = \frac{(I_{120\text{system.overload}})V_{s120}}{1000} \quad KVA_{120} = 3.082\text{W} \]

Combined 230V 1PH System Load (Estimated power system using 230V supply with a step-down transformer)

\[ I_{230\text{pump}} = 10\text{A} \quad P_{230\text{pump}} = I_{230\text{pump}}V_{s230} \quad P_{230\text{pump}} = 2.3 \times 10^{3}\text{W} \]

\[ I_{\text{tsolv230}} = \frac{I_{\text{tsolv}}}{2} \quad I_{\text{tsolv230}} = 0.467\text{A} \]

\[ I_{230\text{system}} = I_{\text{tsolv230}} + I_{230\text{pump}} \quad I_{230\text{system}} = 10.467\text{A} \]

\[ P_{230\text{system}} = (I_{230\text{system}})V_{s230} \quad P_{230\text{system}} = 2.408 \times 10^{3}\text{W} \]
Transformer Sizing \( \text{(kVA required)} \)

\[
I_{t} = 0.935 \text{ A} \quad I_{\text{indicator}} = 0.250 \text{ A} \quad I_{\text{pico.operate}} = 1.504 \text{ A} \quad I_{\text{pump.coil}} = .00125 \text{A}
\]

\[
\text{KVA}_{\text{pwr.on}} = (I_{\text{indicator}} + I_{\text{pico.operate}} + I_{\text{pump.coil}}) \frac{V_{s120}}{1000W} \quad \text{KVA}_{\text{pwr.on}} = 0.202
\]

\[
\text{KVA}_{\text{run}} = (I_{\text{pico.run}} + I_{\text{indicator}} + I_{\text{pump.coil}}) \frac{V_{s120}}{1000W} \quad \text{KVA}_{\text{run}} = 0.037
\]

\[
\text{KVA}_{\text{overload}} = \text{KVA}_{\text{pwr.on}} 1.50 \quad \text{KVA}_{\text{overload}} = 0.303
\]

\[
\text{KVA}_{230\text{system}} = \frac{P_{230\text{system}}}{1000} \quad \text{KVA}_{230\text{system}} = 2.408W
\]

Main Fusing

\[
\text{MainFuseprotection} = I_{230\text{system}} 1.25 \quad \text{MainFuseprotection} = 13.084 \text{ A}
\]

\[
I_{\text{pico.inrush}} = 1.5 \text{ A} \quad \text{fuse at 3 amps with time delay}
\]

\[
I_{\text{so1}} = 0.191 \text{ A} \quad \text{fuse at .25 amps with time delay}
\]

\[
I_{\text{so2}} = 0.191 \text{ A} \quad \text{fuse at .25 amps with time delay}
\]

\[
I_{\text{so3}} = 0.365 \text{ A} \quad \text{fuse at .5 amps with time delay}
\]

\[
I_{230\text{pump}} = 10 \text{ A} \quad \text{fuse main at 15 amps with time delay}
\]

\[
I_{\text{primary.xfm}} = \frac{(0.275W\cdot1000)}{V_{s230}} \quad I_{\text{primary.xfm}} = 1.196 \text{ A} \quad \text{fuse at 2 amps with time delay}
\]

\[
I_{\text{secondary.xfm}} = \frac{(0.275W\cdot1000)}{V_{s120}} \quad I_{\text{secondary.xfm}} = 2.391 \text{ A} \quad \text{fuse at 3 amps with time delay}
\]

Metered Data

Motor Load metered at 18.2A FLA on March 7, 2005 using 206V supplied from building machine shop bus duct.

Motor Load metered at 17.3A FLA on May 2, 2005 using 230V from Generac 3500XL gas generator.
Appendix 4: Electrical Schematics

Figure 3 Power distribution one-line diagram (Note: Pico Input/Output Control can be found in Appendix C)

Figure 4 Power feeder sketch
Appendix 5: Control System Operation and Instructions

The Pico Control System

The packing machine is controlled by the Allen Bradley Pico controller model 1760-L18AWA-EX. The 1760-L18AWA-EX consists of 12 inputs and 6 outputs. The controller was programmed using PicoSoft version 3.0 by Rockwell Automation. The calculated cycle time for the selected device is 9.71ms (102.987 Hs). The cycle time is given in the manual 06/99 AWB 25/28-1304, technical data.

Figure 1 Software validation window

Input Controls

Inputs I1-I9, excluding analog inputs I3, I7 and I8, are used. See Figure 1 for a depiction of our input layout. A total of 2 switches and 4 pushbuttons are used for operation. The switches consist of a 2-position on/off select switch and a 3-position manual/off/auto select switch. The 4 pushbuttons have normally-closed contacts and are used for manual operation of the pivot solenoid, ram solenoid, hydraulic drive-motor solenoid and system reset.

Inputs I1 and I2 provide manual-to-auto operation control respectively and are connected to the 3-position manual/off/auto select switch. Inputs I4 thru I6 provide manual control to the solenoid valves. Input I9 is designated for system reset.
STP ManMode Operation Input Controls

Input I4 controls manual operation for the Pivot solenoid. I4 is programmed with an impulse relay and controlled by a pushbutton. The solenoid can be toggled between signal states with each press of the pushbutton. Input I5 controls manual operation of the Ram solenoid. I5 is programmed as a momentary relay and controlled by a pushbutton. The solenoid signal is normally negated. The signal is then asserted as long as the pushbutton is depressed. Input I6 controls manual operation for the hydraulic motor solenoid. I6 is programmed with an impulse relay and controlled by a pushbutton. The solenoid can be toggled between signal states with each press of the pushbutton. Input I9 controls manual system reset. I9 is programmed to reset the program counter inputs for all stages of the operation sequence.

STPAutoMode Operation Input Timing Controls

Auto operation is controlled by 7 timers, T1 thru T7. The timers control complete cycle duration, pulse, flashing and delay sequences. Timer T1 provides an initial auto start on-delay of 3 seconds. After 3 seconds, timer T2 and T3 are initiated. T2 provides the inner well packing cycle time of 5 minutes and T3 provides a second on-delay for the first-half of the ram cycle. On-delay T3 provides the pivot cylinder sufficient time to extend before ramming sequence begins. T3 initiates timers T4, T5, and T6 for ramming sequence. Timer T4 provides an alternating on/off contact which is set to a designated cycle time. Simultaneously, timers T5 and T6 are activated which provide an off-on delay of 12 seconds between inner well and center ram cycles. Timer T7 provides a complete cycle time of 10 minutes.
Control Outputs

All 6 outputs are utilized for control. The auto sequence functions from outputs Q1, Q2, Q3 and the manual sequence function from outputs Q4, Q5, and Q6.

Q2 receives a single pulse at 113 seconds from T5 which negates the signal to the solenoid. The ram retracts to its initial position and stays off. After the designated delay of 12 seconds, T6 asserts the signal to Q2 to resume ram operation for second half of the complete cycle. A signal diagram shown in Figure 3 shows this delay on output Q2.

Figure 3 Transition timing signal diagram
Figure 4 STP AutoMode Ladder Logic

Figure 5 STP Manual Mode Logic
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Figure 6 Typical Screen Shot (Here were showing the initial power-on delay sequence)
Appendix 6: Electric Panel Parts List

**Electrical panel components:**

- **Enclosure**
  Hoffman Nema12 Control Enclosure
  Hoffman 14P16H Buck-plate

- **(8ft) 12/3 SJOOW SP-2 CORD**

- **(1) HUBBELL HBL6466C PLUG END**

- **(1) Allen-Bradley Indicating Light 800T-P16 Green cap**

- **Wire**
  - 18/2 NPL
  - 16/2 NPL
  - 14/2 NPL
  - 12/2 NPL

- **Wire Nuts**

- **120/240V Controls**
  - (1) Pico 1760-L18AWA-EX
  - (4) 800T-A120T-XA PB
  - (1) 800H-JR2 HOA SW
  - (1) E275 SBE XFM HD
  - (1) AB 100-C12 400 CONTACTOR
  - (1) Overload Relay

- **DIN RAIL Components**
  - (3) 492U fuse blocks
  - (6) 1492H fuse blocks
  - (1) 1492WG10S ground block
  - (20) 1492H WHT
  - (1.5ft) MTL DIN RAIL
  - (1) 3A-LP-TD FUSES
  - (2) 2A-LP-TD FUSES
  - (1) 1A-LP-TD FUSES
  - (2) 15A-LP-TD-FUSES
  - (3) BUSS ABC-1/2 FUSE
  - (1) 8P-GND TERMINAL STRIP

- **Valve and Pump Connection**
  - (3) 1/2 LT NM FLEX
  - (2) 1/2 LT STL CONN
  - (15ft) 16/3 SJOOW SP-2 CORD
  - (3) SJOOW CORD CONN
  - (3) S10LCA120 solenoid coil
  - (3) Parker MFP-5300-108-000 valve plug
## Appendix 7: Budget

### Electrical

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**Total**  $3,070.07
## ENGR339/340 Senior Design Project
### Team 4: Sail Thermal Packing (STP)

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<td>$ 22.00</td>
<td>N</td>
</tr>
<tr>
<td>31-Mar-05</td>
<td>Electrical Enclosure Back Plate</td>
<td>Crescent Electric</td>
<td>$ 11.38</td>
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<tr>
<td>9-Apr-05</td>
<td>Nuts, Bolts, U-bolts</td>
<td>Lowes</td>
<td>$ 17.82</td>
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<td>9-Apr-05</td>
<td>Nuts and Bolts</td>
<td>Lowes</td>
<td>$ 17.30</td>
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<tr>
<td>11-Apr-05</td>
<td>Wires, cables, hole plugs, fuses</td>
<td>Lowes</td>
<td>$ 21.00</td>
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<td>15-Apr-05</td>
<td>Hydraulic Fittings</td>
<td>Bond Fluidaire, Inc.</td>
<td>$ 58.26</td>
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<td>19-Apr-05</td>
<td>Hydraulic Manifolds and Pressure Cage</td>
<td>Bond Fluidaire, Inc.</td>
<td>$ 39.08</td>
<td>N</td>
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<tr>
<td>27-Apr-05</td>
<td>Hydraulic Gear Motor</td>
<td>Bailey Corp. bailey.net.com</td>
<td>$ 99.57</td>
<td>N</td>
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</table>

**Total Cost:** $296.01
# Appendix 8: Schedule

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Management</td>
<td>164 days</td>
<td>Wed 9/11/04</td>
<td>Mon 5/2/05</td>
</tr>
<tr>
<td>Make electronic file of contacts</td>
<td>1 day</td>
<td>Wed 9/11/04</td>
<td>Wed 9/11/04</td>
</tr>
<tr>
<td>Acquire necessary tools</td>
<td>55 days</td>
<td>Wed 9/11/04</td>
<td>Tue 11/30/04</td>
</tr>
<tr>
<td>Meeting minutes</td>
<td>1224 hrs</td>
<td>Wed 9/11/04</td>
<td>Mon 5/2/05</td>
</tr>
<tr>
<td>Breakout meetings</td>
<td>1224 hrs</td>
<td>Wed 9/11/04</td>
<td>Mon 5/2/05</td>
</tr>
<tr>
<td>PMIS Draft</td>
<td>56 days</td>
<td>Wed 9/11/04</td>
<td>Wed 12/14/04</td>
</tr>
<tr>
<td>Project proposal</td>
<td>5 days</td>
<td>Mon 9/11/04</td>
<td>Fri 10/14/04</td>
</tr>
<tr>
<td>Project Objectives</td>
<td>1 day</td>
<td>Fri 10/14/04</td>
<td>Fri 10/14/04</td>
</tr>
<tr>
<td>Preliminary Task Specifications</td>
<td>6 days</td>
<td>Mon 9/11/04</td>
<td>Mon 10/28/04</td>
</tr>
<tr>
<td>Introduction presentation</td>
<td>1 day</td>
<td>Mon 9/11/04</td>
<td>Mon 10/28/04</td>
</tr>
<tr>
<td>Prepare pitch for professional project</td>
<td>21 days</td>
<td>Tue 9/13/04</td>
<td>Tue 11/15/04</td>
</tr>
<tr>
<td>Preliminary Evaluation of Feasibility</td>
<td>4 days</td>
<td>Wed 9/12/04</td>
<td>Mon 10/25/04</td>
</tr>
<tr>
<td>Refine concept(s)</td>
<td>5 days</td>
<td>Tue 9/13/04</td>
<td>Tue 10/26/04</td>
</tr>
<tr>
<td>Prepare design/build station</td>
<td>7 days</td>
<td>Mon 11/14/04</td>
<td>Tue 11/15/04</td>
</tr>
<tr>
<td>Senior Design Progress meetings</td>
<td>20 hrs</td>
<td>Mon 11/14/04</td>
<td>Wed 11/15/04</td>
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<tr>
<td>Preliminary project schedule</td>
<td>5 days</td>
<td>Tue 11/14/04</td>
<td>Mon 11/15/04</td>
</tr>
<tr>
<td>Build Team Folders</td>
<td>121 days</td>
<td>Fri 11/20/04</td>
<td>Fri 12/29/05</td>
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<tr>
<td>Webpage development/revision</td>
<td>23.5 days</td>
<td>Wed 11/12/04</td>
<td>Tue 12/7/05</td>
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<tr>
<td>PMIS Final</td>
<td>10 days</td>
<td>Mon 11/23/04</td>
<td>Fri 12/7/04</td>
</tr>
<tr>
<td>Update Presentation 1</td>
<td>1 day</td>
<td>Mon 11/23/04</td>
<td>Mon 12/24/04</td>
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<tr>
<td>Update Presentation 2</td>
<td>1 day</td>
<td>Mon 12/1/05</td>
<td>Mon 12/1/05</td>
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<tr>
<td>Final project presentation</td>
<td>1 day</td>
<td>Mon 12/20/05</td>
<td>Mon 12/20/05</td>
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<tr>
<td>Secure funding</td>
<td>10-45 days</td>
<td>Wed 9/15/04</td>
<td>Tue 9/18/05</td>
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<tr>
<td>Funding search</td>
<td>41 days</td>
<td>Wed 9/11/04</td>
<td>Wed 11/1/04</td>
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<tr>
<td>Contact James Kaiser</td>
<td>55 days</td>
<td>Fri 9/11/04</td>
<td>Mon 12/7/05</td>
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<tr>
<td>PECI funds meeting</td>
<td>2 hrs</td>
<td>Wed 11/10/04</td>
<td>Wed 11/10/04</td>
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<tr>
<td>Contact companies for subsidiaries</td>
<td>100.5 days</td>
<td>Wed 11/10/04</td>
<td>Tue 11/1/05</td>
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<tr>
<td>Contact membership building directors</td>
<td>39 days</td>
<td>Wed 11/10/04</td>
<td>Tue 11/1/05</td>
</tr>
<tr>
<td>Contact local architects</td>
<td>39 days</td>
<td>Wed 11/10/04</td>
<td>Tue 11/1/05</td>
</tr>
<tr>
<td>Contact local architecture companies</td>
<td>39 days</td>
<td>Wed 11/10/04</td>
<td>Tue 11/1/05</td>
</tr>
<tr>
<td>Governmental aid availability search</td>
<td>39 days</td>
<td>Wed 11/10/04</td>
<td>Tue 11/1/05</td>
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</table>
To Do List Example

1. Finish one of the tasks to meet completion dates (4/9)
   1.1. Complete Basic Assembly
      1.1.1. lift-rings
      1.1.2. side-panels
      1.1.3. add bolt patterns
         1.1.3.1. pump and tank
         1.1.3.2. valve body
         1.1.3.3. panel supports
   1.2. Hook-up Hydraulics (4/11)

2. Assist with debugging timing and sequence of operations (4/16)

3. Design and Test Dirt Backboard (4/16)

   4.1. Smooth frame edges
   4.2. Create warning labels
   4.3. Work-on getting frame and components powder coated/painted


6. Add/complete section of Final Design Report (5/13)


8. Start Power Point Slides For Final Presentation (5/2)

9. Work on Team Poster (4/29)

10. Update Webpage (4/22)

χομπλετε εσφερσηνγ τo ψουρ βεστ αβιλιτ
ψ ανδ ωε ωιλλ
ηασε α θυαλιτψ μαχηνε.
Calvin Engineering Senior Design

Main Frame Detail

<table>
<thead>
<tr>
<th>TITLE</th>
<th>SIZE</th>
<th>DWG NO</th>
<th>REV</th>
</tr>
</thead>
<tbody>
<tr>
<td>MainFrame</td>
<td>A</td>
<td></td>
<td>27</td>
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DRAWN
Dave Allen
4/27/2005

CHECKED
STP

MFG
APPROVED

A
3.00
13.00

B
11.50
14.50

A
12.00

B
37.00
14.70

B
47.00

B
33.00

B
2

A
1

A
6.00
Calvin Engineering Senior Design

Title: Ram Cylinder Arm

Drawn by: Dave Allen
Checked by: STP
Q&A
MFG
Approved

Size: A
DWG No: RamCylinderArm
Rev: 5

Scale: SHEET 1 OF 1
<table>
<thead>
<tr>
<th>DRAWN</th>
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<th>QA</th>
<th>MFG</th>
<th>APPROVED</th>
<th>TITLE</th>
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<th>REV</th>
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</thead>
<tbody>
<tr>
<td>Dave Allen</td>
<td>STP</td>
<td></td>
<td></td>
<td></td>
<td>Calvin Engineering Senior Design</td>
<td>RamHead</td>
<td>3</td>
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</table>

**Figure:**
- **Dimensions:**
  - Ø3.00
  - Ø2.74
  - Ø2.01
  - 7/16-20 Tap

**Notes:**
- 1.13
- 10°
- 52°
- .75
## Appendix 10: Operation Manuals and Instructions

### Table 2

<table>
<thead>
<tr>
<th>Switch/Button/Position</th>
<th>Description</th>
<th>Operation</th>
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<tbody>
<tr>
<td>Switch 1</td>
<td>Main Power On/Off</td>
<td></td>
</tr>
<tr>
<td>Switch 2</td>
<td>Manual / Auto Operation</td>
<td></td>
</tr>
<tr>
<td>White PB</td>
<td>Manual Pivot Cylinder</td>
<td></td>
</tr>
<tr>
<td>Green PB</td>
<td>Manual Ram Cylinder</td>
<td></td>
</tr>
<tr>
<td>Blue PB</td>
<td>Manual Platter Rotation</td>
<td></td>
</tr>
<tr>
<td>Red PB</td>
<td>Manual System Reset</td>
<td></td>
</tr>
<tr>
<td>EM PB</td>
<td>System Emergency Stop</td>
<td></td>
</tr>
<tr>
<td>Position 1</td>
<td>Packing Position</td>
<td></td>
</tr>
<tr>
<td>Position 2</td>
<td>Packing Position</td>
<td></td>
</tr>
</tbody>
</table>
STP Packing Machine Operation Manual

STP AutoMode Operation Sequence

1. Turn Switch 1 to power unit. The machine will wait until further command

2. Remove guide rollers from the guide slots and place empty tire on center of the rotating platter. Replace the guide rollers in the guide slots and pull tire snug against guide rollers.

3. Loosen drive wheel base support nuts and adjust drive wheel so that the wheel is snug against tire tread or surface. Once drive wheel is snug, hold in place and tighten nuts.

Turn Switch 2 to STP AutoMode position. Once switch has been turned to STP AutoMode position the program will initiate sequence and start after initial 20 second delay. Note: While waiting for the delay you may continue to add soil inside the tire.

4. The Pivot cylinder will extend to Position 2 and start the first 2 minute Ram cycle after an 8 second delay.

5. Once the Ram cycle has completed, the Ram cylinder will delay for 15 seconds while the Pivot cylinder retracts to Position 1.

6. After the 15 second delay, the Second Ram cycle will begin and stop after 2 minutes

7. Press the Red Reset PB to initiate another 4 minute cycle if tire is not packed to desired level of compaction.

8. Once the tire is packed to desired level and the current 4 minute cycle is complete, press the Emergency Stop PB to lock-out STP AutoMode program to ensure safety.

9. Loosen the Drive wheel support nuts, back-off the Drive wheel and remove the Guide Rollers.

10. Packed tire may be removed.
1. Turn Switch 1 to power unit. The machine will wait until further command.

2. Remove guide rollers from the guide slots and place empty tire on center of the rotating platter. Replace the guide rollers in the guide slots and pull tire snug against guide rollers.

3. Loosen drive wheel base support nuts and adjust drive wheel so that the wheel is snug against tire tread or surface. Once drive wheel is snug, hold in place and tighten nuts.

4. Turn Switch 2 to STP AutoMode position. Once switch has been turned to STP ManMode position the program will not initiate sequence and operation of cylinders will only react to manual push buttons.

5. To extend the Pivot cylinder to Position 2 press the white PB. To retract the Pivot cylinder, press the white PB again.

6. To operate the Ram cylinder press the green PB. The Ram cylinder will extend and stay extended until the green PB is released.

7. To activate Drive wheel rotation press the blue PB. To deactivate drive wheel rotation, press the blue PB again.

8. Press the EM PB to activate emergency state to stop the hydraulic pump and cylinders in there present position.

   WARNING: If the EM PB is deactivated and either cylinder was in motion prior to turning off the pump, the cylinders will return in motion unless main power is turned off.

9. When finished with STP ManMode, press the red PB, wait for the cylinders to return to retracted position and press the EM PB and switch off main power.