Water Well Drilling Rig

Final Project Report

Sponsor: San Luis Obispo Rotary Club
Tim Cleath
Bob Hather

Prepared by: WHole Engineering
Alex Wargnier awargnie@calpoly.edu
Thad Jablonski tjablons@calpoly.edu
Coel Schumacher cschumac@calpoly.edu

Mechanical Engineering
California Polytechnic State University
San Luis Obispo, CA
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List of Nomenclature

Aquifer: an underground water-bearing stratum of permeable rock, sand, or gravel

Bailer: a long, cylindrical container fitted with a valve at its lower end, used to remove water, sand, mud, drilling cuttings, or oil from a well in cable-tool drilling

Cholera: a water-borne disease, which can spread rampantly when clean water and proper sanitation are not available

Crown Block: The fixed set of sheaves located at the top of the derrick, over which the drilling line is threaded

Derrick: a framework erected over a well for boring, bailing, and lowering casing

Developing world: countries and regions where low per capita income levels and low levels of industrialization exist

Drill string: the assembled set of tools that go subsurface to create the bore for the well; typically comprised of a wire rope, rope socket, drill stem, drill bit and a jar

Dressing: new material welded onto the end of the drill bit where it has become worn

Drilling mud: primarily water, with a thickening agent, In most cases bentonite clay, used during the drilling process both to keep the borehole open and to cause drilled cuttings to float closer to the surface

Guy wire: A rope or cable used to steady a mast or pole.

Jar: a tool used in the drillstring for imparting an upward or downward jar or jolt to the drillpipe should it get stuck in the hole while drilling

Left/Right-Hand Lay Cable: wire rope laid in a helix shape and in a directional wrapping that causes the winding to tighten/loosen during percussive drilling

Pitman Arm: a metal lever which transmits force from the rotating flywheel to the walking beam

Rope socket: a device that connects the drill stem to the wire rope; allows the drill stem to rotate during operation

Sedimentary Rock: rocks created by the gradual compaction and hardening of soils and/or minerals slowly deposited over time and is one of the major groups of rock that makes up the crust of the Earth
Sheave: a wheel or roller with a groove along its edge for holding a belt, rope or cable

Stack valve: allows for selection of a particular type of valve for each hydraulic system

Walking Beam: a mechanism that oscillates at one end and pivots around the other to operate with the pitman arm for transmitting rotary motion from the flywheel to vertical fluctuating motion of the drill string, therefore producing the required motion for drilling

Wire rope: a rope made of small strands of twisted wire around a fiber core; used interchangeably with cable
Abstract
In this report, the improvements of a previously produced cable tool drilling rig are described. The purpose of the rig is to drill water wells for use in Africa in order to provide safe drinking water to many in need. An affordable, effective, and controllable rig is the design goal for this project. With the San Luis Obispo Rotary Club sponsoring the project the design team of WHole Engineering have made necessary design choices to manufacture the product. Actions performed include background research of existing drilling technologies, analysis of top concepts for the controlling mechanism, and selection for the final design. The drilling rig will be modified in many ways to increase control, safety, and provide adequate drilling capabilities. The final design will be operated by a hydraulic system, using chains and sprockets to transmit power to the necessary mechanisms, rather than the tension belts that were present when the design team was assigned to the project.
Chapter 1: Introduction

Sponsor background and Need
Lifewater International and the Rotary Club’s main purpose are to bring clean water to those without access. There are approximately 1.1 billion people worldwide whom cannot access clean drinking water within their means. Unclean water can lead to the spread of disease such as cholera and also inhibit the production of food. Sub-Saharan Africa is one area of the world that is in desperate need for a solution to acquire clean drinking water. Beginning in fall 2008, Cal Poly mechanical engineering students have aided in this need by designing a portable water well drilling rig. A drill rig would make potable water that is stored in aquifers approximately 100 feet below the earth’s surface obtainable. The Rotary Club would like a design that can be reproduced in Africa so entrepreneurs can manufacture the rig there to help their economy grow as well. Jobs would be created from manufacturing and operating the rig as well. It must be manageable to operate and repair in these developing nations as well. Current affordable rigs do not meet the requirement to get through the geology of Africa. Soil in these countries is composed of either crystalline Precambrian basement rock or consolidated sedimentary rock, which the common affordable rotary drilling rig cannot penetrate. A cable tool drill rig will meet the sponsor’s need and is what they have requested. As of January 2010, the stakeholders in this project include the design team of WHole Engineering along with the Rotary Club, those that suffer from lack of potable water and possible businessmen in developing countries.

Problem Definition
WHole Engineering is required to improve the design of an existing cable tool rig for production and use in Sub-Saharan Africa. Major modification includes a controllable drive system powerful enough to drill with a 600 pound bit. A second, stronger drill string must be added for effective drilling. This product must be proven safe and efficient at drilling to the water table using a small gas engine. A bit sized for creating a four inch diameter hole to a depth of 100 ft is required. Overall weight is desired not to exceed the towing capacity of small trucks.
**Objective/Specification Development**

The primary objective is to improve the cable tool drilling rig designed by Cal Poly students that was completed in June 2009. This current device does not meet the customer's specifications set forth in October 2008. The members of WHole Engineering intend to complete the drilling rig so that it meets the customer specifications set in the Table 1 below. This table was produced from sponsor requirements and from our House of Quality design matrix, which can be seen in Appendix A.

Table 1 Design specifications

<table>
<thead>
<tr>
<th>Spec #</th>
<th>Parameter Description</th>
<th>Requirement or Target (units)</th>
<th>Tolerance</th>
<th>Risk</th>
<th>Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Drilling Depth</td>
<td>100 feet</td>
<td>Min</td>
<td>H</td>
<td>A, T</td>
</tr>
<tr>
<td>2</td>
<td>Bore Diameter</td>
<td>4 inches</td>
<td>Min</td>
<td>L</td>
<td>S, T</td>
</tr>
<tr>
<td>3</td>
<td>Drill Bit Weight</td>
<td>600 lb</td>
<td>Min</td>
<td>H</td>
<td>A, I</td>
</tr>
<tr>
<td>4</td>
<td>Safety</td>
<td>0 exposed gears/pulleys</td>
<td>Max</td>
<td>H</td>
<td>I, T</td>
</tr>
<tr>
<td>5</td>
<td>Operators</td>
<td>2 Trained Operators</td>
<td>Target</td>
<td>L</td>
<td>A, T</td>
</tr>
<tr>
<td>6</td>
<td>Drilling components</td>
<td>3 bits</td>
<td>Min</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>7</td>
<td>Robust Design</td>
<td>20 Wells</td>
<td>Min</td>
<td>M</td>
<td>A, S</td>
</tr>
<tr>
<td>8</td>
<td>Transportability</td>
<td>3000 lbs</td>
<td>Max</td>
<td>M</td>
<td>I</td>
</tr>
<tr>
<td>9</td>
<td>Horizontal Sway</td>
<td>6 inches</td>
<td>Max</td>
<td>M</td>
<td>A, T</td>
</tr>
<tr>
<td>10</td>
<td>Operation Speed</td>
<td>50 – 60 rpm</td>
<td>Target</td>
<td>L</td>
<td>A, T</td>
</tr>
</tbody>
</table>

Risk is characterized by high (H), medium (M), and low (L). Compliance shall be confirmed using analysis (A), inspection (I), similarity (S), and/or test (T).

**Discussion of Specifications**

**Specification 1**
The drilling rig shall be capable of drilling to a depth of at least 100 ft. The rationalization being those 100 feet would be the depth at which the water table would be reached. The customer has experience with the water table being located at a maximum depth of 75 to 100 feet in the region that the drilling rig shall be used. Currently the rig does not operate properly, so this is a high risk.

**Specification 2**
The bore diameter designed for shall be 4 inches. This specification comes from the customer requirement to generate a well large enough for a hand pump to be installed into the well. A hole smaller than 4 inches would not be adequate for the end user so it must be at least 4 inches. Most bits used for drilling wells are a minimum of 4 inches, so there is low risk of meeting this goal.
Specification 3
The weight of the drill bit shall be a minimum of 600 pounds. A smaller weight would not be capable of cutting through the ground material that has been described by the customer. The team shall produce a drilling rig capable of operating this size bit, and also acquire a bit for use. The current rig originally was designed to lift a 200 pound bit, so this is a high risk.

Specification 4
The machine shall have no exposed gears, belts, or pulleys. This comes from the customer requirement to have a safe machine that will not injure operators. Due to the nature of the project with heavy machinery in motion, there is a high risk of meeting this goal.

Specification 5
The drilling rig shall be capable of being operated by two trained operators minimum required for operation. Rational for this specification is for safety and ease of operation. Even though this measurement is a minimum the operation complexity should only dictate more than two skilled laborers. Many operators are available, and training is available for the users of this rig, so there is a low risk of meeting this goal.

Specification 6
The drill shall be delivered with a minimum of three drilling attachments. The justification for this specification comes from the need to be able to drill through multiple types of geological material. There must also be a bailer capable of removing material from the bore. A moderate risk is present for meeting this goal due to availability.

Specification 7
The design shall be robust and capable of producing at least twenty wells before requiring major components replaced. This specification does not include routine maintenance and implies that proper user care was taken. Drill bit life is not included in this quantity. There is a moderate risk of this goal being met since endurance testing has not been done.

Specification 8
The combined towing weight shall not be greater than 3000 pounds. This specification comes from the average towing capacity of small size trucks. A moderate risk is present for this specification since part of redesigning this rig is to add weights and components.

Specification 9
The rig shall not sway more than 6 inches in the horizontal direction while in operation. A larger sway would lead to instability and be a safety concern. This specification will be verified through testing and analysis. A moderate risk is present to meet this goal since it has not been proven to handle the loads we will be placing on this rig.
Specification 10
The flywheel of the drilling rig shall operate between 50 and 60 rpm. This is the optimum drilling speed for cable tool drilling rigs. A slower speed will not produce the adequate drilling force and a faster speed will be a safety issue. This specification will be verified through testing. The risk is low for meeting this specification due to the current rig meeting this specification.

Project Management
Due to the complicated nature of the machine each team member will be assigned various aspects of the project. The drilling rig has been broken up into design subsystems that each team member will be responsible for. A list of each group member and his responsibilities is provided below:

Thad Jablonski
- Primary Sponsor Contact
- Financial Planning
- Ordering Parts
- Bearing/Bushing analysis
- Brake comparison and design

Coel Schumacher
- Fabrication analysis
- Stress Testing
- Clutch research and design
- Tooling research and production
- Control placement and interface

Alex Wargnier
- Project progress
- CAD drawings
- Testing Planning and documentation
- Transmission analysis
- Shaft calculations
- Motor sizing and interface
Schedule

Our project must move along according to a predetermined schedule to ensure project completion. Milestone occurrences for this project include:

Receive drilling rig: January 23, 2010
Initial test run of rig: January 23, 2010

Analysis of design improvement concepts:
- Motor sizing: February 23, 2010
- Hydraulic system design: February 25, 2010
- Chains and sprockets: March 9, 2010
- Brake system for main spool: March 11, 2010

Remove Old Components: April 2, 2010

Order Components:
- Steel for spool, derrick extension, and more: March 30, 2010
- Hydraulic motors/pumps: March 30, 2010
- Sprockets: April 30, 2010
- Chains: May 12, 2010
- Hydraulic hoses and fittings: May 12, 2010
- Final parts ordered: May 25, 2010

Manufacture:
- Mount the walking beam: March 30, 2010
- Extend the derrick: April 27, 2010
- Majority of frame modifications complete: April 30, 2010
- Fabricate/Mount Spools: May 4, 2010
- Mount motors and pumps: May 8, 2010
- Install sprockets: May 12, 2010
- Install Chains: May 25, 2010
- Mount hydraulic hoses, control valves, and reservoir: May 25, 2010
- Manufacture pitman arm: May 28, 2010
- Complete Top Sheave mount: May 30, 2010
- Initial run of hydraulic system: June 3, 2010
- Complete ML Brake Fabrication: June 8, 2010
- Complete manufacturing: June 11, 2010

Test new system:
- Dry run of assembled system: October 7, 2010
- Initial drilling test: October 12, 2010
- Observe any areas for improvement: October 12, 2010
- Continue drilling to test performance: November 6, 2010
- Test a new area for versatility: November 6, 2010
Chapter 2: Background

Existing Drilling Products

Manual Drilling – Manual drilling methods include boring and driving. In boring a spiral or hand auger is spun in order to dig into the earth. Shaft extensions are attached as needed to reach the necessary depths. Driving involves using a pointed tool attached to pipe with a weight on the end that acts as a hammer. The tool is pounded into the ground until it can no longer go any further or the water table is reached. Boring and driving are limited to the strength of their operator and cannot get through the metamorphic rock that exists throughout much of Africa. (Gibson, 1971)

Rotary drilling – In rotary drilling a downward force is applied to a bit that rotates or rolls in order to produce a crushing or chipping action on the material. A pit is filled with water to create mud, which then is pumped down the hole via the drill pipe and serves as the drilling fluid. The mud caries the cuttings up to the top of the well while drilling is underway. Although rotary drill work well in soft soils, they are extremely slow in rock formations and require a large amount of water to drill, which may not be available in some remote areas. The schematic to the right (Figure 1) shows the workings of Lifewater’s LS-100, a small, portable, rotary drill. (Lifewater, 2010)

Jetting – This process involves forcing high pressure water through the end of a bit in order to wash away cutting. It is part of the rotary drilling method and can also be used as an addition to cable tool drilling. (Michael, 2008)
Cable tool drilling – This method of drilling involves picking up and dropping a large weight attached to a drill bit. The engine produces circular motion which is converted to vertical oscillations via a pitman arm attached to the walking beam (spudder beam). The walking beam is attached to the drill cable which moves the drill string up and down. It is this pounding action that enables cable tool drill rigs to drill through all types of ground conditions including rock. Well casing is used for the entire depth of the hole to ensure collapse does not occur. Figure 2 provides the basic layout of a typical cable tool drill rig. The Bucyrus-Erie 22W is one of the most common types of cable tool drill rigs in operation today. These machines weigh 9,750 pounds and are capable of drilling to depths greater than 1000 feet. The masts of these machines are 40’ tall and are either truck or trailer mounted. The 22W is the smallest drill rig that was produced by Bucyrus-Erie. (Pees, 2010)

The previous team decided on a cable tool drilling rig mounted on a trailer due the requirements by the sponsor, and due to cost and transportability. Tim Cleath, project sponsor and hydro-geologist, informed the team that the majority of the geology the rig will face will be Precambrian metaphoric rock and consolidated sedimentary rock. Cable tooling is the only portable drilling method that will be able to efficiently and effectively drill through this geology. Larger, more expensive machines would be able to drill, but the goal of this project is produce a relatively inexpensive, portable machine.

A simplified drawing of components of a cable tool rig is provided in Figure 3 on the next page.

Current State of the Art

The most common current technique used to drill water wells uses a rotary drill rig, or other types that are large and expensive. These machines are not affordable for Africans, and not effective at punching through basement rock that exists in the geology of Africa. Cable tool rigs have not been produced in significant quantity in the last 30 years.
Basic components and operation

**Cable** — Connects the bit to the mechanisms which control the motion of the bit

**Derrick** — Supports the top sheave, providing a lifting point above the hole so that the bit can be withdrawn from the hole completely

**Walking Beam** — Oscillates back and forth around the pivot producing up and down motion of the drill bit

**Bit** — End goal of machine is to raise and lower drill bit repeatedly

**Walking Beam Sheave**

**Top Sheave**

**Cable Spool** — Holds excess cable and allows for the bit to be raised and lowered from the hole

**Pivot Point**

**Pitman Arm Pivots** — Allows for Pitman arm to rotate freely

---

**Figure 3 Simplified Cable Tool Rig Components**
**Previously Designed Cal Poly Rig**

The Whole Engineering team has to fully understand how the current rig functions and its limitations before any redesign can occur. The drilling rig is powered by a Honda 13 HP gasoline engine attached to a centrifugal clutch. At 800 rpm the clutch engages to transmit power to the main power shaft at the top of the rig seen in Figure 4. Power can be transmitted to either the main spool or the walking beam using the control levers located at the front of the rig seen in Figure 5. The levers apply pressure to the belts, which serve as the clutching mechanism. While the walking beam is running, the spool needs to be held in place using the disk brake seen in Figure 5.

There are several problems that have been identified with the machine. One problem is that the belt clutching system does not function properly. The belts engage at unwanted times and fail to engage when required to. This inhibits proper drilling and is a major safety concern. Additionally, the brake easily engaged and does not allow cable to be let out while drilling. The members of WHole engineering will be redesigning the power transmission system of the rig in order to solve the control issues as well as adding a fully functioning brake. There are many other changes that will be made to the rig, which will be documented as the design develops.

![Image of a drilling rig with labels for Main power shaft, Belt clutch for Spool, 13 hp engine, Walking Beam, Pitman Arm, and Flywheel.](image-url)

*Figure 4: Spool Power Side of Drilling Rig*
List of Applicable Standards

There are no applicable standards for the construction of cable tool drilling rigs. Robustness must be tested with extensive use of the equipment.
Chapter 3: Design Development

Discussion of Conceptual Designs with Preliminary Analysis

The four main design areas consist of (1) power transmission, (2) power engagement, (3) walking beam control and the (4) main line brake. These are directly related to the three main power systems: the walking beam, main line and sand line. See Appendix B for concept drawings.

The first component that was discussed by the design team was the motor. It is unclear if the 13 Hp gasoline engine can produce adequate torque to move a 600 lb drill bit. In order to determine if the engine is powerful enough, force and acceleration of each component was modeled using a Cal Poly Mechanical Engineering program called Engineering Equation Solver (EES). The result was mixed because of the circular motion of the pitman arm. There seemed to be adequate power through most of the cycle, but there was a certain angle where downward force disappeared. The EES calculation and results are given in Appendix E. The calculation was not enough on its own to verify adequate torque so more research was conducted. The team found information on an existing drill rig owned by Seeds of Hope in San Luis Obispo that is currently being used in Africa. Their rig currently runs on with an 11 Hp gasoline engine and is used with a 675 lb drill bit. The Seeds of Hope drilling rig provided the evidence necessary for the WHole Engineering team to move forward in the design with the current 13Hp engine.

Power Transmission

Ideas for power transmission utilize chains, belts or gears. Gears were considered because they would provide the necessary speed reductions in a relatively small space. They are difficult to mount, but are able to transmit large horsepower. Chains are easier to mount than gears, but take up more space. They are able to handle large enough loads for this application as well. Chains are the easiest of the three to mount and provide a possible clutching system. They do not offer as much control as gears or chains and must be very large in order to handle the working loads. Belts are the least expensive of the three, followed by chains and then gears.

Power Engagement

Power engagement equipment requires switching power on and off for three functions. To do this for the walking beam, main line and sand line a method of engaging and disengaging power is necessary. Belts easily lend themselves to this through adjustable tensioning so that they slip to disengage and are tensioned to engage. However, this leads to increased belt wear and poor control of engagement. The next solution is to use automotive style clutches. Automotive clutches use a flywheel, clutch disk and pressure plate to engage and disengage by clamping the clutch disk between the flywheel and pressure plate. Clutches have better life, power capabilities and control, but the linkages to run them are complicated would be rather complicated. The third solution is to use a hydraulic system. Hydraulic systems have the benefit of engaging very controllable, having a long life and a lot of power. They also provide the majority of the gear reduction required which cuts down on using chains and belts.
Walking Beam

The oscillation of the drill string unit is controlled by the walking beam. The goal is to lift the bit two feet and let it fall unrestricted. The walking beam needs good control to produce this oscillation. The traditional way is to connect it to a rotating disk via a pitman arm. This produces an oscillation where the walking beam experiences accelerations described by a sign wave. This is not completely desirable due to the limitation that the walking beam must oscillate 60 times per minute to work effectively. Another method that helps solve this problem is a cam. By using a cam the ramp up and down of the walking beam can be custom tailored. However, there are some limitations. Certain speeds will work better than others. A third idea is to take advantage of a hydraulic system that would control the walking beam using a hydraulic ram. This would allow great control but may be expensive and hard to design properly. The fourth idea again uses the rotary motion first introduced with one variation. A rotating flywheel will have a second wheel mounted to it that rotates on bearings and is allowed to turn freely in one direction and is driven by the flywheel in the other. This motion would allow the walking beam to be driven at any speed but once the bit falls, it will do so with little restriction.

Main Line Brake

The fourth main design area is the main line brake. The brake must be strong enough to resist the impact force of the bit (transferred by the cable) when it reaches the bottom of the stroke and also have good control to allow the main spool cable to feed out and continue drilling deeper during normal operation. Main line cable is connected to the drill string assembly on one end and is wrapped around the main line spool. This spool needs to be held solid when desired, yet also allow the wire rope to release when needed. This is most readily accomplished with an adjustable brake. There are four types of brakes considered here: automotive drum or disk brakes, an automotive clutch used as a brake, and lastly a band brake. Drum, disk and clutch brakes are readily available and could be sourced from old cars. Disk brakes work by squeezing a disk with two brake pads. Drum brakes are similar except the pads are inside of the drum and are forced outward to engage the drum. A clutch works as described in the power engagement section, but engages a brake pad instead of a powered disk. A band brake operates with an external pad band that engages the outside of a cylinder when the band is clamped. The requirements for the brake consist of good holding power and good control over release. Ease of procurement and positive control are the main concerns.
**Concept Selection**

The selection of concepts is driven by function and ease of application. Due to this project going to Africa, it is important to keep in mind the capabilities of the people and availability of parts and machine tools. Our decision matrices are listed in Appendix A. Concept drawings are in Appendix B-3.

Hydraulic systems can be purchased for use in Africa. However, the machining necessary to implement some of the concepts may be rare. To reduce the possibility of failure in construction the more simplistic designs will be generally favored. Power transmission systems such as chains are more forgiving concerning alignment and will be utilized.

**Description of top concept**

A hydraulic system for controlling the mechanism presents the most potential. It offers better control and easier installation, while the only drawback is availability. Hydraulic systems can be found or delivered to developing nations, and therefore we are choosing to install it on our rig. Three identical motors will be used to simplify the parts that must be purchased, and present the option that only one spare is needed to backup each of the three systems and swapping parts will be simple and possible.

Chains will be used because they are common and easily understood. Precision mounting will also be reduced to make construction easier. Three chain sets will be used in conjunction with sprocket sets. One set of each will be required for the walking beam, main line, and the sand line.

The walking beam will be controlled with a rotary flywheel with the possibility of the one way bearing addition. The best part about this design is that if it fails in testing or results in not offering any benefit it can be welded solid and used as a traditional rotary set up. If it does work it will be a nice addition to the control and efficiency, and it is a concept that we have not seen used on any other rig.

The main line brake will utilize a disk brake similar to the one currently on the rig. Analysis has been done to evaluate the brake’s holding power and a larger brake will be required. See calculations in Appendix E.

**Construction plans**

The first step is to remove the components on the rig that will not be retained. All of the pulleys and belts will be removed as well as the tension clutches. Aside from minor adjustments, some components will be left alone such as the derrick, frame, and walking beam. Other components will be relocated such as the flywheel, main line, and sand line. Shafts and pillow block bearings will be moved as well for better design and utilization.

Once the hydraulic system is properly sized, the pump can be mounted to the gasoline motor. The hydraulic motors will then be mounted in place followed by chain and sprocket sets to transfer power to their respective systems. To accomplish this, the machining of adapters is necessary to mount chain rings to the system shafts. Control valves and a hydraulic reservoir will be mounted with hydraulic lines
connecting the components as required. The walking beam flywheel will have to be machined and installed as well. The brake system for the main line will also have to be machined and mounted. The next step will be to take care of small machining and installation of guards followed by other small machining and installation tasks.

**Proof of concept analysis or testing**

During the design phase of this project we had the major components already on hand. Since the largest portion of the project involved refining and bulking the design, along with installing hydraulic controls, we did not perform initial testing. Once we have the rig operable, tests and analysis will be carried out. A major test will be to find the impact loading on the rig from the drill stem while it does not contact the ground.
Chapter 4: Description of Final Design

Figures 6 and 7 below provide the planned layout for the components of the drill rig. Only the motors are shown for the hydraulic system. The controls, hydraulic tank, and gasoline engine, will be located on the side of the trailer. The motors will be bolted to plate steel welded to the frame.

Figure 6: Preliminary SolidWorks Model (right view)

Figure 7: Preliminary SolidWorks Model (left view)
**Main Line and Sand Line**

The main line spool has been removed from the walking beam and will be replaced with a larger unit to allow for a larger wire rope. A new main line will be constructed from 6 inch outer diameter pipe. It will need to be large enough to accommodate at least 200 feet of 5/8 inch left hand lay cable. It will also have a separator which allows the majority of the cable to be spooled onto one portion with a separate portion allotted for just a few wraps of the outbound cable. A drawing of this feature is shown in Figure 8. This allows for maximum pulling force when desired by decreasing the effective spool diameter as well as protecting the cable from becoming bound up and tangled. The main line must be moved from the initial location on the walking beam shaft because of an inadequacy of space.

A new sand line spool will also be fabricated using the same material as the main line spool. However, the sand line will have more conventional spool construction with only one section for wrapping the cable.

**Power Transmission**

Power will be transmitted to the three main components (main line, sand line, and walking beam) by a hydraulic system. Each component will have an independent hydraulic motor. The hydraulic motors will eliminate the need for clutches and provide exceptional control.

The existing 13hp gasoline motor, even though it may be used near capacity, has been proven sufficient to power the system and a suitable Hydraulic pump was sized to mate with it. The Hydraulic pump will take fluid from the reservoir and supply it to a custom stack valve. A stack valve allows for selection of a particular type of valve for each system. These valves can then be bolted together into one convenient valve unit and will serve to distribute fluid to each system’s hydraulic motor. The hydraulic motors are three of the same type to facilitate repair and replacement.

Both the main line and sand line cable spools will be driven intermittently. The main consumer of power will be the walking beam motor which will run the majority of the time while drilling and therefore was
used to calculate the maximum power requirements of the system. Hydraulic fluid will be returned from the motors to the reservoir in a loop during operation. All of the motors will be set up to run in forward and reverse so that the main and sand line can spool in and out, and while the walking beam only needs to run in one direction, it will have the ability to rotate in both to add flexibility in the event that the bit becomes stuck. Components for the expected hydraulic system are listed in Table 2. Appendix B contains labeled drawings and layouts of the hydraulic system, and three driven systems.

**Table 2. Hydraulic Drive Installation Costs**

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Part Number</th>
<th>Description</th>
<th>Unit Price($)</th>
<th>Quantity</th>
<th>Price($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grainger</td>
<td>6W549</td>
<td>Inlet Section</td>
<td>74.40</td>
<td>1</td>
<td>74.40</td>
</tr>
<tr>
<td>Grainger</td>
<td>6W560</td>
<td>Bolt Kit</td>
<td>10.16</td>
<td>1</td>
<td>10.16</td>
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<tr>
<td>Northern</td>
<td>201617</td>
<td>Outlet End Plate</td>
<td>39.99</td>
<td>1</td>
<td>39.99</td>
</tr>
<tr>
<td>Northern</td>
<td>201614</td>
<td>Valve SVW1DD1</td>
<td>104.99</td>
<td>1</td>
<td>104.99</td>
</tr>
<tr>
<td>Northern</td>
<td>201612</td>
<td>Valve SVW1BA1</td>
<td>79.99</td>
<td>2</td>
<td>159.98</td>
</tr>
<tr>
<td>Northern</td>
<td>201615</td>
<td>Valve SVW1BB1</td>
<td>89.99</td>
<td>1</td>
<td>89.99</td>
</tr>
<tr>
<td>Northern</td>
<td>2040</td>
<td>Flow Control Valve</td>
<td>84.99</td>
<td>1</td>
<td>84.99</td>
</tr>
<tr>
<td>Northern</td>
<td>10600</td>
<td>Hyd. Pump</td>
<td>184.99</td>
<td>1</td>
<td>184.99</td>
</tr>
<tr>
<td>Northern</td>
<td>1039</td>
<td>Hyd. Motor</td>
<td>239.99</td>
<td>3</td>
<td>719.97</td>
</tr>
<tr>
<td>Northern</td>
<td>4052</td>
<td>Hyd. Oil Tank</td>
<td>99.99</td>
<td>1</td>
<td>99.99</td>
</tr>
<tr>
<td>Northern</td>
<td></td>
<td>Hyd. Hoses</td>
<td>15.00</td>
<td>12</td>
<td>180.00</td>
</tr>
<tr>
<td>Northern</td>
<td></td>
<td>Motor-Pump Bracket</td>
<td>60.00</td>
<td>1</td>
<td>60.00</td>
</tr>
<tr>
<td>Northern</td>
<td></td>
<td>Motor-Pump Coupling</td>
<td>38.00</td>
<td>1</td>
<td>38.00</td>
</tr>
<tr>
<td>Northern</td>
<td></td>
<td>Filter</td>
<td>30.00</td>
<td>1</td>
<td>30.00</td>
</tr>
<tr>
<td>Northern</td>
<td></td>
<td>Pressure Gauge</td>
<td>15.00</td>
<td>1</td>
<td>15.00</td>
</tr>
<tr>
<td>Northern</td>
<td></td>
<td>Couplings and Adapters</td>
<td>2.50</td>
<td>15</td>
<td>37.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Total</strong></td>
<td><strong>1929.95</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The total with 25% added for unexpected costs was introduced to the sponsor as the estimated bulk cost for the hydraulic system and was well received.

**Shafts, Bearings, Pillow Blocks**

The drill rig has existing shafts and pillow blocks that will be retained and analysis has been done to verify they are correctly sized. These consist of the main line shaft and walking beam shaft. The new sand line will have a recycled 1 ½ inch shaft and pillow blocks from the previous rig and has been determined sufficient. Work will also be done to reduce bending moments on shafts particularly in the shaft supporting the walking beam sheave.

The pins (shafts) supporting the derrick will be increases in size and relocated, while the pillow blocks previously used will be removed and replaced with a simple steel on steel hinge. The reason for this is
that expensive bearings are unnecessary for a component that rarely moves. Wear from vibration will also be reduced due to using a larger pin and dispersing the force over a larger area.

The pillow blocks from the derrick mount will be recycled for use on the pitman arm. Currently it does not have bearings and by adding them we will reduce wear and friction for robust design.

If necessary, additional Pillow blocks and bearings will be purchased from Central Coast Bearings and Shafts will be purchased from B & B Steel or McMaster Carr.

**Chains and Sprockets**

The initial intent was to use readily available motorcycle chains in order to transmit power from the hydraulic motors to the machine’s shafts. Unfortunately, these chains are not rated to the working load required to operate this machine. Therefore ANSI 60 H series chains will be used to transmit power. These chains have a working load of 2000 lbs, which is larger than the force they can see from the motor torque.

Sprockets were chosen based on necessary chain requirements and gear ratios. The main line will have a 21 tooth to a 54 tooth sprocket and will be required to winch much larger weight so it is a larger gear reduction than the sand line. A 21 tooth to a 30 tooth sprocket will be installed for the sand line and will be required to raise and lower the bailer a longer distance more frequently than the main line. Higher line speeds of the sand line will help reduce overall drilling time. The walking beam will use a 35 tooth to a 60 tooth sprocket to produce a flywheel rotation speed of 60 rpm with the motor spinning at 102 rpm. Smaller sprockets decrease cost, but increase the working load seen by the chain. The walking beam is using the largest driving sprocket because it has the potential to see the largest amount of shock. There are an odd number of teeth on the driving sprocket in order to prevent uneven wear on the chain. (Shigley) Sprocket sizes were also constrained by readily available sizes. Detailed chain and sprocket calculations are provided in Appendix E. Table 3 below provides chain and sprockets that have been selected and the price from McMaster Carr.

**Table 3 Chain and Sprocket Costs**

<table>
<thead>
<tr>
<th>Description</th>
<th>Part Number</th>
<th>Unit Cost ($)</th>
<th>Quantity</th>
<th>Total ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 teeth, 1 3/4&quot; bore</td>
<td>6236K587</td>
<td>84.74</td>
<td>1</td>
<td>84.74</td>
</tr>
<tr>
<td>35 teeth, 1&quot; bore</td>
<td>6236K541</td>
<td>58.84</td>
<td>1</td>
<td>58.84</td>
</tr>
<tr>
<td>21 teeth, 1&quot; bore</td>
<td>6280K301</td>
<td>42.43</td>
<td>2</td>
<td>84.86</td>
</tr>
<tr>
<td>30 teeth, 1 1/2&quot; bore</td>
<td>6236K534</td>
<td>55.86</td>
<td>1</td>
<td>55.86</td>
</tr>
<tr>
<td>54 teeth, 1 3/4&quot; bore</td>
<td>2741T122</td>
<td>80.90</td>
<td>1</td>
<td>80.90</td>
</tr>
<tr>
<td>20' of ANSI 60H chain</td>
<td>7265K522</td>
<td>158.00</td>
<td>1</td>
<td>158.00</td>
</tr>
</tbody>
</table>

**Total**                  |             |               |          | 523.20    |
**Derrick Extension**

The Derrick will be extended in order to accommodate a long enough drill stem and bit. The drill string must be able to be pulled at least seven feet above the hole in order to allow for the installation of casing. With a 16 foot drill stem a twenty foot derrick would not have been sufficient. The extension will be hinged in order for the rig to continue to be towed by a vehicle. Figure 9 shows the derrick in the collapsed position. Figure 10 shows a close up of the hinging mechanism that will be constructed.

This hinge will be constructed from steel rings that will be welded onto the derrick frame. Half of the rings will be on each the derrick extension and half will be on the top of the original derrick for even load distribution. A 6 inch long shaft will be put through the rings of both pieces in order to create a conventional hinge mechanism.

![Figure 9: Modified Derrick Extension in Collapsed Position](image)

![Figure 10: Derrick Extension Hinge](image)
Safety considerations

This project has been under scrutiny for safety concerns from both the past project and the current design. Potential hazards and preventative measures are outlined in table 4 below. For safety in Africa the colors chosen for the drill rig are neutral to prevent any conflicts arising upon delivery to the developing continent. Expanded steel mesh has been installed as a guard on each side of the rig near the moving chains to avoid accidental harm from occurring. The majority of the moving parts are located in the interior of the box frame to maintain a safe distance for anyone near the machine.

Table 4 Safety Risk Analysis and Prevention

<table>
<thead>
<tr>
<th>Item/Area</th>
<th>Risk</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire rope</td>
<td>Pinch fingers</td>
<td>Training and inspection of proper cable operation</td>
</tr>
<tr>
<td>Engine</td>
<td>Noise</td>
<td>Ear Plugs</td>
</tr>
<tr>
<td>Engine</td>
<td>Exhaust inhalation</td>
<td>Open air ventilation</td>
</tr>
<tr>
<td>Pitman arm and Flywheel</td>
<td>Pinched limbs</td>
<td>Location and training</td>
</tr>
<tr>
<td>Rotating parts</td>
<td>Loose items caught</td>
<td>Loose clothing or hair properly secured</td>
</tr>
<tr>
<td>Cable spools</td>
<td>Fingers and hands caught</td>
<td>Guards and training</td>
</tr>
<tr>
<td>Chains and sprockets</td>
<td>Fingers and loose items caught</td>
<td>Guards and training</td>
</tr>
<tr>
<td>Drill bit</td>
<td>Crushing limbs</td>
<td>Training, warnings, using guides and casing</td>
</tr>
<tr>
<td>Derrick</td>
<td>Crush surrounding people/property</td>
<td>Use grounded guy wires and training</td>
</tr>
</tbody>
</table>
Chapter 5: Product Realization

*Manufacturing Processes and Components*

Fabrication of the current drill rig required a great deal of time to deconstruct the previous design. Cutting off many components with a cutting wheel and then using a grinder to remove any excess metal was the process. Grinding down the weld to a smooth surface has made the frame surface ready for painting and for new beams to be attached. Consideration was taken to avoid grinding or cutting into the frame to prevent weakening the steel.

**Walking Beam Counter Weight**

The walking beam has an attachment for an adjustable amount of weights to be placed on top of it to even out the load on the engine. If the precise amount of counter weight is added to the walking beam, the motor will see an equal load in the up and down stroke of the drill bit. This will allow for smooth drilling operation. An extra bar of steel was added to the walking beam with a shaft welded in place to allow for a stack of weights to be added as necessary. Weight lifting weights were chosen because they are easy to add and remove, and are able to provide the large amount of counter weight required. The weight will be held in place on the walking beam using clamping device in order to ensure they do not move during drilling.

**Pitman arm and Flywheel**

The Pitman arm was manufactured from square steel bar stock with end plates welded on. The end plated were constructed from \( \frac{3}{4} \)” plate steel and cut to shape using a plasma cutter. \( \frac{1}{2} \)” holes were drilled into the plate to allow for a pillow block to easily be mounted for each end. A larger bore of 1 \( \frac{1}{2} \)” was drilled for the attachment shaft to the pitman arm. Once the shaft was put in place, it was welded securely in place. The walking beam had two 7” long pieces of 2”x3” steel bars welded to it for mounts. A 1 \( \frac{1}{2} \)” diameter hole was drilled into each of these pieces and a shaft was run through them along with the pillow block.
Derrick Extension

In order to allow for a the use of a 16 foot drill bit, the derrick had to be extended. The addition of the derrick extension to the end of the derrick already in place was done with a hinge. A hinge was needed to limit the length of the derrick extending forward onto the towing vehicle during transport. The hinge was constructed from steel tubing welded intermetantly to the upper and lower portions of the derrick. A pin was then placed running through each of the pieces of tubing. Extensive reinforcement metal plates were welded on to the hinges for added strength. The same steel used in the derrick was used in the derrick extension, ordered from B&B Steel of Santa Maria, CA. Figure 14 displays how the extension folds over and on top of the original derrick. Once unfolded, there are bolt holes in place to ensure a solid connection during drilling operations. The Derrick is held secure using three ¾” bolts. Figure 15 shows a close up
of the hinge constructed from the steel tubing. It also shows the brackets that are used to secure the derrick open when drilling is in operation. The two pieces of the derrick rest up against each other during drilling to prevent movement between them.

**Hydraulic System**

Figure 16 above shows the location of the major hydraulic components for the machine (excluding motors). The location of these components was laid out prior to running the hoses to them. Everything was placed in its final position so that hose lengths could be properly determined. The hoses and fittings were installed by DIESELRO of San Luis Obispo. The tank is able to hold up to 19 gallons of hydraulic fluid, but will generally operate with between 10-15 gallons. The hydraulic filter was also installed by DIESELRO and will prevent contamination from flowing from the hydraulic tank to through the system, which would decrease power output. There was no available pump adaptor for this particular motor so a custom mount had to be created.
Figure 20 shows the construction of the custom mount for the pump. SolidWorks models were created in order to use CNC machines to create the part. The piece was cut from 8” solid aluminum. Figure 19 shows a close up of the custom hydraulic stack valve. Also shown on this picture is the speed controller (running from the center valve), which will allow the operator to control the frequency of the walking beam motion. The stack valve was mounted to the frame with plate steel welded to the frame and strengthened with triangular brackets on each side.

Figure 20 Custom CNC facing the motor mount on a lathe

Figure 19 Stack valve with hydraulic speed control

Figure 18 Adapter for gas and hydraulic motor mounted

Figure 17 Hydraulic pump motor mounted
**Motor Mounts**

The hydraulic motors are front mounted with 4 bolts and could not be mounted to 3”x2” steel bars. Custom motor mounts were required in order to mount the motors to the frame. These mounts were constructed from 3/8” thick plate steel. For ease of manufacturing, one design was used for all three mounts. The mounts were drawn up in SolidWorks and then built using the CNC mill. The mounting holes are slotted to allow for small adjustments to change chain tension. The adjustability varies between vertical and horizontal from the mounts depending on location, but the overall purpose is served.

![Figure 21 Motor mount in final location](image)

**Crown Block**

Mounting of the crown block appeared to be done the safest in the midst of the derrick’s structure. Grade 8 bolts were used along with sheet metal to construct the apparatus. Rubber dampening pads were installed as a force damper. Two sheaves were found to thread the two cable lines through.

![Figure 22 Crown Block mounted inside the derrick extension](image)
Cable Spools

The team fabricated cable spools from ¼” plate steel. In order to cut the spool outer diameter to 14”, precision plasma cutting was used. The main line spool required three 14” OD pieces of steel to construct the separated portion of the spool. The separated portion will allow for decreased slip in the line and preserve the cable during drilling operations. The middle of the three large circular pieces had to have two large rounded notches so that cable is easily able to be fed from one section of the spool to the other. The plasma cutter was able to trace a carefully drawn circle of the desired diameter in order to create a perfect circle for the spools. Figure 22 shows the plasma cutter cutting the plate steel to shape. The inner portion of the spools was constructed from 6” OD steel pipe. The steel pipe had holes drilled and tapped in it so that the cable can be securely fastened to the spool using plate steel and bolts. The size of each spool was calculated to determine the required length for all of the cable to fit on the spool and to prevent runoff during operation. Figure 24 shows the main line cable spool mounted to the frame. The main line cable installed is 6X21 fiber core left lay wire rope. It weighs 0.66 lb/ft, with 200ft it weighs 132 lb overall, and is bright, which means it is not galvanized. Doug Enloe instructed us that left lay wire rope is the industry standard, so that is what we order. It tightens upon ground impact. A proper rope socket allows the cable to freely spin upon ground impact, and one was obtained by the sponsor.
Figure 26 Guard of expanded steel placed over the main spool chain

**Chains and Sprockets**

60 series sprockets were ordered and put on place on the ends of the hydraulic motor shafts and the spools and flywheel for transmitting power. The sprockets came finished from McMaster-Carr with pre cut keyways and set screws. The chain was 60-H series, riveted chain for added strength and came in 10 foot lengths. The chain is to be cut to fit for each location and held together via a master link. The adjustability in the motor mounts will ensure that the chain will be tight and thus prevent slippage.

Figure 27 Walking beam and sand line chains and sprockets prior to guard mounting
Main line Brake

The main line brake is mounted on an angled piece of rectangular tubing. Two calipers were used for greater breaking force to minimize slip of the main line spool when undesired. Controlling the brake presented a challenge and a combination of a lever for coarse adjustments and a compression spring for fine tuning was used. Locating the controls near the motor and the cable was essential to minimize the operators required and also provide ergonomic controls. The brake fluid level is easily monitored next to the controls.
Hydraulic Ram

A hydraulic ram was installed to ease the lifting the derrick. Since the hydraulic system was already installed, with extra hoses, and valve, the ram was added by sponsor Bob Hather. It has a 2 inch shaft with 20 inches of throw, and is overall 24 inches long. A cross beam was added to distribute the lifting force on the derrick to minimize the moment felt at one point.

Figure 30 Red hydraulic ram installed in the frame

Figure 31 Cross beam installed with the hydraulic ram
**Modifications in the Manufacturing Process**

A few modifications were made to our design, along with the order of item production also changed as necessary to avoid rework. The following were modifications necessary for an effective product:

- The control systems on the rig were placed on the right side of the rig to allow an operator to run the rig with their right hand, and feel the cable with their left hand.

- The gas motor was relocated to the end of the right side of the rig near the controls for closer and easier operation.

- The location of the sand line was placed at the very end of the rig to allow space for the flywheel to operate and to minimize interaction with other components. Because of this change, the sand line cable goes directly up to the top sheave, and down to the bailer.

- The hydraulic motors were positioned in optimal locations to allow for solid support and the mounts have adjustable slots for adjustability when the chains are installed.

- With the relocation of controls, the tool rack was cut and moved to the left side of the rig for better ergonomics. It was not welded down since it did not seem necessary.

- Due to strength considerations the crown block was not placed on the very end of the derrick, and was instead placed inside the derrick extension.
Chapter 6: Design Verification

Specifications

The WHole Engineering design team will have to provide proof that the drilling rig passes the specified requirements in table 3. Test descriptions appear after the table with a list of necessary equipment. The last column in table 3 is for specification verification after testing.

Table 5 Specifications to be verified

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Specification Parameter</th>
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<th>Requirement</th>
<th>Value Reached after testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Drilling Depth</td>
<td>Drill to target depth</td>
<td>&gt;100 ft</td>
<td>Not fully tested</td>
</tr>
<tr>
<td>2</td>
<td>Hole Diameter</td>
<td>Measure diameter of drilled hole</td>
<td>&gt;4 inch</td>
<td>5 in</td>
</tr>
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<td>3</td>
<td>Drill String Weight</td>
<td>Weigh Drill String</td>
<td>&gt;600 lb</td>
<td>625 lb</td>
</tr>
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<td>4</td>
<td>Operators</td>
<td>Operate with 2 people</td>
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<td>2 people</td>
</tr>
<tr>
<td>5</td>
<td>Transportability</td>
<td>Weigh trailer</td>
<td>&lt;3000 lb</td>
<td>Estimated &gt;3000 lb</td>
</tr>
<tr>
<td>6</td>
<td>Horizontal Sway</td>
<td>Measure sway of drilling rig</td>
<td>&lt;6 inches</td>
<td>&gt;6 in</td>
</tr>
<tr>
<td>7</td>
<td>Operation Speed</td>
<td>Measure flywheel rotational speed</td>
<td>50-60 rpm</td>
<td>60 rpm</td>
</tr>
</tbody>
</table>

Test 1
In order to verify the drilling rig is capable of reaching the water table, it will be tested to a depth of 100 ft. This test will require at least 20 five foot section of 4in. inner diameter steel tubing (casing) as well as enough fuel and water for the operation. The test will require several drilling bits and the bailer in order to successfully reach the target depth.

Test 2
The bore diameter will be measured using a caliper. Compliance will also be verified during test 1. If the drill bit can fit within the inner diameter of the casing and the casing can be successfully driven into the hole.

Test 3
The drill string will be weighed using a vehicle scale. An engine hoist will be required if the scale is located indoors and the rig cannot be used. If the drill bit weighs less than 600 lbs, a replacement will be needed.

Test 4
This test will be performed during test 1. If it takes more than 2 people for any of the operations during drilling the test is a failure and proper modifications will have to be made to the drilling rig.
Test 5
The completed drilling rig will be weighed on a vehicle scale to ensure it is less than 3000 lbs. Drill bits and additional drilling equipment will be removed from the trailer as well as water from the tank. If failure occurs weight will be removed from non-critical locations in the machine.

Test 6
The horizontal sway of the drilling rig will be measured through the use of observation of various points on the machine. A horizontal sway of more than 6 inches will require additional supports or reinforcements to be added to parts of the machine.

Test 7
The rotational speed of the flywheel will be measured by counting the number of oscillations of the bit in one minute. If the speed is outside of the 50-60 rpm range proper gear reductions will be added or removed from the drilling rig.

Test Results
The drilling rig was tested on Bob Hather’s property. Due to the lack of necessary casing and the extensive time required to drill a full well the rig was only tested to a depth of 25ft. There were no complications and the types of soil encountered included clay, sandstone, and serpentine. The drill rig was able to successfully drill through all the soil types, with some water added, and a summary of the drilling speeds are shown in table below:

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Drill Time (hours)</th>
<th>Drill Depth (ft)</th>
<th>Drilling Speed (ft/hr)</th>
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<tbody>
<tr>
<td>Clay</td>
<td>1</td>
<td>12</td>
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<tr>
<td>Sandstone</td>
<td>3/4</td>
<td>5</td>
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<td>Serpentine</td>
<td>2</td>
<td>4</td>
<td>2</td>
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Table 6 Drilling rates through different types of geology tested
Testing proved a rock could be easily crushed with the force of the buttoned bit in the Figure below.

Figure 32 Drill testing on a rock

Figure 33 Bore hole after a few minutes of drilling with water
Impact Testing:

The crown block was an area of safety concern due to the immense forces that could be seen and potential danger if failure were to occur. In order to determine if the machine would be able to handle the loads the team had to determine the actual forces the crown block welds experienced. An accelerometer ICP from PCB Piezotronics, model Number 353B15 was attached to the drill stem during drilling to calculate the loads that the top would see. This accelerometer can be seen in Figure 34. A Dactron LDS program was used on a borrowed Cal Poly computer for the testing, which the apparatus can be seen in Figure 35.
Results from the accelerometer tests were consistent through four tests and the test readout shown in Figure 36 is from one of the four runs.

![Graph showing g forces acting on the crown block while the drill string does not contact the ground.](image)

**Figure 36** g forces acting on the crown block while the drill string does not contact the ground

The graph shows the worst impact force that the drill bit would experience to be 4.7 g’s. This translates to the crown block seeing a force 2820 lbs. or 1410 lbs. per weld. This was far less than the team initially expected and the rig will be able to handle these loads.

An impact test was also performed with the drill bit contacting the ground. This test allowed the team to calculate the drilling force that the machine was producing and also see the impact the top mount would see when the walking beam would suddenly pull the bit back up while the wire rope went back into tension during the lifting portion of the stroke. Results of the drilling impact on the ground test are shown in Figure 37.
The peak impact acceleration shown on the graph is 11 g’s. This acceleration translates to an impact force of 6600 lbs. on the ground. There is also a smaller jump in acceleration on the graph. This hump is due to the walking beam picking the drill bit back up. The maximum acceleration for picking the bit back up was determined to be 2g’s. This acceleration translates to an impact force of 1200 lbs. on the crown block or 600 lbs. on each of the welded pieces that attach the crown block to the derrick. Based on this force, these welds will not fatigue due to the repeated impact on them.

While testing, the Figure below shows the angular momentum in the flywheel and herringbone gear help maintain a steady rotation for proper operation.
Chapter 7: Conclusions and Recommendations

This project greatly enhanced our collegiate experience and fully challenged the team to learn by doing. Challenges included understanding the sponsor’s need for going in one specific direction to account for all improvements, the time consumed in manual labor removing parts, then reapplying them, working out each new design and ensuring that it all will work together. Additionally challenging was to understand the drilling process and terminology.

We were fortunate to work with great people striving to improve lives and help sustain life in developing countries. This goal has kept the team inspired to construct a functional and robust drilling rig. Professional advice was readily available from an operator’s standpoint, but not on the design engineer’s point of view.

We conclude that the drilling rig constructed is functional and should be able to drill at least ten wells before a few components will need significant attention, with an overall life of 100 wells.

Additional testing is necessary to determine failure points before additional rigs can be constructed. Lifewater of San Luis Obispo, along with the help of several cable tool drillers, will be testing the machine to failure in order to make the necessary changes. There are also changes that can be made in the frame structure and derrick. Since the WHole Engineering Team did not complete the rig from scratch and major changes were made, there are improvements that can be made to simplify the design. The trailer should be custom designed to place the tires further back where the center of mass is to ensure that the suspension can support the impact of drilling. Also, the derrick currently is constructed of steel tubing that requires tube notching and difficult welds. We recommend using rectangular steel similar to the frame in order to make a derrick that can be bolted together. These changes will help make the rig a more effective, cost efficient machine to drill wells for those in need.
References


## Appendix A Decision Matrices, QFD

### Table 7 Walking beam decision matrix

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<tr>
<th>Criteria</th>
<th>weight</th>
<th>Traditional rotary</th>
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<th>Cam</th>
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### Table 8 Power Transmission decision matrix

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Table 9 Power engagement decision matrix

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Table 10 Main line brake decision matrix

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Appendix B Drawing packets

Hydraulic system sketch

Hydraulic System Design

- WB Motor
- Main line Motor
- Sandline Motor
- Flow control valve
- Spool control valve
- Pump (supply)
- Reservoir (return)
- Gasoline motor

(control levers) (hoses)
Brake sketches

- **Main Line Brake**
- **Band Brake**
  - Band
  - \( F \) (Applied Force)
  - Inner Drum

- **Drum Brake**
- **Disk Brake**
- **Clutch as Brake**
  - Pad
  - Disk
Walking Beam Control - the walking beam oscillates to make the bit go up and down.

Rotary

[Sketch of rotary mechanism with WB and cam]

Rotary w/ one way

[Sketch of rotary mechanism with WB and cam]

This allows the WB to move/fall freely (w/ bit) when the flywheel is going slower than optimum (due to desire for increased control).

Hydraulic

[Sketch of hydraulic mechanism with WB]
Chains & Sprockets

Power transmission - Belts \& Chains

3600 RPM → 800 RPM

Motor

Belt/Chain

2:1

Shafts

To Walking Beam

Gear Reduction

2:1

To Walking Beam

* All shafts require some form of bearing *

Gears

To main line \& send line

Mechanical Engineering
Power engagement (clutch)

Belt:

Clutch:

Engaged

Disengaged

Automotive Clutch

Hydraulic

Fluid in from pump

Fluid to actuator

Shaft output

* Requires F to engage *
### Table 11 Parts ordered details

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Appendix C List of Donors and Vendors

Donors

**Doug Enloe**
PO Box 1698
Nipomo, CA 93444
(805) 343-1698
*Donations: Professional advice, Rope Socket and other parts offered*
Approx value: $200#

**Rod Thompson**
12264 Topa Lane
Santa Paula, CA 93060
(805) 660-2453
*Donations: drill bit, sheaves, bailer*
Approx value: $900

**Stephen Michl of Michl Tool Works**
445 So. Ojai St
Santa Paula, CA 93060
(805) 525-6638
*Donations: bearings shafts flywheel*
Approx value: $900

**Paul Hofmeister of Hofmeister Const**
1114 Ayers Ave
Ojai, CA 93023
(805) 640-8318
*Donations: Drill string*
Approx value $1,200

**Ray Newmyer**
PO Box 5, 11481 2nd Ave
Hooper, CO 81146
*Donations: Professional advice*
Approx value: $400#
Vendors

**McMaster-Carr**  
(609)223-4200

**Grainger**  
(800)323-0620

**Northern Tool**  
(800) 221-0516

**OnlineMetals.com**  
(800) 704-2157

**Landmann Wire Rope Products Inc.**  
(800) 344-6751

**Central Coast Bearing**  
860 Capitolio Way Ste A  
San Luis Obsipo, CA 93401  
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**Precision Machine**  
3055 McMillan Avenue  
San Luis Obsipo, CA 93401  
(805) 544-5694

**B&B Steel**  
1233 Furukawa Way  
Santa Maria, CA 93458  
(805) 349-9991

**Home Depot**  
1551 Froom Ranch Way  
San Luis Obsipo, CA 93405  
(805) 596-0857

**Kelly Supply Company Direct**  
(800) 918-8939

**Heacock Trailers and Truck Accessories**  
417 Traffic Way  
Arroyo Grande, CA 93420  
(805) 489-8442

**Preferred Pump And Equipment**  
1740 Carlotti Dr  
Santa Maria, CA 93454  
(805) 922-8510

**Royal Supply**  
7050 E. 54th Place  
Commerce City, CO 80022  
(303) 286-1704
Appendix D Vendor supplied Component Specifications and Data Sheets

D-1 Component price and specifications sheets

PRINCE Inlet Section

Hydraulics > Valves > Hydraulic Manual Stack Valve Systems

Stack Valve Inlet Section, 12 GPM, 500-1600 PSI

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grainger Item #</td>
<td>6W543</td>
</tr>
<tr>
<td>Price (ea.)</td>
<td>$74.40</td>
</tr>
<tr>
<td>Brand</td>
<td>PRINCE</td>
</tr>
<tr>
<td>Mfr. Model #</td>
<td>SV124</td>
</tr>
<tr>
<td>Ship Qty.</td>
<td>1</td>
</tr>
<tr>
<td>Sell Qty. (Will-Call)</td>
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</tr>
<tr>
<td>Ship Weight (lbs.)</td>
<td>4.1</td>
</tr>
<tr>
<td>Usually Ships*</td>
<td>1-3 Days</td>
</tr>
<tr>
<td>Catalog Page No.</td>
<td>3515</td>
</tr>
<tr>
<td>Country of Origin</td>
<td>USA</td>
</tr>
</tbody>
</table>

Qty. [ ]

☐ Add Grainger TripleGuard® repair & replacement coverage for $16.95 each.

View Catalog Page  View Printable Page

The "Usually Ships*" reflects when an item is generally expected to ship from Grainger based on its stocking location. Real-time availability.
PRINCE Bolt Kit, For 4 Section

Hydraulics > Valves > Hydraulic Manual Stack Valve Bolt Kits

Stack Hydraulic Valve Bolt Kit, Number of Work Stations 4, 12 GPM

Grainger Item # 6W563
Price (ea.) $10.16
Brand PRINCE
Mfr. Model # 654301004
Ship Qty. 1
Sell Qty. (Will-Call) 1
Ship Weight (lbs) 0.75
Usually Ships** Today
Catalog Page No. 3615
Country of Origin USA
(Country of Origin is subject to change)

Price shown may not reflect your price. Sign in or register.

Qty. 

Add to Order  Add to Personal List

The "Usually Ships" reflects when an item is generally expected to ship from Grainger based on its stocking location. Real-time availability information will be shown during the checkout process and on the e-mail order confirmation for U.S. and Puerto Rico - US customers only. Please allow additional delivery time for international orders.
Prince Standard Outlet End Plate, Model# SVE21

Overview
Sectional body hydraulic directional control valves for mobile and industrial hydraulic systems. Power beyond plug capability. Use with double-acting cylinders. U.S.A.

Product shown is representational; actual unit is outlet end plate body only.

Features + Benefits
- Inlet or outlet section not included
- Does not include through-bolt kit
- Standard Outlet End Plate, top and side ports
- Adjustable pressure range from 1500–2000 PSI
- Precision ground spools
- 1–10 sections per valve bank
- Load checks on each section
- Hard chrome-plated spools
- Compact construction
- Reversible handle
- Parallel circuit construction
- Foot mounting
- Max. 12 GPM and 180°F
- 3/4-16 ORB, #8 SAE working port, 7/8-14 ORB, #10 SAE inlet and outlet ports
Prince Control Valve — 4-Way/4-Position, Model# SVW1DD1

In Stock
Ship Wt. 5.0 lbs.
Item# 201614

Only $104.99

Overview
Sectional body hydraulic directional control valves for mobile and industrial hydraulic systems. For use with double-acting cylinders. Power beyond plug capability. U.S.A.

Product shown is representational; actual unit is single-valve body only.

Features + Benefits
• Single-valve body only
• Inlet or outlet section not included
• Does not include through-bolt kit
• Float section can be placed anywhere within the stack assembly
• Net more than one float section per assembly
• Precision ground spouts
• 1-10 sections per valve bank
• Load checks on each section
• Hard chrome-plated spouts
• Compact construction
• Reversible handle
• Parallel circuit construction
• Foot mounting

Key Specs
• Max. Flow (GPM): 12
• Working Port (in.): 3/4-10 ORB, 8
• Max. PSI: 3,000
• Directional Control: 4-way, 4-position
• Adjustable Release Pressure PSI: 1,500 - 3,000
Prince Control Valve — 4-Way/3-Position Cylinder Spool, Model# SVW1BA1

In Stock
Ship Wt. 5.0 lbs.
Item #: 201012
Only $79.99

Overview
Sectional body hydraulic directional control valves for mobile and industrial hydraulic systems. For use with double-acting cylinders. U.S.A.

Product shown is representational, actual unit is single-valve body only.

Features + Benefits
- Single-valve body only
- Inlet or outlet section not included
- Does not include through-bolt kit
- Precision ground spools
- 1-10 sections per valve bank
- Load checks on each section
- Hard chrome-plated spools
- Compact construction
- Reversible handle
- Parallel circuit construction
- Foot mounting

Key Specs
- Max. Flow (GPM): 12
- Inlet Port (in.): 7/8-14 ORB
- Outlet Port (in.): 7/8-14 ORB
- Working Port (in.): 3/4-18 ORB
- Max. PSI: 3,000
- Directional Control: 4-way, 3-position
- Adjustable Release Pressure PSI: 1,500 - 3,000
Prince Control Valve — 4-Way/3-Position, Detent, Model# SVW1BB1

In Stock
Ship Wt. 5.0 lbs.
Item# 201815
Only $89.99

Overview
Sectional body hydraulic directional control valves for mobile and industrial hydraulic systems. For use with double-acting cylinders. U.S.A.

Product shown is representational; actual unit is single-valve body only.

Features + Benefits
• Single-valve body only
• Inlet or outlet section not included
• Does not include through-bolt kit
• 4-Way/3-Position Detent
• Precision ground spools
• 1-10 sections per valve bank
• Load checks on each section
• Hard chrome-plated spools
• Compact construction
• Reversible handle
• Parallel circuit construction
• Foot mounting
• 3/4-10 ORB, 7/8-14 ORB

Key Specs
• Inlet Port (in.): 10 SAE
• Working Port (in.): 8 SAE
• Max. PSI: 3,000
• Max. Flow (GPM): 12
• Adjustable Release Pressure PSI: 1,500 - 3,000
Prince Adjustable Flow Control Valve — 1/2in. Port Size, Model# PFC51-1/2

Overview
The Prince Adjustable Flow Control Valve controls the speed of hydraulic motors. This type of valve will start and stop a hydraulic motor or cylinder and vary the speed over a wide range. Once the speed is set it will remain constant regardless of load variation. Any remaining flow is bypassed to the excess flow port to return to tank or to power another hydraulic function.

Features & Benefits
- Rated up to 3500 PSI
- Rated Flow 0-16 GPM

Key Specs
- Port Size (in.): 1/2
- Max. Flow (GPM): 16
- Max. PSI: 3,000

What’s Included
- (1) Control valve

Contact Northern Tool + Equipment, we are here to help you:
Business/Consumer Sales: 1-800-221-0515 (24/7)
Customer Service: 1-800-222-5381 (8-5 CST M-F)
Product Information Assistance: productexperts@northerntool.com
Store Locator: www.northerntool.com/store/
Haldex High Performance Gear Pump .976 Cu. In., Model# WP09A1B160L03BA102N

Overview
Compact, high-performance package is constructed of high-strength aluminum housing with cast iron end covers. Ideal for a wide variety of applications such as material handling, aerial lifts, turf care, agriculture and construction. Low- Noise pumps have SAE A 2-bolt mounts and SAE O-ring side ports. W900 Series: 90% efficiency, 3/4in. keyed shaft. U.S.A.

Features + Benefits
- Displacement Cubic In.: .976
- Maximum Flow at 1800 RPM: 7.49 GPM
- Maximum Flow at 3600 RPM: 14.99 GPM
- Maximum RPM at 4000 PSI: 3000
- Outlet: 7/8in.-14
- Rotation: CDV

Key Specs
- Max. PSI: 4,000
- Shaft Diameter (In.): 3/4
- ORP: 7.49, 14.99
- Material: Aluminum and cast iron
- Rotations Per Minute: 600 - 4,000
Dynamic Low Speed, High Torque Hydraulic Motor — 15.8 GPM, 1250 PSI

Overview
For light- and medium-duty applications. Replacement for Charlynn K, White KS and Ross TRW MG series. Maximum inlet pressure is 2500 PSI and maximum back pressure is 1000 PSI. Fully reversible. 4-bolt mount. 1in. x 1 3/4in. shaft has 1/4in. keyway. 1/2in. NPTF ports. Orbital Gerotor Principle. 1-year limited warranty.

Features & Benefits
• 1-year limited warranty

Key Specs
• Mounting Type: 4 bolt
• Shaft Dimensions: Diameter x L (in.): 1 x 1 3/4
• Port Size (in.): 1/2 NPTF
• Displacement (cu. in.): 23.0
• Max. RPM: 150
• Max. PSI: 1250
• Max. Torque (In.-lbs.): 3,720
• Max. Flow (GPM): 15.0
Prince PTO
Tractor Pump

Gear-type, heavy-duty pump is designed for PTO drive operation on tractors of all sizes. No additional gearing is required. These pumps feature self-adjusting wear plates that seat off leakage and offset any wear or expansion that may occur during the life of the pump. High tensile aluminum housing, minimum gear clearance, cast iron endplates. Internal splined shafts go all the way through and are supported on both sides by roller bearings. All models have a #10 SAE inlet port and two #12 SAE outlet ports. Include #12 SAE to 34" NPT female adapter. Reservoir must be at least as large as the GPM of the pump. U.S.A.

<table>
<thead>
<tr>
<th>Item</th>
<th>GPM</th>
<th>RPM</th>
<th>Dist./Spline</th>
<th>Ship Wt.</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1051-2501</td>
<td>11.4</td>
<td>540</td>
<td>1 1/2&quot;/6-spline</td>
<td>37 lbs.</td>
<td>$799*</td>
</tr>
<tr>
<td>1052-2501</td>
<td>23</td>
<td>1000</td>
<td>1 1/2&quot;/21-spline</td>
<td>36 lbs.</td>
<td>$799*</td>
</tr>
<tr>
<td>1050-2501</td>
<td>21</td>
<td>540</td>
<td>1 1/2&quot;/6-spline</td>
<td>41 lbs.</td>
<td>$869*</td>
</tr>
<tr>
<td>1051-2621</td>
<td>40</td>
<td>1000</td>
<td>1 1/2&quot;/21-spline</td>
<td>41 lbs.</td>
<td>$869*</td>
</tr>
</tbody>
</table>

Tri-Power Hand Pump
P带有a hydraulic press, pum, pum, snowblade, platform, frame straightener and other low-flow equipment, 3 positions. 1 1/2 cu. in. per stroke @ 1500 PSI, 2 1/2 cu. in. per stroke @ 200 PSI, 3 1/2 cu. in. per stroke @ 3000 PSI, 1-gallon reservoir. Inlet check valve, pressure valve. Pressure port 3/8" NPT. Applied handle force 60-65 lbs. Use on up to 200 cu. inch, single- or double-acting cylinder. 16'/L, U.S.A. Ship Wt. 33 lbs.

<table>
<thead>
<tr>
<th>Item</th>
<th>GPM</th>
<th>RPM</th>
<th>Dist./Spline</th>
<th>Ship Wt.</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1098-2601</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$339*</td>
</tr>
</tbody>
</table>

Rule of Thumb for Hydraulic Motor Applications
For longer motor life and better performance, we recommend that the operating pressure be kept below 1000 PSI by selecting the next larger size motor.

1 HP electric motor equals 1/12 HP hydraulic motor
1 HP gasoline engine equals 2/3 HP hydraulic motor
1 HP hydraulic motor equals 1/12 HP gasoline engine
1 HP hydraulic motor equals 2/3 HP electric motor

Heavy-Duty Hydraulic Motors for High Torque, Low Speed!
- Max. inlet pressure 5000 PSI; 1/2" NPT ports
- For high and medium-duty applications; fully reversible
- Replacement for Charlynn 11", White HB and Rosa TRV MG series
- 4-bolt mount; orbital Gerotor Principle

<table>
<thead>
<tr>
<th>Item</th>
<th>Max. Displacement (in. cu.)</th>
<th>Max. GPM</th>
<th>Max. RPM</th>
<th>Max. Torque (in. lbs.)</th>
<th>Ship Wt.</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1001-2601</td>
<td>3.0</td>
<td>12</td>
<td>1000</td>
<td>2200</td>
<td>7.8 lbs</td>
<td>$799*</td>
</tr>
<tr>
<td>1003-2601</td>
<td>8.07</td>
<td>14</td>
<td>750</td>
<td>2000</td>
<td>1437 lbs</td>
<td>$899*</td>
</tr>
<tr>
<td>1004-2601</td>
<td>15.15</td>
<td>16</td>
<td>400</td>
<td>1800</td>
<td>2305 lbs</td>
<td>$999*</td>
</tr>
<tr>
<td>1007-2501</td>
<td>17.9</td>
<td>14</td>
<td>250</td>
<td>1600</td>
<td>2690 lbs</td>
<td>$229*</td>
</tr>
<tr>
<td>1008-2501</td>
<td>24.4</td>
<td>14</td>
<td>150</td>
<td>1300</td>
<td>3392 lbs</td>
<td>$239*</td>
</tr>
</tbody>
</table>

Order Anytime 1-800-556-7885 - NorthernTool.com
### Hydraulic Oil Steel Tanks

<table>
<thead>
<tr>
<th>Item</th>
<th>Gallons</th>
<th>Dimensions</th>
<th>Suction/Return Port</th>
<th>Port Mount</th>
<th>Discount Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>4096-2601</td>
<td>2.6</td>
<td>9”L x 8”H</td>
<td>1/2”</td>
<td>3/4”</td>
<td>4 bolt 14 lbs.</td>
</tr>
<tr>
<td>4090-2601</td>
<td>4.8</td>
<td>15”L x 9”W x 8”H</td>
<td>1/2”</td>
<td>3/4”</td>
<td>4 bolt 22 lbs.</td>
</tr>
<tr>
<td>4091-2601</td>
<td>7</td>
<td>16”L x 10”W x 10”H</td>
<td>2”</td>
<td>1”</td>
<td>2 bolt 27 lbs.</td>
</tr>
<tr>
<td>4052-2601</td>
<td>10</td>
<td>17”L x 11”W x 12”H</td>
<td>2”</td>
<td>1”</td>
<td>2 bolt 29 lbs.</td>
</tr>
<tr>
<td>4053-2601</td>
<td>12</td>
<td>18”L x 11”W x 14”H</td>
<td>2”</td>
<td>1”</td>
<td>2 bolt 40 lbs.</td>
</tr>
<tr>
<td>4059-2601</td>
<td>19.5</td>
<td>22”L x 14”W x 14”H</td>
<td>2”</td>
<td>1”</td>
<td>4 bolt 48 lbs.</td>
</tr>
</tbody>
</table>

### 15-Gallon Side Mount Hydraulic Reservoir

- 13-gauge HY-PRO steel with welded mounting angles, 1/4 turn chrome filler cap with brass trimmer. Oil level gauge with temperature indicator. Interchangeable between suction and discharge 2” NPT suction and male thread. 11-gallon usable capacity.
- Powder-coat finish, USA.
- Ship Wt. 57 lbs.
- Item No. 4054-2601
- Discount Price $129

### 25-Gallon Side Mount Hydraulic Reservoir

- Usable capacity of 18 gallons. Otherwise similar to Item No. 4054, USA.
- Ship Wt. 73 lbs.
- Item No. 4054-2601
- Discount Price $139

### Hose Barb Fittings

<table>
<thead>
<tr>
<th>Item</th>
<th>NPT Thread</th>
<th>I.D.</th>
<th>Barb End Length</th>
<th>Discount Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>109018-2601</td>
<td>3/4”</td>
<td>3/4”</td>
<td>1.35”</td>
<td>$1.59</td>
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<tr>
<td>109001-2601</td>
<td>1”</td>
<td>1”</td>
<td>1.35”</td>
<td>$1.49</td>
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<tr>
<td>109002-2601</td>
<td>1 1/4”</td>
<td>1 1/4”</td>
<td>1.65”</td>
<td>$1.49</td>
</tr>
</tbody>
</table>

### Hydraulic Suction Hoses

- 1004, internally reinforced suction return hose, USA.
- Item No. 109003-2601 | 1” x 72” | 4 lbs. | $29 |
| 109004-2601 | 1” x 72” | 7 lbs. | $39 |
| 109005-2601 | 1” x 180” | 12 lbs. | $79 |
| 109006-2601 | 1” x 180” | 19 lbs. | $79 |

### Reusable Hose Couplings

- Male plug NPTF.

<table>
<thead>
<tr>
<th>Item</th>
<th>Size</th>
<th>Wire</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRRM6-2601</td>
<td>1”</td>
<td>1</td>
<td>$1.99</td>
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<tr>
<td>SRRM8-2601</td>
<td>3/4”</td>
<td>1</td>
<td>$1.79</td>
</tr>
<tr>
<td>SRRM12-2601</td>
<td>1”</td>
<td>1</td>
<td>$1.89</td>
</tr>
<tr>
<td>SRRM16-2601</td>
<td>1”</td>
<td>2</td>
<td>$1.89</td>
</tr>
<tr>
<td>SRRM20-2601</td>
<td>1”</td>
<td>2</td>
<td>$1.89</td>
</tr>
</tbody>
</table>

### Female Thread (27 JIC Swivel)

- Reusable fitting for female SAE 37° Female thread on both ends.

<table>
<thead>
<tr>
<th>Item</th>
<th>Size</th>
<th>Wire</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRF60-2601</td>
<td>1”</td>
<td>1</td>
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<tr>
<td>SRF80-2601</td>
<td>3/4”</td>
<td>1</td>
<td>$1.79</td>
</tr>
<tr>
<td>SRF12-2601</td>
<td>1”</td>
<td>2</td>
<td>$1.89</td>
</tr>
<tr>
<td>SRF16-2601</td>
<td>1”</td>
<td>2</td>
<td>$1.89</td>
</tr>
</tbody>
</table>

### Hydraulic Break-Away Couplers

- Use one size larger that hole is to prevent waxyness. Not for use on the suction line of our 2-stage pumps. Ship Wt. 1 lbs.

<table>
<thead>
<tr>
<th>Item</th>
<th>Size</th>
<th>Ship Wt.</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>50044-2601</td>
<td>1/8”</td>
<td>2 lbs.</td>
<td>$1.99</td>
</tr>
<tr>
<td>50043-2601</td>
<td>3/8”</td>
<td>2 lbs.</td>
<td>$1.99</td>
</tr>
<tr>
<td>50042-2601</td>
<td>3/8”</td>
<td>2 lbs.</td>
<td>$1.99</td>
</tr>
<tr>
<td>50041-2601</td>
<td>3/4”</td>
<td>2 lbs.</td>
<td>$1.99</td>
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</table>

### Straight Swivel Adapter

<table>
<thead>
<tr>
<th>Item</th>
<th>F</th>
<th>NPSM</th>
<th>M</th>
<th>NPTF</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1AD06-2601</td>
<td>1/4”</td>
<td>3/8”</td>
<td>1/4”</td>
<td>$1.99</td>
<td></td>
</tr>
<tr>
<td>S1AD08-2601</td>
<td>3/8”</td>
<td>3/8”</td>
<td>3/8”</td>
<td>$1.99</td>
<td></td>
</tr>
<tr>
<td>S1AD08-2601</td>
<td>3/8”</td>
<td>1/2”</td>
<td>1/2”</td>
<td>$1.99</td>
<td></td>
</tr>
<tr>
<td>S1AD12-2601</td>
<td>1/2”</td>
<td>1/2”</td>
<td>1/2”</td>
<td>$1.99</td>
<td></td>
</tr>
<tr>
<td>S1AD12-2601</td>
<td>1/2”</td>
<td>1/2”</td>
<td>1/2”</td>
<td>$1.99</td>
<td></td>
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### 90 Degree Elbow

<table>
<thead>
<tr>
<th>Item</th>
<th>M</th>
<th>NCPE</th>
<th>M</th>
<th>NPTF</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1ECB90S-2601</td>
<td>1/4”</td>
<td>3/8”</td>
<td>1/4”</td>
<td>$1.99</td>
<td></td>
</tr>
<tr>
<td>S1ECB90S-2601</td>
<td>3/8”</td>
<td>3/8”</td>
<td>3/8”</td>
<td>$1.99</td>
<td></td>
</tr>
<tr>
<td>S1ECB90S-2601</td>
<td>3/8”</td>
<td>1/2”</td>
<td>1/2”</td>
<td>$1.99</td>
<td></td>
</tr>
<tr>
<td>S1ECB90S-2601</td>
<td>1/2”</td>
<td>1/2”</td>
<td>1/2”</td>
<td>$1.99</td>
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</tr>
</tbody>
</table>

### Reducer Bushing

<table>
<thead>
<tr>
<th>Item</th>
<th>M</th>
<th>NCPE</th>
<th>M</th>
<th>NPTF</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1C04-2601</td>
<td>1/4”</td>
<td>3/8”</td>
<td>1/4”</td>
<td>$1.99</td>
<td></td>
</tr>
<tr>
<td>S1C08-2601</td>
<td>3/8”</td>
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### CALL Us for Our Full Line of Hydraulic Fittings

Order Toll Free - 24 Hours, 7 Days a Week

---

**IMPOR**

**NEW A**

To help keep track of what's going on, we have a new system in place. It's called the "Activity Tracker," and it allows us to see what's happening at any given time. This will help us stay organized and focused.

---

**GENERAL**

**ACCOUNT**

For any questions or concerns, feel free to reach out to our customer support team. They're always happy to help.

---

**BUSINESS**

In good quality products, we believe in doing business the right way. We don't cut corners, and we stand behind our work. That's why we offer a satisfaction guarantee on all of our products. If you're not happy, we'll make it right.

---

**ACCEPT**

We're accepting applications for new clients. If you're interested, please fill out the form below and we'll be in touch.

---

**RESPOND**

Revolve! (rounds balance, less than sixty days from date of invoice. Net - 30 days.)

---

**FINANCE**

Revolve! Charges which are sixty days or more delinquent are subject to interest charges. The interest rate is 1% per month, or the maximum rate allowed by law, whichever is higher.

---

**Loop**

We're always looking for new drivers. If you're interested, please fill out the form below and we'll be in touch.

---

**NO**

No, we do not accept checks on a personal or business account. We prefer to receive payment by credit card or bank transfer.

---

**DISCLAIMER**

We do not accept responsibility for any errors or omissions in the information provided on this page. The information is provided "as is" and without warranty of any kind, either expressed or implied.

---

**CALL**

If you have any questions or need further assistance, please call us at 1-800-XYZ1234. We're here to help.

---

**MECHANICAL**

**ENGINEERING**

We design and manufacture high-quality mechanical and engineering solutions to meet your specific needs.

---

**GALAPOLY**

A leading manufacturer of innovative solutions for the aerospace, defense, and heavy industries. Our products are proudly made in the USA.
Hydraulic Pump Mounting Bracket

In Stock
Ship Wt: 5.0 lbs
Item#: 3042
Only $59.99

Overview
With Northern's mounting brackets, you can speed assembly time, ensure shaft alignment and improve compactness and appearance at a reasonable price. 2-bolt brackets for J.S. Barnes 22 and 29 GPM pumps. Fit our items 1657 and 1059 pumps.

Features & Benefits
- Fits: 16, 11, 16 and 18 HP Briggs STD or IC/IP
- Fits: 12, 15 and 18 HP Tecumseh
- Fits: 8, 16 and 11 HP Honda

Key Specs
- Bracket Length (in.): 6
- Bolt Circle (in.): 5 1/2
- Mounting Type: 2 bolt
NorthStar Steel Hydraulic Oil Tank — 10 Gallon

In Stock
Ship Wt. 35.0 lbs.
Item# 4052

Only $99.99

Overview
Features sturdy 12-gauge steel welded construction. Welded-on mounting brackets. Includes clip-on style breather cap. Suction strainer Item# 4010 fits oil tank Item# 4052 (strainer not included).

Features + Benefits
• Replacement parts available from Northern or a Northern retail store

Key Specs
• Capacity (gal.): 10
• Suction Port (in.): 2
• Return Port (in.): 1
• Mount Type: 2 bolt
• Material Type: Steel
• Dimensions L x W x H (in.): 17 3/4 x 11 x 12
### BMP/BMPH 250

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<td>490 (1076)</td>
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### Mechanical Engineering - ribs of a rib
SHAFT SEAL RATED PRESSURE

CASE DRAIN

In applications without a motor drain line, the pressure exerted on the shaft seal is marginally in excess of the return line pressure. When the drain line is used the pressure exerted on the shaft seal is equal to the return line pressure.

SHAFT ROTATION DIRECTION

RADIAL FORCES

Status of the shaft’s radial force

F_r = \frac{900 \times 10^5}{n^2} \text{ daN}

F_r = \text{Radial Force (daN)}

L = \text{Distance (mm)}

n = \text{Speed (rpm)}

Rhomb-flange L=30mm
Square-flange L=24mm
W900
Hydraulic Gear Pump
Featuring Integrated Valve Packages

- Pressure
  - (P1) 276 BAR (4000 PSI)
  - (P2) 300 BAR (4400 PSI)

- Speed
  - 4000 RPM
  - Min. 500 RPM at 4000 PSI (276 BAR)
  - Continuous

- Efficiency
  - Overall > 90%
  - Volumetric 98%
  - Mechanical 92%

The W900 is one family in the W Series of high performance gear pumps. It is a through-bushing type design constructed of high strength aluminum housings. The W Series is suitable for a wide range of equipment applications from material handling, agricultural, construction and paving to aerial lifts, winch and turf care.

The hydraulic performance, flexibility, high efficiency, low and high speed operation, low noise performance and the variety of options have established the W Series as the standard by which other pump performance is measured. This catalog illustrates the options available for the W900 family as well as performance and dimensional information. An easy to follow ordering guide is also included.

Haldex continues improvement efforts to produce the W900 pump which is ideally suited to low noise applications. Contact your local Haldex representative for information about how the W900 can meet your specific needs.

### Performance Information

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Outstanding Hydraulic Products, Service and Expertise, Worldwide
W900 SERIES PUMPS WITH SAE "A" 2-BOLT MOUNT, 3/4" DIA. SAE "A" STRAIGHT SHAFT, AND SAE STRAIGHT THREAD SIDE PORTS

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W900 SERIES PUMPS WITH SAE "A" 2-BOLT MOUNT, 9 TOOTH SAE "A" SPUR SHAFT, AND SAE STRAIGHT THREAD SIDE PORTS

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W900 SERIES PUMPS WITH SAE "A" 2-BOLT MOUNT, 11 TOOTH SAE "A" SPUR SHAFT, AND SAE STRAIGHT THREAD SIDE PORTS

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<tr>
<th>DISPLACEMENT</th>
<th>CC</th>
<th>ROTATION</th>
<th>IN</th>
<th>OUT</th>
<th>MODEL</th>
<th>CATALOG</th>
<th>X-REF</th>
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<tbody>
<tr>
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<td>16</td>
<td>CW</td>
<td>1-1/16-12</td>
<td>3/8-16</td>
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HALES-W900 SERIES PUMPS 1-3/4" X 5/16-12 X 10
Haldex (www.haldex.com), headquartered in Stockholm, Sweden, is a provider of proprietary and innovative solutions to the global vehicle industry, with focus on products in vehicles that enhance safety, environment and vehicle dynamics. Haldex is listed on the Nasdaq OMX Stockholm Stock Exchange.

PRODUCT RANGE

HE Powerpacks
12/24 VDC and 4 - 4.1 MW 400 VAC modular power packs
HE Base Powerpacks
12/24 VDC, modular power packs in various configurations

Pressure converters
3 - 300 bar, connecting/disconnecting

W100 Hydraulic pumps
9.5 - 2.5 to 227 bar

W300 Hydraulic pumps
9.8 - 5.1 to 220 bar

W300 hydraulic pumps / motors
3 - 30 bar, 270 bar

W500 hydraulic pumps / motors
3 - 55 bar, 275 bar

W1000 the quiet pumps
9 - 22 bar, 200 bar

W2600 hydraulic pumps
15 - 55 bar, 175 bar

W5500 hydraulic pumps / motors
19 - 50 bar, 275 bar

F15 PERNIA linear drive pumps
15 - 41 bar, 275 bar

F15 PERNIA linear drive pumps
19 - 50 bar, 275 bar

2630HP Golist hydraulic pumps / motors
24 - 56 bar, 370 bar

CVA universal gear pumps
1.3 - 65 bar, 160 bar

GC Hydraulic pumps / motors
1.6 - 11.5 bar, 275 bar

Hydraulic pumps
9.8 - 35.5 bar, 201 bar

E-series hydraulic pumps
9.8 - 25.5 bar, 275 bar

Rotary snow blowers
9.8 - 15 bar, 300 bar

Transmission pumps

Check all well site components before any casting starts and observe the right to modify specifications without prior notice. Haldex also applies to producers deeply involved, provided that such modifications can be made without affecting technical specifications, etc. Guidelines in the material and properties of the respective source.
W900 pump .976 in$^3$/rev

HP vs. RMP @ 1300 psi

GPM vs. RPM @1300 psi
Appendix E Support analysis

Impact Force

\[ F = \omega + \omega \left[ 1 + \left( \frac{2 \pi \frac{K}{\omega}}{w} \right) \right]^{1/2} \]  

\[ \text{(Shigley's)} \]

\[ K_{\text{cable}} = \frac{AE}{L} \]

\[ A = \pi d^2 = \pi (0.5)^2 = 0.115 \text{ in}^2 \quad \text{(oil drilling book)} \]

\[ E = 12 \times 10^6 \text{ psi} \]

\[ K = \left( \frac{0.115}{12} \right) \left( \frac{12 \times 10^6}{12^2} \right) = 220,800 \text{ lbf/ft} \]

\[ h = 24 \text{ ft} \]

\[ W = 600 \text{ lbf} \]

\[ K_{\text{rig}} \rightarrow \text{rig flexes under loading, approximated as} \]

\[ X = 0.25 \text{ in under 1000 lbf} \]

\[ F = KX = 1000 = K \left( \frac{25}{12} \right) \quad K_{\text{rig}} = 48,000 \text{ lbf/ft} \]

\[ K_{\text{total}} = \left( \frac{1}{220,800} + \frac{1}{48,000} \right)^{-1} = 39,428.6 \]

\[ F = 600 + 600 \left[ 1 + \frac{2(2)(39,428.6)}{600} \right]^{1/2} \]

\[ F = 10,346 \text{ lbf} \]
Line Speed Gear Reductions (for main and sand lines)

Sand line will have 4" spool that is 12" when full

\[ \frac{100 \text{ ft}}{120 \text{ s}} = 0.833 \text{ ft/s} \]

With empty spool \( \phi = 4" \)

\[ 0.833 \text{ ft/s} \times \frac{1}{2} \times \frac{12}{1.02} = 5.0 \text{ rad/s} \approx 47.7 \text{ rpm} \]

With full spool

\[ 0.833 \text{ ft/s} \times \frac{1}{60} \times \frac{12}{1.02} \times \frac{1}{2 \pi} \times \frac{1}{60} \approx 15.9 \text{ rpm} \]

Take average of 30 rpm

Motor will operate between 80 - 100 rpm

Will need 1:3 gear ratio for both main line and sand line

Torque motor = 3794 in-lbs

After reduction \( T = 11232 \text{ in-lb} \)

at \( 4" \)\( \phi \) \( F = \frac{11232 \text{ in-lbs}}{2 \text{ in}} = 5616 \text{ lbs} \)

at \( 12" \)\( \phi \) \( F = \frac{11232 \text{ in-lbs}}{6 \text{ in}} = 1872 \text{ lbs} \)

enough to lift 600 lb bit
Chain Sizing

- Main line and sand line need 1:3 gear ratio

60 series chain has working load of 1980 lb
50 series has working load of 1400 lb

14 to 42 teeth
3.74” to 10.46”

\[ F = \frac{3744 \text{ in} \cdot \text{lb}}{3.74} = 1002 \text{ lb} \]

18 to 59 teeth
9.7” to 13.35”

\[ F = \frac{3744 \text{ in} \cdot \text{lb}}{9.7} = 382 \text{ lb} \]

Will use 18 to 59 teeth

For walking beam use 16 to 24 teeth

\[ F = \frac{3744 \text{ in} \cdot \text{lb}}{11.22} = 334.4 \text{ lb} \]

60 series chain is required
Pitman Arm strength (fatigue)

Material: Unknown Steel

Use $S_{ut} = 43$ kpsi

$S_e = 0.5 S_{ut} = 21.5$ kpsi

$k_a = 1.43 S_{ut} - 0.085$

$k_a = 1.43(43) - 0.085 = 0.973$

$k_b = 1$

$k_c = 0.25$

$k_d = 1$

$k_e = 1 - (0.08)(3.091) = 0.753$ (99.9% reliability)

$k_e = 1$

$S_e = 13.4$ kpsi

$\sigma_m = 0$

$\sigma_a = \frac{6000 \ lb}{(0.25) (1.5) in^2} = 16$ kpsi

$N_e = \frac{1}{\sigma_a + \frac{\sigma_m}{S_{ut}}} = \frac{1}{16 + 0} = 0.0625$

Need to increase to at least $1.5'' \times 0.5''$
Hydraulic System Calculations

Given: 13 Hp Gasoline Motor

Hydraulic Pump

\[
\text{Pump GPM} = \frac{1028 \text{ (Gas HP)}}{1250} = 10.69 \text{ GPM}
\]

\[
\Rightarrow \text{Northern Pump} \ 10599 - 2601 (\Psi) 169.99\text{Psi}
\]

Displacement = 1.976 in\(^3\)

Flow rate @ 3600 RPM = 14.99 GPM

Hydraulic Motor

\[
\Rightarrow \text{Northern Pump Item # 1039}
\]

\[
\text{Max RPM} = 150 \quad 15.8 \text{ GPM} \quad 1250 \text{ Psi}
\]

Max torque = 3720 in-lbs

Will this torque work?

18 in diameter spool (outside coil)
4:1 gear reduction.

\[
\frac{3720 \text{ in-lbs}}{4} = 1653 \text{ lbs} \Rightarrow \text{this should be good for lifting 800 lb bit.}
\]

Line speed

Spool RPM = \(\frac{150}{4} = 37.5\)

Line speed = \(37.5 \times (18.77) = 2120 \text{ in/min} \Rightarrow 176 \text{ ft/min}

\(5\) sec to lift bit 15 ft.
\[ M_{\text{rot}} \cdot g \cdot L_{\text{beam}} - T_{\text{beam}} - M_{\text{beam}} \cdot g \cdot \frac{L_{\text{beam}}}{2} = -M_{\text{rot}} \cdot L_{\text{beam}} \cdot a_1 - M_{\text{beam}} \cdot L_{\text{beam}} \cdot \frac{a_2}{2} + I_{\text{beam}} \cdot \alpha \\
+ I_{\text{ramp}} \cdot \alpha \\
\]

\[ a_1 = \alpha \cdot L_{\text{beam}} \]

\[ a_2 = \alpha \cdot \frac{L_{\text{beam}}}{2} \]

\[ I_{\text{beam}} = \frac{M_{\text{beam}}}{L_{\text{beam}}^2} \\
I_{\text{ramp}} = M_{\text{ramp}} \cdot R_{\text{ramp}}^2 \\
T_{\text{motor}} = 200 \]

\[ W_{\text{rot}} = 800 \]

\[ W_{\text{beam}} = 100 \]

\[ W_{\text{ramp}} = 60 \]

\[ M_{\text{rot}} = \frac{W_{\text{rot}}}{g} \]

\[ M_{\text{beam}} = \frac{W_{\text{beam}}}{g} \]

\[ M_{\text{ramp}} = \frac{W_{\text{ramp}}}{g} \]

\[ g = 32.2 \]

\[ R_{\text{ramp}} = 1 \]

\[ L_{\text{beam}} = 3 \]

\[ T_{\text{beam}} = L_{\text{arm}} \cdot F_{\text{arm}} \]

\[ F_{\text{arm}} = T_{\text{ramp}} \cdot \frac{\sin \theta}{R_{\text{ramp}}} \]

\[ T_{\text{motor}} = \frac{T_{\text{ramp}}}{\text{Ratio}} \]

\[ \text{Ratio} = 6 \]

\[ L_{\text{arm}} = 3 \]

\[ \alpha = 0 \]
SOLUTION

Unit Settings: [kJ]/[C]/[kPa]/[kg]/[degrees]

\[
\begin{align*}
\alpha &= 0 \text{ [rad/s}^2]\numbereq{1} \\
a_x &= 0 \text{ [ft/s}^2]\numbereq{2} \\
g &= 32.2 \text{ [ft/s}^2]\numbereq{3} \\
J_{\text{beam}} &= 1.863 \text{ [lb*ft}^2]\numbereq{4} \\
L_{\text{beam}} &= 3 \text{ [ft]}\numbereq{5} \\
M_x &= 24.84 \text{ [lb*ft}^2]\numbereq{6} \\
\text{Ratio} &= 6 [-]\numbereq{7} \\
\theta &= 38.68 \text{ [deg]}\numbereq{8} \\
J_{\text{wheel}} &= 1200 \text{ [lb*ft}^2]\numbereq{9} \\
W_{\text{beam}} &= 100 \text{ [lb]}\numbereq{10} \\
W_{\text{wheel}} &= 50 \text{ [lb]}\numbereq{11}
\end{align*}
\]

\[
\begin{align*}
a_1 &= 0 \text{ [ft/s}^2]\numbereq{12} \\
F_{\text{arm}} &= 750 \text{ [lb]}\numbereq{13} \\
l_{\text{beam}} &= 2.329 \text{ [lb*ft}^2]\numbereq{14} \\
L_{\text{arm}} &= 3 \text{ [ft]}\numbereq{15} \\
M_{\text{beam}} &= 3.106 \text{ [lb*ft}^2]\numbereq{16} \\
M_{\text{wheel}} &= 1.863 \text{ [lb*ft}^2]\numbereq{17} \\
R_{\text{wheel}} &= 1 \text{ [ft]}\numbereq{18} \\
T_{\text{beam}} &= 2250 \text{ [lb*ft]}\numbereq{19} \\
T_{\text{motor}} &= 200 \text{ [lb*ft]}\numbereq{20} \\
W_{\text{a}} &= 800 \text{ [lb]}\numbereq{21}
\end{align*}
\]

No unit problems were detected.
Brake force from hydraulic system. A car alignment

\[ \sum M_A = -18\pi (100 \text{ lb}) + F_B (6\text{ in}) = 0 \]

\[ F_B = 300 \text{ lb} \]

Applied over a 5/8" bore, \( A = \pi r^2 = \pi \left( \frac{5}{8} \right)^2 = 0.3068 \)

\[ P_B = 977.3 \frac{\text{lb}}{\text{in}^2} \]

Same pressure applied to 2" dia slave cylinder. \( A = \pi \left( \frac{1}{2} \right)^2 = 0.7854 \)

\[ F_S = \left( \frac{977.3 \text{ lb}}{\text{in}^2} \right) \left( 0.7854 \text{ in}^2 \right)^2 \]

\[ F_S = 18,850 \text{ lb} \]

Brake Pad: Standard

Continued on next page...
Force to stop impact load of 10,000 lb @ 10 ft per sec with 2-3 ft d.a

Size disk brake = 9 in lever arm

Torque produced: \(10,000 \text{ lb} \times 9 \text{ in} = 90,000 \text{ in lb}\)

Disk brake

Assume uniform wear

\[ F = \frac{\Delta \theta}{2} \cdot \frac{P_a}{\tan\left(\frac{\theta}{2}\right)} \]

- \(R_1 = 6 \text{ in}, R_2 = 8 \text{ in}\)
- \(P_a = \frac{90,000 \text{ lb}}{\frac{28.35 \text{ in}}{360^\circ}} \left(\frac{6 \text{ in} \times 8 \text{ in} - \left(6 \text{ in}\right)^2}{2 \times 6 \text{ in} \times 8 \text{ in}}\right)\)

- \(P_a = 7,421 \text{ lb in}\)

\[ F = \frac{2(90,000 \text{ lb} \times 9 \text{ in})}{28.35 \text{ in}} \left(\frac{7,421 \text{ lb in}}{28.35 \text{ in}} \left(8 \text{ in} - \left(6 \text{ in}\right)^2\right)\right) \]

- \(F = 42,857 \text{ lb}\) required on brake pad

Circumference = 2π\(r\),

\(C = 50 \text{ in}\),

\(4 \text{ in over } 50 \text{ in}\) is 7.95\%,

convert to \(\Delta \theta\)

\[ \frac{7.95 \times 180^\circ}{150^\circ} = 28.65^\circ\]

Assumptions

- Worn brake pad
- \(f = 0.3\)
- \(\Delta \theta = 28.65^\circ\) initially

From previous page \(F_2 = 48,850 \text{ lb}\)

\[ \Rightarrow \text{The disk brake with } 3 \text{ in cylinder}
\]

and sized above works
### Appendix F Gantt Chart

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
<th>Predecessors</th>
<th>Resource Name</th>
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<td>Tue 1/3/10</td>
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<td>Fri 2/12/10</td>
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<td>Fri 2/22/10</td>
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<td>Mon 2/25/10</td>
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<tr>
<td>Machine adaptors &amp; small components</td>
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<td>Tue 4/2/10</td>
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<td>Mount Chucks &amp; spindles to main control</td>
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<td>Mount controls</td>
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<td>Manufacturing and Tool Review</td>
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<td>Fri 2/22/10</td>
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<td>Thu 4/16/10</td>
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<td>Fri 4/17/10</td>
<td>Fri 4/17/10</td>
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<tr>
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<td>1.5 days</td>
<td>Fri 4/17/10</td>
<td>Fri 4/17/10</td>
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<td>1.5 days</td>
<td>Fri 4/17/10</td>
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<td>Log entry daily</td>
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<td>Fri 5/17/10</td>
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<td>Mon 5/17/10</td>
<td>Fri 5/17/10</td>
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Appendix G Part Drawings
<table>
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<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Frame and Derrick</td>
<td>R002</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Walking Beam</td>
<td>W001</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Flywheel</td>
<td>R105</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Hydraulic Motor</td>
<td>N/A</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Sprocket 60b21</td>
<td>N/A</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Sprocket 60b54</td>
<td>N/A</td>
<td>1</td>
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<tr>
<td>7</td>
<td>Sprocket 60b60</td>
<td>N/A</td>
<td>1</td>
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<tr>
<td>8</td>
<td>Sprocket 60b35</td>
<td>N/A</td>
<td>1</td>
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<tr>
<td>9</td>
<td>Brake Rotor</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Pitman Arm</td>
<td>R106</td>
<td>1</td>
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<tr>
<td>11</td>
<td>Motor mount</td>
<td>M101</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>Sprocket 60b30</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>Hydraulic Ram</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>Main Line Spool</td>
<td>S001-1</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>San Line Spool</td>
<td>S001-2</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>Brake Assembly</td>
<td>R104</td>
<td>1</td>
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</table>
**Frame With Shafts**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>PART #</th>
<th>QTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.75&quot;X32&quot; Shaft</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>1.75&quot;X2.75&quot; Shaft</td>
<td>N/A</td>
<td>1</td>
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<td>21</td>
<td>Frame Components</td>
<td>R004</td>
<td>7</td>
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<td>42</td>
<td>1.75&quot; Pillow Block</td>
<td>N/A</td>
<td>8</td>
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<td>43</td>
<td>1.75&quot;X11&quot; Shaft</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>50</td>
<td>Center WB Mount</td>
<td></td>
<td>1</td>
</tr>
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**Material:** Steel

**Paint:**

**Dimensions:**
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**Scale:** 1:20

**Drawing Date:** 11/28/10

**Drawn by:** A. Wargnier

**Title:** Frame With Shafts

**Comments:**
<table>
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<tr>
<th>ITEM</th>
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<th>QTY.</th>
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<tbody>
<tr>
<td>1</td>
<td>Frame Sections</td>
<td>R005</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Derrick Mount</td>
<td>R101</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>TR 3x2x0.1875 (4.5&quot;)</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Cross Member</td>
<td>R102</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Control Mount</td>
<td>R103</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Ram Mount 1</td>
<td>D103-1</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Ram Mount 2</td>
<td>D103-2</td>
<td>1</td>
</tr>
<tr>
<td>ITEM</td>
<td>DESCRIPTION</td>
<td>PART #</td>
<td>QTY.</td>
</tr>
<tr>
<td>------</td>
<td>------------------------------</td>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>1</td>
<td>Center WB Mount</td>
<td>F001</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Rear</td>
<td>F002</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Top</td>
<td>F003</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Center Flywheel Mount</td>
<td>F004</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Front</td>
<td>F005</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Right Side</td>
<td>F006</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Left Side</td>
<td>F007</td>
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</table>
Center WB Mount

**ITEM** | **DESCRIPTION** | **PART #** | **QTY.**
---|---|---|---
1 | TR 3x2x0.1875 (64.25") | N/A | 1
2 | TR 3x2x0.1875 (64.25") | N/A | 1
3 | TR 3x2x0.1875 (18.1") | N/A | 2
4 | TR 3x2x0.1875 (72") | N/A | 1

**MATERIAL**: Steel

**FINISH**: Paint

**APPLICATION**: Do not scale drawing

**SCALE**: 1:20

**DRAWN**: A. Wargnier 11/29/10

**TITLE**: Center WB Mount

**SIZE**: Sheet 1 of 1
<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>PART #</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TR3x2x0.1875 (20&quot;)</td>
<td>N/A</td>
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<tr>
<td>2</td>
<td>TR3x2x0.1875 (18&quot; Spool Only)</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>TR3x2x0.1875 (6.8&quot;)</td>
<td>N/A</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>TR3x2x0.1875 (72&quot;)</td>
<td>N/A</td>
<td>1</td>
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<tr>
<td>5</td>
<td>TR3x2x0.1875 (6.3&quot;)</td>
<td>N/A</td>
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<tr>
<td>6</td>
<td>TR3x2x0.1875 (18&quot; Spool and Motor)</td>
<td>N/A</td>
<td>1</td>
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<tr>
<td>7</td>
<td>TR3x2x0.1875 (70&quot;)</td>
<td>N/A</td>
<td>3</td>
</tr>
</tbody>
</table>
# Top

## DRAWING INFORMATION

- **NAME**: A. Wargnier
- **DATE**: 11/29/10
- **SCALE**: 1:20
- **SIZE**: A
- **DWG. NO.**: F003
- **REV**: A

## UNLESS OTHERWISE SPECIFIED:

- **DIMENSIONS ARE IN INCHES**
- **TOLERANCES**:
  - **FRACTIONAL**: ±1/16
  - **ANGULAR**: ±1 Deg
  - **ONE PLACE DECIMAL**: ±.05

## INTERPRET GEOMETRIC TOLERANCING PER:

- **MATERIAL**: Steel
- **FINISH**: Paint

## ITEM

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>PART #</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TR3x2x0.1875 (72&quot;)</td>
<td>N/A</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>TR3x2x0.1875 (29.28&quot;)</td>
<td>N/A</td>
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</tr>
<tr>
<td>3</td>
<td>TR3x2x0.1875 (17.5&quot;)</td>
<td>N/A</td>
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</tbody>
</table>

## PROPELTY AND CONFIDENTIAL

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**NOTICE**

- **APPLICATION**: DO NOT SCALE DRAWING
- **NEXT ASSY**: USED ON
- **FINISH**: Paint
- **MATERIAL**: Steel

- **Q.A.**:
- **ENG APPR.**:
- **MFG APPR.**
**Center Flywheel Mount**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>PART #</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TR3x2x0.1875 (72&quot;)</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>TR3x2x0.1875 (26&quot;)</td>
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<td>1</td>
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<tr>
<td>3</td>
<td>TR3x2x0.1875 (6.78&quot;)</td>
<td>N/A</td>
<td>3</td>
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<tr>
<td>4</td>
<td>TR3x2x0.1875 (28&quot;)</td>
<td>N/A</td>
<td>1</td>
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<tr>
<td>5</td>
<td>TR3x2x0.1875 (28&quot; Motor)</td>
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**Table Notes:**
- Dimensions are in inches.
- Tolerances: Fractional ±1/16, Angular ±1 Deg, One place decimal: ±0.05.
- Angular: 1 Deg
- Material: Steel
- Finish: Paint
- Application: DO NOT SCALE DRAWING

**Title Block:**
- Scale: 1:20
- Sheet: 1 of 1
- Title: Center Flywheel Mount
- Drawing number: F004
### Diagram Details

**Detail A**: Scale 1:10

**Detail B**: Scale 1:10

**Detail C**: Scale 1:20

**Notes**:
- Pipe to be notched as shown (Dimension is pre-notched length)
- Dimensions are in inches.
- Tolerances: Fractional ± 1/16
- Angular ± 5°
- One place decimal ± 0.05

### Item List

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
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<th>QTY.</th>
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</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>2</td>
<td>2.5&quot;X2.25&quot; TUBE (6&quot;)</td>
<td>N/A</td>
<td>14</td>
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<tr>
<td>3</td>
<td>2.5&quot;X2.25&quot; TUBE (9&quot;)</td>
<td>N/A</td>
<td>10</td>
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<tr>
<td>4</td>
<td>Gusset (Holes)</td>
<td>D101-1</td>
<td>4</td>
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<tr>
<td>5</td>
<td>Gusset</td>
<td>D101-2</td>
<td>2</td>
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<tr>
<td>6</td>
<td>Derrick Hinge Ring 1</td>
<td>D102-1</td>
<td>3</td>
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<tr>
<td>7</td>
<td>Derrick Hinge Ring 2</td>
<td>D102-2</td>
<td>1</td>
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<td>8</td>
<td>Derrick Extension</td>
<td>D002</td>
<td>1</td>
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<td>9</td>
<td>L3x3x0.25x3 (5/8&quot; Hole)</td>
<td>N/A</td>
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<td>10</td>
<td>Derrick L bracket</td>
<td>D104</td>
<td>1</td>
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<tr>
<td>11</td>
<td>Ram Mount Plate (9&quot;X6&quot;x0.25&quot;)</td>
<td>N/A</td>
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<tr>
<td>12</td>
<td>TR 3x2x0.1875 (11.5&quot;)</td>
<td>N/A</td>
<td>1</td>
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<tr>
<td>13</td>
<td>TR 3x2x0.1875 (8&quot;)</td>
<td>N/A</td>
<td>1</td>
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<tr>
<td>14</td>
<td>Ram Mount 1</td>
<td>D103-1</td>
<td>1</td>
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<tr>
<td>15</td>
<td>Ram Mount 2</td>
<td>D103-2</td>
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### Additional Information

- Scale: 1:60
- SolidWorks Student License
- Academic Use Only

**Title**: Derrick

**DWG. NO.**: D001

**REV**: A

**Sheet 1 of 1**
<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
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<th>QTY.</th>
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<tbody>
<tr>
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<td>TR 3x2x0.1875 (6&quot; Top)</td>
<td>D105</td>
<td>2</td>
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<tr>
<td>2</td>
<td>TR 3x2x0.1875 (10&quot; , 45 deg)</td>
<td>D106-1</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>TR 3x2x0.1875 (7.75&quot;, 2X 45 Deg)</td>
<td>D106-2</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Top Sheave Mount Plate Steel</td>
<td>D107-1</td>
<td>2</td>
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<tr>
<td>5</td>
<td>Top Sheave Mount Bolted Plate Steel</td>
<td>D107-2</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Top Sheave</td>
<td>N/A</td>
<td>2</td>
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<tr>
<td>7</td>
<td>Rubber Top Mount</td>
<td>N/A</td>
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</tbody>
</table>

**Derrick Top Mount**

**UNLESS OTHERWISE SPECIFIED:**
- DIMENSIONS ARE IN INCHES
- TOLERANCES:
- FRACTIONAL ±1/16
- ANGULAR ±5 Deg
- ONE PLACE DECIMAL ±0.05

**APPLICATION**
- DO NOT SCALE DRAWING

**MATERIAL**
- Steel

**FINISH**
- Paint

**FINISH**
- Paint

**COMMENTS:**
- Weld D107-1 and D107-2 With Ends Flush

**SHEET 1 OF 1**

**SCALE:** 1:14

**REV**: A
Note:
Use 1/4" Minimum thickness Plate Steel

Gusset

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16
ANGULAR ±5 Deg
ONE PLACE DECIMAL ± .05
TWO PLACE DECIMAL ± .05

INTERPRET GEOMETRIC TOLERANCING PER:

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UNLESS OTHERWISE SPECIFIED:

DRAWN: A. Wargnier 11/23/10
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:

UNSUPPORTED MATERIAL:
Plate Steel

NEXT ASSY
USED ON
FINISH
Paint
APPLICATION
DO NOT SCALE DRAWING

SIZE
A
DWG. NO.
D101
REV

SCALE: 1:4
SHEET 1 OF 1
Note:
Use 1\" pin to create hinge

Derrick Hing Ring

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
FRACTIONAL: ±1/16
ANGULAR: ±5 Deg
ONE PLACE DECIMAL: ±.05
TWO PLACE DECIMAL: ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: Steel

FINISH:
Paint

APPLICATION:

DO NOT SCALE DRAWING

A. Wargnier 11/23/10

DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:

TOLERANCES:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL: ±1/16
ANGULAR: ±5 Deg
ONE PLACE DECIMAL: ±.05
TWO PLACE DECIMAL: ±.005

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Note:
Use 1/4" minimum thickness plate steel.

D103-1

D103-2

Ram Mount

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Note:
1. 1/4" minimum thickness steel
2. Bolt using 3/4" Bolt, Washer, Lock Washer and Nut

Derrick L Bracket

3X Ø0.75

3.0

3.0

9.0

1.25

3.0

0.25

2.0

2.0

0.25

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRAC TIONAL ±1/16
ANGULAR ±5 Deg
ONE PLACE DECIMAL ±0.05
Note: Use minimum 3/8" thick plate steel.

**Top Sheave Mount**

D107-1

D107-2

**Material:** Steel

**Finish:** Paint

**Application:** Used on

**Drawn by:** A. Wargnier 11/23/10

**Scale:** 1:4

**Title:** Top Sheave Mount

**Drawings:**
- **D107-1**
  - 2.0 x 12.0
  - Ø 1.5
  - 0.375
  - 4.0

- **D107-2**
  - 2.30 x 3.0
  - 2X Ø 0.625
  - 0.60
  - 3.0
  - 3.5
  - 0.375

**Tolerances:**
- DIMENSIONS ARE IN INCHES
- FRACTIONAL ±1/16
- ANGULAR ±1 Deg
- ONE PLACE DECIMAL ±.05

**Interpret Geometric Tolerancing Per:**

**Notes:**
- Use minimum 3/8" thick plate steel

**Proprietary and Confidential:**

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Note:
Use 3/8" minimum thickness plate steel
Derrick Mount

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16
ANGULAR ± 1 DEG
ONE PLACE DECIMAL ± .05

INTERPRET GEOMETRIC TOLERANCING PER:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16
ANGULAR ± 1 DEG
ONE PLACE DECIMAL ± .05

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R004 R001
MATERIAL Steel

NEXT ASSY USED ON
APPLICATION Paint
FINISH

Paint

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16
ANGULAR ± 1 DEG
ONE PLACE DECIMAL ± .05

INTERPRET GEOMETRIC TOLERANCING PER:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16
ANGULAR ± 1 DEG
ONE PLACE DECIMAL ± .05

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R004 R001
MATERIAL Steel

NEXT ASSY USED ON
APPLICATION Paint
FINISH

Paint
Note: Construct from 1/4" minimum thickness plate steel

Control Mount

MATERIAL: Steel
FINISH: Paint
APPLICATION: Used on NEXT ASSY
INTERPRET GEOMETRIC TOLERANCING PER:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGLULAR ±1 Deg
ONE PLACE DECIMAL ±0.05

UNLESS OTHERWISE SPECIFIED:

SCALE: 1:5
NOT TO BE SCALABLE DRAWING

DRAWN: A. Wargnier
DATE: 11/28/10

REVISED DRAWING NUMBER: R103

SHEET 1 OF 1
Note:
1. Weld 1.5"X2.5" shaft into flywheel to attach to pitman arm.
2. Thicker flywheel may be used for increased angular momentum.
1. Pitman arm mount to be same shape as pillow block base.
2. Use 1/2" bolts to connect pillow block to mount.

### Item Description

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>PART #</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TS 1.5x1.5 (21&quot;)</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Pitman Arm Mount</td>
<td>N/A</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>1.5&quot; Pillow Block</td>
<td>N/A</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Pitman Arm Support</td>
<td>N/A</td>
<td>4</td>
</tr>
</tbody>
</table>
Note: Made from 1/4" plate steel
Note: Made from 6.5"X6.25" Steel Pipe

Scale: 1:4

Spool Center

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Note:
Shaft collar used to secure weight plate stack

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pitman Arm Attachment</td>
<td>W003</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>WB Shaft (1.75&quot;X28&quot;)</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Walking Beam Frame</td>
<td>W002</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>12&quot; Dia Pulley</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Pulley Shaft (1.5&quot;X6.75&quot;)</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Weight shaft (2&quot;X1.5&quot;X14&quot;)</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Weight plate</td>
<td>N/A</td>
<td>6</td>
</tr>
</tbody>
</table>
C6X8.2 Members

1. C6x8.2x6 N/A 2
2. C6x8.2 (Angled) N/A 2
3. C6x8.2x40 N/A 2
4. TR3x2x0.1875 (12.25") N/A 4
5. TR3x2x0.1875 (2" Hole) N/A 1

Walking Beam Frame
Pitman Arm Attachment

**Table: Item Description**

<table>
<thead>
<tr>
<th>ITEM</th>
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<th>PART #</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TR 3x2x0.1875 (7&quot;)</td>
<td>N/A</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Shaft 1.5&quot;x8&quot;</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Shaft Collar</td>
<td>N/A</td>
<td>2</td>
</tr>
</tbody>
</table>

**Dimensions:**
- **\( \phi 1.5 \)**
- **5.25**
- **7.0**
- **1.5**
- **3.65**

**Material:** Steel

**Finish:** Paint

**Notes:**
- DO NOT SCALE DRAWING
- UNLESS OTHERWISE SPECIFIED:
  - SCALE: 1:4
  - Dimenions are in inches
  - Fractional: ±1/16
  - Angular: ±1 Deg
  - One place decimal: ±.05
- Interpret geometric tolerancing per:
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