H2OASIS INNOVATIONS

Design of a Down-hole, Rock Drilling System

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Contents

1. INTRODUCTION TO PROBLEM

Mission Statement

We are proud to support Water4 Foundation in their perpetual journey to access water in the most remote parts of the world. We focus directly on designing and building a water-well drilling contraption that will bore through any condensed rock layer discovered. The drilling task will be accomplished while providing: a safe experience for the user, customer satisfaction, and most importantly, clean water to the public. We at H2Oasis Innovations believe it is a fundamental obligation to assist a neighbor in need, and we will do everything in our power to accomplish this goal.

Problem Statement

We were presented with the problem of drilling through consolidated rock layers. We are focused on supplying the world with clean water through the creation of a rock drill capable of reaching water sources cheaply and efficiently. This includes working with the Water4 Foundation in a joint effort to have a global impact by providing clean water to all.

2. STATEMENT OF WORK

Scope

We have been given the task of designing a rock drilling system for water well completion particularly in Africa. This design will be used as a solution for the Water4 Foundation in Oklahoma City, OK. Water4 is responsible for aiding several villages internationally in their search for clean drinking water. Water4 takes drilling kits overseas and teaches national hands to drill and complete water wells. This not only aids the individuals in sustaining life, but also creates jobs for thousands of people.

The biggest obstacle to overcome for Water4 is digging through rock layers with hand tools. Our design will allow the workers to complete wells in a much shorter time. This design needs to be convenient for worker use as well as achieving time efficiency. The finished product will have the ability to reduce the drilling time of an individual well by hundreds of hours.

Location

The majority of our work will be performed on the Oklahoma State University campus. We will utilize the computer laboratories provided by the Biosystems Engineering (BAE) department as well as the machining shop. We will need to build and test our system in the BAE shop after designing detailed concepts on the computer using SolidWorks and AutoCad. Additional testing will also take place in various drilling sites around Stillwater and Elk City OK, as well as Longview, TX.

Period of Performance

We plan to present design concepts on April 25, 2013 to BAE faculty and Water4 staff. Following the final design approval, project supplies and materials will be ordered and acquired starting on January 14, 2013. Once materials are purchased, construction will begin immediately. Final prototype will be completed April 25, 2013. Table 1 shows the list of deliverables and their dates.

Table 1: Deliverables Schedule

Date	Task	Deliver to:
29-Oct-12	SOW Due	Instructors
2-Nov-12	WBS Due	Instructors
5-Nov-12	Task list due	Instructors
12-Nov-12	Design concepts due	Instructors/Sponsor
19-Nov-12	1st draft report due	Instructor
6-Dec-12	Final presentation	Instructor
10-Dec-12	Web page due	Instructor
14-Dec-12	Self, peer and class evaluations due	Instructor
7-Jan-13	Revised Gantt Chart and list of deliverables	Instructor
14-Jan-13	Order Project Supplies and Materials	Instructor
11-Mar13	First Rough Draft of Final Report due	Instructor
25-Mar13	Fabrication Completion Deadline	Instructor
1-Apr-13	Second Draft of Final Report due	Instructor
8-Apr-13	Testing Completion Deadline	Instructor
15-Apr-13	Preliminary Presentations in class	Instructor
22-Apr-13	Presentation revisions due, Finalize Reports	Instructor
25-Apr-13	Presentations to clients	Instructor
29-Apr-13	Turn in notebooks, deliver items to client	Instructor

Acceptance Criteria

Quality – Water4 organization will base the quality of our work on the drilling outcome. We will have to maintain the integrity of the hole and drill through the rock without contaminating the water. If we can achieve these two goals, our system will be viewed as successful.

Time – Fast penetration rates are desired but not necessary. Since the final design is going to be a demo prototype, proof of concept is the major goal.

Quantity – In order to achieve satisfactory acceptance criteria for quantity, our system will need to drill through multiple hole sites before needing repair or non-typical maintenance.

We estimate standard maintenance will take place approximately every ten holes. Meeting these criteria will ensure optimum drilling performance while maintaining an acceptable budget.

3. TASK LIST

We have developed a task list to meet our deliverables schedule. We have listed these tasks thoroughly in the work breakdown structure found in Appendix B.

4. MARKET RESEARCH

Value Proposition

For Water4 Foundation

The project design will allow Water4 Foundation's partners to drill in more locations; therefore, they will be more efficient in providing access to safe drinking water in the developing world. A main concern for Water4 and other non-profit organizations is finding an inexpensive and sustainable method for drilling through rock layers so that they can extend their service to a greater number of people.

For Society

It is estimated that in 2008, there were 884 million people who did not use improved drinking water sources; 37% of whom lived in Sub-Saharan Africa. At the current rate of progress, 672 million people will not use improved drinking water sources in 2015 (UNICEF & WHO 2011). Our project design will focus on direct savings in terms of drilling time for people in the developing world. According to UNICEF, machine drilled wells are very high in quality, but also very expensive. The cost of a machine drilled well varies between countries and will generally be in the range of US$ 5,000 – 15,000 for a 30-meter deep well (UNICEF, 2009). What we suggest is implementing a transportable and easy-use drill machine that allows users to go as deep as they want, at an affordable price for Water4's partnerships around the world. By doing this, we can improve our partnerships' capacity to create sustainable jobs and empower communities in developing countries.

Industry Analysis

Development investment contributions committed to achieve water access are categorized under the local public sector, the local private sector, the international public sector, and the international private sector. Water4, as well as many other NGO´s are categorized under the international private sector; all these efforts have had important impacts in the water and sanitation sector. According to Newton (2011), in the mid-1990s, total annual investments in the water and sanitation sector in developing countries were approximately $28 billion. Of this, 65-70% was contributed by the local public sector, 5% from the local private sector, 10-15%, from international donors and NGOs, and 10-15% from the international private sector (Newton, 2011).

In contrast, total average aid commitments to water and sanitation in 2009-2010 reached $8.3 billion. Of this, 70.98% (or $5.8 billion) was contributed by OCDE Development Assistant Committee (DAC) countries. The bilateral providers of development assistance in 2009-10 were as follows:

- Japan (on average $2.3 billion per year)
- Germany ($802 million)
- France ($652 million)
- 27.08% (or $2.2billion) was contributed by multilateral agencies.

The multilateral providers were as follows:

- International Development Association - $475 million

- EU institutions - $618 million
- Asian Development Foundation - $297 million
- African Development Foundation - $244 million
- Arab Foundation - $91 million
- UNICEF - $47 million
- The remaining 0.012% is attributed to NGO´s in which Water4 is aggregated.

Market Analysis

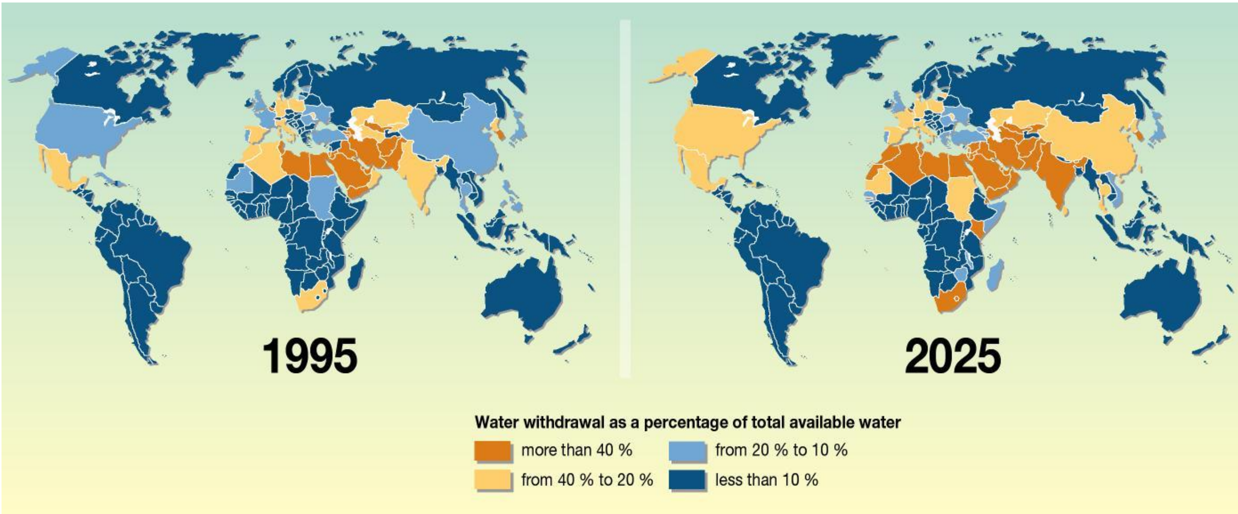
Target market

Water4's market includes a number of organizations and businesses with which Water4 partners in about 30 countries - mainly in Africa and Latin America. Some of Water4's partners are U.S. or U.K. mission organizations, some are NGO's, and some are natives of the areas who wanted to start a business that would provide for their families while working for the good of their communities. Water4 estimates that one out of five wells started by their partners have been abandoned due to rock layers through which they did not have the ability to bore. Water4 could potentially expand to include other partners and countries. A table in Appendix G shows the countries to which Water4 has been and the number of partners they have in each place. In the next section, we will discuss the areas where the proposed drilling system could be used.

Target Market – Drilling System

Hydrologists typically assess scarcity by looking at the population-water equation. An area is experiencing water stress when annual water supplies drop below 1,700m^3 per person. When annual water supplies drop below 1,000m^3 per person, the population faces water scarcity, and below 500m^3 is considered "absolute scarcity". Countries located both in the Maghreb and Middle East zone experience huge water withdrawals as percentage of total renewable water. This is mainly due to water pressures in agriculture.

Map 1: World water withdrawals as percentage of total renewable water



Source: UNEP. http://www.unep.org/dewa/vitalwater/article141.html

On the other hand, there are several countries where water is available but they have neither the resources needed nor the capability to drill water wells. According to the World Bank (2012), there are several countries whose rural population barely has access to improved water sources. The more prominent ones are:

- Somalia (7% of urban population)
- Democratic Republic of the Congo (27%)
- Ethiopia (34%)
- Mozambique (29%)
- Madagascar (34%)
- Papua New Guinea (33%)
- Sierra Leone (35%)
- Republic of the Congo (32%)
- Afghanistan (42%)

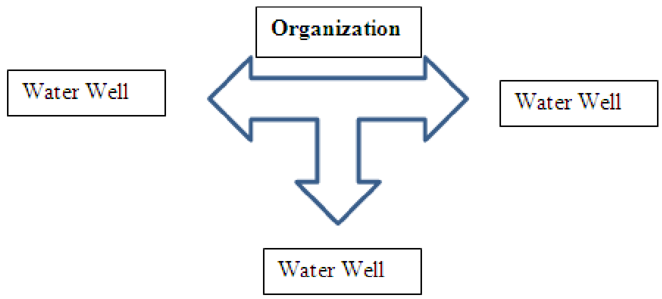
Even though the need is evident in these countries, Water4 operates with local and international partnership networks in some specific areas mostly in the Sub Saharan countries. This partnership network in Sub-Saharan countries is consistent with the fact that rural access to safe drinking water in these areas needs to be improved.

The Competition

The industry of charitable foundations offering access to clean water in rural areas is diverse. The "competition" varies greatly in method and costs of operation. Table 2 compares Water4's budget alongside other charities and organizations. The expected budget for the new hydraulic drilling system being designed by the engineering team to drill deep wells is $25,000. However, this drilling system will be used more as a "hot-shot" crew which will be transported to each well that runs into a consolidated rock layer. The financial analysis was based on one system per 20 wells. In reality, a unit should be able to drill hundreds upon hundreds of wells. For each well affected by this drilling system it would cost an additional $1,250 bringing the total for Water4 to approximately $2,150. This cost is still much cheaper than any other organizations methods.

Most other organizations working toward the goal of clean water for everyone collect donations to bring a drilling unit into an area that is lacking access to clean water. They will drill a well and then leave the community. Some of them start programs to educate and train the residents of the community on sanitization, hygiene, and how to maintain their well. Water4 uses a different approach. They find partners in the areas that need water and provide the equipment and training so that they can use those techniques in the future so that the number of wells drilled will multiply. The diagrams below represent the approach of Water4 Foundation compared to a typical charity drilling water wells.

Typical Charity



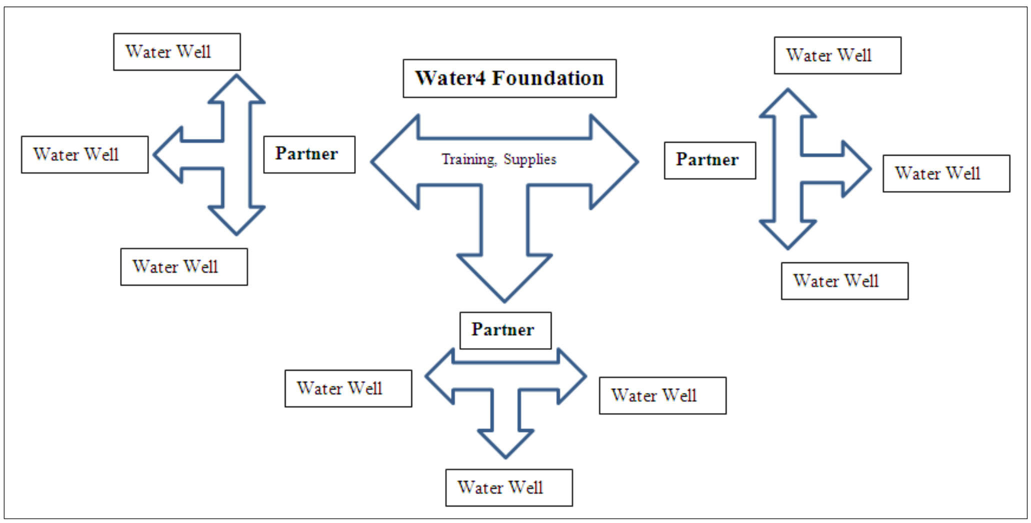


Table 2: Market competition breakdown

Organization	Water4 Foundation	The Water Project	Water.org	Lifewater International	Global Water	Covenant Life Foundation	Water Wells for Africa
	Hand Drilling Costs:						
Per Person	$6	$20	$25		$10 / $15 / $90		
Per Family	$24/family of four	$100/family					
Per Pump	$200 per pump to serve hundreds	$1,500/hand pump					
Per Shallow Well	$900 per well for a village		$7,000-$30,000	$5,000	$2,500 hand dug, $7,500 drilled		
Other	$5,000 for a drill kit capable of drilling 50 wells	$500/classroom					
Per Deep Well	$2,150 expected for drilling system			$15,000	$45,000 with electric pump	$13,000	$7,000

The new drilling system will be faster and more powerful than Water4's current method for removing rock. The more advanced technology may be more difficult to maintain in areas where replacement parts or tools are hard to find. As it will be explained in the design section, maintenance cost of this new drill machine will be low and easy to replace.

Existing Products

DeepRock Manufacturing – Model M60

- TECHNICAL SPECIFICATIONS
    - 25 HP Diesel Engine
    - Hydraulic power rotation and feed control
    - Weight: 1850 lbs. (220 ft. of drill stem included)

    - Gorman-Rupp mud pump
    - 300 ft. capability.
- PROS
    - Proven design
    - Minimal physical requirements
    - Substantial depth capability
    - Hydraulic variability
- CONS
    - Heavy machine to set in the back of a truck
    - Expensive (Approximately $20,000)
    - Produced only for difficult soils
    - Minimal rock cutting ability
    - Requires significant water use for lubrication
    - Long trips in and out of hole

Boremaster ZX-1000

Specifications

- Portable, Easy to move
- Kohler, Electric Start, Electronic Ignition, EPA Approve Engine
- 12 Volt Power Winch
- Belt Drive, high Torque Transmission
- High Powered Gasoline and Diesel Rigs

Pros

- Easy to maneuver and transport
- Simple design allowing cost to be more inexpensive than other similar products ($6245.00)
- Easy operation allowing no extensive training for operation

Cons

- Wheels are not sufficient for the type of terrain being transported in
- Is not designed to drill through rock
- Requires significant water usage to cut through material
- Long trips in and out of hole

Marketing Plan

Product

The product is going to be a hydraulic drilling system designed to bore through consolidated rock layers. It is described in more detail in the design section. The advantage of this product over hand-drilling is greater power and control than is possible with non-mechanized methods.

Promotion

Water4 should promote the new drill system by communicating directly with their existing partners and any new ones they might gain in the future. Demonstrations and field displays would gain group's interest and allow for improved visual understanding. They could also use their website and other related internet sites to get the word out to relevant organizations.

Price

The price of the hydraulic drilling system will be as low as possible, since Water4 is a non-profit organization. The expected production cost is estimated at approximately $20,000. Water4 would like to profit from the production of these systems so there will be a percentage increase in order to reach a selling price. Some organizations Water4 partners with will be able to afford this price, while others may not. Caleb Holsey, the Global Project Manager from Water4, said in our email correspondence that Water4 might be able to help out those with smaller budgets interested in purchasing the drill by reducing the cost, offering a payment plan, or even helping to raise funds. The key principle behind this drilling system is that it will be able to be used at multiple well drilling sites. This means that the organizations purchasing this equipment will be able to only purchase one drilling system for multiple different wells. This process will dilute the cost per well drastically making it a much more probable investment.

Place

The method in which Water4 distributes this product is fundamental to its success. Due to the amount of wells that this drilling system can reach and produce it will allow many of Water4's partners able to afford it. With this being said, there are many organizations with which Water4 could enter into a partnership that have the necessary funds to purchase the rock drill. For the few that can't, Water4 will be able to set up additional funding and payment plans.

Strategy

Water4 should promote the new drill design to their partners and emphasize the new abilities they will have to drill through consolidated rock. Whether these organizations are non-profits, missions, or for-profit enterprises, they are still motivated to bring clean water to as many people as possible. With a proper understanding of what the new drill will be capable of, the upside will be greater than the downside. Utilization of this system will allow them to reach more people in their communities who are suffering from lack of clean water.

5. DESIGN RESEARCH

We researched and analyzed the key components that would go into our system in order to be successful. Listed below is the analysis that we started with for this design project.

Design Analysis

Under the assumption the team decides to go with a fully hydraulic design using down-hole drilling system, the following calculations and information must be determined.

- What bit will be used
- Force applied to bit for most efficient cutting
- Most efficient bit rotational speed
- Torque applied to drilling stem caused by bit
- Torque required to properly size hydraulic motor
- Flow rate/pressure requirement of properly sized hydraulic pump
- Engine Power/Torque requirements to run hydraulic pump
- Drilling tower strength and weight distribution
- Material – Quartzite, Martensite and Dolomite. We had to consider the material compressive strength, density, and hardness rating.
- Bit - Design and function of the bit. Reverse clutch to help with grab and stall.
- Motor – 2 and 1/8 progressive cavity motor. 9 feet long. 100 pounds. Going with this motor will allow slower flow rates with the least amount of vibration reverberating through system.

What are similar items or solutions for your project problem?

There are a couple different solutions out there that deal with water well drilling. Most of these discuss drilling through dirt and mud, and not compressed layers of rock. They have good concepts to follow and items that could work with our problem. Most use hydraulics to drive the system. It would provide the best variability to ensure torque would be continuous and maximized. To reach the proper depth, we will use an oil rig system to feed the pipe down the hole and make connections for the sections we will need to use. Oil rig systems could solve our problem, but they would be too big and expensive to be a viable solution. There are downsized systems that are feasible, but are still very technical and expensive to own and operate. Integration of these ideas will bring about a rock drilling system that should yield the proper specifications we require.

What characteristics are technically possible but not included in existing products? Why?

One characteristic that is not included in existing products is the idea of making the solution completely mechanical. A jack could be used to pull/put the pipe into the ground, and a mechanical hammer drill that was driven by a hand crank could be used to do the actual drilling. Even though this design is plausible, it may not be efficient enough to meet material removal rate requirements.

Durability, reliability, maintenance costs and maintenance requirements

Drill bit – Depending on the type of material you're cutting through (in this case quartzite, dolomite, etc.) bits are replaced as needed.

Lubrication – Re-lubricating pipes, fittings, and engines are reapplied during every usage.

Fluids - Maintain fluid cleanliness as well as temperature to keep proper viscosity.

Parts - Schedule component change-outs to ensure parts do not fail.

Maintenance costs are relatively cheap and low cost. Requirements for maintenance would be proper lubrication and changing bits. It would also consist of replacing parts to ensure safety and reliability.

Are there safety issues that must be addressed?

Yes. There are definitely safety issues that must be addressed in this project, as well as almost every engineering project.

1) We must ensure that the well is not contaminated with anything that could be a potential harmful agent to a human being (motor oil, diesel, impure water).
2) Weight safety of the solution must also be considered.
3) Exposed moving parts in the system mechanically must be shielded to protect operators.
4) Using a hydraulic system we must have safety relief valves in place to ensure pressure does not build up causing injury.

Patents

Drilling Machine for Drilling Holes in Rocks (See Appendix A) - The relevance of this patent is to observe the early concept of a truck mounted drilling system with a vertical design and stand. This will let us better understand our mounted system without infringing on their technology. Patent date was January 21, 1992.

Telescopic Rock Drill Feed (See Appendix A) - We used this design patent to determine a way to add addition pipe segments while drilling. This patent gives us a better idea and vision of sending oil rig pipe down a vertical hole to drill through rock. Patent date was April 3, 1974.

Drill Rig Assembly (See Appendix A) - Relevant for the use of a truck mounted system with a lifting mechanism attached to a drilling rig. Drawings of a vertical system will give us a good vision of where to go in our early stage design concepts. Patent date was July 3, 1990.

6. PRODUCT SPECIFICATIONS

The Water4 Organization out of Oklahoma City, Okla. has requested a rock drilling system with the following specifications: maximum system weight of 2,250 pounds; hole drilling capability of 6 inches in diameter and 60 inch depth. We were instructed to research and test a rock drill bit as well as the size of engine necessary to run our hydraulic pump and motor. Our design will need to have custom fabrication to return fluid to the top of the hole. Also, Water4 would like total materials cost to be below $25,000.

7. CUSTOMER REQUIREMENTS

The Water4 Foundation has asked us to produce a rock drill with the following requirements:

1. Capability to drill through rocks such as quartzite, granite and others.
2. Material costs should not exceed $25,000.
3. Entire unit must weigh below the payload capacity of commonly found pickups. (Approximately 2,000 pounds)
4. Unit must be capable of drilling through aforementioned rock up to 7 inches in diameter and 10 foot deep.
5. Pneumatic or hydraulic system.
6. If hydraulic, oil must be food grade.
7. Drill bit cannot be lubricated.

Above were the specific requirements presented to us. These requirements must be made, but there were also multiple preferences voiced by Water4. These are listed below.

1. No drilling stems down-hole.
2. Gasoline powered system.

3. No air sent down-hole.
4. A bit recovery system requiring no joint disconnection.
5. Avoid the use of drilling mud.

8. DESIGN CONCEPTS

Design 1: *Down-hole Motor with Coiled Tubing Setup*

Our initial design concept was a high tech idea that is being utilized in directional natural gas drilling. We will construct our system on a trailer to improve mobility and expand the operating space. This design will feature a rock bit attached to a down-hole progressive cavity motor. The motor will be attached to a stabilizer to ensure a central contact point with the rock. The stabilizer will be connected to coil tubing that will run up and out of the hole. The tubing will be connected helically to a spool with a pump in place to transfer the hydraulic fluid to the progressive cavity motor. An engine will power the pump, providing constant flow rate and pressure. In order to handle tubing in and out of the hole with ease, we will feature a small motor attached to the spool. We will feature three sub-designs in relation to this system. We will be using a biodegradable hydraulic fluid down-hole to create rotation within our progressive cavity motor in sub-design one. The second sub-design will feature a glycol and water mixture. Our final sub-design will utilize water and air. Using these fluids will help preserve the integrity of the well in the case of a leak or rupture. Sub-design one, we will run a hydraulic return line up the hole starting at the rock bit connection to close the loop in our system. After this is done, we will be reusing all of the hydraulic fluid after it has passed through our cavity motor. Our design will also feature water for lubrication flowing out of the jets in the rock bit. This will be achieved by running a separate line down-hole that will be attached to our flexible tubing. It will be connected to the bit section just after the division created to return hydraulic fluid to the surface.

We will exhaust the water through the bit face and provide a force to disturb the shavings in order to suspend them. This will be necessary to achieve a maximum material removal rate. Sub-design two will be very similar with the use of a glycol and water mixture instead of hydraulic fluid. This will be exhausted at the bit to provide lubrication and will need to be retrieved by a pump above the hole. Sub-design three will feature air driving the cavity motor and water to lubricate the bit. The air will be exhausted with a return line up the hole. This will prevent blowout or stalling. With these designs, we believe we will be able to drill through any form of consolidated rock layers that Water4 could see.

Parts included for Design:

- Drill Bit – Carbide Mills provided by Thru-Tubing Solutions. (See attached Appendix for spec sheet) Designs can include several features including:
    - Standard and reverse clutch
    - Flat, convex, or concave bottom
    - Tapered, step, string, or watermelon profiles
    - Crushed carbide, Star Cut carbide, or carbide inserts
    - Straight or Twister mill bodies

Figure 1- Carbide Drilling Mills

- Engine – We will use a Briggs and Stratton engine to provide our pump with the necessary power. (See Appendix for spec sheet)

Figure 2- Briggs and Stratton Engine

- Motor – Our system will feature a 2.13-inch progressive cavity motor provided by Thru-Tubing Solutions. It will be attached down-hole. (See Appendix for spec sheet)

Figure 3- Down-hole motor

- Pump – We have chosen to go with an Eaton heavy duty pump.
- Reservoir – Decision to come after testing.
- Heat Exchanger – Decision to come after testing.
- Coiled Tubing – Our system will feature coiled tubing provided by PolyFlow Inc. Utilized for its tensile strength and ability to be reeled on a spool. (See Appendix)

Figure 4- PolyFlow tubing

- Stabilizer – The stabilizer that will be mounted above the motor in order to square up our system down-hole will be provided by Thru-Tubing solutions.
- Water Tank – Decision to come after testing.
- Hydraulic Hose – Eaton hydraulic hose. Size specifications to come in the spring.
- Hydraulic Fittings – Eaton fittings as well. Size specifications to come in the spring.
- Trailer – Decision to come in the spring whether or not to build or purchase.

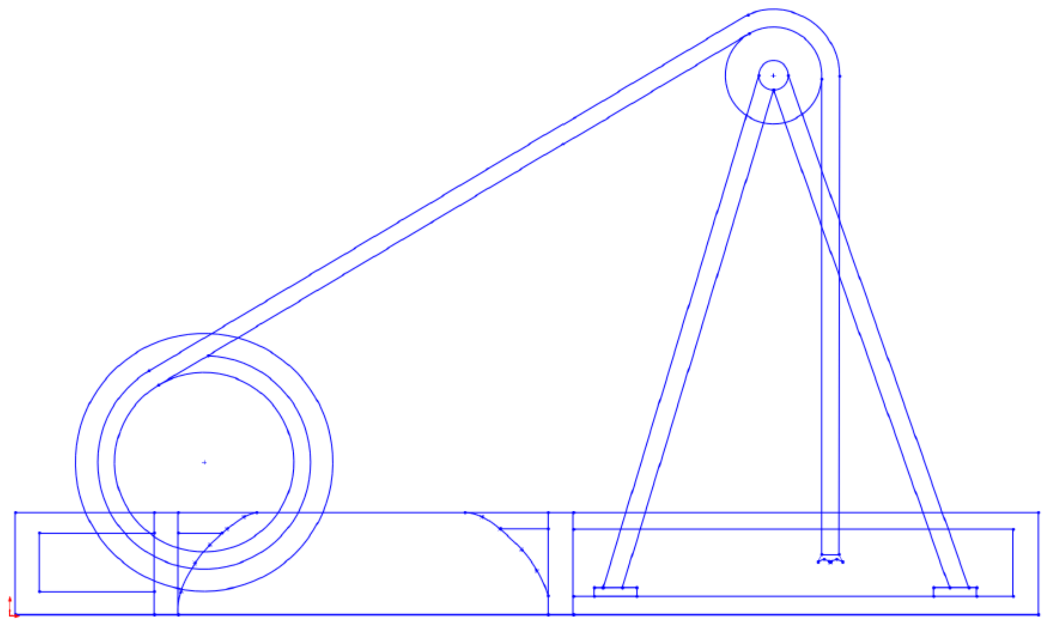


Figure 5: Rough Sketch of trailer mount with coiled tubing. Notice the swing-set design for stability. Our freshmen team has been given the task of designing the trailer so that the swing-set can be mobilized off of the trailer.

Design 2: *Conventional down-hole stem with motor at surface*

Our second design is going to feature a more traditional method of drilling. We will place the system on a trailer to improve mobility. Our system will feature an engine above the surface connected to a pump to achieve the necessary power input. We will use a hydraulic pump capable of pushing the required amount of fluid to our motor to provide fluid. This motor will then rotate drilling stem within the hole that will be attached to a bit at the surface of the rock layer. We intend to use the same carbide drilling mills as the previous design concept. This design will feature significantly more weight than Design 1 within the hole. With that said, we will have a tower stand and a smaller hydraulic motor to retrieve the stem and bit. The operator of the system will have to connect and send stem down within the hole in sections. The advantage of this design is a reduction in cost of the complete system. (Drawing to come)

Parts include for Design:

- Drill Bit – Carbide Mills provided by Thru-Tubing Solutions. (See attached Appendix for spec sheet) Designs can include several features including:
    - Standard and reverse clutch
    - Flat, convex, or concave bottom
    - Tapered, step, string, or watermelon profiles
    - Crushed carbide, Star Cut carbide, or carbide inserts
    - Straight or Twister mill bodies

Figure 6- Carbide Drilling Mills

- Engine – We will use a Briggs and Stratton engine to provide our pump with the necessary power. (See Appendix for spec sheet)

Figure 7- Briggs and Stratton Engine

- Motor – For this design, we will use a Char-Lynn 10000 Series hydraulic motor. It will be placed above ground and attached to our tower stand. (See Appendix for spec sheet)

Figure 8- Char-Lynn motor

- Pump – Our system will feature an Eaton heavy duty piston pump to achieve the required amount of flow.
- Reservoir – Decision to come in the spring after testing.
- Heat Exchanger – Decision to come in the spring after testing.
- Drill Stem – Decision to come in the spring after testing.
- Hydraulic hose – We will be using Eaton hydraulic hose for our system. Size specifications will come in the spring.

Figure 9- Eaton hydraulic hose

- Hydraulic connections and fittings – Eaton hydraulic fittings.
- Trailer – Decision to be made in the spring whether or not to build or purchase.

After all of the designs were carefully analyzed, a proposed budget of each was made (Appendix F).

1. CALCULATIONS

In order to determine the appropriate hydraulic pump and motor design for the stem option, chart analysis and calculations had to be done. Through discussion with industry professionals, we assumed we would need approximately 1,500 pound-feet (18,000 pound-inches) of torque applied from the hydraulic motor. Knowing this, we went to Char-Lynn's line of hydraulic motors and found the 40.6 in^3/r, 10000 Series motor was the best fit. From this chart, using torque calculated earlier, our pump would be required to flow 12 gallons per minute at 3,000 psi as can be seen in Appendix C. Using this information, the 3.0 in^3/r was determined the pump of choice due to its availability and ability to produce both the pressure and flow needed to power the motor.

Using the power equation as can be seen in Appendix E and the "Rule of 1500" which states moving one gallon per minute with one horsepower will produce 1,500 psi, engine size was determined. As can be seen in Appendix D, 24 horsepower is capable of producing the 12 gallons per minute at 3,000 psi required to produce 18,000 lb.-in from the hydraulic motor.

10. FINAL DESIGN CONCEPT

During the fall presentation, we provided a statement from Thru-Tubing professionals which stated that 20 GPM would be able to power our down-hole motor, using a reverse-clutch mill. After conclusion of the presentation, our sponsor informed us they were interested in seeing testing results of various bits and different sized motors which can be seen in Table 1. The sponsor was curious to see if 20 GPM would be able to drive the different motors or if a higher flow rate would be needed to prevent stalling. After the testing was performed (Table 1), we delivered the results to our sponsor. They then revealed to us they were interested in a closed-loop hydraulic system which would serve as a demo for their company. This demo would show what they were interested in doing at a larger scale with one of the motors tested in Table 1. A 1.9" down-hole motor was then chosen as the demo product. This design would specialize in hydraulics, where the motor was hydraulically powered, and recirculation was used. The design allowed us to also use a hydraulic motor on our reel where flow was diverted for hydraulic power to lower and raise the down-hole motor. The smaller size of this demo product will allow the system to be stored on a flatbed truck. This will be convenient for Water4 to use to show customers the possibility of a larger design in the future.

11. FABRICATION AND VALIDATION/TESTING OF DESIGN OR PROTOTYPE

Part of the system is the 18 HP Briggs and Stratton Engine. We were able to obtain a slightly used engine which met the requirements needed. After adding a few necessary parts and a few hours of labor the engine was up and running at required levels. Through testing we were able to find the appropriate speed to effectively run the rest of our system.

Another step of fabrication for the system is the hydraulic rerouting coupling. This will be connected within the down-hole motor and will reroute the hydraulic fluid back up to the surface to be reused again in the system. The key principle of this component is to re-direct the fluid before it is ejected out of the bit and into the hole, since Water4 wanted a dry drilling process. Thru-Tubing Solutions will be machining this component for us and has taken the down-hole motor so that they can fit the piece onto the motor properly.

12. TESTING RESULTS

A. After talking with our sponsor, we were under the impression that we were to determine the optimum motor size and bit that would give us the highest penetration rates. With this knowledge, we were only curious in testing the 2.13” and 2.88” sized motors. We travelled to Longview, TX as well as Elk City, OK to acquire proper testing results for the down-hole motors. The trip down to Longview was to test the torque and pressure of the motors at flow rates ranging from 20 to 50 GPM. The trip to Elk City was taken to measure the penetration rates of the bits and the motors through the rock material. The type of rock that was used to mimic quartzite was chert. Chert has approximately the same level of hardness as quartzite and is more common in this region making it easier to acquire. The testing results from Elk City are as follows:

Table 3: Elk City Testing Results

	Total Depth in hole (in.)		20 GPM for all tests.			
Hole 1	4.75					
Hole 2	4.50					
Hole 3	2.00					
Hole 4	4.75					
2.13 Motor				**2.88 Motor**		
Roller Cone	**Drilling Time**	**Penetration(in.)**		**Roller Cone**	**Drilling Time**	**Penetration(in.)**
Hole 2	15 mins	0.75		**Hole 1**	13 mins	4.80
	15 mins	1.25			10.5 mins	3.60
	15 mins	1.00				
Reverse Clutch	**Drilling Time**	**Penetration (in.)**		**Reverse Clutch**	**Drilling Time**	**Penetration (in.)**
Hole 4	15 mins	1.25		**Hole 4**	15 mins	1.80
	15 mins	0.00				
Bear Claw	**Drilling Time**	**Penetration (in.)**		**Bear Claw**	**Drilling Time**	**Penetration (in.)**
Hole 4	15 mins	0.96		**Hole 1**	15 mins	1.92
	15 mins	0.24			15 mins	0.84

B. After fabrication was concluded, we tested our closed-loop drilling system in order to meet our client's requirements. We were successful in containing fluid in our system and not exhausting anything at the bit. We were also able to control the entire system hydraulically in order to make it quicker tripping in and out of the hole. We believe this is a perfect system for a demo application, and look forward to seeing the larger, production model Water4 builds in the future.

13. DISCUSSION/ANALYSIS

TBA

14. BUDGET

Project Budget

15. RECOMMENDATIONS/CONCLUSIONS

A. Closed-loop system

In order to increase penetration rates, we would recommend using the 2.88" progressive cavity motor for this system. We would like to flow at least 40 GPM down-hole. To do this, we would increase our pump size, and increase our engine to a 32 HP engine minimally.

C. Alternative Design

After evaluating the project in terms of efficiency, practicality, and financial feasibility, we recommend that the final design should not be a closed-loop hydraulic system. Numerous drilling professionals we have talked to have instructed us to use a fluid to remove cuttings from the surface of the rock. With a closed-loop system, we cannot exhaust fluid at the bit to remove these particles and keep them suspended in a viscous solution. This problem causes cuttings to continuously be re-ground which causes penetration rates to drop significantly. Another main concern of not using an exhausting fluid is bit wear. Drill bits are not cheap. Once the whole system is paid for, drill bits will be the only major cost left to worry about. In the absence of lubrication and fresh rock to drill, the bits will wear even faster. We did not see exhausting a water-heavy fluid to be a problem. After the fluid tank was initially filled, we could re-use the water several times.

In terms of providing an actual size system, we would recommend using the 2.88" motor along with a tri-cone bit. The results from Table 1 show that this system would provide the fastest penetration rates. In this system we would approximately use a Tutthill HD

Process pump combined with a 40 HP diesel engine. We would recommend changing the reel motor to an electrically driven motor so that hydraulic power would not be an issue.

Overall, the team began to ask the question, “At what point does the value of water override the cost of gasoline and the moral obligation to provide an efficient system when using fossil fuels.” A closed-loop hydraulic system would be extremely inefficient, pumping water from over 140ft down-hole vertically to be re-pressured and sent back down-hole. H2Oasis estimated that over 30% more fuel would be needed to accomplish this task compared to allowing water to naturally rise in the annulus and be collected at the borehole. We believed that if water in these areas is scarce, fuel will most likely be scarce as well.

This design would in fact be more fuel efficient, time of drilling would be greatly reduced, and financial costs would be less than or equal to the current design when looking to the future product. If reaching the water table is our ultimate goal for this project, we would highly recommend using this system to do it fast and efficiently.

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Appendix A

United States Patent [19]

Brazell, II

[11] **Patent Number: 4,938,296**

[45] **Date of Patent: Jul. 3, 1990**

[54] **DRILL RIG ASSEMBLY**

[75] Inventor: **James W. Brazell, II,** Atlanta, Ga.

[73] Assignee: **Pacer Works, Ltd.,** Atlanta, Ga.

[21] Appl. No.: **256,699**

[22] Filed: **Oct. 12, 1988**

[51] **Int. Cl.**[5] **F21B 7/02**

[52] **U.S. Cl.** **173/22;** 173/28; 173/163; 173/164

[58] **Field of Search** 173/164, 2, 39, 43, 173/163, 22, 28

[56] **References Cited**

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Primary Examiner—Frank T. Yost

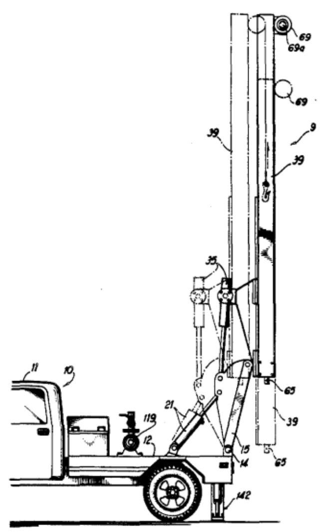
Assistant Examiner—Willmon Fridie, Jr.

Attorney, Agent, or Firm—Hurt, Richardson, Garner, Todd & Cadenhead

[57] **ABSTRACT**

A drill rig assembly adapted to be mounted on a vehicle and having a pivotal link assembly mounted to the vehicle. Attached in slidable relationship to the link assembly is a mast assembly containing feed means and rotary means fully enclosed within the mast assembly. An electronic level within the mast assembly automatically maintains the mast assembly in a predetermined, angular position. The drill rig assembly is capable of drilling either vertically or at selected, incremental angles. The drill rig assembly is designed to be safe in operation and lightweight, while providing performance characteristics of larger drill rigs.

18 Claims, 8 Drawing Sheets



US005082068A

United States Patent [19]

Cornell

[11] **Patent Number: 5,082,068**

[45] **Date of Patent: Jan. 21, 1992**

[54] **DRILLING MACHINE FOR DRILLING HOLES IN ROCKS**

[75] Inventor: **Ron A. Cornell,** Hastings, N.Y.

[73] Assignee: **Syracuse Utilities, Inc.,** Brewerton, N.Y.

[21] Appl. No.: **491,544**

[22] Filed: **Feb. 23, 1990**

[51] **Int. Cl.**[5] **E21B 7/02**

[52] **U.S. Cl.** **173/22;** 173/28; 173/39

[58] **Field of Search** 173/22, 28, 163, 164, 173/39, 43, 104

[56] **References Cited**

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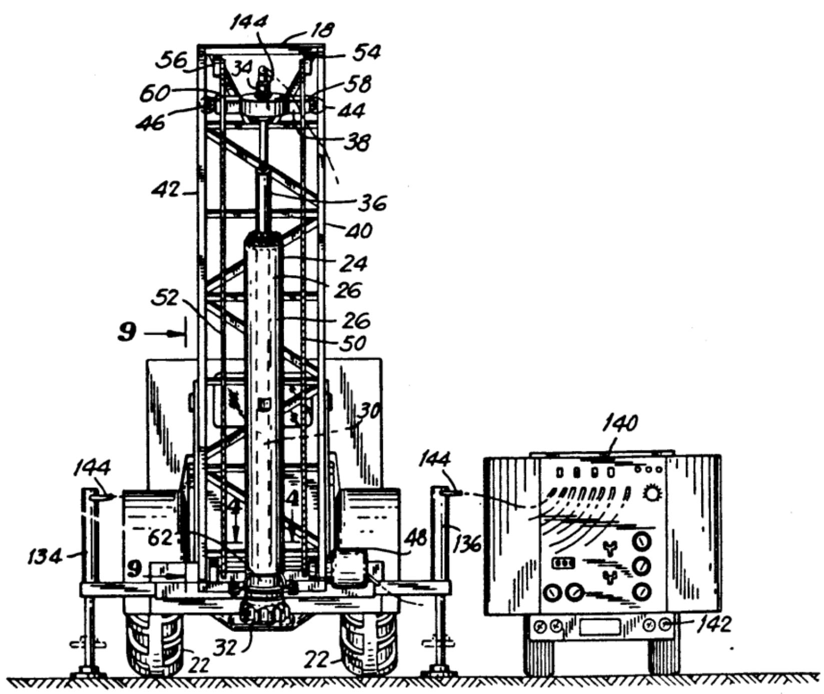
Primary Examiner—Timothy V. Eley
Assistant Examiner—Willmon Fridie, Jr.
Attorney, Agent, or Firm—Kane, Dalsimer, Sullivan, Kurucz, Levy, Eisele and Richard

[57] **ABSTRACT**

A truck-mounted rock drilling machine for pole holes consists of a pivotable boom mounted on the truck bed and a jack-hammer-like mechanism mounted on the boom. The jack hammer like mechanism is driven from a compressor which is preferably mounted on a separate trailer.

11 Claims, 7 Drawing Sheets



United States Patent [19]

Boom et al.

[11] **3,880,244**

[45] **Apr. 29, 1975**

[54] **TELESCOPIC ROCK DRILL FEED**

[75] Inventors: **Clarence O. Boom**, Littleton; **Laurence B. Hanson**, Pine, both of Colo.

[73] Assignee: **Gardner-Denver Company**, Quincy, Ill.

[22] Filed: **Feb. 4, 1974**

[21] Appl. No.: **439,516**

Related U.S. Application Data

[62] Division of Ser. No. 315,055, Dec. 14, 1972, Pat. No. 3,807,510.

[52] **U.S. Cl.** **173/19**; 74/841; 408/11

[51] **Int. Cl.** **E21c 5/02**

[58] **Field of Search** 173/19, 21, 147, 160; 408/10, 11, 12; 74/841

[56] **References Cited**

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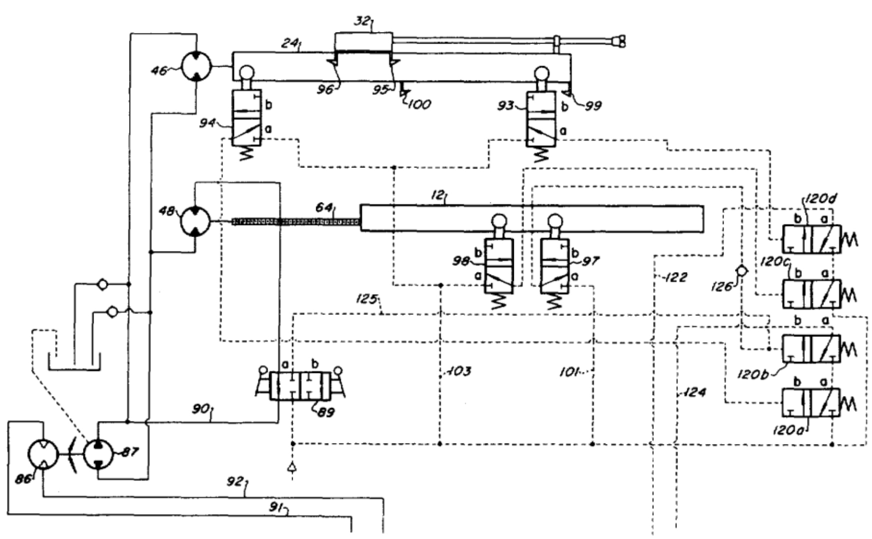
Primary Examiner—Ernest R. Purser
Attorney, Agent, or Firm—M. E. Martin

[57] **ABSTRACT**

A rock drill feed mechanism in which a drill motor is reversibly driven along a guideway by a rotatable power screw. The guideway is slidably mounted on an elongated support for reversible movement therealong by a second power screw mounted on the guideway. The power screws are driven independently by fluid motors and may be selectively controlled to operate the feed mechanism in a telescoped condition for movement of the drill motor alone or movement of the drill motor and the guideway to extend the useful feed length. A control circuit includes sensing devices for determining when the feed mechanism is fully telescoped or fully extended for reversing and shutting off the drill motor, respectively.

5 Claims, 7 Drawing Figures



Appendix B

WBS 1.0 – Design Down-hole Rock Drill

Design a drilling system to successfully go through hard rock encountered when digging water wells.

1.1 Drill bit interface

Analyze and reverse engineer the necessary requirements present at the face of the rock material.

1.1.1 Material of drill bit

Test and determine the proper classification of bit to be utilized in our system. Design based on thermal resistance, hardness, cutting efficiency, and lifespan of bit.

1.1.2 Calculate dimensions

Determine a recommendation for bit size based on diameter, boring capability, and blade dimensions.

1.1.3 Inlet and outlet

Test and analyze flow into the drill bit as well as the lubrication jet outlets. We will test the speed of the fluid flow, the efficiency at different flow rates, and the capability as it relates to material removal rates.

1.2 Motor

Determine the amount of rpms this motor will have to allow the drill bit to be effective. Also determine the down force needed.

1.2.1 Dimensions

Measure the outside diameter of the motor to determine the appropriate clearance for the casing in the hole. We will also be measuring the efficiency of the motor which will allow us to determine the necessary torque and down force needed to power the drill bit.

1.2.2 Specifications

The determination of the viscosity limitations and pressure requirements will be evaluated. We will assess the necessary spec sheets and run tests to determine this.

1.2.3 Modifications

The stem will need to be modified in order to allow for multiple inlets and outlets. The motor will need one inlet/outlet pair for the pumping oil and another inlet/outlet pair for the drilling mud.

1.3 Coil tubing setup

Coil tubing will be needed in order to deliver the necessary fluids down the hole. It will also be used to extend and retract the drilling mechanism down hole.

1.3.1 Length

1.3.2 Material

Determine the pressure requirements that the fluids and tensions will apply to the tubing. Calculate and measure the appropriate dimensions for down hole deliverance.

1.3.3 Thickness

The thickness of the coil tubing will need to be determined in order to evaluate proper diameter and pressure requirements. Different materials will be researched to determine which thickness will be most optimal.

1.4 Trailer mount

The trailer mount will need to be one that allows ease of transportation in rough terrains. It will also have certain modifications and specifications that allow for the drilling system to operate and transport.

1.4.1 Type of Trailer

The trailer type will be determined by the size of the drilling system. This will also determine the weight limit that the trailer will have.

1.4.2 Modifications

The necessary modifications will be to have a maneuverable hitch to allow for easy transportation through tougher terrains. The trailer will also have a center hole for the drill to move through.

1.5 Hydraulic pump and motor setup

Determine the type of pump to deliver the appropriate fluid flow requirements for the pump to operate effectively.

1.5.1 Type of pump and motor

The pump and motor requirements will involve proper power and rpm calculations in order to properly remove an acceptable amount of rock. The type of fluid being used in the motor and pump will also necessitate calculations.

1.5.2 Specifications

The weight, size, hip, etc. will be determined in order to choose the best fit motor and pump.

1.6 Interface

We will be collaborating and testing the best possible means of making the most effective and efficient down hole drilling system.

1.6.1 Efficiency

1.7 Project Management

Time evaluation and project distribution will be the main milestones that determine the flow of our project management.

1.7.1 Time efficiency

In order to effectively complete our project in a timely fashion, time efficiency is a key factor in our project that will be followed to the highest precision.

1.7.2 Project distribution

Our group must maintain high communication in order to sustain high production efficiency.

WBS 2.0 - Documentation

Proper documentation must be taken in order to produce fluid and organized maintenance of our project.

2.1 Drafting

Drafting will be done for every aspect of our project with multiple variations and prototypes.

2.1.1 Dimensions

Dimensions are all standard sizes and are calculated for every part in our assembly.

WBS 3.0 – Engineering Review and Approval

All aspects of the down hole drilling system will be reviewed and approved.

3.1 Review and Approve Engineering

We will have meeting to evaluate the engineering of the project and review all of the designs.

3.2 Review, approve, and finalize drawings

We will review all finalizations of the project and have meetings to verify all designs.

WBS 4.0 – Fabricate and Procure System Materials

All materials will be obtained in a timely fashion and will be chosen with detailed specifications. Materials that are in need of customization and fabrication will also be done in a timely fashion.

4.1 Procure Materials

All materials will be obtained in a timely fashion and will be chosen with detailed specifications.

4.1.1 Main Materials

Certain materials will be acquired by Water4 while all other main materials will be purchased from companies and manufacturers.

4.2 Fabricate trailer mount and any assemblies needed

All fabrications needed will be done in a timely fashion and will be done with safety being the first priority.

4.2.1 OSU BAE Shop

Most fabricating will be done at the BAE design Shop

4.2.2 By Stock parts and modify them as needed

Parts in need of fabrication will be purchased as stock parts and then modified to necessary design configurations.

WBS 5.0 – Integration of System

All parts will be assembled in the most efficient location to provide maximum effectiveness.

5.1 Populate Trailer

All parts on the trailer will be assembled for both maximum operational efficiency and transformational efficiency

5.1.1 Part Location

All parts will be located for maximum assembly and disassembly efficiency.

5.2 Integrate Hydraulic Components

Hydraulic components will be located to perform at optimum levels.

5.2.1 Specifications

Size and other specification requirements will be taken into account for location position.

5.2.2 Order of assembly

The order of part assembly will be taken into account for location position. This will allow for ease of access and maximum time efficiency.

5.2.3 Evaluation

Total evaluation of the integration of the system will be determined in order to produce the most efficient design.

5.3 Functional Checks

Functional check will be administered in order to produce the ideal down hole rock drilling system.

5.3.1 Troubleshooting

Multiple troubleshooting evaluations are anticipated and time is scheduled for such matters to make the appropriate adjustments and predictions.

5.3.2 Finalization

The finalization of the project will be determined by the entirety of the group.

Appendix C

665 cm³/r [40.6 in³/r]
Pressure Bar [PSI]

Flow LPM [GPM]	[250] 15	[500] 35	[750] 50	[1000] 70	[1250] 85	[1500] 105	[1750] 120	[2000] 140	[2250] 155	[2500] 170	[2750] 190	[3000] 205	[3250] 225	[3500] 240	[3750] 260
[1] 3,8	[1470] 165 4	[3010] 340 3	[4550] 515 3	[6100] 690 2	[7630] 860 1										
[2] 75	[1480] 165 10	[3020] 340 9	[4560] 515 8	[6110] 690 7	[7650] 865 7	[9200] 1040 6	[10740] 1215 5	[12280] 1385 4	[13830] 1565 3	[15370] 1735 2	[16910] 1910 1				
[4] 15	[1470] 165 22	[3010] 340 21	[4550] 515 20	[6100] 690 19	[7640] 865 18	[9190] 1040 17	[10730] 1210 16	[12270] 1385 15	[13820] 1560 14	[15360] 1735 13	[16900] 1910 12	[18450] 2085 11	[19990] 2260 10	[21540] 2435 9	[23080] 2610 8
[8] 30	[1440] 165 44	[2980] 335 43	[4530] 510 42	[6070] 685 41	[7610] 860 40	[9160] 1035 39	[10700] 1210 38	[12250] 1385 37	[13790] 1560 36	[15330] 1730 35	[16880] 1905 34	[18420] 2080 33	[19960] 2255 32	[21510] 2430 32	[23050] 2605 31
[12] 45	[1400] 160 67	[2950] 335 66	[4490] 505 65	[6040] 680 64	[7580] 855 63	[9120] 1030 62	[10670] 1205 61	[12210] 1380 60	[13750] 1555 59	[15300] 1730 58	[16840] 1905 57	[18380] 2075 56	[19930] 2255 55	[21470] 2425 54	[23020] 2600 53
[16] 61	[1360] 155 89	[2910] 330 88	[4450] 505 87	[5990] 675 86	[7540] 850 85	[9080] 1025 84	[10620] 1200 83	[12170] 1375 82	[13710] 1550 81	[15260] 1725 80	[16800] 1900 79	[18340] 2070 78	[19890] 2245 77	[21400] 2420 76	
[20] 76	[1310] 150 112	[2860] 375 111	[4400] 495 110	[5940] 670 109	[7490] 845 108	[9030] 1020 107	[10580] 1195 106	[12120] 1370 104	[13660] 1545 103	[15210] 1720 102	[16750] 1890 101	[18300] 2070 100	[19840] 2240 99		
[24] 91	[1260] 140 135	[2800] 315 134	[4350] 490 132	[5890] 665 131	[7440] 840 130	[8980] 1015 129	[10520] 1190 128	[12070] 1365 127	[13610] 1540 126	[15150] 1710 124	[16700] 1885 123	[18240] 2060 122			
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[45] 170	[920] 105 254	[2460] 280 252	[4000] 450 251	[5550] 625 249	[7090] 800 248	[8630] 975 247	[10180] 1150 245	[11720] 1325 244	[13260] 1500 243	[14810] 1675 242					
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[70] 265	[380] 45 396	[1930] 220 393	[3470] 390 391	[5010] 565 390	[6560] 740 388	[8100] 915 387	[9640] 1090 385	[11190] 1265 384							

[3470] Torque [lb-in]
390 Nm
391 Speed RPM

Appendix D

	Pressure (psi)					
Flow Rate (GPM)	5 hp	10 hp	16 hp	24 hp	28 hp	31 hp
1	7500.0	15000.0	24000.0	36000.0	42000.0	46500.0
2	3750.0	7500.0	12000.0	18000.0	21000.0	23250.0
3	2500.0	5000.0	8000.0	12000.0	14000.0	15500.0
4	1875.0	3750.0	6000.0	9000.0	10500.0	11625.0
5	1500.0	3000.0	4800.0	7200.0	8400.0	9300.0
6	1250.0	2500.0	4000.0	6000.0	7000.0	7750.0
7	1071.4	2142.9	3428.6	5142.9	6000.0	6642.9
8	937.5	1875.0	3000.0	4500.0	5250.0	5812.5
9	833.3	1666.7	2666.7	4000.0	4666.7	5166.7
10	750.0	1500.0	2400.0	3600.0	4200.0	4650.0
11	681.8	1363.6	2181.8	3272.7	3818.2	4227.3
12	625.0	1250.0	2000.0	3000.0	3500.0	3875.0
13	576.9	1153.8	1846.2	2769.2	3230.8	3576.9
14	535.7	1071.4	1714.3	2571.4	3000.0	3321.4
15	500.0	1000.0	1600.0	2400.0	2800.0	3100.0
16	468.8	937.5	1500.0	2250.0	2625.0	2906.3
17	441.2	882.4	1411.8	2117.6	2470.6	2735.3
18	416.7	833.3	1333.3	2000.0	2333.3	2583.3
19	394.7	789.5	1263.2	1894.7	2210.5	2447.4
20	375.0	750.0	1200.0	1800.0	2100.0	2325.0
21	357.1	714.3	1142.9	1714.3	2000.0	2214.3
22	340.9	681.8	1090.9	1636.4	1909.1	2113.6
23	326.1	652.2	1043.5	1565.2	1826.1	2021.7
24	312.5	625.0	1000.0	1500.0	1750.0	1937.5
25	300.0	600.0	960.0	1440.0	1680.0	1860.0
26	288.5	576.9	923.1	1384.6	1615.4	1788.5
27	277.8	555.6	888.9	1333.3	1555.6	1722.2
28	267.9	535.7	857.1	1285.7	1500.0	1660.7
29	258.6	517.2	827.6	1241.4	1448.3	1603.4
30	250.0	500.0	800.0	1200.0	1400.0	1550.0
31	241.9	483.9	774.2	1161.3	1354.8	1500.0
32	234.4	468.8	750.0	1125.0	1312.5	1453.1
33	227.3	454.5	727.3	1090.9	1272.7	1409.1
34	220.6	441.2	705.9	1058.8	1235.3	1367.6
35	214.3	428.6	685.7	1028.6	1200.0	1328.6
36	208.3	416.7	666.7	1000.0	1166.7	1291.7
37	202.7	405.4	648.6	973.0	1135.1	1256.8
38	197.4	394.7	631.6	947.4	1105.3	1223.7
39	192.3	384.6	615.4	923.1	1076.9	1192.3
40	187.5	375.0	600.0	900.0	1050.0	1162.5

Appendix E

Hydraulic Power developed by the Pump

$$P = \frac{\Delta p * Q}{1714}$$

P = Power (HP)

Q = Flow rate (GPM)

ΔP = Pressure differential

Hydraulic Power developed by the Motor

$$P = \frac{T * N}{5252}$$

P = Power (HP)

T = Torque (ft.-lb.)

N = Rotational Speed (RPM)

Appendix F

Design concepts								
	Stem		Progressive Cavity w/ water-glycerol		Progressive Cavity w/ hydraulics and water		Progressive Cavity w/ air and water	
Component	**Cost**	**Weight (lbs)**	**Cost**	**Weight (lbs)**	**Cost**	**Weight (lbs)**	**Cost**	**Weight (lbs)**
Drill Bits (2)	$600.00	75.0	$600.00	75.0	$600.00	75.0	$600.00	75.0
Stabilizer	X	50.0	$250.00	50.0	$250.00	50.0	$250.00	50.0
Engine (31 hp)	$1,453.00	150.0	$1,453.00	150.0	$1,453.00	150.0	$1,453.00	150.0
Engine (16 hp)		-	-		-		-	
Hydraulic Motor	$1,590.00	100.0	-	-	-	-	-	-
Progressive Cavity Motor	-	-	$15,300.00	100.0	$15,300.00	100.0	$15,300.00	100.0
Stem/Coil Tubing	$3,480.00	1200.0	$235.00	38.0	$235.00	38.0	$235.00	38.0
Pump(s)	$2,000.00	60.0	$3,000.00	60.0	$1,493.00	60.0	$1,493.00	60.0
Connections	$2,000.00	100.0	$300.00	100.0	$300.00	100.0	$300.00	100.0
Trailer	$2,000.00	X	$1,700.00	X	$1,700.00	X	$1,700.00	X
Water Tank (Loaded)	$400.00	4172.0	$400.00	4172.0	$400.00	4172.0	$400.00	4172.0
Hydraulic/Air Hose	X	X	X	X	$3,500.00	90.0	$600.00	20.0
Air Compressor	X	X	X	X	X	X	$5,000.00	600.0
TOTAL	**$12,923.00**	**5832.0**	**$23,238.00**	**4670.0**	**$25,231.00**	**4835.0**	**$27,331.00**	**5365.0**

Appendix G

Country	Full Time Teams	Part Time Teams	Inactive
Angola	10		
Brazil			X
Chile			X
China			X
Ecuador			X
Ethiopia		4	
Ghana	10	1	
Guatemala		1	
Guinea		1	
Haiti		2	
Honduras			X
Kenya	1		
Malawi		1	1
Mali	10		
Nepal		1	
Nicaragua		2	
Niger	10		
North Korea			X
Peru			X
Rwanda	2		
Sierra Leone	1		
South Sudan			X
Togo	1		
Uganda	2	5	
Zambia	1	1	
Totals	48	19	

H2OASIS INNOVATIONS

"Saving lives one drop at a time."

Down-hole Rock Drill

Michael Chavez **Heath Hendricks**

George Tietz **Tyler Zimbelman**

Overview

- Water4/Problem Statement
- Client Requirements
- Obstacles and Current Designs
- Objective
- January 1st Designs
- Preliminary Testing
- Final Design/Associated Tasks
- Problems
- Drawings
- Testing
- Financial Analysis
- Future Work

H2OASIS INNOVATIONS

water4 foundation

Empowering Communities One Well At A Time

- The Water4 Foundation is a public charity based out of Oklahoma City, Oklahoma.
- Founded by Dick and Terri Greenly.
- https://water4.org/media/

https://water4.org/about-us/

H2OASIS INNOVATIONS

Problem

- Consolidated rock layers within the borehole impede the water well drilling system from completion.
- Workers are left with either digging out the rock with hand tools or breaking through the layer using a cable tool system.
- These methods take days to remove the rock layer before workers can continue drilling.

Objective

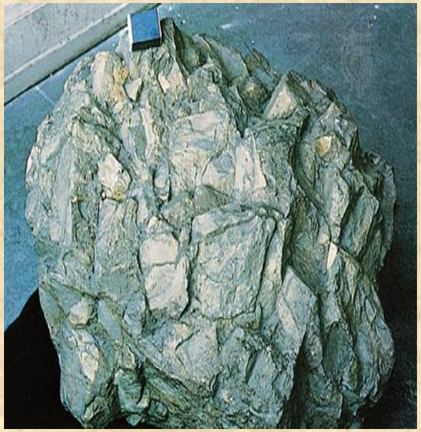
- Design a rock drilling system for water wells.
- Design budget is initially set at $25,000

Client Requirements

- “Hot Shot” Crew
- Truck mounted unit independent of current methods
- Multiple holes can be drilled daily

Client Requirements

- Must drill through material as dense as quartzite
- Quick trips in and out of borehole.
- Maximum depth of 150 feet
- Easily Operable
- Able to be transported in rough terrain.



Quartzite
7 on Mohs Hardness scale

H2OASIS INNOVATIONS

Obstacles

Design: *Progressive Cavity Motor with Coiled Tubing*


Progressive Cavity Motor

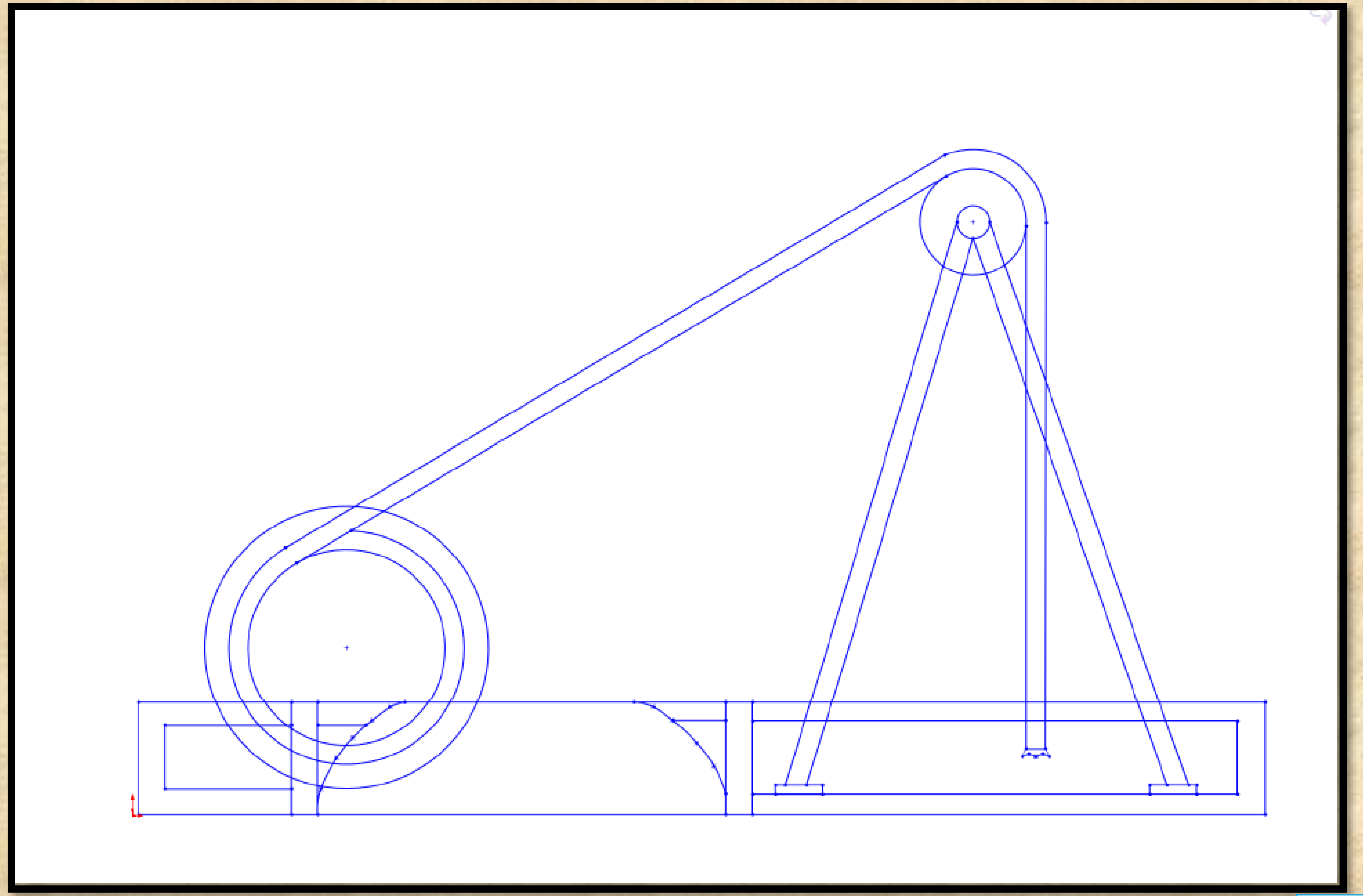
- Fluid power to progressive cavity motor via coiled tubing.
- Coiled tubing provides quick trips in and out of hole.

H2OASIS INNOVATIONS

Key Component: Progressive Cavity Motor

- http://www.youtube.com/watch?v=jRC_O7hQBgc

Initial Design Drawing



Sub-Design 1: *Closed-loop hydraulic power*

- Features a down-hole progressive cavity motor to spin a bit at the rock surface.

- Motor is attached to coiled tubing at the top surface.

- Hydraulic fluid is pumped through the tubing to power the motor for drilling. The fluid returns in hydraulic hose to surface and is recirculated in system.

Sub-Design 2: *Water power exhausted at bit*

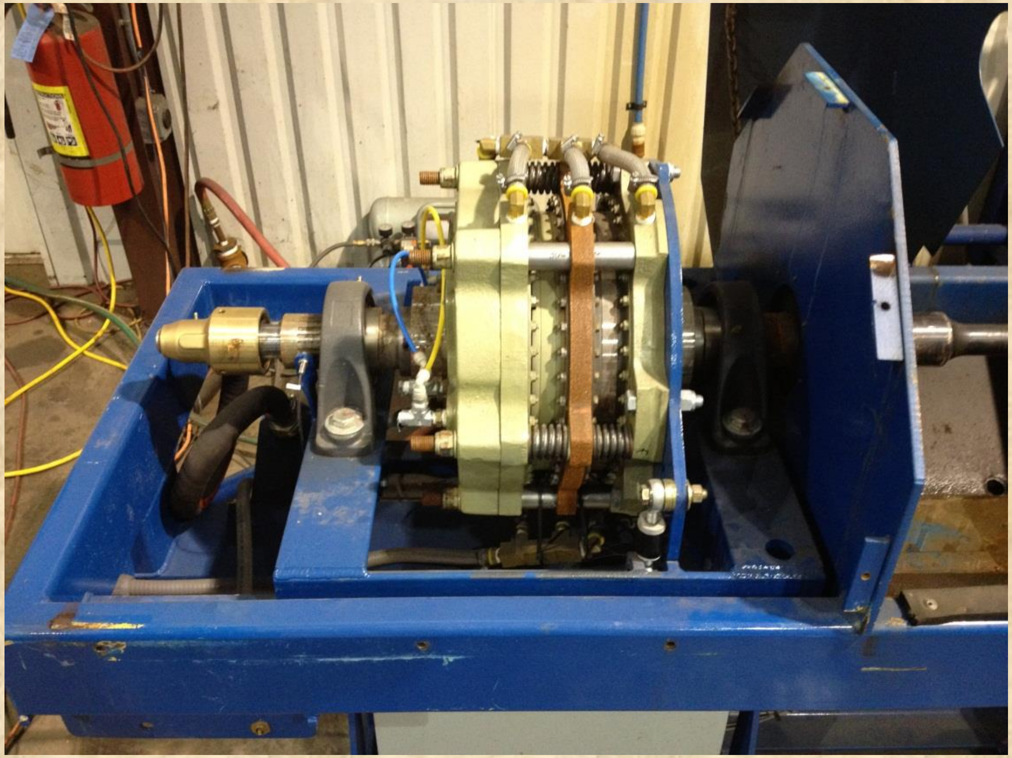
- Features a down-hole progressive cavity motor to spin a bit at the rock surface.
- Motor is attached to coiled tubing at the top surface.
- Fluid medium is pumped through the power section for drilling, lubrication, and cuttings removal.

Preliminary Testing for Design Selection

- Thru-Tubing Solutions
  - Longview, TX: Flow rates affecting torque capabilities.
  - Elk City, OK: Penetration rates through chert rock found using flow rates found in Longview.
- Progressive Cavity Motors Used
  - 2-1/8'' and 2-7/8'' OD

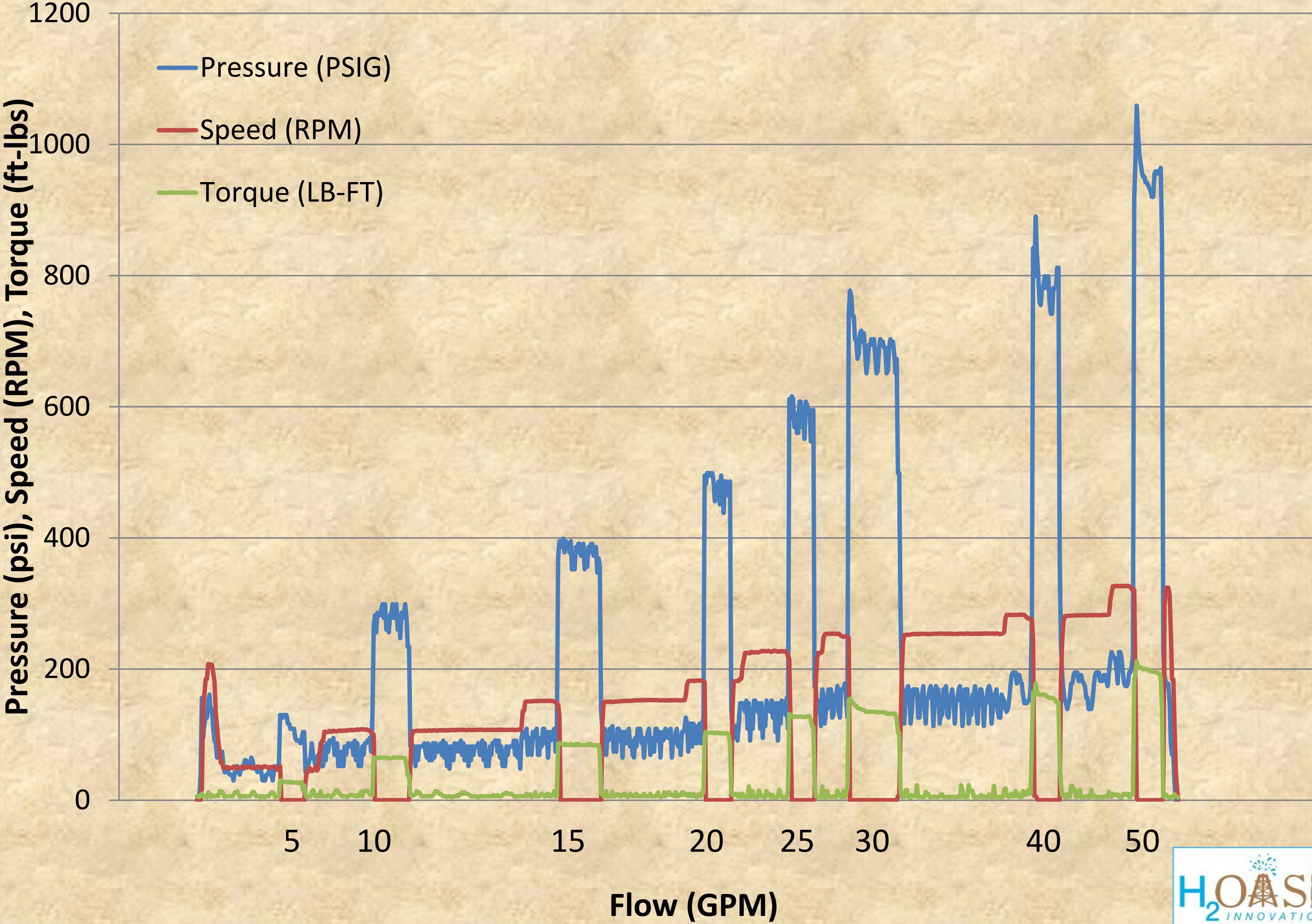
Thru Tubing Solutions Longview, TX

- Goal
  - Determine the following..
    - Maximum flow rate
    - Maximum pressure
    - Stall point

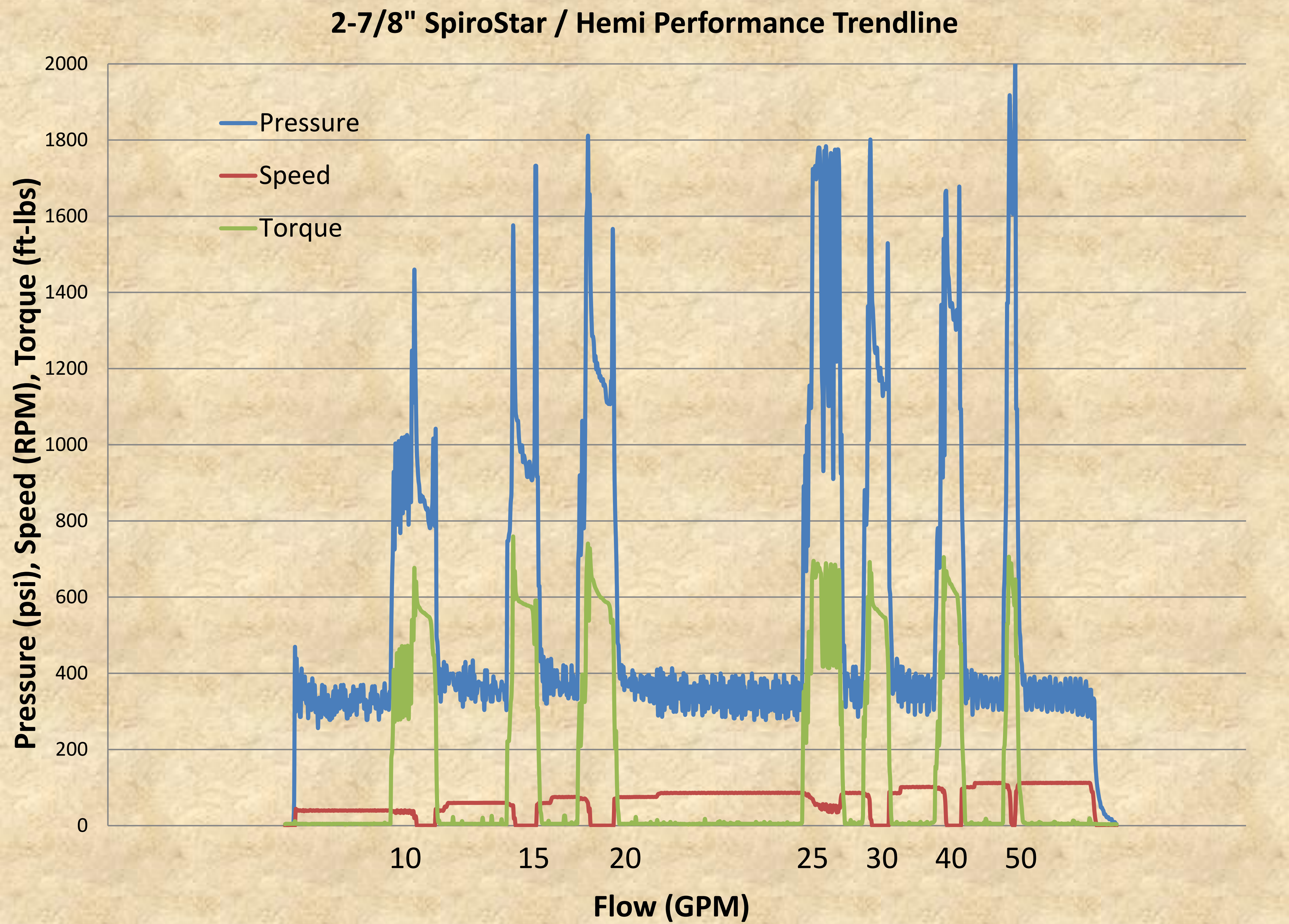


H2OASIS INNOVATIONS

2-1/8" Roper Performance Trendline



H2OASIS INNOVATIONS


2-7/8" SpiroStar / Hemi Performance Trendline
Pressure
Speed
Torque
Pressure (psi), Speed (RPM), Torque (ft-lbs)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
10
15
20
25
30
40
50
Flow (GPM)

Elk City Testing

- Testing of penetrations rates using 700 lbs of force
- Tested with 25 GPM

- Items tested

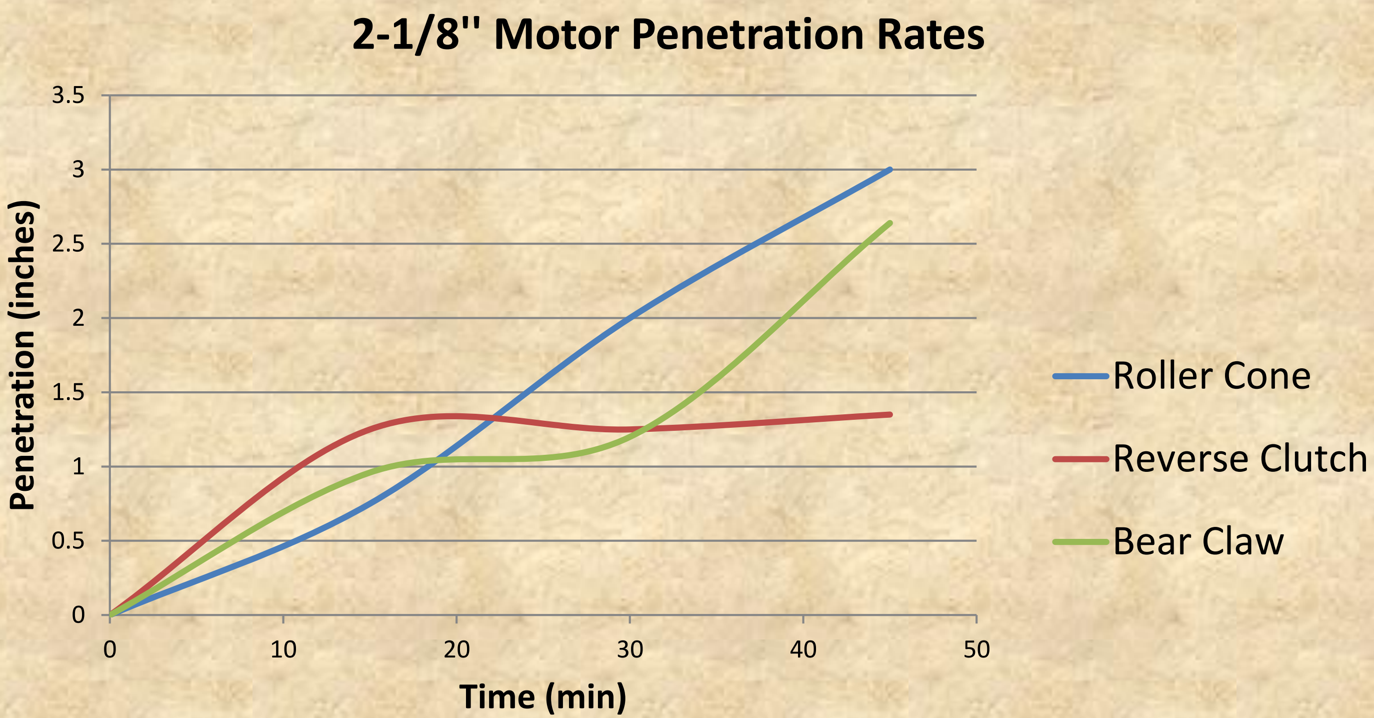
1. 2-1/8'' and 2-7/8'' Motor
2. 3 drill bits (Tri-cone, button, reverse-clutch)

Drill Bits

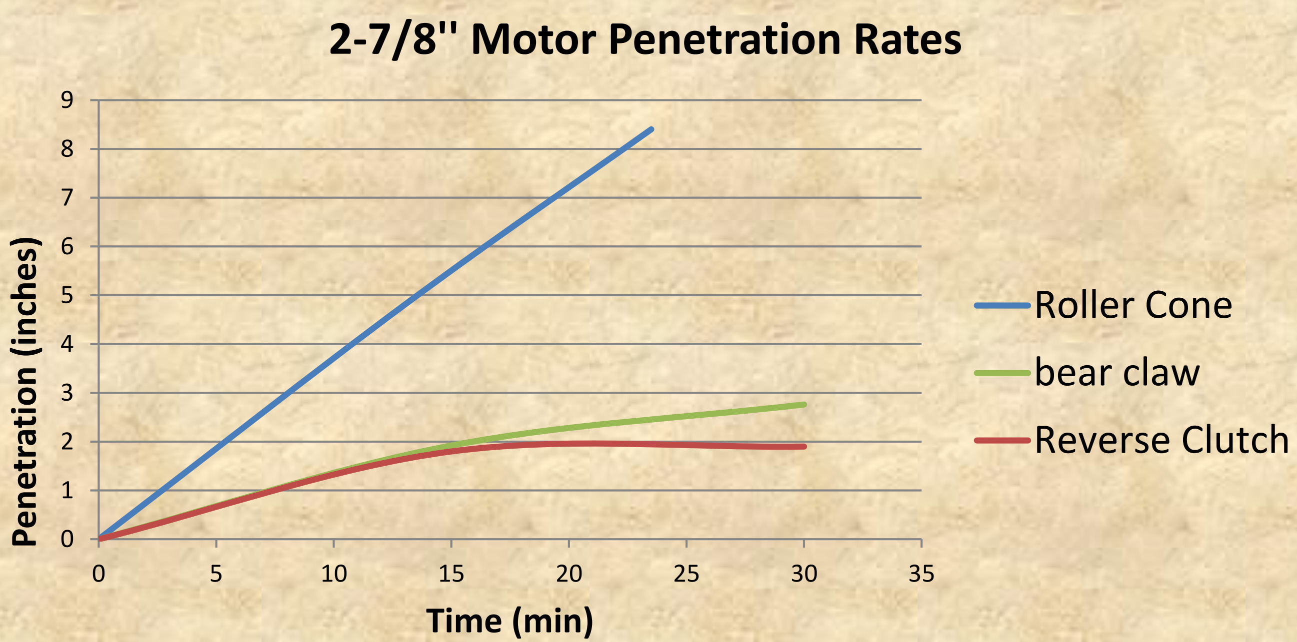
Tri-Cone

Button

Reverse-clutch



2-1/8'' Motor Penetration Rates
3.5
3
2.5
2
1.5
1
0.5
0
Penetration (inches)
0
10
20
30
40
50
Time (min)
Roller Cone
Reverse Clutch
Bear Claw



2-7/8'' Motor Penetration Rates
9
8
7
6
5
4
3
2
1
0
Penetration (inches)
0
5
10
15
20
25
30
35
Time (min)
Roller Cone
bear claw
Reverse Clutch

Finalized Design (Demo Unit)

- Closed-loop hydraulic system controlling two motors.

- 1.69’’ down-hole motor attached to kevlar tubing.

- Hydraulically controlled hose reel.

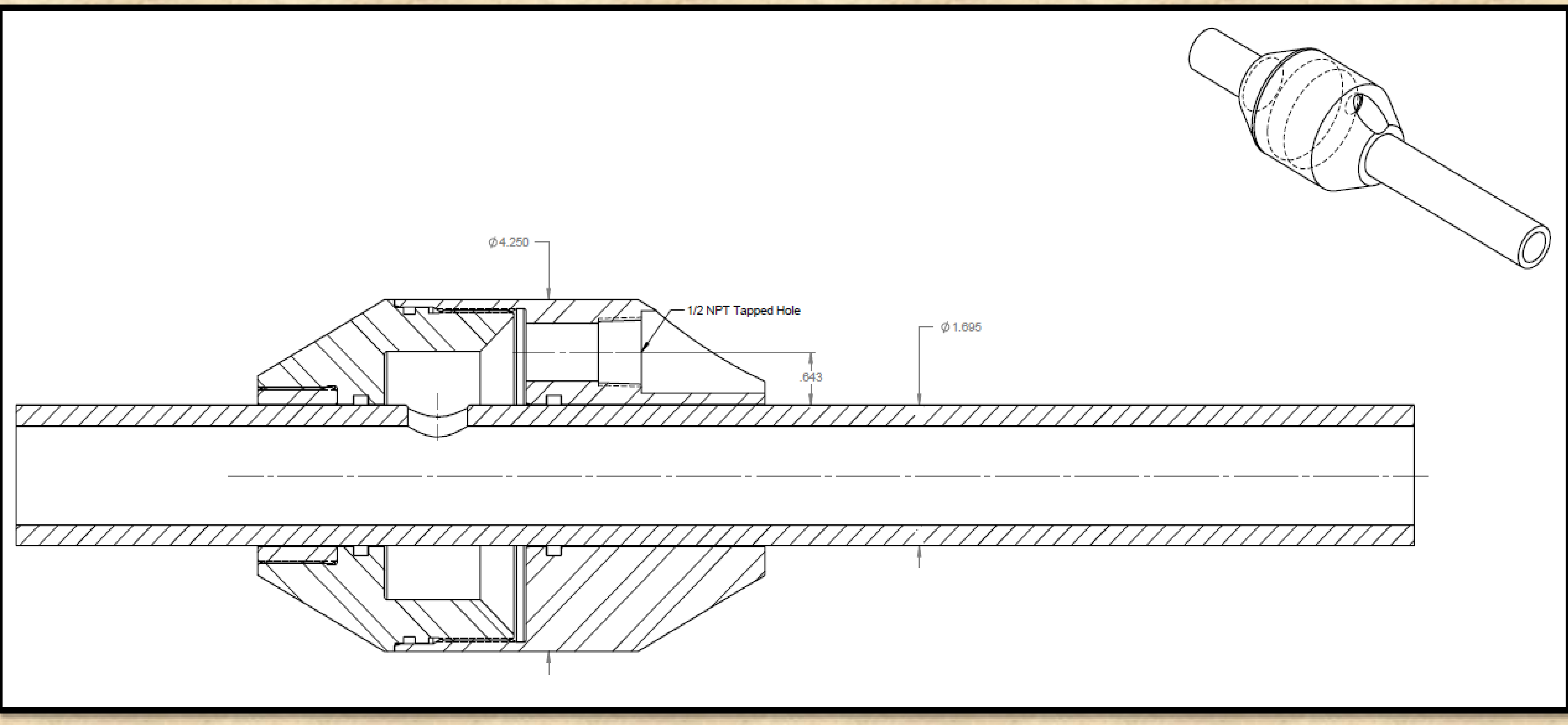
Main Tasks

- Progressive Cavity Motor Modifications
  - Hydraulic return line needed
- Support Frame
  - Vertical support of down-hole motor
- Hydraulic Power Unit
  - Engine, pump, valves, and reservoir
- Reel Stand
  - Support rotating coiled tubing
  - Transport hydraulic fluid

Challenges with Down-Hole Motor

- Recirculating fluid to surface
  - Return line must be protected
  - Custom fabrication needed (Thru Tubing)
  - Efficiency (hose size)
  - Bit size increases with hose size

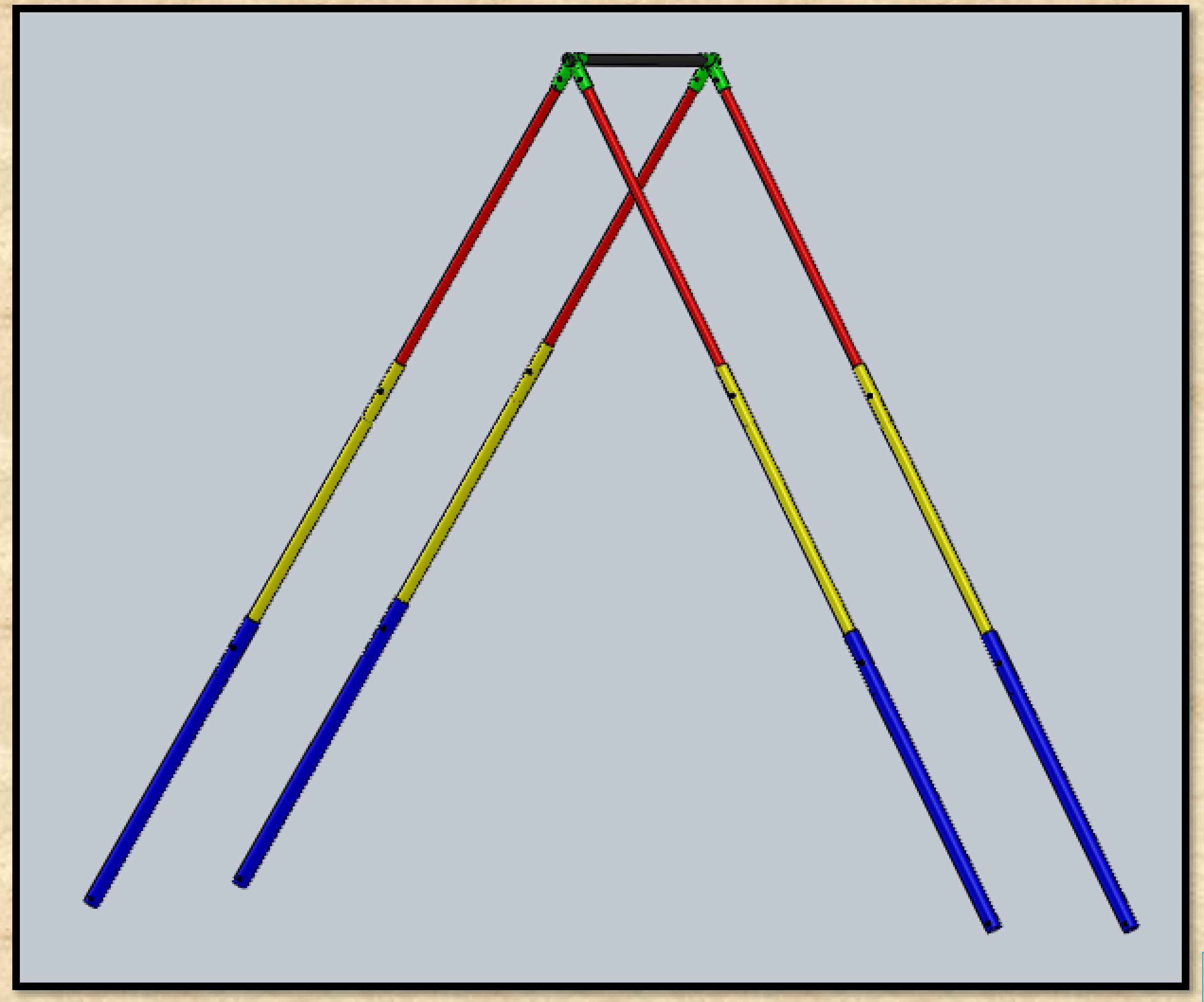
Progressive Cavity Modification Drawing



Progressive Cavity Modification

H2OASIS INNOVATIONS

Telescoping Support Drawing

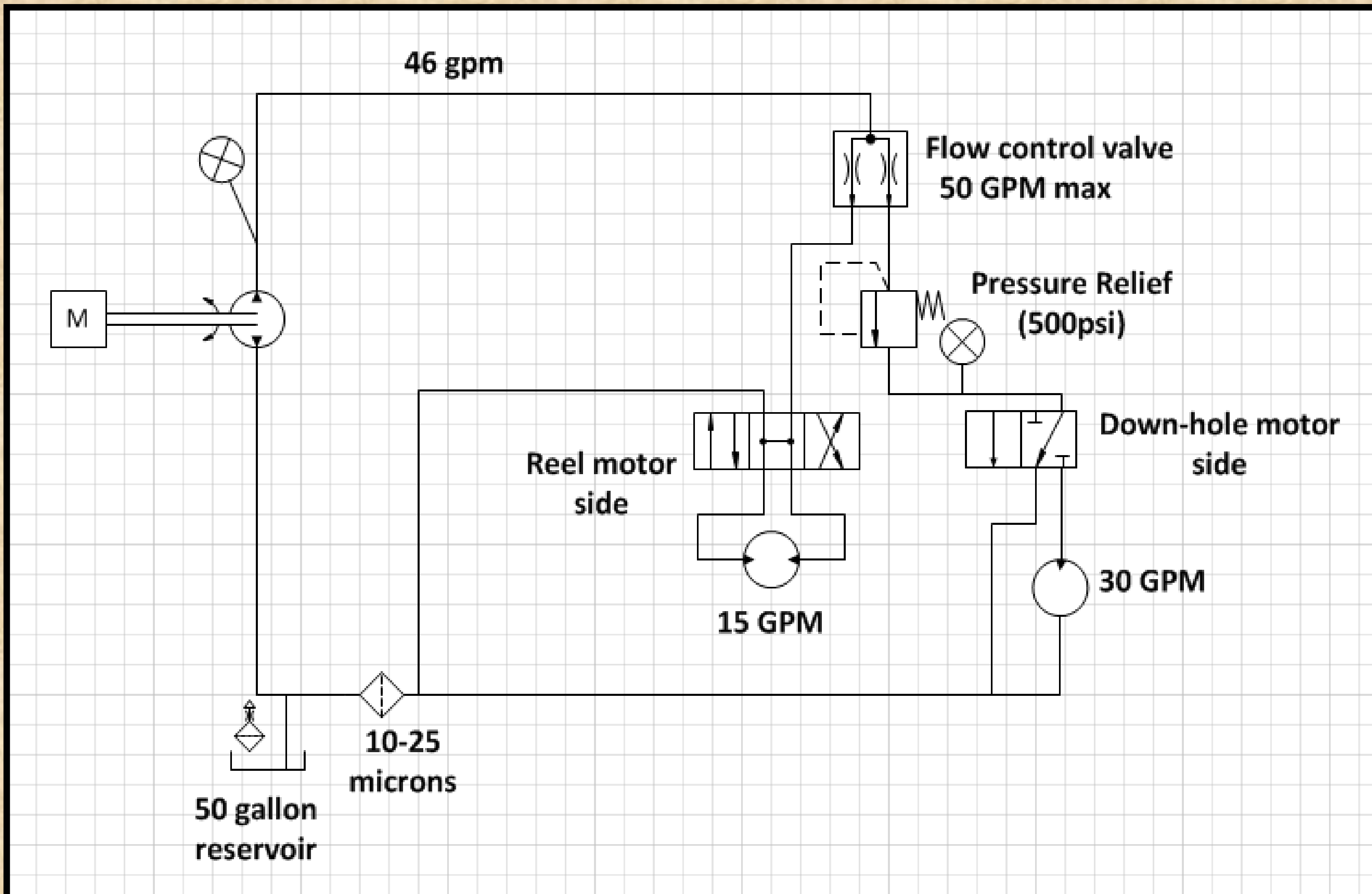


Telescoping Support

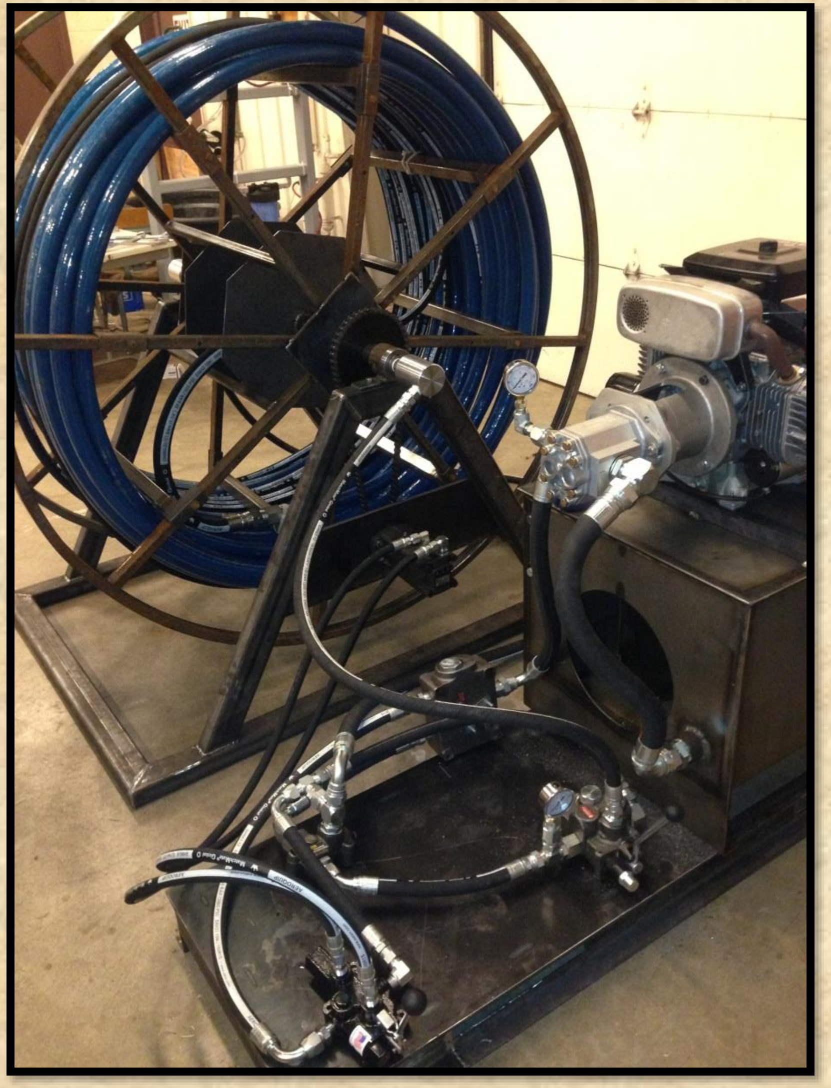
Challenges with Hydraulics

- 18 HP engine
- Hydraulic motor sizing
  - Large radius of reel combined with 300 lb load
  - High torque vs low RPM required (3:1 reduction)
- High flow vs low pressure and low flow vs high pressure in hydraulic system
  - 30:70 Flow control valve

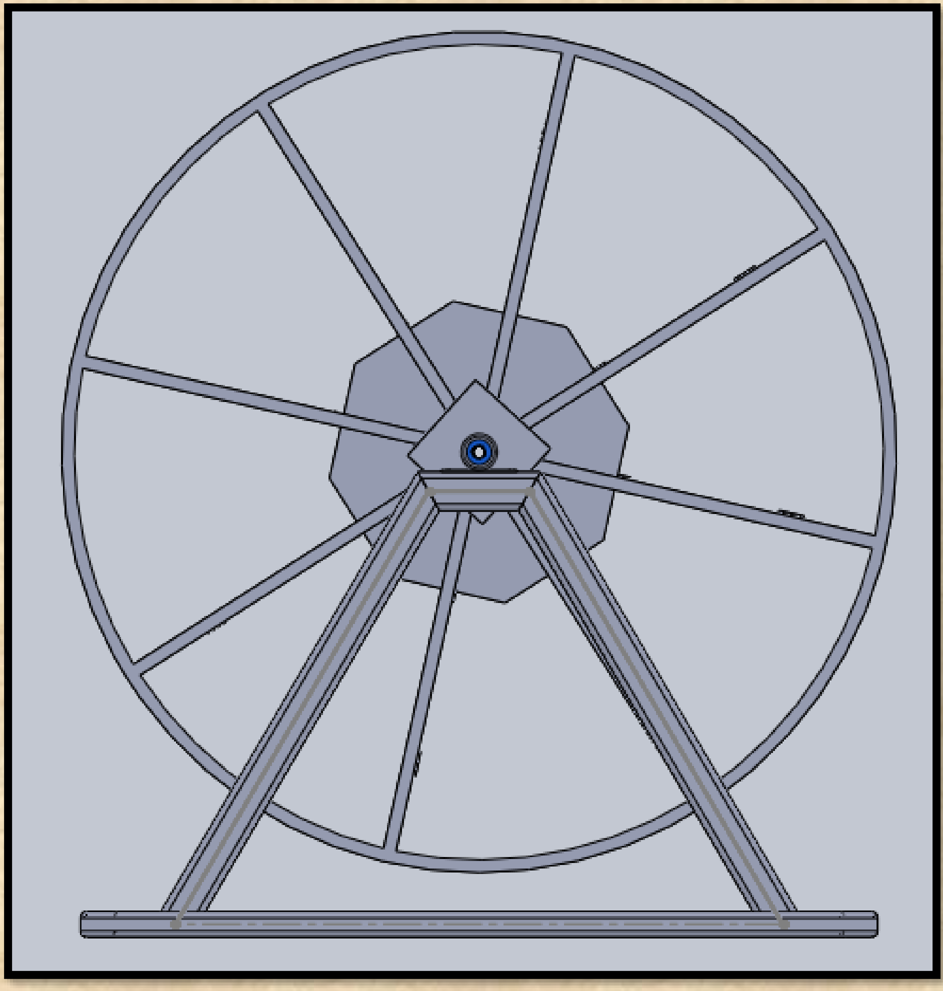
Hydraulic Schematic

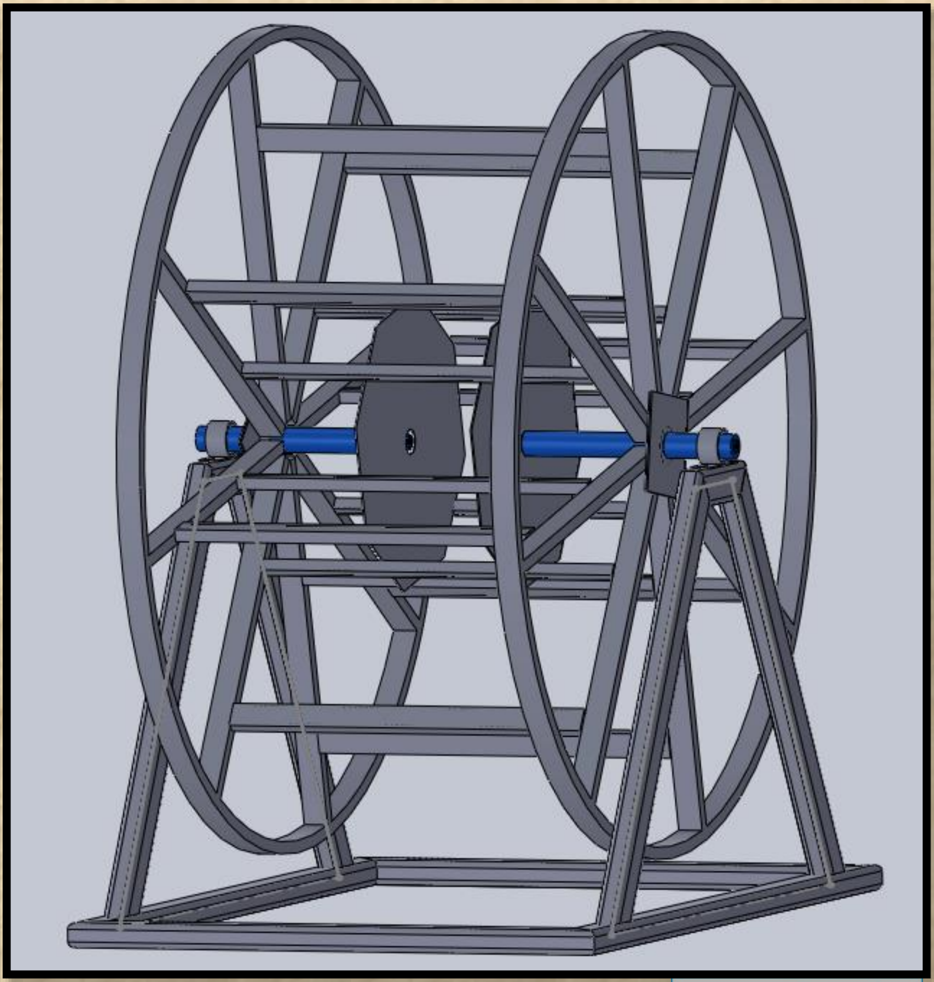


Hydraulic System



Reel Stand Drawing

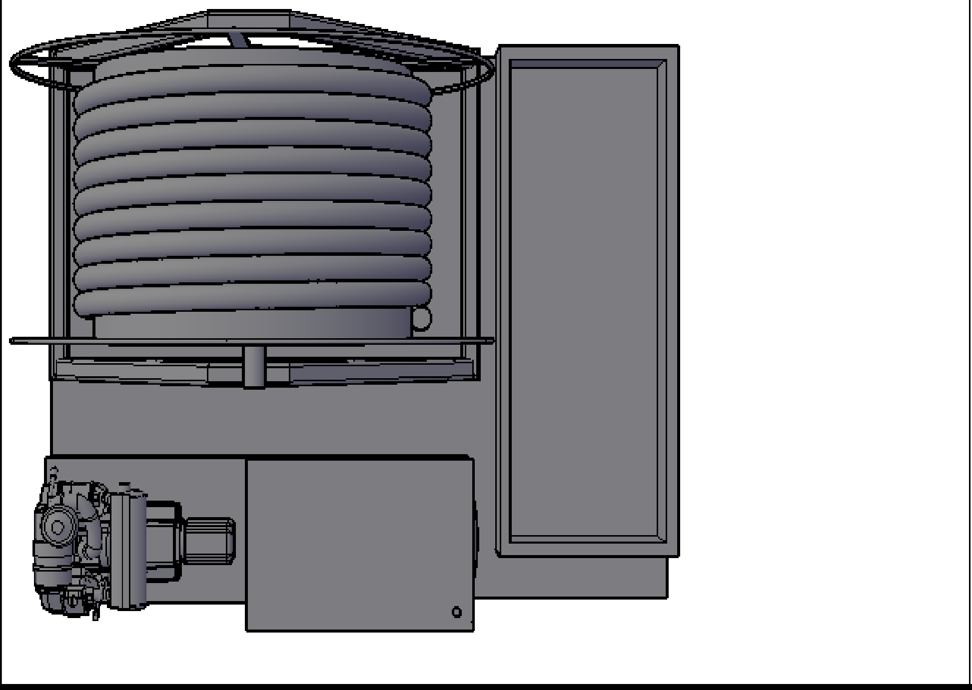


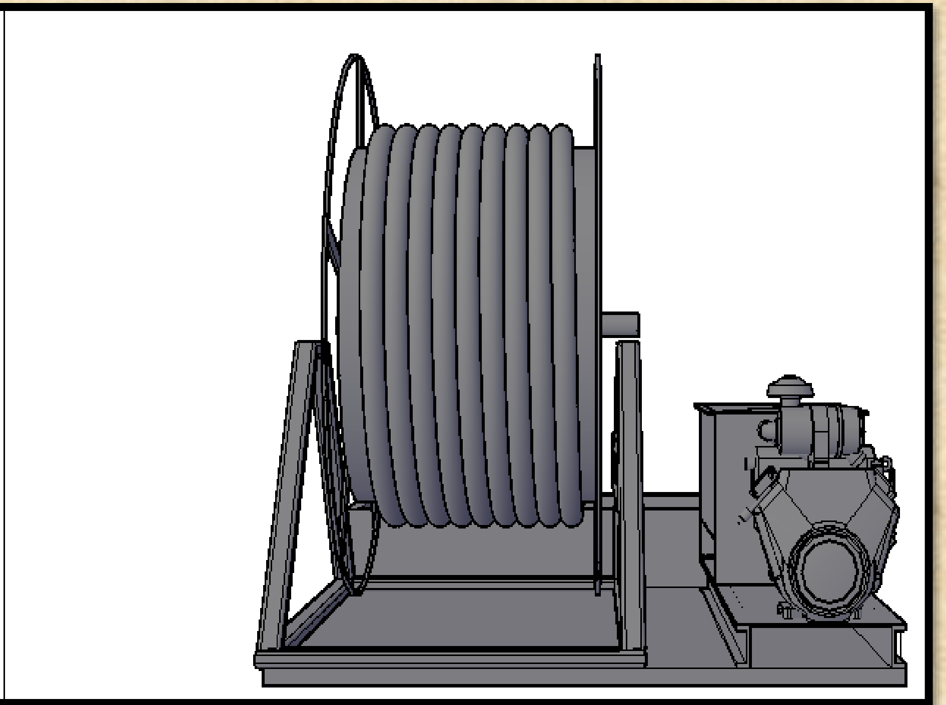


H2OASIS INNOVATIONS

Reel Stand

Flatbed Assembly Drawing

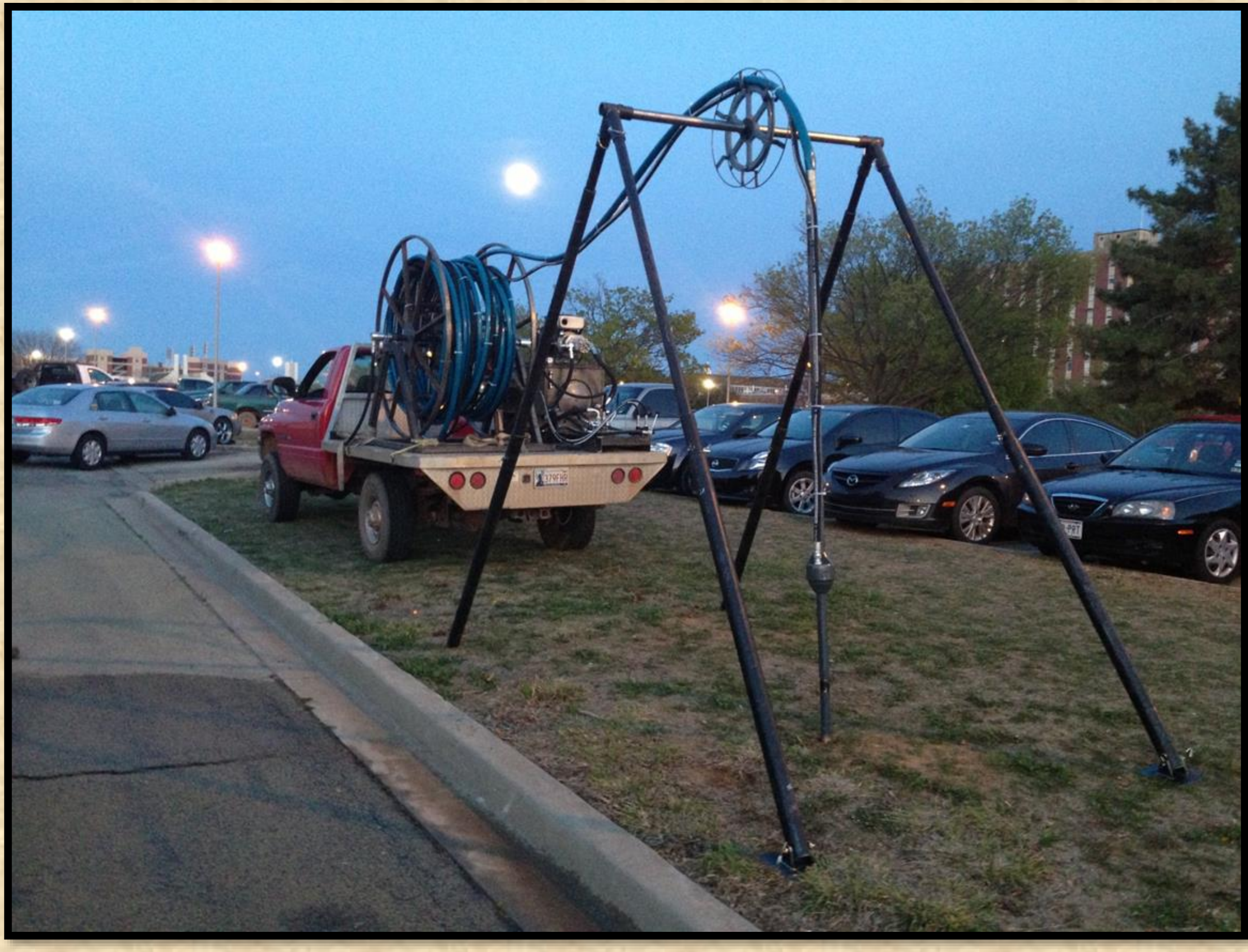




Flatbed Assembly

Testing

- Proof of concept
- Demo Application



Financial Analysis

- $25,000 Budget
- Material cost totaled: $19,172*
- Donations: Hydraquip Distribution, Thru Tubing

Future Work

- Improve penetration
  - Upscale of Demo
  - Add weight down-hole
  - 2-1/8’’ or 2-7/8’’ progressive cavity motor
  - Larger engine and pump for more flow
  - Modification to auger and drill simultaneously

Acknowledgments

- Wayne Kiner
- Dr. Paul Weckler
- Water4 Foundation
- ThruTubing Solutions
- Hydraquip Distribution
- Biosystems Shop and Crew
- Dr. James Hardin
- Dr. James Puckette
- Dr. Peter Clark

H2OASIS INNOVATIONS

Questions?

Design of a Down-hole, Rock Drilling System

Michael Chavez, Heath Hendricks,

George Tietz, Tyler Zimbelman

Contents

1. INTRODUCTION TO PROBLEM

Mission Statement

H_2Oasis Innovations is proud to support Water4 Foundation in their perpetual journey to find and obtain water in the most remote parts of the world. We focus directly on designing and building a water-well drilling contraption that will bore through any condensed rock layer discovered. The drilling task will be accomplished while providing: a safe experience for the user, customer satisfaction, and most importantly, clean water to the public. We at H2Oasis Innovations believe it is a fundamental obligation to assist a neighbor in need, and we will do everything in our power to accomplish this goal.

Problem Statement

H_2Oasis Innovations was presented with a problem of drilling through consolidated rock layers. We are focused on helping the world's clean water epidemic through the creation of a rock drill capable of reaching water sources cheaply and efficiently. This includes working with the Water4 Foundation in a joint effort to have a global impact through a common ground, clean water.

2. STATEMENT OF WORK

Scope

H2Oasis Innovations has been given the task of designing a rock drilling system for water well completion particularly in Africa. This design will be used as a solution for the Water4 Foundation in Oklahoma City, OK. Water4 is responsible for aiding several villages internationally in their search for clean drinking water. Water4 takes drilling kits overseas and teaches national hands to drill and complete water wells. This not only aids the individuals in sustaining life, but also creates jobs for thousands of people.

The biggest obstacle to overcome for Water4 is digging through rock layers with hand tools. Our design will allow the workers to complete wells in a much shorter time. This design needs to be convenient for worker use as well as achieving time efficiency. The finished product will have the ability to reduce the drilling time of an individual well by hundreds of hours.

Location

The majority of our work will be performed on the Oklahoma State University campus. We will utilize the computer laboratories provided by the Biosystems Engineering department as well as the machining shop. We will need to build and test our system in the BAE shop after designing detailed concepts on the computer using SolidWorks. Additional testing will also take place in various drilling sites around Stillwater, OK.

Period of Performance

H2Oasis Innovations plans to present design concepts on December 6, 2012 to BAE faculty and Water4 staff. Following design approval, we plan to begin acquiring material for project January 7, 2013. Once materials are purchased, construction will begin February 1, 2013. Final prototype will be tested and completed April 15, 2013.

Deliverables schedule

Date	Task	Deliver to:
29-Oct-12	SOW Due	Instructors
2-Nov-12	WBS Due	Instructors
5-Nov-12	Task list due	Instructors
12-Nov-12	Design concepts due	Instructors/Sponsor
19-Nov-12	1st draft report due	Instructor
6-Dec-12	Final presentation	Instructor
10-Dec-12	Web page due	Instructor
14-Dec-12	Self, peer and class evaluations due	Instructor

Acceptance Criteria

Quality – Water4 organization will base the quality of our work on the drilling outcome. We will have to maintain the integrity of the hole and drill through the rock without contaminating the water. If we can achieve these two goals, our system will be viewed as successful.

Time – The acceptable time criteria will be based on the material removal rate. Based on research of traditional drilling systems, our goal is to be able to remove an inch of material per minute. We will vary the flow rate of lubrication at the bit based on the material to achieve the highest material rate of removal. This will ensure the fastest drilling time through the rock.

Quantity – In order to achieve satisfactory acceptance criteria for quantity, our system will need to drill through multiple hole sites before needing repair or non-typical maintenance. We estimate standard maintenance will take place approximately every ten holes. Meeting these criteria will ensure optimum drilling performance while maintaining an acceptable budget.

3. TASK LIST

H_2Oasis Innovations has developed a task list to meet our deliverables schedule. We have listed these tasks thoroughly in the work breakdown structure found in Appendix B.

4. MARKET RESEARCH

Value Proposition

For Water4 Foundation

The project design will allow Water4 Foundation's partners to drill in more locations; therefore, they will be more efficient in providing access to safe drinking water in the developing world. A main concern for Water4 and other non-profit organizations is finding an inexpensive and sustainable method for drilling through rock layers so that they can extend their service to a greater number of people.

For Society

It is estimated that in 2008, there were 884 million people who did not use improved drinking water sources; 37% of whom lived in Sub-Saharan Africa. At the current rate of progress, 672 million people will not use improved drinking water sources in 2015 (UNICEF & WHO 2011). The main value proposition our project design will help to achieve is direct savings in terms of both money and time for people in the developing world. According to UNICEF, machine drilled wells are very high in quality, but also very expensive. The cost of a machine drilled well varies between countries and will generally be in the range of US$ 5,000 – 15,000 for a 30-meter deep well (UNICEF, 2009). What we suggest is implementing a transportable and easy-use drill machine that allows users to go as deep as they want, going through rock layer as well at an affordable price for Water4's partnerships around the world. By doing this, we can improve our partnerships' capacity to create sustainable jobs and empowering communities in developing countries.

According with Water Wells for Africa, in-terms of direct economic reward, every dollar invested in water and sanitation yields a $9 return. Also, in Sub-Saharan Africa, 68% of the rural population lost between 1 and 3 hours per day collecting insufficient, contaminated water (Water Wells for Africa, 2012). Data from 45 countries reveals that in 12% of households children carry the responsibility of collecting water (UNICEF & WHO 2010). Our mission represents health improvements for communities, time savings for families so they can focus more on any other activities.

Industry Analysis

According to the North American Industry Classification System (NAICS), well drilling services are comprised in the industry code number 213111. This industry gather establishments primarily engaged in the construction of water and sewer lines, mains, pumping stations, treatment plants, and storage tanks. All structures (including buildings) that are integral parts of water and sewer networks are included in this industry (NAICS, 2012).

Development investment contributions committed to achieve water access are categorized under the local public sector, the local private sector, the international public sector, and the international private sector. Water4, as well as many other NGO´s are categorized under the international private sector; all these efforts have had important impacts in the water and sanitation sector. According to Newton (2011), in the mid-1990s, total annual investments in the water and sanitation sector in developing countries were approximately $28 billion. Of this, 65-70% was contributed by the local public sector, 5% from the local private sector, 10-15%, from international donors and NGOs, and 10-15% from the international private sector (Newton, 2011).

In contrast, total average aid commitments to water and sanitation in 2009-2010 reached $8.3 billion. Of this, 70.98% (or $5.8 billion) was contributed by OCDE Development Assistant Committee (DAC) countries. The bilateral providers of development assistance in 2009-10 were as follows:

- Japan (on average $2.3 billion per year)
- Germany ($802 million)
- France ($652 million)
- 27.08% (or $2.2billion) was contributed by multilateral agencies.

The multilateral providers were as follows:

  - International Development Association - $475 million
  - EU institutions - $618 million
  - Asian Development Foundation - $297 million
  - African Development Foundation - $244 million
  - Arab Foundation - $91 million
  - UNICEF - $47 million
  - The remaining 0.012% is attributed to NGO´s in which Water4 is aggregated.

Market Analysis

Target market

Water4's market includes of a number of organizations and businesses with which Water4 partners in about 30 countries - mainly in Africa and Latin America. Some of Water4's partners are U.S. or U.K. mission organizations, some are NGO's, and some are natives of the areas who wanted to start a business that would provide for their families while working for the good of their communities. Water4 estimates that one out of five wells started by their partners have been abandoned due to rock layers through which they did not have the ability to bore.

Water4 could potentially expand to include other partners and countries. In the next section, we will discuss the areas the new drilling system would be most likely to succeed.

The following table shows the countries to which Water4 has been and the number of partners they have in each place.

Water4 Partners – Tables and Map

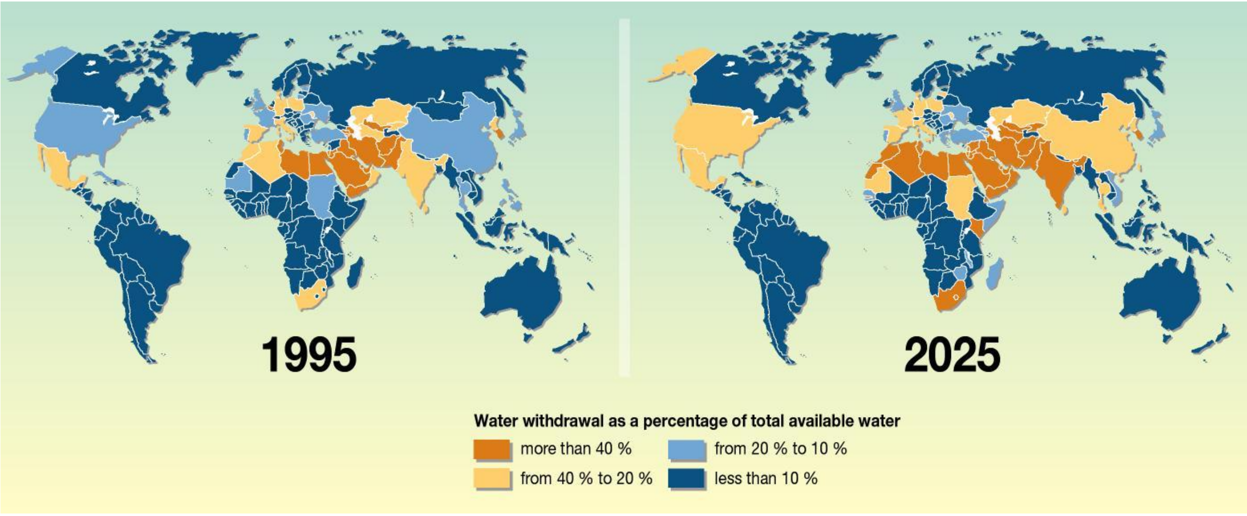
Via email correspondence with Water4's Project Manager (Appendix B)

Country	Full Time Teams	Part Time Teams	Inactive
Angola	10		
Brazil			X
Chile			X
China			X
Ecuador			X
Ethiopia		4	
Ghana	10	1	
Guatemala		1	
Guinea		1	
Haiti		2	
Honduras			X
Kenya	1		
Malawi		1	1
Mali	10		
Nepal		1	
Nicaragua		2	
Niger	10		
North Korea			X
Peru			X
Rwanda	2		
Sierra Leone	1		
South Sudan			X
Togo	1		
Uganda	2	5	
Zambia	1	1	
Totals	48	19	

Target Market – Drilling System

Hydrologists typically assess scarcity by looking at the population-water equation. An area is experiencing water stress when annual water supplies drop below 1,700m^3 per person. When annual water supplies drop below 1,000m^3 per person, the population faces water scarcity, and below 500m^3 is considered "absolute scarcity". Countries located both in the Maghreb and Middle East zone experience huge water withdrawals as percentage of total renewable water. This is mainly due to water pressures in agriculture.

Map x: World water withdrawals as percentage of total renewable water



Source: UNEP. http://www.unep.org/dewa/vitalwater/article141.html

The following table shows some important facts about these North African countries. These locations have relatively high DGP per capita incomes, High Human Development Index, and relative high total Economically Active Population. Nonetheless, their water resources per capita are extremely low: these countries require deeper ground water wells and also they have economic sources to handle their needs.

Facts about Northern African countries in 2011

Rural population	Total economically active population	HDI	Country	Water resources: total internal renewable (Km^3/yr.)	GDP per capita (USD)	Water resources: total renewable per capita (actual) (m^3/inhab/yr.)
11,840,000	15,285,000	0.698	Algeria	11,250,000	$5,000	324.3
46,599,000	26,977,000	0.644	Egypt	1,800,000	$2,922	694.2
1,407,000	2,351,000	0.76	Libya	700,000	$10,872	109
13,281,000	11,965,000	0.582	Morocco	29,000,000	$3,161	898.6
3,424,000	3,993,000	0.698	Tunisia	4,195,000	$4,592	433.7

Source: FAO AQUASTAT http://www.fao.org/nr/water/aquastat/dbase/index.stm

On the other hand, there are several countries where water is available but they have neither the resources needed nor the capability to drill water wells. According to the World Bank (2012), there are several countries whose rural population barely has access to improved water sources. The more prominent ones are:

- Somalia (7% of urban population)
- Democratic Republic of the Congo (27%)
- Ethiopia (34%)
- Mozambique (29%)
- Madagascar (34%)
- Papua New Guinea (33%)
- Sierra Leone (35%)
- Republic of the Congo (32%)
- Afghanistan (42%)

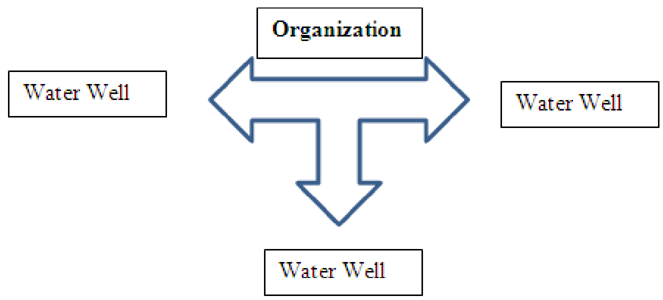
Even though the need is evident in these countries, Water4 operates with local and international partnership networks in some specific areas mostly in the Sub Saharan countries. This partnership network in Sub-Saharan countries is consistent with the fact that rural access to safe drinking water in these areas needs to be improved. Also, the resources needed to buy our suggested product will need to enhance our partnerships to not specific water-related nonprofits.

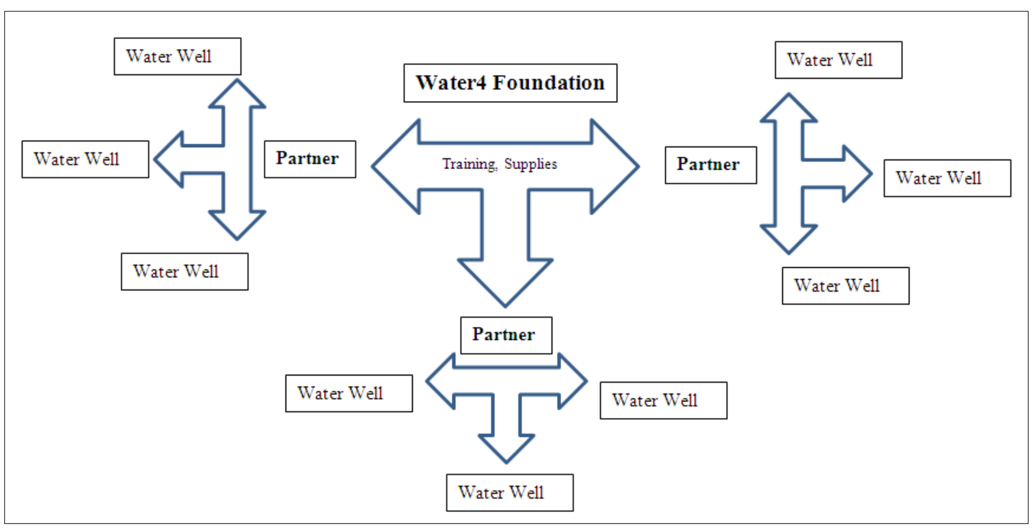
The Competition

The industry of charitable foundations offering access to clean water in rural areas is diverse. The "competition" varies greatly in method and costs Covof operation. Other organizations with the same goal include The Water Project, Water.org, Lifewater International, Water Wells for Africa, and many others. All of them use different approaches and techniques, from the highly technologically advanced drilling units to smaller operations like Water4. Global Water offers a deep well with an electric pump in Africa for about $45,000. A deep well drilled by Lifewater International will cost about $15,000. Water4, on the other hand, drills wells for about $900 with their hand-drilling methods. The expected budget for the new hydraulic drilling system being designed by the engineering team to drill deep wells is $25,000. However, this drilling system will be used more as a "hot-shot" crew which will be transported to each well that runs into a consolidated rock layer. Each drilling system is estimated to be used for approximately every 20 wells, greatly reducing the cost. For each well affected by this drilling system it would cost an additional $1,250 bringing the total for Water4 to approximately $2,150. This cost is still much cheaper than any other organizations methods.

Most other organizations working toward the goal of clean water for everyone collect donations to bring a drilling unit into an area that is lacking access to clean water. They will drill a well and then leave the community. Some of them start programs to educate and train the residents of the community on sanitization, hygiene, and how to maintain their well. Water4 uses a different approach. They find partners in the areas that need water and provide the equipment and training so that they can use those techniques in the future so that the number of wells drilled will multiply. The diagrams below represent the approach of Water4 Foundation compared to a typical charity drilling water wells.

Typical Charity





The following table summarizes the water well drilling costs for Water4 Foundation and some of the major players in this field.

Organization	Water4 Foundation	The Water Project	Water.org	Lifewater International	Global Water	Covenant Life Foundation	Water Wells for Africa
	Hand Drilling Costs:						
Per Person	$6	$20	$25		$10 / $15 / $90		
Per Family	$24/family of four	$100/family					
Per Pump	$200 per pump to serve hundreds	$1,500/hand pump					
Per Shallow Well	$900 per well for a village		$7,000-$30,000	$5,000	$2,500 hand dug, $7,500 drilled		
Other	$5,000 for a drill kit capable of drilling 50 wells	$500/classroom					
Per Deep Well	$2,150 expected for drilling system			$15,000	$45,000 with electric pump	$13,000	$7,000

The new drilling system will be faster and more powerful than Water4's current method for removing rock. The more advanced technology may be more difficult to maintain in areas where replacement parts or tools are hard to find. As it will be explained in the design section, maintenance cost of this new drill machine will be low and easy to replace.

Existing Products

DeepRock Manufacturing – Model M60

- TECHNICAL SPECIFICATIONS
    - 25 HP Diesel Engine
    - Hydraulic power rotation and feed control
    - Weight: 1850 lbs. (220 ft. of drill stem included)

- Gorman-Rupp mud pump
- 300 ft. capability.

- PROS
  - Proven design
  - Minimal physical requirements
  - Substantial depth capability
  - Hydraulic variability
- CONS
  - Heavy machine to set in the back of a truck
  - Expensive (Approximately $20,000)
  - Produced only for difficult soils
  - Minimal rock cutting ability
  - Requires significant water use for lubrication

Boremaster ZX-1000

Specifications

- Portable, Easy to move
- Kohler, Electric Start, Electronic Ignition, EPA Approve Engine
- 12 Volt Power Winch
- Belt Drive, high Torque Transmission
- High Powered Gasoline and Diesel Rigs

Pros

- Easy to maneuver and transport
- Simple design allowing cost to be more inexpensive than other similar products ($6245.00)
- Easy operation allowing no extensive training for operation

Cons

- Wheels are not sufficient for the type of terrain being transported in
- Is not designed to drill through rock
- Requires significant water usage to cut through material

Marketing Plan

Product

The product is going to be a hydraulic drilling system designed to bore through consolidated rock layers. It is described in more detail in the design section. The advantage of this product over hand-drilling is greater power and control than is possible with non-mechanized methods.

Promotion

Water4 should promote the new drill system by communicating directly with their existing partners and any new ones they might gain in the future. Demonstrations and field displays would gain group's interest and allow for improved visual understanding. They could also use their website and other related internet sites to get the word out to relevant organizations.

Price

The price of the hydraulic drilling system will be as low as possible, since Water4 is a non-profit organization. The expected production cost is estimated at approximately $20,000. Water4 would like to profit from the production of these systems so there will be a percentage increase in order to reach a selling price. Some organizations Water4 partners with will be able to afford this price, while others may not. Caleb Holsey, the Global Project Manager from Water4, said in our email correspondence that Water4 might be able to help out those with smaller budgets interested in purchasing the drill by reducing the cost, offering a payment plan, or even helping to raise funds. The key principle behind this drilling system is that it will be able to be used at multiple well drilling sites. This means that the organizations purchasing this equipment will be able to only purchase one drilling system for multiple different wells. This process will dilute the cost per well drastically making it a much more probable investment.

Place

The method in which Water4 distributes this product is fundamental to its success. Due to the amount of wells that this drilling system can reach and produce it will allow many of Water4's partners able to afford it. With this being said, there are many organizations with which Water4 could enter into a partnership that have the necessary funds to purchase the rock drill. For the few that can't, Water4 will be able to set up additional funding and payment plans.

Strategy

Water4 should promote the new drill design to their partners and emphasize the new abilities they will have to drill through consolidated rock. Whether these organizations are non-profits, missions, or for-profit enterprises, they are still motivated to bring clean water to as many people as possible. With a proper understanding of what the new drill will be capable of, the upside will be greater than the downside. Utilization of this system will allow them to reach more people in their communities who are suffering from lack of clean water.

5. DESIGN RESEARCH

H_2Oasis Innovations researched and analyzed the key components that would go into our system in order to be successful. Listed below is the analysis that we started with for this design project.

Design Analysis

Under the assumption the team decides to go with a fully hydraulic design using down-hole drilling system, the following calculations and information must be determined.

- What bit will be used
- Force applied to bit for most efficient cutting
- Most efficient bit rotational speed
- Torque applied to drilling stem caused by bit
- Torque required to properly size hydraulic motor
- Flow rate/pressure requirement of properly sized hydraulic pump
- Engine Power/Torque requirements to run hydraulic pump
- Drilling tower strength and weight distribution
- Material – Quartzite, Martensite and Dolomite. We had to consider the material compressive strength, density, and hardness rating.
- Bit - Design and function of the bit. Reverse clutch to help with grab and stall.
- Motor – 2 and 1/8 progressive cavity motor. 9 feet long. 100 pounds. Going with this motor will allow slower flow rates with the least amount of vibration reverberating through system.

What are similar items or solutions for your project problem?

There are a couple different solutions out there that deal with water well drilling. Most of these discuss drilling through dirt and mud, and not compressed layers of rock. They have good concepts to follow and items that could work with our problem. Most use hydraulics to drive the system. It would provide the best variability to ensure torque would be continuous and maximized. To reach the proper depth, we will use an oil rig system to feed the pipe down the hole and make connections for the sections we will need to use. Oil rig systems could solve our problem, but they would be too big and expensive to be a viable solution. There are downsized systems that are feasible, but are still very technical and expensive to own and operate. Integration of these ideas will bring about a rock drilling system that should yield the proper specifications we require.

What characteristics are technically possible but not included in existing products? Why?

One characteristic that is not included in existing products is the idea of making the solution completely mechanical. A jack could be used to pull/put the pipe into the ground, and a mechanical hammer drill that was driven by a hand crank could be used to do the actual drilling. Even though this design is plausible, it may not be efficient enough to meet material removal rate requirements.

Durability, reliability, maintenance costs and maintenance requirements

Drill bit – Depending on the type of material you're cutting through (in this case quartzite, dolomite, etc.) bits are replaced as needed.

Lubrication – Re-lubricating pipes, fittings, and engines are reapplied during every usage.

Fluids - Maintain fluid cleanliness as well as temperature to keep proper viscosity.

Parts - Schedule component change-outs to ensure parts do not fail.

Maintenance costs are relatively cheap and low cost. Requirements for maintenance would be proper lubrication and changing bits. It would also consist of replacing parts to ensure safety and reliability.

Are there safety issues that must be addressed?

Yes. There are definitely safety issues that must be addressed in this project, as well as almost every engineering project.

1) We must ensure that the well is not contaminated with anything that could be a potential harmful agent to a human being (motor oil, diesel, impure water).
2) Weight safety of the solution must also be considered.
3) Exposed moving parts in the system mechanically must be shielded to protect operators.
4) Using a hydraulic system we must have safety relief valves in place to ensure pressure does not build up causing injury.

Patents

Drilling Machine for Drilling Holes in Rocks (See Appendix A) - The relevance of this patent is to observe the early concept of a truck mounted drilling system with a vertical design and stand. This will let us better understand our mounted system without infringing on their technology. Patent date was January 21, 1992.

Telescopic Rock Drill Feed (See Appendix A) - We used this design patent to determine a way to add addition pipe segments while drilling. This patent gives us a better idea and vision of sending oil rig pipe down a vertical hole to drill through rock. Patent date was April 3, 1974.

Drill Rig Assembly (See Appendix A) - Relevant for the use of a truck mounted system with a lifting mechanism attached to a drilling rig. Drawings of a vertical system will give us a good vision of where to go in our early stage design concepts. Patent date was July 3, 1990.

6. PRODUCT SPECIFICATIONS

The Water4 Organization out of Oklahoma City, Okla. has requested a rock drilling system with the following specifications: maximum system weight of 2,250 pounds; hole drilling capability of 6 inches in diameter and 60 inch depth. We were instructed to research and test a rock drill bit as well as the size of engine necessary to run our hydraulic pump and motor. Our design will need to have custom gearing to increase the torque. Also, Water4 would like total materials cost to be below $25,000.

7. CUSTOMER REQUIREMENTS

The Water4 Foundation has asked H_2Oasis Innovations to produce a rock drill with the following requirements:

1. Capability to drill through rocks such as quartzite, granite and others.
2. Material costs should not exceed $25,000.
3. Entire unit must weigh below the payload capacity of commonly found pickups. (Approximately 2,000 pounds)
4. Unit must be capable of drilling through aforementioned rock up to 7 inches in diameter and 10 foot deep.
5. Pneumatic or hydraulic system.
6. If hydraulic, oil must be food grade.
7. Drill bit cannot be lubricated.

Above were the specific requirements presented to H_2Oasis Innovations. These requirements must be made, but there were also multiple preferences voiced by Water4. These are listed below.

1. No drilling stems down-hole.
2. Gasoline powered system.
3. No air sent down-hole.
4. A bit recovery system requiring no joint disconnection.
5. Avoid the use of drilling mud.

8. DESIGN CONCEPT

Design 1: *Down-hole Motor with Coiled Tubing Setup*

Our initial design concept was a high tech idea that is being utilized in directional natural gas drilling. We will construct our system on a trailer to improve mobility and expand the operating space. This design will feature a rock bit attached to a down-hole progressive cavity motor. The motor will be attached to a stabilizer to ensure a central contact point with the rock. The stabilizer will be connected to coil tubing that will run up and out of the hole. The tubing will be connected helically to a spool with a pump in place to transfer the hydraulic fluid to the progressive cavity motor. An engine will power the pump, providing constant flow rate and pressure. In order to handle tubing in and out of the hole with ease, we will feature a small motor attached to the spool. We will feature three sub-designs in relation to this system. We will be using a biodegradable hydraulic fluid down-hole to create rotation within our progressive cavity motor in sub-design one. The second sub-design will feature a glycol and water mixture. Our final sub-design will utilize water and air. Using these fluids will help preserve the integrity of the well in the case of a leak or rupture. Sub-design one, we will run a hydraulic return line up the hole starting at the rock bit connection to close the loop in our system. After this is done, we will be reusing all of the hydraulic fluid after it has passed through our cavity motor. Our design will also feature water for lubrication flowing out of the jets in the rock bit. This will be achieved by running a separate line down-hole that will be attached to our flexible tubing. It will be connected to the bit section just after the division created to return hydraulic fluid to the surface. We will exhaust the water through the bit face and provide a force to disturb the shavings in order to suspend them. This will be necessary to achieve a maximum material removal rate. Sub-design two will be very similar with the use of a glycol and water mixture instead of hydraulic fluid. This will be exhausted at the bit to provide lubrication and will need to be retrieved by a pump above the hole. Sub-design three will feature air driving the cavity motor and water to lubricate the bit. The air will be exhausted with a return line up the hole. This will prevent blowout or stalling. With these designs, we believe we will be able to drill through any form of consolidated rock layers that Water4 could see.

Parts included for Design:

- Drill Bit – Carbide Mills provided by Thru-Tubing Solutions. (See attached Appendix for spec sheet) Designs can include several features including:
    - Standard and reverse clutch
    - Flat, convex, or concave bottom
    - Tapered, step, string, or watermelon profiles
    - Crushed carbide, Star Cut carbide, or carbide inserts
    - Straight or Twister mill bodies

Figure 1- Carbide Drilling Mills

- Engine – We will use a Briggs and Stratton engine to provide our pump with the necessary power. (See Appendix for spec sheet)

Figure 2- Briggs and Stratton Engine

- Motor – Our system will feature a 2.13-inch progressive cavity motor provided by Thru-Tubing Solutions. It will be attached down-hole. (See Appendix for spec sheet)

Figure 3- Down-hole motor

- Pump – We have chosen to go with an Eaton heavy duty big ass pump.
- Reservoir – Decision to come after testing.
- Heat Exchanger – Decision to come after testing.
- Coiled Tubing – Our system will feature coiled tubing provided by PolyFlow Inc. Utilized for its tensile strength and ability to be reeled on a spool. (See Appendix)

Figure 4- PolyFlow tubing

- Stabilizer – The stabilizer that will be mounted above the motor in order to square up our system down-hole will be provided by Thru-Tubing solutions.
- Water Tank – Decision to come after testing.
- Hydraulic Hose – Eaton hydraulic hose. Size specifications to come in the spring.
- Hydraulic Fittings – Eaton fittings as well. Size specifications to come in the spring.
- Trailer – Decision to come in the spring whether or not to build or purchase.

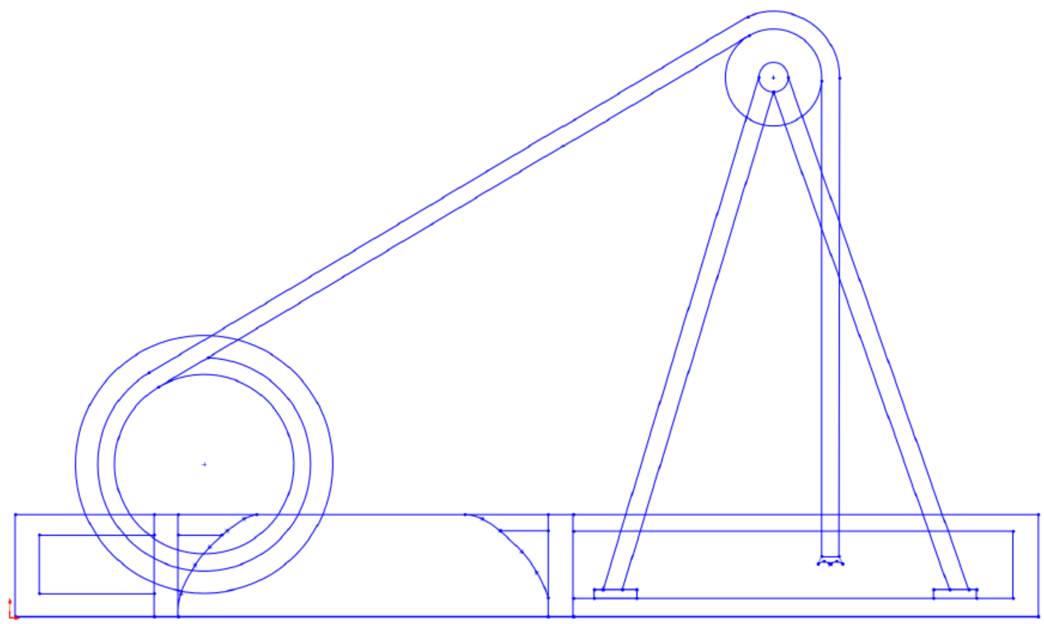


Figure 5: Rough Sketch of trailer mount with coiled tubing. Notice the swing-set design for stability. Our freshmen team has been given the task of designing the trailer so that the swing-set can be mobilized off of the trailer.

Design 2: *Conventional down-hole stem with motor at surface*

Our second design is going to feature a more traditional method of drilling. We will place the system on a trailer to improve mobility. Our system will feature an engine above the surface connected to a pump to achieve the necessary power input. We will use a hydraulic pump capable of pushing the required amount of fluid to our motor to provide fluid. This motor will then rotate drilling stem within the hole that will be attached to a bit at the surface of the rock layer. We intend to use the same carbide drilling mills as the previous design concept. This design will feature significantly more weight than Design 1 within the hole. With that said, we will have a tower stand and a smaller hydraulic motor to retrieve the stem and bit. The operator of the system will have to connect and send stem down within the hole in sections. The advantage of this design is a reduction in cost of the complete system. (Drawing to come)

Parts include for Design:

- Drill Bit – Carbide Mills provided by Thru-Tubing Solutions. (See attached Appendix for spec sheet) Designs can include several features including:
    - Standard and reverse clutch
    - Flat, convex, or concave bottom
    - Tapered, step, string, or watermelon profiles
    - Crushed carbide, Star Cut carbide, or carbide inserts
    - Straight or Twister mill bodies

Figure 6- Carbide Drilling Mills

- Engine – We will use a Briggs and Stratton engine to provide our pump with the necessary power. (See Appendix for spec sheet)

Figure 7- Briggs and Stratton Engine

- Motor – For this design, we will use a Char-Lynn 10000 Series hydraulic motor. It will be placed above ground and attached to our tower stand. (See Appendix for spec sheet)

Figure 8- Char-Lynn motor

- Pump – Our system will feature an Eaton heavy duty piston pump to achieve the required amount of flow.
- Reservoir – Decision to come in the spring after testing.
- Heat Exchanger – Decision to come in the spring after testing.
- Drill Stem – Decision to come in the spring after testing.
- Hydraulic hose – We will be using Eaton hydraulic hose for our system. Size specifications will come in the spring.

Figure 9- Eaton hydraulic hose

- Hydraulic connections and fittings – Eaton hydraulic fittings.
- Trailer – Decision to be made in the spring whether or not to build or purchase.

9. DESIGN ANALYSIS

In order to determine the appropriate hydraulic pump and motor design for the stem option, chart analysis and calculations had to be done. Through discussion with industry professionals, we assumed we would need approximately 1,500 pound-feet (18,000 pound-inches) of torque applied from the hydraulic motor. Knowing this, we went to Char-Lynn's line of hydraulic motors and found the 40.6 in^3/r, 10000 Series motor was the best fit. From this chart, we determined at over 18,000 in-lbs., our pump would be required to flow 12 gallons per minute at 3,000 psi as can be seen in Appendix C. Using this information, the 3.0 in^3/r was determined the pump of choice due to its availability and ability to produce both the pressure and flow needed to power the motor.

Using the power equation as can be seen in Appendix E and the "Rule of 1500" which states moving one gallon per minute with one horsepower will produce 1,500 psi, engine size was determined. As can be seen in Appendix D, 24 horsepower is capable of producing the 12 gallons per minute at 3,000 psi required to produce 18,000 lb.-in from the hydraulic motor.

10. BUDGET

Project Budget

Design concepts								
	Stem		ressive Cavity w/ water-glyc		sive Cavity w/ hydraulics an		gressive Cavity w/ air and w	
Component	Cost	Weight (lbs)	Cost	Weight (lbs)	Cost	Weight (lbs)	Cost	Weight (lbs)
Drill Bits (2)	$600.00	75.0	$600.00	75.0	$600.00	75.0	$600.00	75.0
Stabilizer	X	50.0	$250.00	50.0	$250.00	50.0	$250.00	50.0
Engine (31 hp)	$1,453.00	150.0	$1,453.00	150.0	$1,453.00	150.0	$1,453.00	150.0
Engine (16 hp)		-	-		-		-	
Hydraulic Motor	$1,590.00	100.0	-	-	-	-	-	-
Progressive Cavity Motor	-	-	$15,300.00	100.0	$15,300.00	100.0	$15,300.00	100.0
Stem/Coil Tubing	$3,480.00	1200.0	$235.00	38.0	$235.00	38.0	$235.00	38.0
Pump(s)	$2,000.00	60.0	$8,500.00	60.0	$1,493.00	60.0	$1,493.00	60.0
Connections	$2,000.00	100.0	$300.00	100.0	$300.00	100.0	$300.00	100.0
Trailer	$2,000.00	X	$1,700.00	X	$1,700.00	X	$1,700.00	X
Water Tank (Loaded)	$400.00	4172.0	$400.00	4172.0	$400.00	4172.0	$400.00	4172.0
Hydraulic/Air Hose	X	X	X	X	$3,500.00	90.0	$600.00	20.0
Air Compressor	X	X	X	X	X	X	$5,000.00	600.0
TOTAL	$12,923.00	5832.0	$28,738.00	4670.0	$25,231.00	4835.0	$27,331.00	5365.0

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Appendix A

United States Patent [19]
Brazell, II

[11] **Patent Number: 4,938,296**
[45] **Date of Patent: Jul. 3, 1990**

[54] **DRILL RIG ASSEMBLY**

[75] Inventor: **James W. Brazell, II**, Atlanta, Ga.

[73] Assignee: **Pacer Works, Ltd.**, Atlanta, Ga.

[21] Appl. No.: **256,699**

[22] Filed: **Oct. 12, 1988**

[51] **Int. Cl.**[5] **F21B 7/02**
[52] **U.S. Cl.** **173/22**; 173/28; 173/163; 173/164
[58] **Field of Search** 173/164, 2, 39, 43, 173/163, 22, 28

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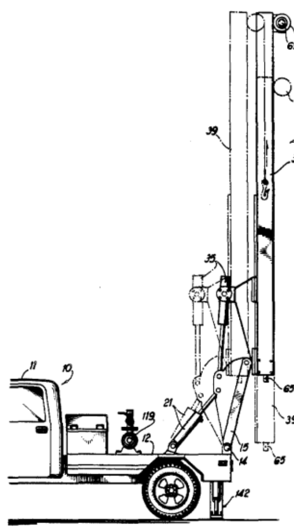
Primary Examiner—Frank T. Yost
Assistant Examiner—Willmon Fridie, Jr.
Attorney, Agent, or Firm—Hurt, Richardson, Garner, Todd & Cadenhead

[57] **ABSTRACT**

A drill rig assembly adapted to be mounted on a vehicle and having a pivotal link assembly mounted to the vehicle. Attached in slidable relationship to the link assembly is a mast assembly containing feed means and rotary means fully enclosed within the mast assembly. An electronic level within the mast assembly automatically maintains the mast assembly in a predetermined, angular position. The drill rig assembly is capable of drilling either vertically or at selected, incremental angles. The drill rig assembly is designed to be safe in operation and lightweight, while providing performance characteristics of larger drill rigs.

18 Claims, 8 Drawing Sheets



US005082068A

United States Patent [19]

Cornell

[11] **Patent Number: 5,082,068**

[45] **Date of Patent: Jan. 21, 1992**

[54] **DRILLING MACHINE FOR DRILLING HOLES IN ROCKS**

[75] Inventor: **Ron A. Cornell**, Hastings, N.Y.

[73] Assignee: **Syracuse Utilities, Inc.**, Brewerton, N.Y.

[21] Appl. No.: **491,544**

[22] Filed: **Feb. 23, 1990**

[51] **Int. Cl.**[5] **E21B 7/02**

[52] **U.S. Cl.** **173/22**; 173/28; 173/39

[58] **Field of Search** 173/22, 28, 163, 164, 173/39, 43, 104

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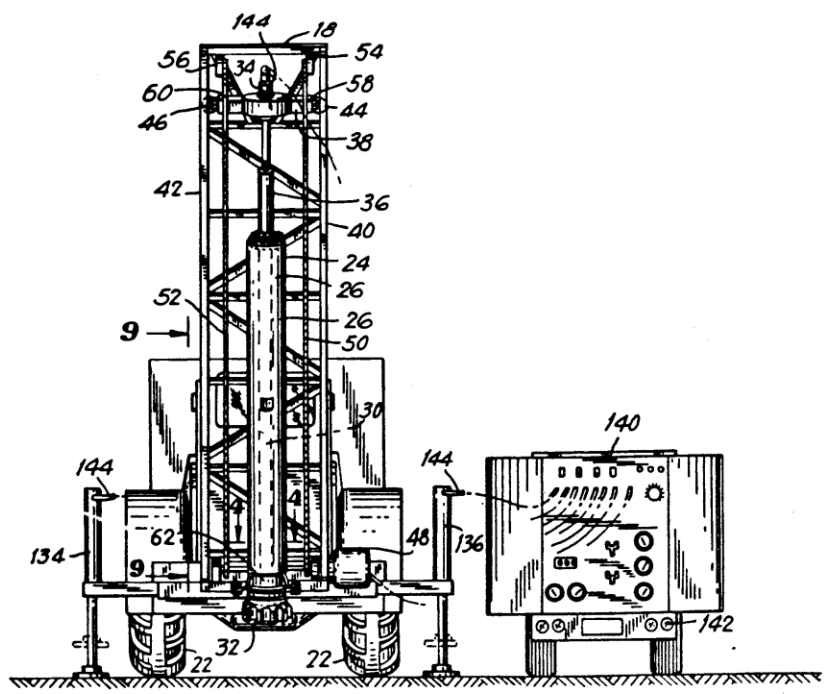
Primary Examiner—Timothy V. Eley
Assistant Examiner—Willmon Fridie, Jr.
Attorney, Agent, or Firm—Kane, Dalsimer, Sullivan, Kurucz, Levy, Eisele and Richard

[57] **ABSTRACT**

A truck-mounted rock drilling machine for pole holes consists of a pivotable boom mounted on the truck bed and a jack-hammer-like mechanism mounted on the boom. The jack hammer like mechanism is driven from a compressor which is preferably mounted on a separate trailer.

11 Claims, 7 Drawing Sheets



United States Patent [19]

Boom et al.

[11] **3,880,244**

[45] **Apr. 29, 1975**

[54] **TELESCOPIC ROCK DRILL FEED**

[75] Inventors: **Clarence O. Boom**, Littleton; **Laurence B. Hanson**, Pine, both of Colo.

[73] Assignee: **Gardner-Denver Company**, Quincy, Ill.

[22] Filed: **Feb. 4, 1974**

[21] Appl. No.: **439,516**

Related U.S. Application Data

[62] Division of Ser. No. 315,055, Dec. 14, 1972, Pat. No. 3,807,510.

[52] **U.S. Cl.** **173/19**; 74/841; 408/11
[51] **Int. Cl.** **E21c 5/02**
[58] **Field of Search** 173/19, 21, 147, 160; 408/10, 11, 12; 74/841

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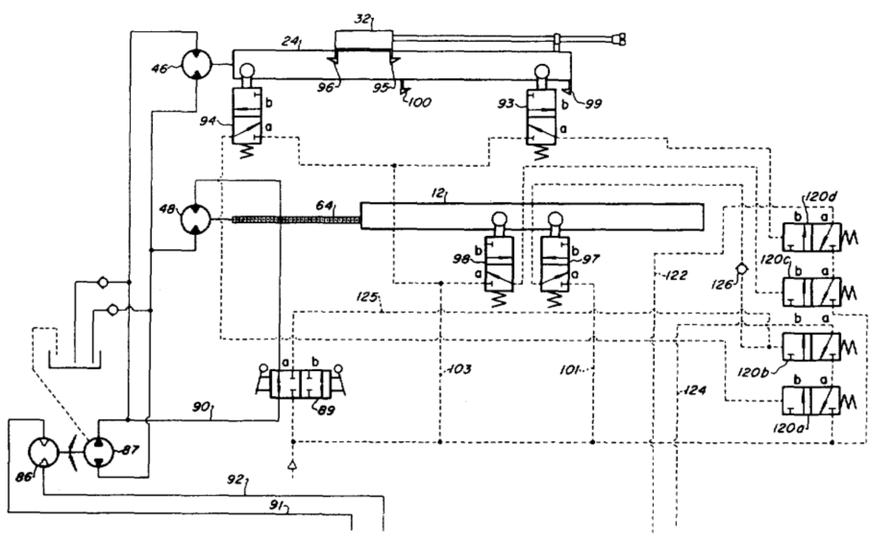
Primary Examiner—Ernest R. Purser
Attorney, Agent, or Firm—M. E. Martin

[57] **ABSTRACT**

A rock drill feed mechanism in which a drill motor is reversibly driven along a guideway by a rotatable power screw. The guideway is slidably mounted on an elongated support for reversible movement therealong by a second power screw mounted on the guideway. The power screws are driven independently by fluid motors and may be selectively controlled to operate the feed mechanism in a telescoped condition for movement of the drill motor alone or movement of the drill motor and the guideway to extend the useful feed length. A control circuit includes sensing devices for determining when the feed mechanism is fully telescoped or fully extended for reversing and shutting off the drill motor, respectively.

5 Claims, 7 Drawing Figures



Appendix B

WBS 1.0 – Design Down-hole Rock Drill

Design a drilling system to successfully go through hard rock encountered when digging water wells.

1.1 Drill bit interface

Analyze and reverse engineer the necessary requirements present at the face of the rock material.

1.1.1 Material of drill bit

Test and determine the proper classification of bit to be utilized in our system. Design based on thermal resistance, hardness, cutting efficiency, and lifespan of bit.

1.1.2 Calculate dimensions

Determine a recommendation for bit size based on diameter, boring capability, and blade dimensions.

1.1.3 Inlet and outlet

Test and analyze flow into the drill bit as well as the lubrication jet outlets. We will test the speed of the fluid flow, the efficiency at different flow rates, and the capability as it relates to material removal rates.

1.2 Motor

Determine the amount of rpms this motor will have to allow the drill bit to be effective. Also determine the down force needed.

1.2.1 Dimensions

Measure the outside diameter of the motor to determine the appropriate clearance for the casing in the hole. We will also be measuring the efficiency of the motor which will allow us to determine the necessary torque and down force needed to power the drill bit.

1.2.2 Specifications

The determination of the viscosity limitations and pressure requirements will be evaluated. We will assess the necessary spec sheets and run tests to determine this.

1.2.3 Modifications

The stem will need to be modified in order to allow for multiple inlets and outlets. The motor will need one inlet/outlet pair for the pumping oil and another inlet/outlet pair for the drilling mud.

1.3 Coil tubing setup

Coil tubing will be needed in order to deliver the necessary fluids down the hole. It will also be used to extend and retract the drilling mechanism down hole.

1.3.1 Length

1.3.2 Material

Determine the pressure requirements that the fluids and tensions will apply to the tubing. Calculate and measure the appropriate dimensions for down hole deliverance.

1.3.3 Thickness

The thickness of the coil tubing will need to be determined in order to evaluate proper diameter and pressure requirements. Different materials will be researched to determine which thickness will be most optimal.

1.4 Trailer mount

The trailer mount will need to be one that allows ease of transportation in rough terrains. It will also have certain modifications and specifications that allow for the drilling system to operate and transport.

1.4.1 Type of Trailer

The trailer type will be determined by the size of the drilling system. This will also determine the weight limit that the trailer will have.

1.4.2 Modifications

The necessary modifications will be to have a maneuverable hitch to allow for easy transportation through tougher terrains. The trailer will also have a center hole for the drill to move through.

1.5 Hydraulic pump and motor setup

Determine the type of pump to deliver the appropriate fluid flow requirements for the pump to operate effectively.

1.5.1 Type of pump and motor

The pump and motor requirements will involve proper power and rpm calculations in order to properly remove an acceptable amount of rock. The type of fluid being used in the motor and pump will also necessitate calculations.

1.5.2 Specifications

The weight, size, hip, etc. will be determined in order to choose the best fit motor and pump.

1.6 Interface

We will be collaborating and testing the best possible means of making the most effective and efficient down hole drilling system.

1.6.1 Efficiency

1.7 Project Management

Time evaluation and project distribution will be the main milestones that determine the flow of our project management.

1.7.1 Time efficiency

In order to effectively complete our project in a timely fashion, time efficiency is a key factor in our project that will be followed to the highest precision.

1.7.2 Project distribution

Our group must maintain high communication in order to sustain high production efficiency.

WBS 2.0 - Documentation

Proper documentation must be taken in order to produce fluid and organized maintenance of our project.

2.1 Drafting

Drafting will be done for every aspect of our project with multiple variations and prototypes.

2.1.1 Dimensions

Dimensions are all standard sizes and are calculated for every part in our assembly.

WBS 3.0 – Engineering Review and Approval

All aspects of the down hole drilling system will be reviewed and approved.

3.1 Review and Approve Engineering

We will have meeting to evaluate the engineering of the project and review all of the designs.

3.2 Review, approve, and finalize drawings

We will review all finalizations of the project and have meetings to verify all designs.

WBS 4.0 – Fabricate and Procure System Materials

All materials will be obtained in a timely fashion and will be chosen with detailed specifications. Materials that are in need of customization and fabrication will also be done in a timely fashion.

4.1 Procure Materials

All materials will be obtained in a timely fashion and will be chosen with detailed specifications.

4.1.1 Main Materials

Certain materials will be acquired by Water4 while all other main materials will be purchased from companies and manufacturers.

4.2 Fabricate trailer mount and any assemblies needed

All fabrications needed will be done in a timely fashion and will be done with safety being the first priority.

4.2.1 OSU BAE Shop

Most fabricating will be done at the BAE design Shop

4.2.2 By Stock parts and modify them as needed

Parts in need of fabrication will be purchased as stock parts and then modified to necessary design configurations.

WBS 5.0 – Integration of System

All parts will be assembled in the most efficient location to provide maximum effectiveness.

5.1 Populate Trailer

All parts on the trailer will be assembled for both maximum operational efficiency and transformational efficiency

5.1.1 Part Location

All parts will be located for maximum assembly and disassembly efficiency.

5.2 Integrate Hydraulic Components

Hydraulic components will be located to perform at optimum levels.

5.2.1 Specifications

Size and other specification requirements will be taken into account for location position.

5.2.2 Order of assembly

The order of part assembly will be taken into account for location position. This will allow for ease of access and maximum time efficiency.

5.2.3 Evaluation

Total evaluation of the integration of the system will be determined in order to produce the most efficient design.

5.3 Functional Checks

Functional check will be administered in order to produce the ideal down hole rock drilling system.

5.3.1 Troubleshooting

Multiple troubleshooting evaluations are anticipated and time is scheduled for such matters to make the appropriate adjustments and predictions.

5.3.2 Finalization

The finalization of the project will be determined by the entirety of the group.

Appendix C

665 cm³/r [40.6 in³/r]
Pressure Bar [PSI]

Flow LPM [GPM]	[250] 15	[500] 35	[750] 50	[1000] 70	[1250] 85	[1500] 105	[1750] 120	[2000] 140	[2250] 155	[2500] 170	[2750] 190	[3000] 205	[3250] 225	[3500] 240	[3750] 260
[1] 3,8	[1470] 165 4	[3010] 340 3	[4550] 515 3	[6100] 690 2	[7630] 860 1										
[2] 7,5	[1480] 165 10	[3020] 340 9	[4560] 515 8	[6110] 690 7	[7650] 865 7	[9200] 1040 6	[10740] 1215 5	[12280] 1385 4	[13830] 1565 3	[15370] 1735 2	[16910] 1910 1				
[4] 15	[1470] 165 22	[3010] 340 21	[4550] 515 20	[6100] 690 19	[7640] 865 18	[9190] 1040 17	[10730] 1210 16	[12270] 1385 15	[13820] 1560 14	[15360] 1735 13	[16900] 1910 12	[18450] 2085 11	[19990] 2260 10	[21540] 2435 9	[23080] 2610 8
[8] 30	[1440] 165 44	[2980] 335 43	[4530] 510 42	[6070] 685 41	[7610] 860 40	[9160] 1035 39	[10700] 1210 38	[12250] 1385 37	[13790] 1560 36	[15330] 1730 35	[16880] 1905 34	[18420] 2080 33	[19960] 2255 32	[21510] 2430 32	[23050] 2605 31
[12] 45	[1400] 160 67	[2950] 335 66	[4490] 505 65	[6040] 680 64	[7580] 855 63	[9120] 1030 62	[10670] 1205 61	[12210] 1380 60	[13750] 1555 59	[15300] 1730 58	[16840] 1905 57	[18380] 2075 56	[19930] 2255 55	[21470] 2425 54	[23020] 2600 53
[16] 61	[1360] 155 89	[2910] 330 88	[4450] 505 87	[5990] 675 86	[7540] 850 85	[9080] 1025 84	[10620] 1200 83	[12170] 1375 82	[13710] 1550 81	[15260] 1725 80	[16800] 1900 79	[18340] 2070 78	[19890] 2245 77	[21400] 2420 76	
[20] 76	[1310] 150 112	[2860] 375 111	[4400] 495 110	[5940] 670 109	[7490] 845 108	[9030] 1020 107	[10580] 1195 106	[12120] 1370 104	[13660] 1545 103	[15210] 1720 102	[16750] 1890 101	[18300] 2070 100	[19840] 2240 99		
[24] 91	[1260] 140 135	[2800] 315 134	[4350] 490 132	[5890] 665 131	[7440] 840 130	[8980] 1015 129	[10520] 1190 128	[12070] 1365 127	[13610] 1540 126	[15150] 1710 124	[16700] 1885 123	[18240] 2060 122			
[28] 106	[1200] 135 157	[2750] 310 156	[4290] 485 155	[5840] 660 154	[7380] 835 153	[8920] 1010 151	[10470] 1185 150	[12010] 1355 149	[13550] 1530 148	[15100] 1705 147	[16640] 1880 146				
[32] 121	[1140] 130 180	[2690] 305 179	[4230] 480 177	[5770] 650 176	[7320] 825 175	[8860] 1000 174	[10400] 1175 173	[11950] 1350 172	[13490] 1525 170	[15040] 1700 169	[16580] 1875 168				
[36] 136	[1080] 120 202	[2620] 295 201	[4160] 470 200	[5710] 645 199	[7250] 820 198	[8800] 995 196	[10340] 1170 195	[11880] 1340 194	[13430] 1515 193	[14970] 1690 191	[16510] 1865 190				
[40] 151	[1010] 115 225	[2550] 290 224	[4100] 465 222	[5640] 635 221	[7180] 810 220	[8730] 985 219	[10270] 1160 217	[11810] 1335 216	[13360] 1510 215	[14900] 1685 214	[16440] 1855 212				
[45] 170	[920] 105 254	[2460] 280 252	[4000] 450 251	[5550] 625 249	[7090] 800 248	[8630] 975 247	[10180] 1150 245	[11720] 1325 244	[13260] 1500 243	[14810] 1675 242					
[60] 227	[610] 70 338	[2150] 245 336	[3700] 420 335	[5240] 590 334	[6780] 765 332	[8330] 940 331	[9870] 1115 329	[11420] 1290 328	[12960] 1465 327						
[70] 265	[380] 45 396	[1930] 220 393	[3470] 390 391	[5010] 565 390	[6560] 740 388	[8100] 915 387	[9640] 1090 385	[11190] 1265 384							

[3470] } Torque [lb-in]
390 } Nm
391 } Speed RPM

Appendix D

	Pressure (psi)					
Flow Rate (GPM)	5 hp	10 hp	16 hp	24 hp	28 hp	31 hp
1	7500.0	15000.0	24000.0	36000.0	42000.0	46500.0
2	3750.0	7500.0	12000.0	18000.0	21000.0	23250.0
3	2500.0	5000.0	8000.0	12000.0	14000.0	15500.0
4	1875.0	3750.0	6000.0	9000.0	10500.0	11625.0
5	1500.0	3000.0	4800.0	7200.0	8400.0	9300.0
6	1250.0	2500.0	4000.0	6000.0	7000.0	7750.0
7	1071.4	2142.9	3428.6	5142.9	6000.0	6642.9
8	937.5	1875.0	3000.0	4500.0	5250.0	5812.5
9	833.3	1666.7	2666.7	4000.0	4666.7	5166.7
10	750.0	1500.0	2400.0	3600.0	4200.0	4650.0
11	681.8	1363.6	2181.8	3272.7	3818.2	4227.3
12	625.0	1250.0	2000.0	3000.0	3500.0	3875.0
13	576.9	1153.8	1846.2	2769.2	3230.8	3576.9
14	535.7	1071.4	1714.3	2571.4	3000.0	3321.4
15	500.0	1000.0	1600.0	2400.0	2800.0	3100.0
16	468.8	937.5	1500.0	2250.0	2625.0	2906.3
17	441.2	882.4	1411.8	2117.6	2470.6	2735.3
18	416.7	833.3	1333.3	2000.0	2333.3	2583.3
19	394.7	789.5	1263.2	1894.7	2210.5	2447.4
20	375.0	750.0	1200.0	1800.0	2100.0	2325.0
21	357.1	714.3	1142.9	1714.3	2000.0	2214.3
22	340.9	681.8	1090.9	1636.4	1909.1	2113.6
23	326.1	652.2	1043.5	1565.2	1826.1	2021.7
24	312.5	625.0	1000.0	1500.0	1750.0	1937.5
25	300.0	600.0	960.0	1440.0	1680.0	1860.0
26	288.5	576.9	923.1	1384.6	1615.4	1788.5
27	277.8	555.6	888.9	1333.3	1555.6	1722.2
28	267.9	535.7	857.1	1285.7	1500.0	1660.7
29	258.6	517.2	827.6	1241.4	1448.3	1603.4
30	250.0	500.0	800.0	1200.0	1400.0	1550.0
31	241.9	483.9	774.2	1161.3	1354.8	1500.0
32	234.4	468.8	750.0	1125.0	1312.5	1453.1
33	227.3	454.5	727.3	1090.9	1272.7	1409.1
34	220.6	441.2	705.9	1058.8	1235.3	1367.6
35	214.3	428.6	685.7	1028.6	1200.0	1328.6
36	208.3	416.7	666.7	1000.0	1166.7	1291.7
37	202.7	405.4	648.6	973.0	1135.1	1256.8
38	197.4	394.7	631.6	947.4	1105.3	1223.7
39	192.3	384.6	615.4	923.1	1076.9	1192.3
40	187.5	375.0	600.0	900.0	1050.0	1162.5

Appendix E

Hydraulic Power developed by the Pump

$$\boldsymbol{P = \frac{\Delta p * Q}{1714}}$$

P = Power (HP)

Q = Flow rate (GPM)

ΔP = Pressure differential

Hydraulic Power developed by the Motor

$$\boldsymbol{P = \frac{T * N}{5252}}$$

P = Power (HP)

T = Torque (ft.-lb.)

N = Rotational Speed (RPM)

Appendix F

H2OASIS INNOVATIONS

"Saving lives one drop at a time."

Down-hole Rock Drill

Michael Chavez **Heath Hendricks**

George Tietz **Tyler Zimbelman**

Mission Statement

H_2Oasis Innovations is proud to support Water4 Foundation in their perpetual journey to find and obtain water in the most remote parts of the world. We at H2Oasis Innovations believe it is a fundamental obligation to assist a neighbor in need, and we will do everything in our power to accomplish this goal.

water4 foundation

Empowering Communities One Well At A Time

- The Water4 Foundation is a public charity based out of Oklahoma City, Oklahoma.

- Founded by Dick and Terri Greenly.

- Water4 takes drilling kits overseas and teaches nationals to drill and complete water wells.

https://water4.org/about-us/

H2OASIS INNOVATIONS

Problem

- Consolidated rock layers within the borehole impede the water well drilling system from completion.
- Workers are left with either digging out the rock with hand tools or breaking through the layer using a cable tool system.
- These methods take days to remove the rock layer before workers can continue drilling.

H2OASIS INNOVATIONS

Cable Tool Method

A-frame for cable tool method

Bulldozer tooth and spike tooth are used to chip away rock layers

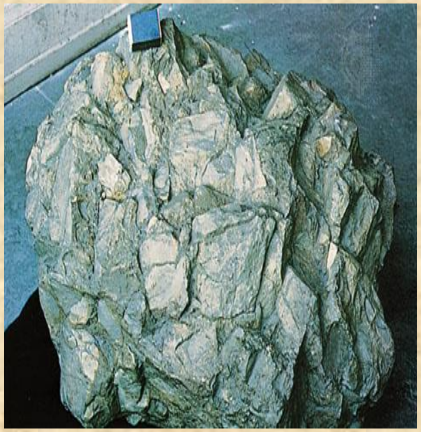
Objective

- Design a rock drilling system for water wells.
- Design budget is initially set at $25,000

H2OASIS INNOVATIONS

Client Requirements

- Must drill through material as dense as dolomite and quartzite
- Maximum depth of 150 feet
- Time efficient
- Easily Operable
- Able to be transported in rough terrain.



Quartzite
7 Mohs Hardness scale

Dolomite
3.5 Mohs hardness scale

H2OASIS INNOVATIONS

Constraints

- Materials and fluids cannot contaminate the surrounding environment
- Non-electrically powered
- Limited fluid resources

Standards and Regulation for Water Well Construction

- The code of practice was established by the Rural Water Supply Network (RWSN).

- Intended to be used as the foundation for the development of national protocols for cost-effective water well provision

- Ethiopia, Ghana, Nigeria, Niger, Mozambique, Burkina Faso and Zambia are among some who enforced the code.

Standards and Regulations

Code of Practice for cost effective Boreholes (Water Well Construction)

Figure 1: Scope and Focus of the Code of Practice

Business Competitors

- There are many organizations who are helping communities in there search for clean water.

(Covenant Life Foundation)

(Global Water)

Water4 vs. Competitor Drilling Cost

Organization	Water4 Foundation	The Water Project	Water.org	Lifewater International	Global Water	Covenant Life Foundation	Water Wells for Africa
	Hand Drilling Costs:						
Per Person	$6	$20	$25		$10 / $15 / $90		
Per Family	$24/family of four	$100/family	$100/family of four				
Per Pump	$200 per pump to serve hundreds	$1,500/hand pump					
Other	$5,000 for a drill kit capable of drilling 50 wells	$500/classroom					
Per Well	$2,150 expected for drilling system	$20,000		$15,000	$45,000 with electric pump	$13,000	$7,000

Current Methods

Pros

- Able to drill efficiently
- Use sophisticated equipment
- Self-sustaining rigs capable of drilling entire operations

Current Methods

Cons

- Too expensive for targeted clients to afford
- Not able to be transported in rough terrain

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Terrain

Ghana, Africa

Togo, Africa

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Products

DeepRock Manufacturing-Model M60

Pros

- Proven design
- Minimal physical requirements
- Substantial depth capability
- Hydraulic variability

Cons

- Produced exclusively for difficult soils
- Minimal rock cutting ability

Boremaster ZX-1000

Pros

- Easy to maneuver and transport
- Inexpensive
- Easy operation

Cons

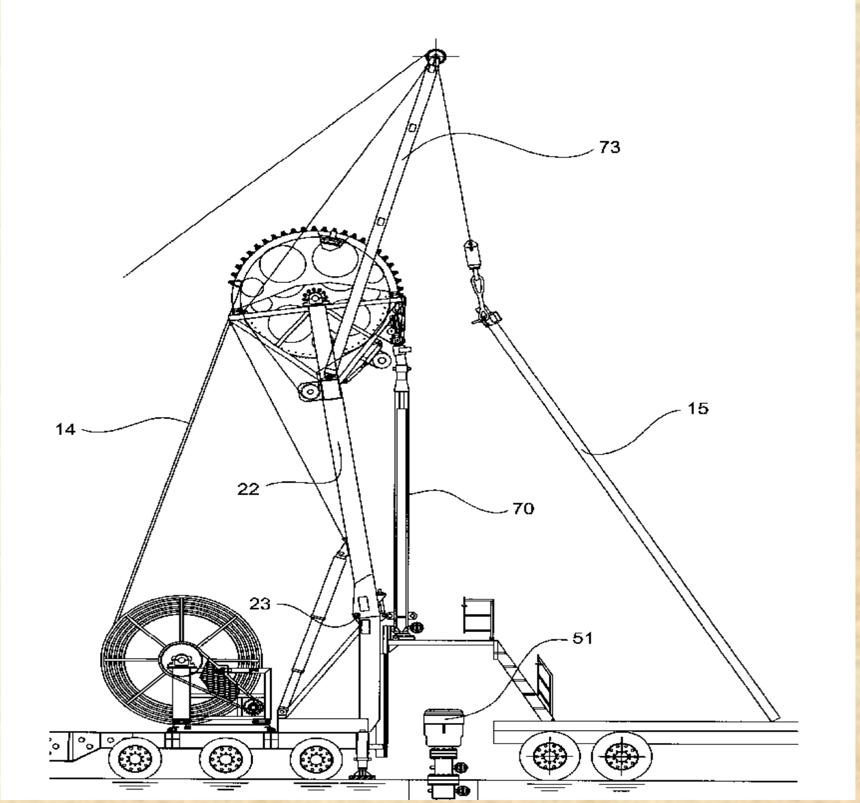
- Insufficient for rural African terrain
- Not designed to drill through rock

H2OASIS INNOVATIONS

Patents

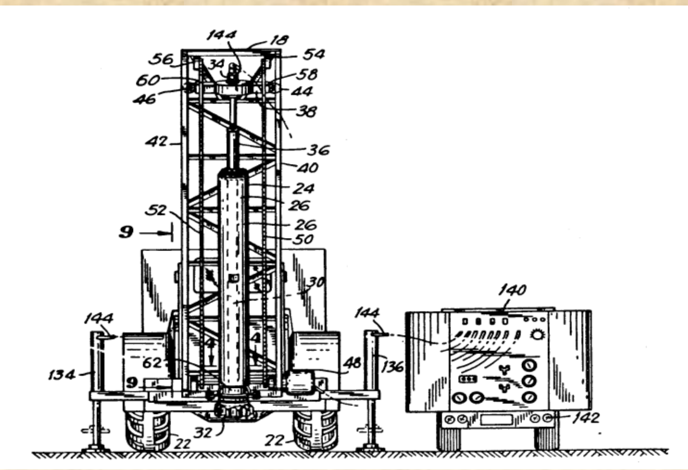
Coiled Tubing Drilling Rig

- Utilizes coiled tubing for down hole drilling
- Intricate design for deep well drilling



Patents

Drilling Machine For Drilling Holes In Rocks



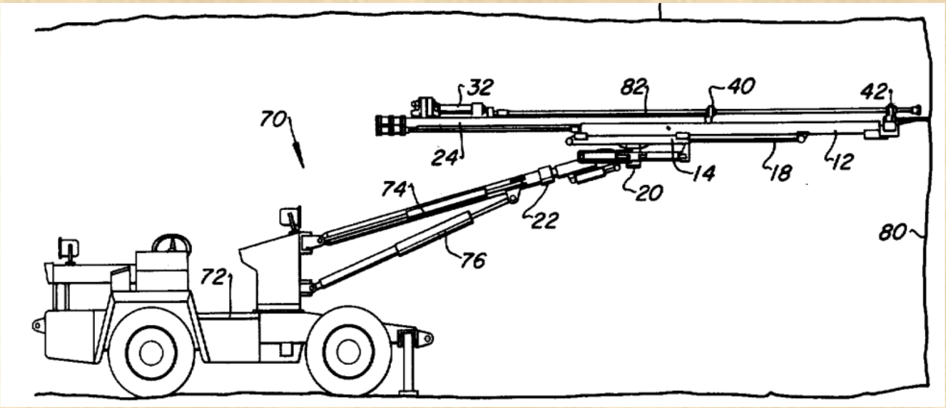
- A truck-mounted rock drilling machine for pole holes
- Consists of a pivotal boom mounted on the truck bed and a jack hammer like mechanism mounted on the boom
- The compressor which operates the jack hammer is mounted on a separate trailer

Patents

Telescopic Rock Drill Feed

- A drill feed mechanism in which a drill motor is reversibly driven along a guide way by a rotatable power screw.

- A control circuit includes sensing devices for determining when the mechanism is fully telescoped.



Design Analysis

- Innovative design
- Potential marketability for Design4
- Present demand

Design 1: *Progressive Cavity Motor with Coiled Tubing*

Progressive Cavity Motor

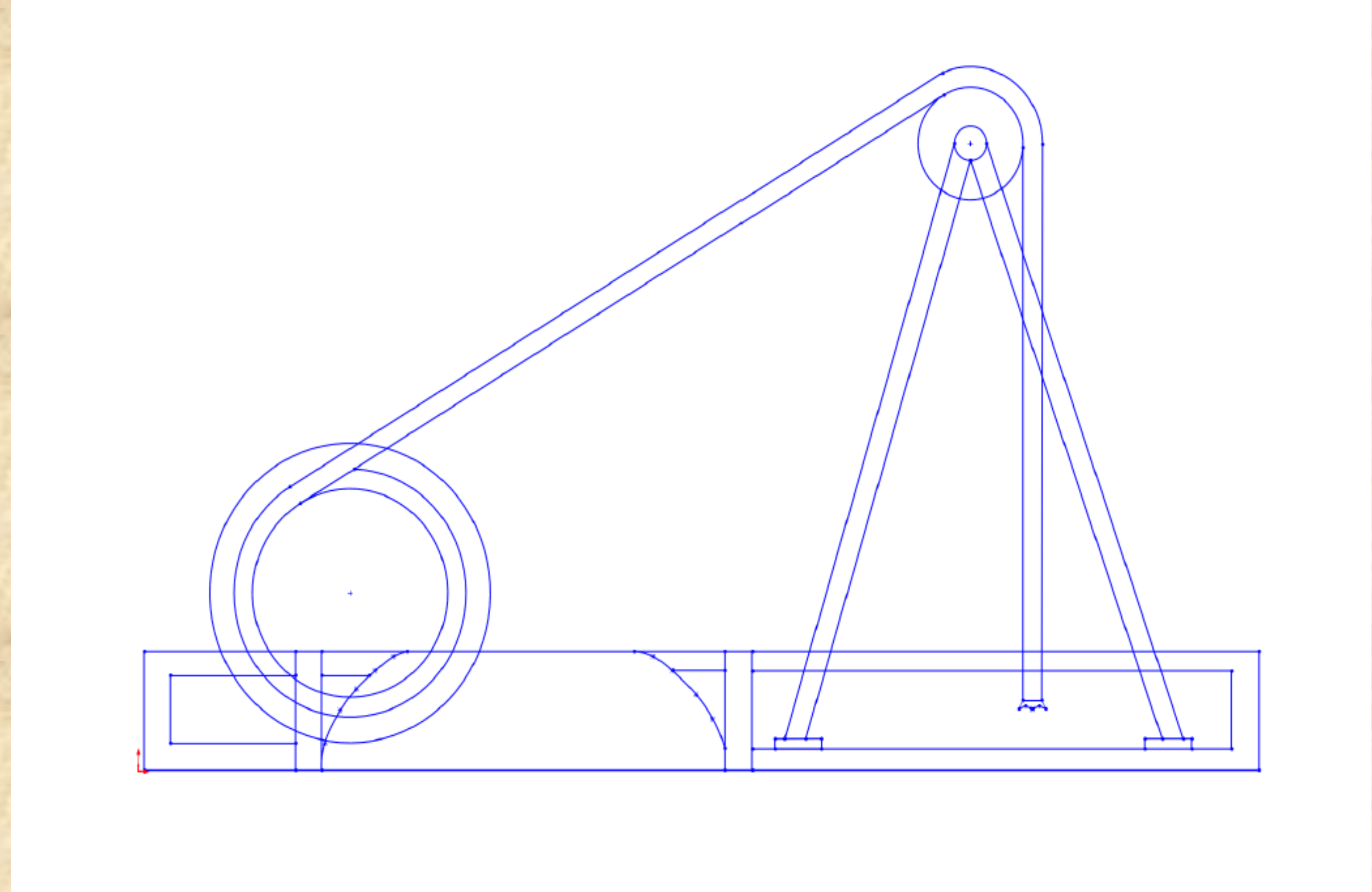
- Motor is connected to bit down-hole and provides the rotation needed.

- Specifications

    Weight – 100 lbs.

    Length – 9 ft.

Rough Draft Design 1



Coiled tubing is attached to the progressive cavity motor on a swing-set support.

Sub-Design 1

- *Down-hole Motor with Coiled Tubing Setup with water and air*
- Features a down-hole progressive cavity motor to spin a bit at the rock surface.
- Motor is attached to coiled tubing at the top surface.
- Water and air is pumped through the tubing to power the motor for drilling.

Sub-Design 2

- *Down-hole Motor with Coiled Tubing Setup with hydraulic fluid and water.*
- Features a down-hole progressive cavity motor to spin a bit at the rock surface.
- Motor is attached to coiled tubing at the top surface.
- Hydraulic fluid is pumped through the tubing to power the motor for drilling while water is used to cool the bit interface.

Sub-Design 3

- *Down-hole Motor with Coiled Tubing Setup with glycerol and water.*
- Features a down-hole progressive cavity motor to spin a bit at the rock surface.
- Motor is attached to coiled tubing at the top surface.
- Water/Glycerol mixture is pumped through the power section for drilling, lubrication, and gel strength.

Design Concept

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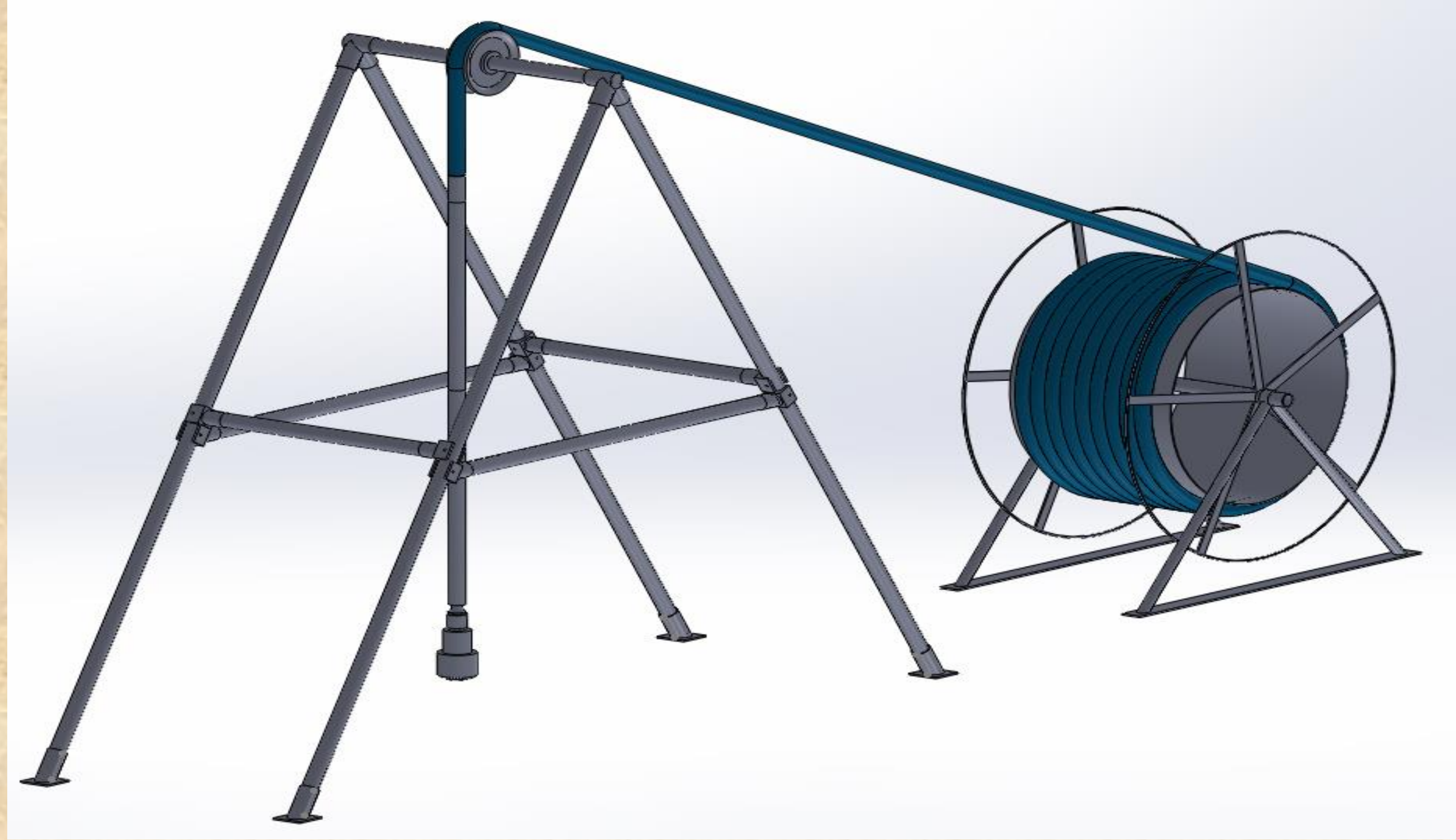
Concept cont'd



Hydraulic Power developed by the Pump

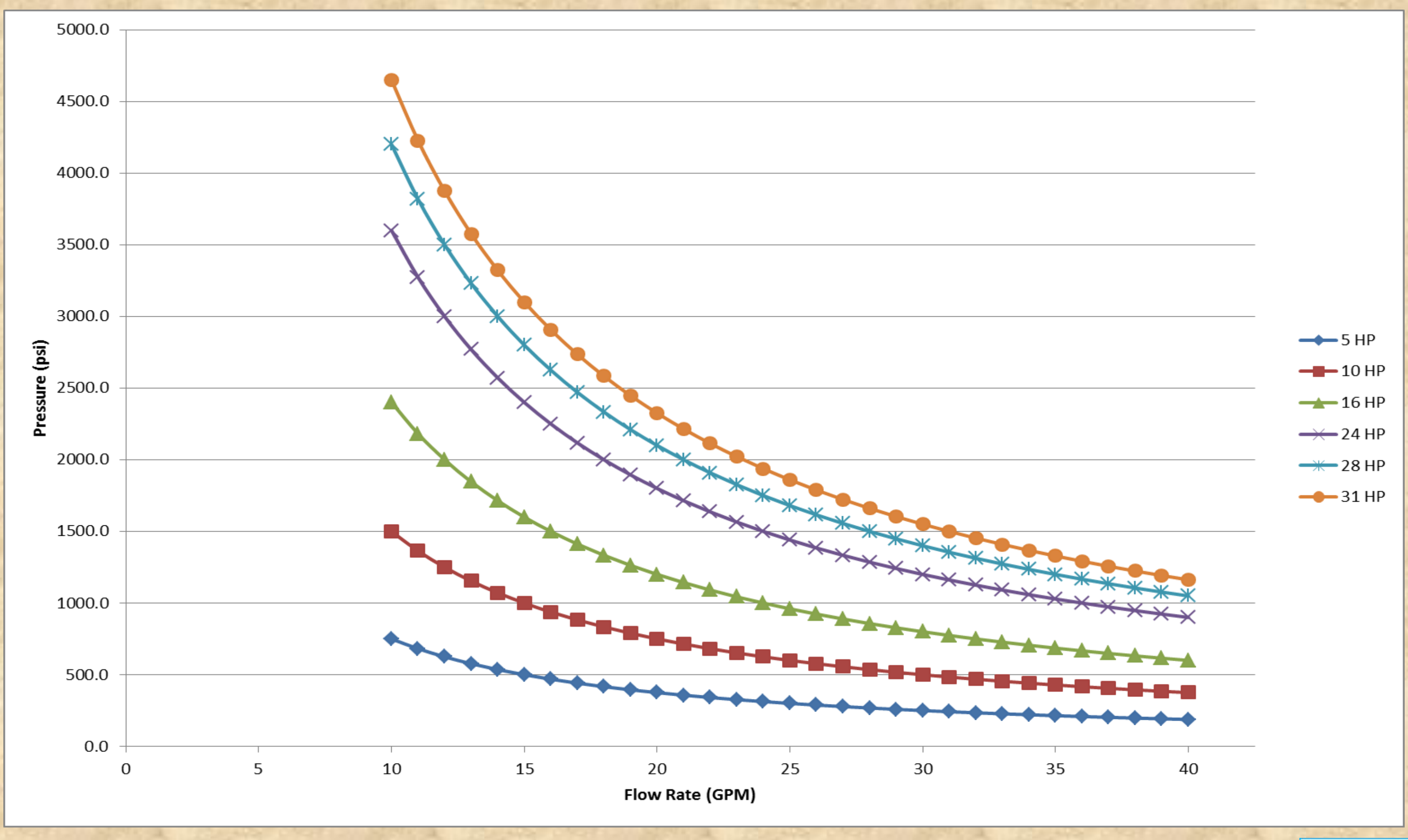
$$\boldsymbol{P} = \frac{\Delta \boldsymbol{p} * \boldsymbol{Q}}{\mathbf{1714}}$$

P = Power (HP)

Q = Flow rate (GPM)

Δp = Pressure differential

Flowrate vs Pressure for HP



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Design 2: Traditional Approach

- *Conventional down-hole stem with motor at surface*
- Features an engine, pump and motor at the top of the hole.
- Motor rotates stem, attached to a bit down-hole

Hydraulic Power developed by the Motor

$$P = \frac{T * N}{5252}$$

P = Power (HP)

T = Torque (ft.-lb.)

N = Rotational Speed (RPM)

General parts needed

Drill Bits

- Carbide Mills
- Standard Reverse clutch
- Flat, concave, or reverse bottom
- Tapered, step, string or watermelon profiles
- Crushed carbide, Star Cut carbide, or carbide inserts
- Straight or Twister mill bodies

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General Parts Needed Cont'd

<u>Engine</u>

- Briggs and Stratton Horizontal shaft engine
- 31 Gross HP

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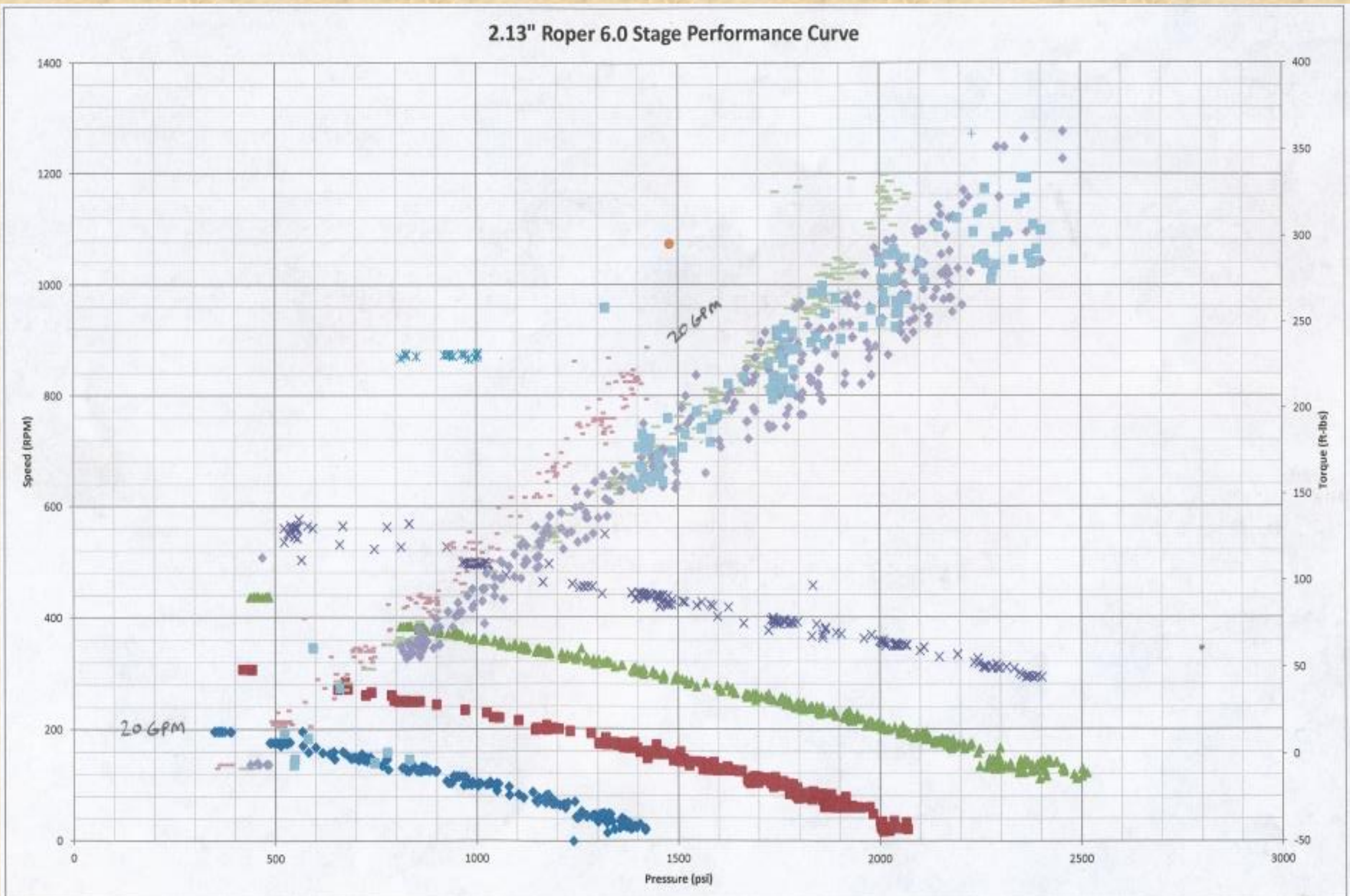
Parts for design

Tuthill HD 120A Series

- Flow Rate: 30 Gal/100 Rev
- Max Pressure: 450 PSI
- Capable of flowing high viscosity fluids

Eaton 72400 Variable Piston Pump

- Flow Rate: 47 GPM
- Max Pressure: 5000 PSI
- Compact size

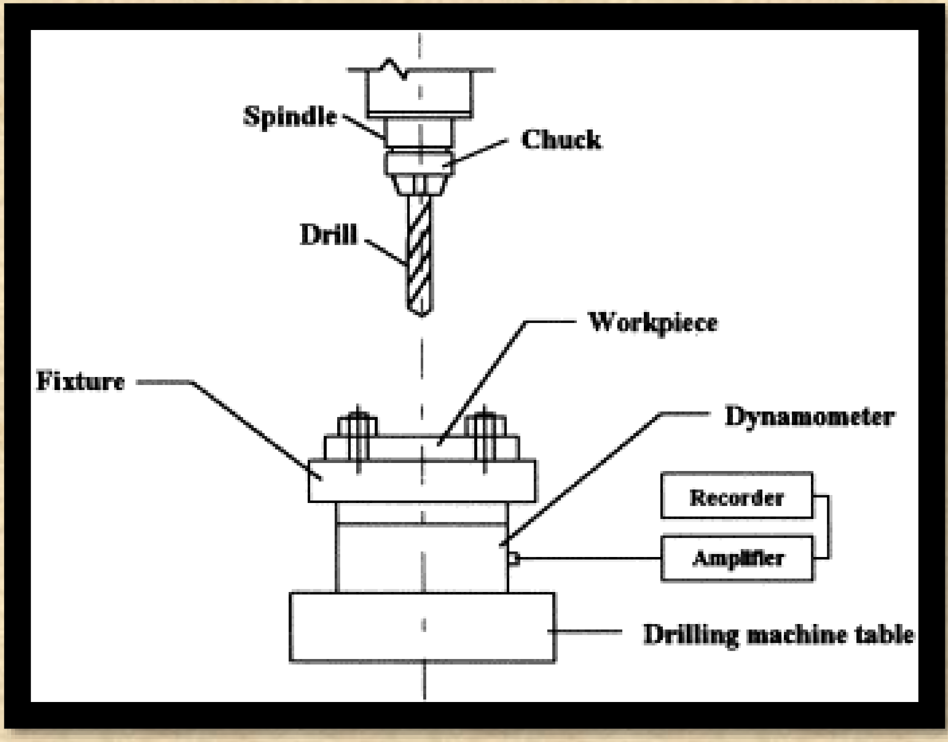


2.13" Roper 6.0 Stage Performance Curve
Speed (RPM)
Torque (ft-lbs)
Pressure (psi)
0
200
400
600
800
1000
1200
1400
-50
0
50
100
150
200
250
300
350
400
500
1000
1500
2000
2500
3000
20 GPM
20 GPM

H2OASIS INNOVATIONS

Testing Analysis

- Dyno Test
- Material Removal Rate
- Penetration Rate
- Necessary Fluid Properties



Factors Affecting Penetration Rate

- Formation Characteristics-Compressible strength of formation
- Drilling Fluid Properties- Penetration rate tends to decrease with increasing fluid density, viscosity, and solids content. Tends to increase with filtration rate.
- Operating Conditions-weight above bit and rotary speed
- Bit Tooth Wear- Grinding vs. Cutting
- Bit Hydraulics: Jet size and velocity.

Acceptable Criteria

- Transportable in rural terrain
- Will bore through quartzite
- Easily operable
- Non-potent to well
- Water4 Approval

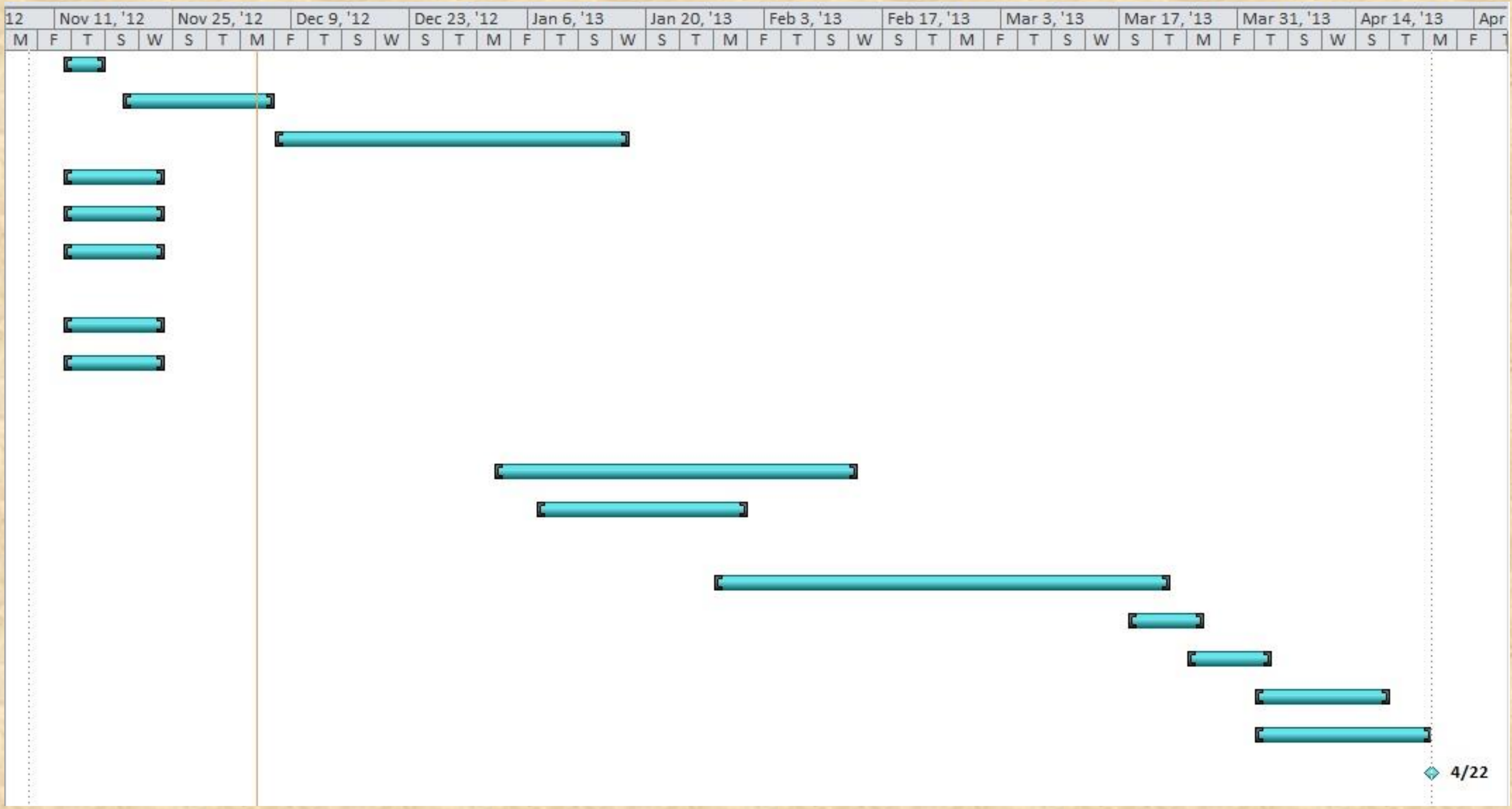
Design concepts

	Stem		Progressive Cavity w/ water-glycerol		Progressive Cavity w/ hydraulics and water		Progressive Cavity w/ air and water	
Component	Cost	Weight (lbs.)	Cost	Weight (lbs.)	Cost	Weight (lbs.)	Cost	Weight (lbs)
Drill Bits (2)	$600.00	75.0	$600.00	75.0	$600.00	75.0	$600.00	75.0
Stabilizer	X	50.0	$250.00	50.0	$250.00	50.0	$250.00	50.0
Engine (31 hp)	$1,453.00	150.0	$1,453.00	150.0	$1,453.00	150.0	$1,453.00	150.0
Engine (16 hp)		-	-		-		-	
Hydraulic Motor	$1,590.00	100.0	-	-	-	-	-	-
Progressive Cavity Motor	-	-	$15,300.00	100.0	$15,300.00	100.0	$15,300.00	100.0
Stem/Coil Tubing	$3,480.00	1200.0	$235.00	38.0	$235.00	38.0	$235.00	38.0
Pump(s)	$2,000.00	60.0	$8,500.00	60.0	$1,493.00	60.0	$1,493.00	60.0
Connections	$2,000.00	100.0	$300.00	100.0	$300.00	100.0	$300.00	100.0
Trailer	$2,000.00	X	$1,700.00	X	$1,700.00	X	$1,700.00	X
Water Tank (Loaded)	$400.00	4172.0	$400.00	4172.0	$400.00	4172.0	$400.00	4172.0
Hydraulic/Air Hose	X	X	X	X	$3,500.00	90.0	$600.00	20.0
Air Compressor	X	X	X	X	X	X	$5,000.00	600.0
TOTAL	$12,923.00	5832.0	$28,738.00	4670.0	$25,231.00	4835.0	$27,331.00	5365.0

Schedule

Task Name	Duration	Start	Finish
Drafting	5 days	Mon 11/12/12	Fri 11/16/12
Presentation	14 days	Mon 11/19/12	Thu 12/6/12
Adjustments	30 days	Fri 12/7/12	Thu 1/17/13
Drill bit interface	10 days	Mon 11/12/12	Fri 11/23/12
Stem/Pump	10 days	Mon 11/12/12	Fri 11/23/12
Coiled Tubing setup	10 days	Mon 11/12/12	Fri 11/23/12
Trailer Mount	10 days	Mon 11/12/12	Fri 11/23/12
Hydraulic pump/motor setup	10 days	Mon 11/12/12	Fri 11/23/12
Procure Materials	31 days	Wed 1/2/13	Wed 2/13/13
Brainstorm and evaluate	19 days	Mon 1/7/13	Thu 1/31/13
Fabrication	40 days	Mon 1/28/13	Fri 3/22/13
Populate Trailer	7 days	Mon 3/18/13	Tue 3/26/13
Integration	8 days	Mon 3/25/13	Wed 4/3/13
Anaylis/Testing	12 days	Tue 4/2/13	Wed 4/17/13
Modification	15 days	Tue 4/2/13	Mon 4/22/13
Finalization	5 days	Tue 4/16/13	Mon 4/22/13

Gantt Chart



12
Nov 11, '12
Nov 25, '12
Dec 9, '12
Dec 23, '12
Jan 6, '13
Jan 20, '13
Feb 3, '13
Feb 17, '13
Mar 3, '13
Mar 17, '13
Mar 31, '13
Apr 14, '13
Apr
M F T S W S T M F T S W S T M F T S W S T M F T S W S T M F T S W S T M F T S W S T M F
4/22

Promotional Plan

- Develop promotional brochure
- Develop promotional Website
- Potential ASABE Conference senior design contestants

H2OASIS INNOVATIONS

Acknowledgments

- Dr. Paul Weckler
- Water4 Foundation
- Dr. James Hardin
- Dr. James Puckette
- Dr. Peter Clark
- ThruTubing Solutions
- Wayne Kiner

Questions?

H_2OASIS

INNOVATIONS