Rotary Impact Hammer Drill Stand

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EXECUTIVE SUMMARY: Final Report

Project Description: In commercial and industrial building construction, hand held rotary impact hammer drills (RIHD) are used to bore holes in the underside of reinforced concrete slabs where fasteners are inserted to support piping and ventilation systems. Overhead drilling with RIHD causes extreme physical exertion and hand-arm vibrations while covering the worker in dust and debris. Overhead drilling with RIHD may lead to on-site injuries when the RIHD hits steel reinforcement beams in the concrete. The objective of this project is to design and fabricate a RIHD stand that reduces the physical exertion of the construction worker as well as increases the safety of their occupation. The design should help deflect dust and debris created by the drilling as well as to improve the efficiency of the overhead drilling process. The following are the engineering specifications:

- Max. Input Drilling Force (30 lbs)
- Max. Torque on User (5 ft-lbs)
- Max. Torque on Stand (5 ft-lbs.)
- Stand Weight (25 lbs.)
- Drill Travel (4.5 in)
- Holes per Minute (1 hole/min)
- Stand Lifetime (1 year)
- Price ($100)
- Max. Height at Extension (8.5 ft)
- Min. Height (7.5 ft)
- Drill Attach/Detach Time (5 min)
- Amount of Dust Deflected (95%)
- Stand Safety Factor in Shear (1.5)
- Stand Safety Factor in Yield (1.5)

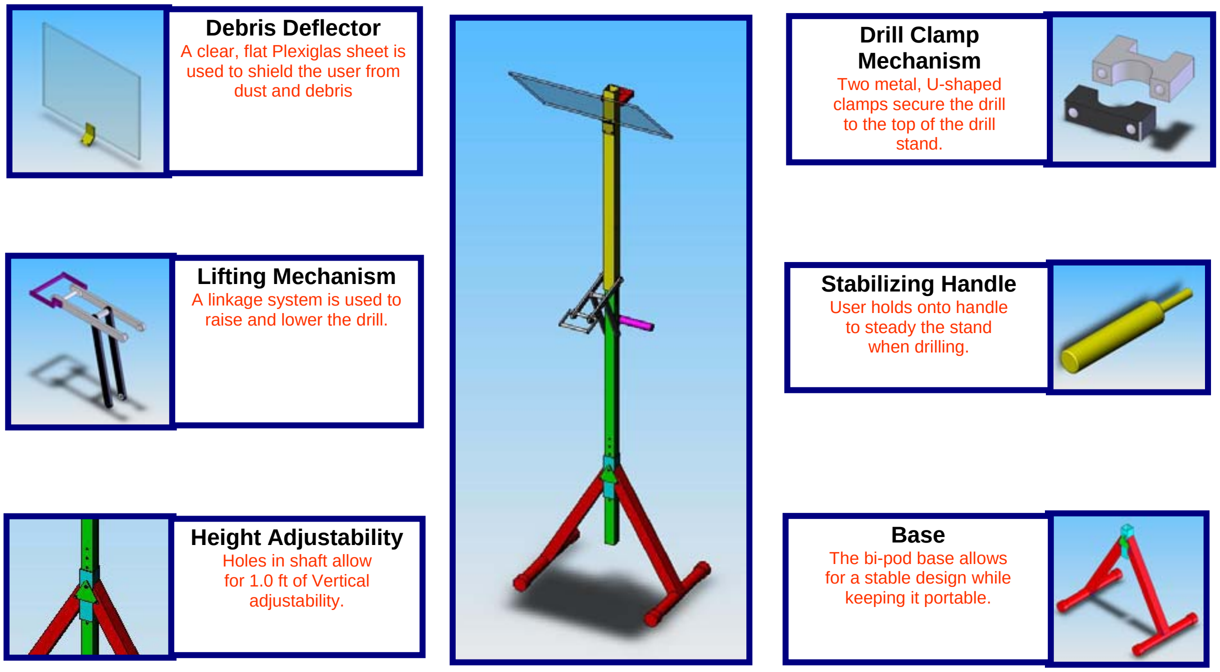
Final Design and Manufacturing: Our final design can be broken down into six parts, shown in Figure A1. Two metal u-clamps will secure the drill in place and a plate will shield the operator from dust and debris. The lifting mechanism consists of a linkage system and handle. The force exerted by the operator will raise the drill to the ceiling and drill the hole. The worker holds on to the stabilizing handle while drilling to steady the stand. The bi-pod base is height adjustable as well and as portable, easy to use, and robust. The stand consists of two aluminum shafts that slide together. A mill was used to drill all holes and slots as well as to fabricate the drill clamp. A band saw was used to cut the links out of a steel plate. The laser cutter was used to shape the debris deflector.

Validation: Our project was tested in two ways. The first was on-site testing at a parking structure on Ann Street in Ann Arbor, Michigan. The drill successfully drilled into the concrete with acceptable force (per Customer Requirements). Our sponsor used the drill stand and was impressed with the final product. Our second type of testing involves quantitative measurements such as force and height. We measured the dimensions of the stand and found them to be within the spec. The weight of the stand was slightly over the designed amount.

Critique: One critique of our design is that the base is slightly unsteady. We could modify the base by designing it to adjust to uneven surfaces. We discovered two faults with our design during our on-site validation. During drilling, dust covers the deflector making it difficult to align the drill bit. A coating should be applied to the Plexiglas to prevent dust build-up. Also dust from drilling collects inside the shafts and causes the tubing to bind. A cap over the top tube will prevent dust from entering. A sleeve over the sliding mechanism will prevent dust build-up.

Conclusion: Overall, our design is a success. It meets all the challenges given in the project description. With a few modifications, this product could soon be used on actual construction sites.

Figure A1: *Final Design for the Rotary Impact Hammer Drill Stand*



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Problem Description

In commercial and industrial building construction, hand held RIHD are used to bore holes in the underside of reinforced concrete slabs. These holes are near one half inch in diameter and are two to three inches deep. Anchors and fasteners are inserted into the holes to support HVAC piping as well as electrical systems. Overhead drilling with RIHD causes extreme physical exertion and hand-arm vibrations while covering the worker in dust and debris. Construction workers may have to drill up to 100 holes a day which will lead to muscle fatigue. The workers will have to take frequent breaks which will cost time and money. Overhead drilling with RIHD can also lead to on-site injuries. The RIHD may hit steel reinforcement beams in the concrete, creating too much torque and making the drill itself torque out of the construction worker's hands. Workers can hurt their arms or be thrown off their scaffolding. The objective of this project is to design and fabricate a RIHD stand that reduces the physical exertion of the construction worker as well as increases the safety of their occupation. The design should help remove the dust and debris created by the drilling as well as increase the efficiency of the overhead drilling process.

Professor John Everett [1], of the University of Michigan, is our sponsor for this project. He belongs to the Civil and Environmental Engineering faculty at the University. This project has been previously attempted by a former ME 450 group, but they were unsuccessful in completing the project assignments. This problem has been addressed by other sources, but no marketable product has been produced.

Benchmarks and Information Sources

There are many different problems that surface when using a rotary impact hammer drill overhead. There is fatigue from lifting the drill, fatigue from the force needed to drill into the surface, potential hazards of drill lock when drilling through two types of surfaces (like concrete and steel), and falling dust and debris irritating or hurting the operator. The most significant problem is the shoulder and back pain created when drilling overhead. We searched the internet and talked to active construction workers to discover any solutions to the above problems already existent in industry. We spoke with the superintendent, Jonathan Woodsum, of a construction job for Barton Marlow. At the site with him and Professor Everett, we discussed the issues with drilling overhead and got first hand experience operating the drill without any equipment aids. The drill stands we found did not quite fit our purpose since they were only for smaller drills and not used for overhead drilling. These drill stands worked to minimize the force needed by the operator to drill into the surface, but they did not solve the other drilling issues, such as drill lock, falling dust and debris, and fatigue from lifting the drill.

We found a drill stand which solves one of the problems that have come up when drilling overhead. This is the McGovern Lever [2] shown in Figure 1. The lever uses an adjustable see-saw which is connected to a post with the drill attached to the top of the post. The lever is pressed on by foot to lift the drill into the ceiling surface. This eliminates the strain which was in the shoulders when drilling by hand overhead since the post supports the weight of the drill and the foot supplies the energy to drill into the concrete. The cost of the McGovern Lever is $35. We have decided to use this as our benchmark and create a drill stand which will do even more for the worker while remaining inexpensive.

Figure 1: *The McGovern Lever at work in the field*

Figure 2: *The drill stand created by the Center to Protect Worker's Rights*

Some problems we plan to solve with our drill stand that are not accomplished by the McGovern Lever are creating a lift which is attached to a free standing base and eliminating the debris which falls during drilling. The first of these issues is currently being addressed by the Center to Protect Worker's Rights. They have designed a drill stand which is attached to the lift which is operated by pulling up with one hand while the other is used to steady the drill (shown in Figure 2). This design does not help with steadying the drill if a strong torque is exerted, or with protecting the worker against dust and debris. It only eliminates the overexertion in the arms and back from the overhead drilling.

The additional torque induced on the worker due to drill locking could injure them or move the stand. We have researched how to eliminate the risk of the drill locking when it drills into or hits a steel reinforcement beam in concrete. In order for the drill not to injure the worker or move the stand, we have decided to focus our attention for our prototype on designing a stand which will fit a single drill, the Bosch 11255VSR, which includes a clutch to help eliminate immediate risk of the drill locking. The majority of RIHD drills are equipped with a clutch, but we have chosen the Bosch drill to be fixated to our stand. We have also decided to include a switch in a handle attached to the stationary shaft which will stop the drilling process when let go of by the operator. If the drill encounters a strong torque which the clutch cannot handle, the operator can let go of the handle and the drill will stop. To help steady the stand if this occurs, there is a stabilizing handle for the non-operating arm to hold that will help to safely distribute the torque to the operator's body. Our drill stand will improve upon all of the problems associated with overhead drilling, making it safer and easier than ever for the worker.

Customer Requirements and Engineering Specifications

The customer requirements listed below were compiled by talking to our sponsor as well as asking construction workers what they felt. In order for construction workers to use this product, it must be portable, easy to use, inexpensive, and safe. These are our top priorities since the worker will not use the product if it does not include these requirements.

Customer Requirements

1. **Light weight** – heavy equipment fatigues the workers and is difficult to maneuver. Current weight targeted at about 40 pounds.
2. **Portable** – holes must be drilled in set anchor locations and the tool must be moved from one location to the next frequently. Furthermore, obstacles and low ceilings require it to fit through "tight" areas.
3. **Height adjustable** – the ceiling is assumed to be a constant 8 feet from ground reference. However, small variations in this height call for height adjustability.
4. **Inexpensive** – consumer will not purchase product if it is too expensive.
5. **Fit one drill size** – Our prototype will be confined to one drill type only.
6. **Drill easily attached and removed** – drilling into concrete is not always overhead. The drill must be detachable for use in drilling into walls and other locations.
7. **Easy to use/handle** – if it is difficult to use, it could pose a safety threat to workers in their complex environment. Everything must work smoothly.
8. **Low force needed to drill/steady drill** – once again, fatigue is a major issue. The device should be engineered to minimize muscle fatigue, especially on the shoulders, arms and hands. A lever utilizing body weight to force the drill upward is under consideration.
9. **Low vibrations exerted on user** – vibrations and impulses not only fatigue the worker but threaten long term effects such as carpal-tunnel syndrome and tendonitis. The stand should take these vibrations away from the user.
10. **Less dust and debris** – concrete dust and debris fall into the workers face and eyes from overhead operation. The device should divert this debris to the ground.
11. **Safe**
    a. **Prevents over-torque** – hitting re-bar when drilling through the concrete is a major issue. A drill bit that gets "stuck" on a piece of re-bar would cause the drill to whip around violently, with enough force to break wrists and arms. The drill should have "over-torque" protection such as a clutch.
    b. **No sharp edges** – the user's close interaction with the tool calls for smooth edges.
    c. **No pinch-points** – for the protection of the worker's fingers in particular, the device should be designed to minimize exposure to pinches and binds.
12. **Drill supported above head** – drilling operations we are concerned with are exclusively overhead for mounting support anchors into the concrete.
13. **Non-corrosive material** – we don't want our device to rust. Exposure to moisture and outside elements is likely in a construction setting.
14. **Hole Alignment** – there must be an easy way to line up the stand so the hole drilled is in the accurate location.
15. **Robust** – big guys, big jobs, tough tools. Must be fit for heavy duty work.
16. **Drill Travel** – the worker must be able to drill into the concrete the distance they desire.

Our engineering specifications listed below were developed by quantifying our customer requirements. Some of the specifications are rough estimates since we do not know enough about the project to make extremely accurate judgments on their values. The engineering targets are based off information our sponsor has given us about customer expectations and practicality on the construction site.

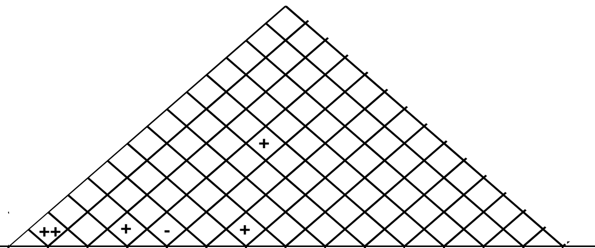
Engineering Specifications

1. Maximum inputted drilling force – 30 lbs
2. Maximum torque on user – 5 ft-lbs
3. Maximum torque on stand – 5 ft-lbs
4. Weight of stand– 25 lbs
5. Price – $100
6. Maximum height at extension – 8.5 feet
7. Drill travel with handle – 4.5 in
8. Minimum height – 7.5 feet
9. Time to attach and remove drill – 5 min
10. Average # of holes drilled per minute – ≈ 1
11. Stand lifetime – 1 year full warranty
12. Amount of dust deflected – 95%
13. Safety factor of stand yielding in shear – 1.5
14. Safety factor of stand yielding in axial compression – 1.5

Quality Function Development

The following QFD chart (Figure 3) shows the correlation between engineering specifications and customer requirements. The correlation values used are 9 (strongly related), 3 (somewhat related), 1 (weakly related), and _ (totally unrelated). We determined the weight of customer requirements by comparing the importance of each of them. We used '*' for the requirements that are necessary for the stand. We chose the McGovern Lever as our design benchmark and rated each of the requirements on a scale of 1 to 5.

Figure 3: *Quality Function Development Chart*



Customer Requirements / Engineering Specifications	weight	Maximum vertical force needed to drill (force exerted by user)	Maximum torque force needed to steady drill (force exerted by user)	Maximum torque stand can handle	Weight of stand	Price	Dimensions at extension	Dimensions when collapsed (for storage)	Time to attach and remove drill	Amount of dust deflected	Drill Travel	Holes per minute drilled	Safety factor of stand in shear	Safety factor of stand in yield	Stand lifetime	**Competitor (Benchmark)**	**Plan**
1. Light weight	*	1	3	3	9	3						3	9	9	3	4	5
2. Portable	*				9				9			3				4	5
3. Height adjustable	5					1	9	3			9					2	3
4. Inexpensive	4				3	9	3	3					9	9	9	4	4
5. Fit one drill size	3	9	9	3	3	3	3		9		1					5	5
6. Drill easily attached and removed	6								9							4	5
7. Easy to use/handle	*	9	9	9	9		9	9	9		1	3				5	5
8. Low force needed to drill/steady drill	*	9	9	9									9	9		3	4
9. Low vibrations exerted on user	7	9	9	9	9								9	9		4	4
10. Less dust and debris	8						3			9						1	4
11. Safe																	
a. Prevents over-torque (arm-rest)	*		9	9	1								9			1	5
b. No sharp edges	2							1	1							2	4
c. No pinch-points	1							1	1							1	3
12. Drill supported above head	*	1		1									3	3	1	5	5
13. Non-corrosive material	1														9	5	5
14. Drill Travel	9	3			1	1	9	3			9	9				5	5
15. Hole alignment	3	3	3		3	3	1	1	1							1	3
Units		N	N.m	N.m	kg	$	m	m	sec	%	m	#	#	#	yrs		
TOTAL		126	99	72	102	68	174	60	87	72	129	81	99	99	45		
Normalized		0.15	0.12	0.08	0.12	0.08	0.20	0.07	0.10	0.08	0.15	0.09	0.12	0.12	0.05		
Importance Rating		2	4	10	4	10	1	13	8	10	2	9	4	4	14		
Target (Plan)		133	6.8	6.8	11	100	2.7	1.8	300	95	0.1	1	1.5	1.5	1		
Competitor (Benchmark)																	

Concept Generation

When we began designing our final concept, we started by taking the basic design of what we wanted and came up with different ideas for each of them. We began with designs for the base of the stand, and then moved on to lifting motion mechanisms which would drive the drill up vertically into the concrete. We then discussed different debris deflectors which would divert the dust and debris from the workers face and body. Finally we designed types of drill clamping mechanisms, which would hold the drill steady while it was drilling. The different base designs are located in Appendix A. The different designs for the lifting motion mechanism can be seen in Appendix B. The designs for the debris deflectors can be seen in Appendix C. The different drill clamping mechanisms are in Appendix D.

Base Designs: We had many different base designs that are shown in Appendix A. We had a single pole, free-standing tri-pods, a bi-pod design, a single platform w/ball and socket design and tri-pods which allowed rotation in the shaft with a bearing. The tri-pod (Drawings 3 & 4) feature was our most popular choice because it would allow the stand to be free-standing. Our only problem with it was safety, we thought that three legs sticking out may get in the way and be easy to trip on. This is why we thought of the bi-pod (Drawing 5) design which would give the operator more room to work around the stand. Almost all of these designs included height adjustability, where notches in the shaft allowed the height to be changed and secured with pins. They all also allowed the shaft to be adjusted so to be able to drill on an angle with adjustments either on the bottom of the stand legs (Drawings 3-5).

Lifting Motion Mechanisms: We came up with numerous and creative systems that allowed our drill to perform our desired vertical motion. As seen from the drawings in Appendix B we had five primary designs that included a lever, gear train system, a rack and pinion, and linkages both contained within a housing and outside of a housing. The lever concept (Drawing 10) was the first concept that was brought up. It was basically a lever mounted to a cam shaft. The large size of the required cam led us to think of possible gear systems. Our first gear train system (Drawing 9) was designed with two separate gears and a driving chain. The desired motion could be obtained, but there were numerous moving parts and would be difficult to fit within a housing. From here we came up with a rack and pinion design (Drawing 8). For a long time, this was our first choice. The system performed the required motion and also had the gears safely contained in a housing to prevent any pinch points. But the manufacturability for the prototype made us nervous. From here we came up with linkages systems (Drawings 6 & 7). Most of these mechanisms include the handle which, when pressed down using force from the arm and help by the weight of the body, would move the shaft vertically and operate the drill. They also all include an arm hold for safety and resistance to torque if the drill locks. These mechanisms had all the characteristics we wanted and the manufacturing process was much simpler.

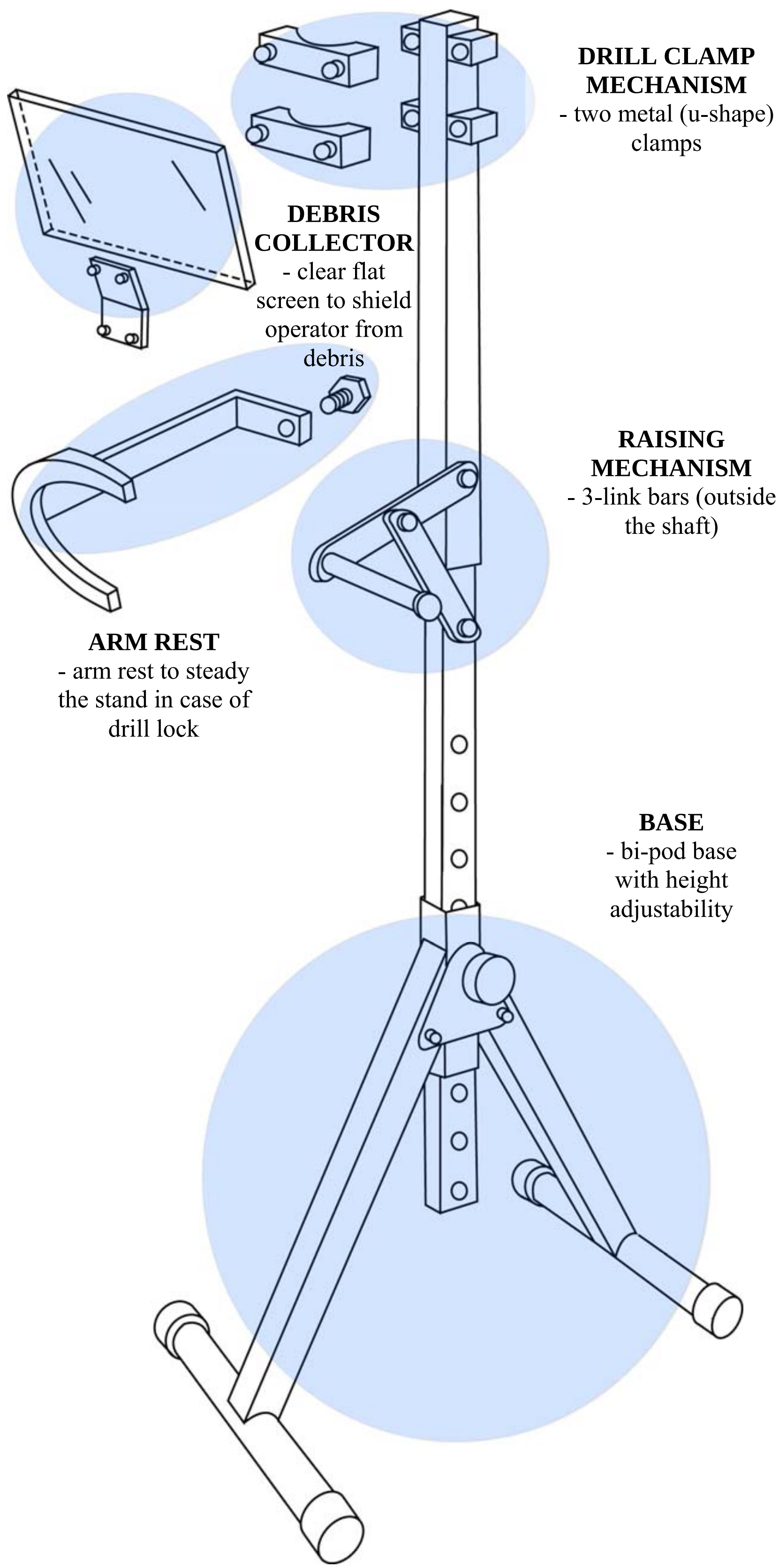
Debris Deflectors: For debris deflectors we had five major designs in Appendix C. A vacuum which collects the debris (Drawing 13), a mesh collector which only catches large debris (Drawing 14), a clear bowl which surrounds the drill (Drawing 15), a clear folded and slanted plate (Drawing 11), and clear flat slanted plate (Drawing 12). The vacuum design we thought wouldn't collect a lot of the debris and may be too troublesome to use. We thought the worker may not waste his time to even turn it on. The mesh collector, though it was a good design, only catches large debris and would not prevent dust from falling onto the operator. The clear bowl design would catch all of the dust and debris but would not have anyplace for it to go but build up and would be cumbersome to clean. Our best bets were the clear folded and slanted plate and the clear flat slanted plate. These plates would shield the dust and debris from the operator and would allow it to simple slide off the plate to the ground. We decided to use the clear flat slanted plate because its design is simpler and less expensive and it would work just as well as the folded plate.

Drill Clamping Mechanisms: Five clamping designs were debated for attaching the drill to the lifting shaft. Appendix D shows the drawings for 1 metal u-clamp (Drawing 19), 2 straps with straight shaft (Drawing 18), 2 metal clamps with straight shaft (Drawing 17), 2 straps with crooked shaft (Drawing 16), and 2 metal clamps with crooked shaft (Drawing 20). Because the straps may loosen from the vibrations created by the drill, we decided that the sturdiest design would be one with 2 metal u-clamps which would affix the drill to the shaft. The 2 metal u-clamps on the straight shaft was then decided upon since it is the simplest design and easiest to manufacture.

Final Design Concept

Our final design concept is shown in Figure 4 above. It features the bi-pod base with adjustable feet for different drilling angles, an adjustable shaft which is secured with pins to the base, the links which allow the drill, with the force exerted on by the operator, to rise to the ceiling and drill the hole, 2 metal u-clamps which secure the drill in place, a plate which will shield the operator from dust and debris, and a handle which operates the drill along with an arm hold used to steady the stand in case of drill lock. The motion of the linkage system for the drill motion is modeled in Appendix E.

Figure 4: *Final design concept*



Selection Process

Our team selected our final design concept by analyzing Pugh matrices (see Appendix F) and implementing common sense. We broke the Pugh matrices into our four basic design areas of bases, lifting motion mechanisms, debris deflectors and drill clamping mechanisms. In the separate categories we inserted our top five designs and compared them against each other. We compared the different designs by scoring them on a 0 (low), 4 (moderate), and 9 (high) scale of how well they met the design requirements. We then weighted these scores based on the importance of each customer requirement. We then looked at the overall weighted scores and used our common sense to find the best design. The Pugh matrices for these design areas can be seen in Appendix F.

Similarly, we looked at the difficulty of manufacturing the prototype of the desired design concept. We had to keep in mind that we are working with a budget, limited part availability and access to manufacturing processes. After selecting each component, we discussed the readiness of parts or manufacturability. If parts or tooling were too expensive or unavailable we discussed implementing our second highest ranked design from the Pugh matrices.

After analyzing the Pugh charts and selecting designs from each, we began investigating how well each piece could be mated. We did this so that we could be certain that our design concepts would not only work well together, but also be aesthetically pleasing. We believe that all our selected components will mesh well together and look nice at the same time.

Engineering Analysis

Analysis of Forces and Torques Exerted on the User

Our first step in analyzing our design concept was determining the setup of our lifting motion mechanism. We began by modeling our design with ADAMS 2005. Appendix E shows this ADAMS model. In ADAMS we experimented with different dimensions of the linkages in our design to minimize the force the user needs to operate the drill and make sure that our drill travels the desired distance, 4.5 in. We made sure the force on the user is less than 30 lbs with a safety factor of 1.5. We also determined the maximum torque which would be exerted on the user's stabilizing handle in the case of drill lock. We did this by applying the maximum torque the drill can give out, 2.2 ft-lbs which is 39.6 in-lbs with a 1.5 safety factor, and stabilizing the shaft in ADAMS to find the torque which would be exerted on this handle. Appendix G displays two figures which show the results of our analysis. Figure G1 plots on the left axis drill travel as a function of the time and it is just over 4.5 inches. The right axis of the plot shows the maximum inputted drilling force and the force of the drill on the shaft with a safety factor of 1.5 as a function of time. This is only 25 lbs with a safety factor of 1.5 on the user in order to operate the drill with 50 lbs being applied to the shaft. Figure G2 shows the force and torque as a function of the distance the drill travels. To obtain these plots we applied a constant force of 50 lbs to the outer tube, this value we obtained from the 30 lbs maximum force inputted with a safety factor of 1.5. In order to determine the amount which would operate the drill we experimented with different forces on the operating handle and found that with only 16.67 lbs of force (25 lbs with a safety factor of 1.5) the drill could be lifted and have a travel distance of 4.5 inches. The next figure in Appendix G, Figure G3, shows the maximum torque which would be exerted on the user at the stabilizing handle as 39.6 in-lbs, this being the worst case scenario, which is equal to the torque which the drill can give out if it locks with the 1.5 safety factor.

Analysis of Forces and Torques Exerted on Stand Materials
The analysis we performed for the forces and torques exerted on the user during operation of the drill can also be applied to the material used in the shafts and links. Because the forces and torques exerted on the shaft and the operating handle, which is attached to the lifting motion mechanism, are not significantly high, we had a lot of choice of materials to choose from. We assumed from the beginning that we would like to work with an Aluminum alloy and we decided to go with 6063 T5 Aluminum alloy. This alloy's tensile yield strength is 21000 psi and the shear strength is 17000 psi [5]. Finding the forces applied with the yield stress over the cross-sectional area of both shafts separately, we see that the force to yield in tensile is 19,687 lbs for the upper shaft and 17,062 lbs for the lower shaft. From these values we can see that even with our greatest forces exerted on the shaft in tensile, our design will not exceed these values. This is true in compression as well with a compressive yield strength which is exceedingly larger than that in tensile. Because the links and handle will also be made with this material and the pins for our design will be made of steel, they will also be able to handle the forces associated with our maximum load. Steel has a tensile yield strength of 58,015 psi, compressive strength of and shear strength of 50,038 psi [6].

In order to determine if our stand can withstand the applied torque the drill can put out we modeled the torque as a moment being applied to the side of the upper shaft at a distance of 1 inch from the center of the shaft. The torques associated with the shear strength over this area for the upper shaft is equal to 1,328 ft-lbs and for the lower shaft is equal to 1,151 ft-lbs. From this analysis we have found that our stand should be able to withstand our largest torques exerted on it. Because the links and handle will be made of 6063 T5 Aluminum alloy and the pins for our design will be made of steel, they will also be able to handle these torques.

Analysis to Determine Height and Length Dimensions for RIHD Stand
Calculated Lengths and Distances: The following are various lengths and distances calculated using a "statics" approach. The hand written work performed to determine these dimensions is located in Appendix H.

1) Length of bottom (inner) tube — 61 1/4"

2) Length of top (outer) tube — 38 3/4"

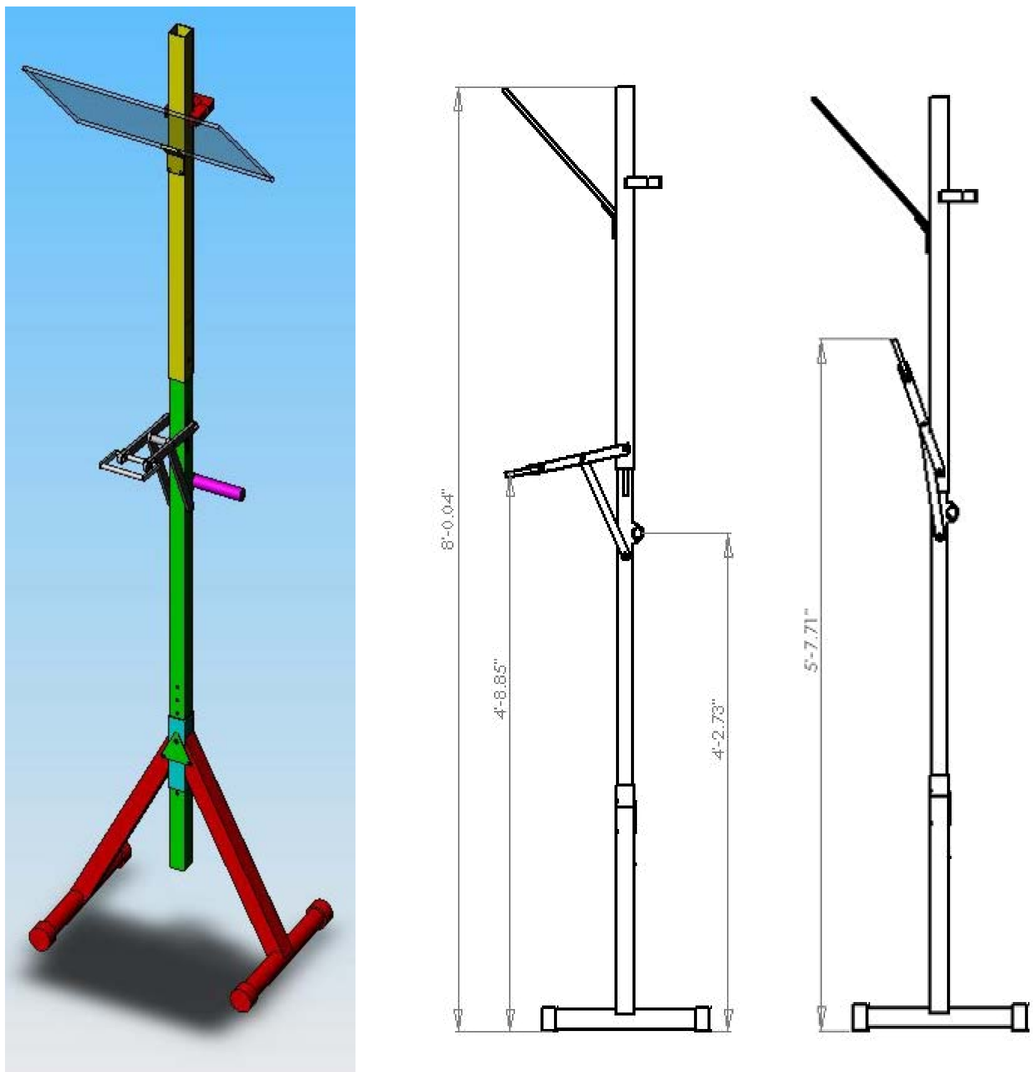
3) Distance of lower link pin (connected to bottom tube) to bottom of top tube (at rest) — 4.18"

4) Distance of upper link pin (connected to upper tube) to bottom of top tube (constant) — 2.00"

Final Design Description
Figure 5 shows our final design for the Rotary Impact Hammer Drill stand. This design differs slightly from our final design concept shown in Figure 4 on page 7. We modified the lifting mechanism so there are links on both sides of the tube with the handle connecting them. We also changed the armrest into a handle the worker would grip while drilling. This

stabilizing handle would have a rubber padding to dampen vibrations and would still allow the user to brace the stand against large drill torques. The trigger to operate the drill would also be located on this stabilizing handle.

Figure 5: *Final design with dimensions designed in Solid Works*



Bill of Materials
Appendix I shows our Bill of Materials (BOM) with dimensioned drawings for each component and assembly. We divided the stand into the following subassemblies:

Base: The base is divided into two separate components: the bipod base and the adjustable pin. The bipod base is designed to be extremely stable while remaining lightweight. The base will be made of 6063 T5 aluminum to make it strong and lightweight. Appendix J shows a dimensioned drawing of the base component. The adjustable pin is used to secure the pin at different desired heights.

Vertical Shaft Tubing: The tubing consists of two 6063 T5 aluminum alloy tubes of different sizes that allow for telescoping. The inner tube connects to the bipod base and has holes to allow for height adjustment. The holes are spaced 1.5 inches apart and allow one and a half feet of height adjustment. The outer tube fits over the inner tube with a minimum overlapping distance of 1 foot at full extension. The inner tube is 61 ¼ inches long and the outer tube is 38 ¾ inches long. Appendix K shows the dimensions of the tubing components.

Lifting Mechanism: The lifting mechanism consists of a set of two links on each side of the stand connected with a handle. Appendix E shows the Adams Model of the movement of one side of the link system. The upper links are all of 12 inches long while the lower links are 11 inches long, as shown in Appendix L. The links will be made of 6063 T5 aluminum and secured in place with steel pins. The lower steel pin will extend entirely through the inner tubing so one pin holds both links on the right and left side. The upper steel pin is located where the inner and outer tubing overlap. This steel pin will extend through both the inner and outer tubing to connect the right and left side links, as shown in Appendix L. The pin will be connected to the outer tubing and the inner tubing will have a slot which will allow the pin to move vertically with the outer tube.

Operating Handle: The steel operating handle, connected to the lifting mechanism, will allow the user a comfortable way to drill upwards into the concrete. Secured in place by steel pins, the handle will attach itself to either side of the links with 5 inches of space for a hand to be placed. The handle is shown in Appendix L along with the lifting mechanism. A rubber covering will surround the operating handle and help to dampen the vibrations due to drilling.

Stabilizing Handle: The stabilizing handle is a piece of round stock aluminum 6 inches long with 0.5 inch diameter, shown in Appendix M. The stabilizing handle will be screwed into the inner tube, directly below the lifting mechanism. This handle can be screwed into either side of the stand so it can be operated by both right- and left-handed people. The stabilizing handle will have a rubber covering around it which will dampen the vibrations due to drilling.

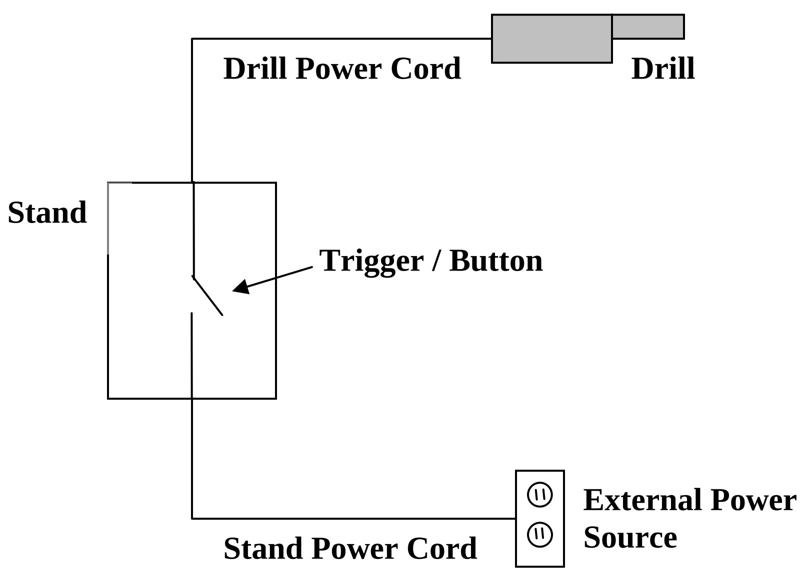
Debris Deflector: The debris deflector will be a slab of Plexiglas, 24 inches by 18 inches by 0.5 inches. A bracket will connect the Plexiglas to the drill stand. The slab will be positioned on the handle side of the stand, angled downward, as shown in Appendix N. The angle allows for the dust and debris from drilling to be diverted to the ground, leaving the glass clear to see the drill in action.

Drill Clamps: The drill is connected to the stand using a clamp milled from a block of 6063 T5 aluminum and one U-clamp. The upper clamp secures the drill to the stand near the nose end of the drill. The lower clamp secures the section of the drill near the handle. Appendix O shows the dimensions of the clamp we will create with the block of aluminum. Our dimensions were determined by measuring our Bosch hammer drill in the desired location of the clamps. The top clamp will be welded to the stand, and nuts and bolts will attach the separate pieces surrounding the top of the drill. The U-clamp is connected to the stand by nuts and bolts on each side of the drill. These nuts can be tightened differently, depending on the size of the drill used.

Drill: The drill clamping device allows for a universal drill fit which means any Rotary Impact Hammer Drill with a clutch will work in our stand.

Electrical Wiring: The electrical components of our project include a power cord, power outlet, and trigger. Figure 6 shows a schematic diagram of our wiring system. The power cord of the drill will plug directly into an outlet built into the stand. The stand will have a separate power cord which will plug into an external electrical source. A trigger or button will be wired in series between the drill cord and the power cord. The trigger on the drill will be locked in the on position when the drill is clamped to the stand. Since the button on the stand is in series between the power source and the drill, it will regulate power to the drill.

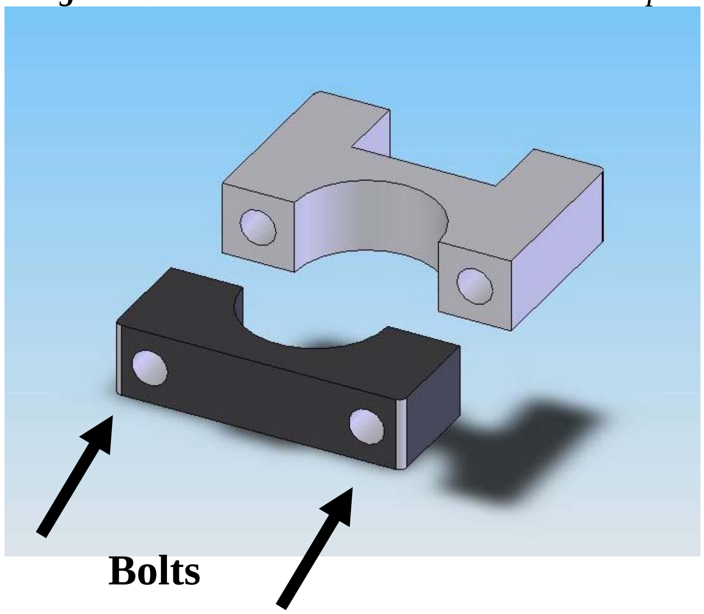
Figure 6: *Schematic diagram of electrical wiring system in the drill stand*



Operation of Device

Clamping Drill to Stand: The drill is held in the desired clamping position. The upper clamp is placed in position and the bolts are tightened by hand as shown in Figure 7 on the following page. Repeat this step with the lower clamp to the desired tightness. Plug the drill power cord into the outlet located on the drill stand. Lock down the drill trigger to keep the drill permanently turned on. The drill will not turn on yet since it is only connected to the stand.

Figure 7: *Attach the drill to the stand with clamps*

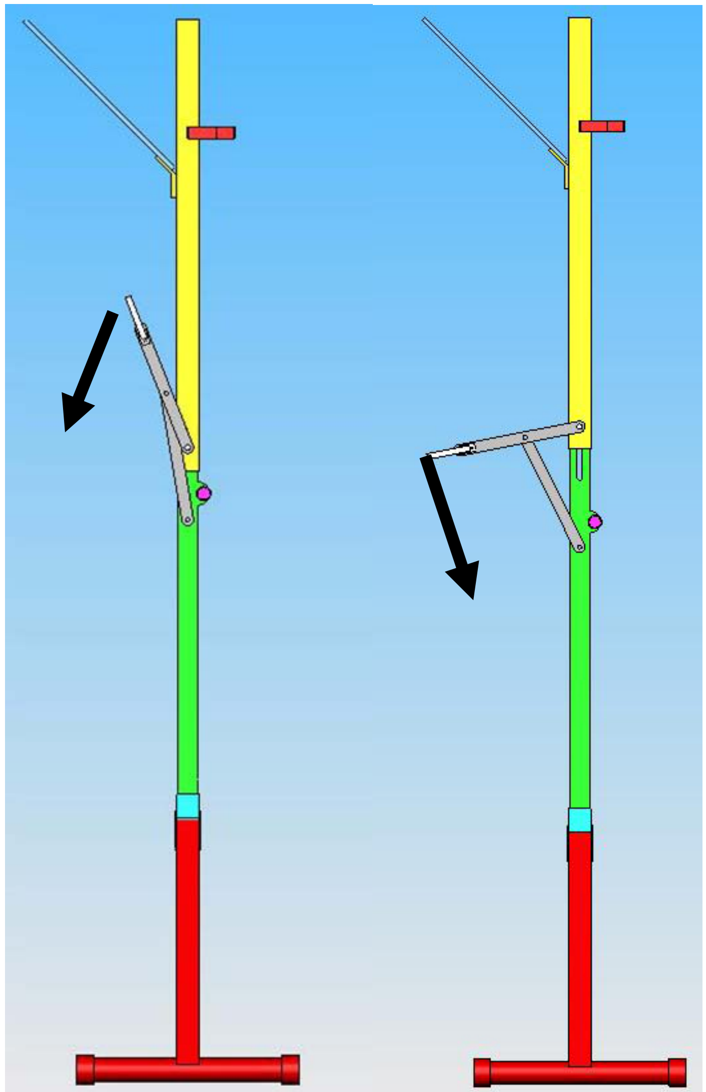


Lifting Drill to Ceiling: The drill stand must first be adjusted to the right height. Remove the adjustable pin from the base and slide the tubing up or down until the top of the drill bit is between one and two inches away from the ceiling, as shown in Figure 8 on the following page. Line the tip of the drill bit up with the location of the hole by sliding the base. Make sure the stand power cord is plugged into an electrical source. Place your left arm on the arm hold in order to steady the stand. Press the trigger button located on the stand to start the drill. The trigger button must be held down to keep the drill turned on. Once the button is released, power to the drill will automatically stop. Grab the handle and push down in a slow and steady fashion to raise the drill to the desired height. Slowly lift the handle back to its resting position and release the trigger button. Repeat this procedure for as many holes as desired.

Prototype Description

The prototype design is similar to the above final design description with a few changes. Our final design concepts calls for a universal drill fit. Our prototype will be designed using one single drill, a Bosch 11255VSR. The drill clamping devise can be easily changed for other drill types for the final design. To ensure that our prototype works well, it has been designed to make sure it works with the one drill in our possession. One other change with our prototype when compared to our final design is the base. We are using a base already in production in order to save time and money in our prototype construction. This base is made of steel and is heavier than desired for the final prototype. Our final design will consist of an aluminum base made in the same design as the prototype stand.

Figure 8: *Press down on the operating handle while pressing the trigger with the opposite hand in order to operate the drill*



Prototype Manufacturing Plan

Our manufacturing plan consists of purchasing some pre-made components while constructing the rest from raw materials.

Base: In order to save time and money we purchased a base already made. It is made of steel and uses two screws to secure the inner aluminum tubing to the desired height.

Vertical Shaft Tubing: The tubing will be made with two 6063 T5 Aluminum Alloy tubes, both with 1/8 inch thickness. The tubes will have outer widths, 1 ¾ inch and 2 inches, which will allow the smaller tube to slide easily inside the outer tube. A band saw will be used to machine the tubing to the desired lengths of 5 feet for the inner/lower tube and 4 feet for the outer/upper tube. A drill press will be used to machine the adjustable height holes, ½ inch diameter, into the lower tube. We will use a mill to machine the slots located in each of the tubes. This component will take a moderate time to produce. The extent of the time will be sanding down the inner tube so it will slide well inside the outer tube. Tolerances are extremely important in the size of the aluminum tubes. If the inner tube is sanded too much, there will be a lot of play where the tubes other lap. If the inner tube is not sanded down enough, the tubes may get stuck together and not slide.

Lifting Mechanism: With a ½ inch thick aluminum sheet, we will trace an outline of the size and shape of the links. A band saw will be used to cut the link out. A drill press will then be used to drill the pin holes in the links. The lifting mechanism will take the majority of the component construction time. Four links have to be cut out of an aluminum sheet, as well as the handle. Tolerances are also very important to this component because the links must be the right size. If the links are not aligned correctly on both sides, the handle will not move smoothly or even at all.

Stabilizing Handle: A piece of round stock aluminum with a 1.25 inch diameter will be cut using a band saw to 6 inches. One end of the aluminum piece will be threaded. A rubber coating, similar to a bike handle, will be slid over the remaining aluminum piece. The stabilizing handle will then be screwed into a hole in the inner tubing at the desired location. This component will take minimal time and the tolerances are not as important. The only requirement is the handle must be able to screw into the inner tube.

Debris Deflector: Plexiglas with dimensions 24 inches by 24 inches by ½ inches will be connected to the outer tube with a bracket. Nuts and bolts will hold the Plexiglas with a bracket to the drill stand. Holes will be made using a drill press. This component will take minimal time and tolerances are not important. This piece just needs to attach securely to the stand.

Drill Clamps: We will make the bottom U-clamp by buying a thin round piece of aluminum with two threaded ends and bending it into a U-shape. This U-clamp will line up with two holes on the stand. These holes will be made by drilling holes in two blocks of aluminum and welding them to the outer tubing in the desired location. The ends of the U-clamp will slide through both holes and nuts will be tightened on the ends to secure the clamp. This U-clamp will be made to secure the drill's handle. An upper clamp will be used to secure the top of the drill near the drill bit. This clamp will be made by milling half of the area of the drill top into 2 aluminum blocks. Two holes will then be drilled and threaded into the 2 pieces on both sides. One of the blocks will then be cut to fit around the outer tubing and welded to the outer tubing in the desired location. The two blocks will then be able to be connected together surrounding the top of the drill with nuts and bolts. This component will take a moderate amount of time since bending, drilling, milling and welding are all involved. The tolerances are important between all of the clamps, and the holes of the blocks welded to the outer tubing are important to make sure the U-clamp can slide through them and tighten snuggly.

Electrical Wiring: We will purchase a power cord and outlet along with a trigger button. We will wire the power cord, trigger, and outlet together in series in that order. All of the exposed wires will be placed in a small box with the trigger button on the outside. This box will be welded to the drill stand. This component will not take much time. Stephen Kozak, a

Chief Engineer of Ford Motor Co. has offered to help with the construction of the electrical components.

Assembly: The assembly will take about the same amount of time as the construction of the actual components. First, we will cut the aluminum tubing to the desired length and connect them to the base. Once this part is finished and working correctly, the raising mechanism will be connected. This part is the most important since it is the base of our project. This will take time since we will have to pin the links to the tubing correctly and make sure the mechanism works. The tubes will have to be lined up correctly with the links set in place. The pins will then be connected through the tubes and links and finally secured. The handle will then connect to the links, and this will finish the lifting mechanism. The drill clamping devise will be connected next. We did not connect it before the lifting mechanism because we do not want to finalize the height before the lifting mechanism is attached. The aluminum blocks will be welded near the top of the stand in the proper location. Finally, the Plexiglas will be added in the proper location above where the user would be standing.

Validation Plan

Our project was tested in two ways. The first was our on-site testing where we used our drill stand in a parking structure on Ann Street in Ann Arbor, Michigan. Our stand worked well drilling into the concrete ceiling. It took a low amount of force to push down on the handle and drill into the concrete. Torque on the stand was not an issue while drilling. The stand did not have to be restrained from moving during the drilling. The stand was easy to move around the construction sight and the electrical wiring system worked perfectly. Our sponsor, Professor Everett, tried out our stand and liked our final design. He is going to continue testing our stand at construction sites in the upcoming months. There were a few problems during our on-site testing. During drilling, dust would collect on the Plexiglas debris deflector, making it hard to see the drill and drill bit. We also had a problem with dust collecting in-between the aluminum tubing where it slides up and down. This made it hard to move the shaft up and down.

Our second type of testing involves quantitative measurements such as force and height. We compared these measurements to our engineering specifications to evaluate our drill stand design.

Validated Specifications

Maximum inputted drilling force – Spec 30 lb, Measured 25 lbs: At the on-site testing, we measured the force it takes to drill into the concrete by using a fish scale. The force needed to drill was constant at roughly 25 lbs. This is 5 lbs less than our engineering specification.

Maximum height at extension – Spec 8.5 feet, Measured 8.5 feet: We adjusted the base to its highest position and push the handle all the way down to raise the drill to its maximum height. This height was measured to be 8.5 feet, exactly the designed height of our stand.

Minimum height – Spec 7.5 feet, Measured 7.5 feet: We adjusted the base to its lowest position and measured the height. This also met our engineering specification of 7.5 feet.

Weight of stand– Spec 25 lbs, Measured 33lbs: Our measured weight is 8 lbs our specification. Since this is our prototype stand, it's weight is not accurate to the production weight. The links and base of the prototype are made of steel for convenience. Production units will be made entirely from aluminum which will decrease the weight.

Drill travel with handle – Spec 4.5 inches, Measured 4.5 inches: We measured the height of the drill when the stand was at rest. We then pushed the handle down to extend the drill up and measured its height at the maximum position. The difference between these two measurements is the drill travel distance.

Time to attach and remove drill – Spec 5 minutes, Measured 7.5 minutes: We recorded the time it took the drill to be connected to the stand. This time is over of specifications by 2.5 minutes. The time is 7.5 minutes because we are using a prototype stand. The attach/detach rate will be faster for production pieces.

Average # of holes drilled per minute – Spec 1 hole/min, Measured 3 holes/min: We recorded the number of holes drilled in one minute to be 3 holes. The stand is easy to move and line up which allows it to drill holes efficiently.

Specifications Not Validated

Price – $100: We will be able to quote the price of our prototype, but not the price of a production unit. We will have a rough estimate of the material costs of the stand so we will be able to derive an estimate of the final cost.

Stand lifetime – 1 year full warranty: We will not be able to conduct sufficient life testing with our allotted time and budget. Seeing how well the stand works in the field, we think it should be able to withstand one year of use.

Amount of dust deflected – 95%: The amount of dust deflected is a hard amount to measure without special equipment. We will be able to estimate the percentage of dust deflected as about 90%, though the dust tended to stick to the Plexiglas, which was undesirable.

Maximum torque on user/stand – 5 ft-lbs: We cannot quantitatively evaluate this specification due to limitations in our equipment. We can perform analysis using Adams to evaluate the performance of the stand with different torque values.

Safety factor of stand yielding in shear and compression– 1.5: We cannot physically test the safety factor. Our concept was designed around a safety factor of 1.5. We performed analysis in Adams based off of this safety factor.

Design Critique

The majority of our design critiques were discovered during our on-site validation testing. The drill stand worked well in the field, but there were a few flaws we did not know about until the testing.

Dust Builds Up On Debris Deflector: During our drilling, we discovered that the dust collects on the Plexiglas deflector. This makes it difficult to see the drill bit going into the concrete. This makes it hard to align the drill to a specific location. A simple way to solve this problem is to apply a slippery coating to the Plexiglas to prevent dust build-up.

Base Slightly Unstable: The bi-pod base rocks slightly when placed on any uneven surface. We did not find this to be a major problem during our on-site testing. One way to solve this problem is to design the base so it can be adjusted to uneven surfaces.

Dust Effects Sliding Mechanism: During our on-site testing, a large amount of dust collected inside the aluminum tubing, causing them to bind. In our prototype, hollow aluminum tubes were used for the shafts. This hollow top allowed a large portion of the concrete dust to get into the overlapping section between tubes. To fix this problem, a cap can be placed over the top tube which will prevent dust from entering the inside of the stand. A sleeve over can be placed over the sliding mechanism to prevent dust build-up.

Span of Height Adjustability: One problem we faced at the construction site was finding a ceiling low enough for our stand to reach. Since it was a parking structure, most of the ceilings were 10 feet high. We designed our stand around specifications given to us by our sponsor. He said assume the ceiling was 8 feet tall. It would be very easy to make a stand reach 10 feet high. The upper tubing would have to be extended 2 feet and this problem would be solved.

Designsafe Analysis

After finishing our design we implemented Designsafe software to learn more about the different risks and hazards associated with our RIHD stand. We found a few hazards where the associated risk is too high and a plan must be made to reduce this risk. We came up with plans to reduce the risk of all the moderate risk levels to low or negligible. These plans include

- Improving the base design to avoid any instability in the stand.
- Put a sleeve on the sliding area of the tubes to prevent dust and debris from enter the tubes and prevent pinching.
- Extend the stabilizing handle out to transfer the force of over-torque to the entire body and not just the arm.
- Put a dry mat underneath the drill when operating in wet floor conditions.
- Adjust the operating handle so as the force needed to drill is reduced.
- Design stand to collapse to smaller dimensions in order to attach/detach drill.

- Decrease the weight of the stand for easier maneuvering.
- Use increasingly durable material.

With these improvements the risk of each of the hazards is reduced. We can't hope to eliminate all of the risk, only to reduce it to nearly none. To determine overall safety, every hazard has to be analyzed and its risk assessed. Although the probabilities of some hazards are minimal not all precautions can eliminate the possibility of every risk during drill stand operation. By combining the design of our drill stand with both the above safety outlines and competent workers, we believe we have a successful and minimal risk product.

Recommendations

In order for our design to be used in the real world some adjustments must be made. When visiting a construction site to validate our prototype, a few issues arose. We found that although the debris deflector does a good job with blocking debris, dust collects on it making it difficult to see the drill bit. Our recommendation on improving this is to apply a thin wax coating on the plastic that would allow for the dust to run off of the Plexiglas. We saw that dust also affects the lifting motion mechanism. To remedy this problem, a cap should be attached to the top tube to prevent dust from falling inside. A sleeve should also be used to cover the sliding mechanism so dust doesn't collect on it. We also found that it is difficult to keep our stand steady on uneven surfaces. Therefore, we recommend adding feet to the base that are easy to adjust to different surfaces. Another problem that surfaced was the range of height for which we could drill. The height drilled can easily be increased by extending the length of the top tube until the stand reaches the desired height. Other recommendations we would like to give are painting the RIHD stand to prevent rusting and rounding dangerous sharp edges.

Conclusions

In commercial and industrial building construction, hand held rotary impact hammer drills (RIHD) are used to bore holes in the underside of reinforced concrete slabs. Overhead drilling with RIHD causes extreme physical exertion and hand-arm vibrations while covering the worker in dust and debris. Overhead drilling with RIHD can also lead to on-site injuries. Workers can hurt their arms or be thrown off their scaffolding when the drill hits steel reinforcement beams in the concrete. During our research, we discovered a couple of existing mechanisms used to help with the muscle fatigue felt with overhead drilling. These mechanisms do not cover the other problems stated earlier. Our design concept uses a Bosch RIHD connected to an aluminum stand. A lifting mechanism consisting of links is used to raise and lower the drill. A Plexiglas slab above the user will shield them from dust and debris. An arm hold on the side of the stand will stable the device and allow the user to reinforce the stand when a steel beam is hit in the concrete. Our team's design has been created by following our customer requirements as well as talking to our sponsor and construction workers in the field.

Acknowledgements

We appreciate all the help and encouragement we have received from all of our instructors and classmates this term. We would like to give a special thanks to Professor Steve Skerlos for giving us all of the background information we needed to become an efficient group and begin designing our project. We want to thank our sponsor Professor John Everett for his help in the implementation of our RIHD stand. We would also like to acknowledge John Woodsum and the Barton Marlow Corporation for the use of their facilities for testing purposes. Finally, we would like to thank our section instructor Mr. W. Ross Morrow for guiding us through the designing process; we really appreciated all of his help.

References

[1] Professor John Everett, Civil and Environmental Engineering, University of Michigan, everett@umich.edu

[2] Construction Occupational Health Program. (March 2003). Bright Ideas #8 McGovern Lever. Retrieved January 14, 2006 http://www.uml.edu/college/she/WE/COHP/Documents/Bi8.pdf

[3] Jonathan Woodsum, superintendent, Barton Marlow construction job

[4] Stephen Kozak, Chief Engineer, Ford Motor Co., kzkspeed@ameritech.net

[5] ASM Aerospace Specification Metals Inc. Aluminum 6063 T5. Retrieved March 12, 2006. http://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA6063T5

[6] Wikipedia, The Free Encyclopedia. Tensile Strength and Shear Strength. Retrieved March 12, 2006. http://en.wikipedia.org/wiki/Tensile_strength

Figure 5: *Gantt chart showing our estimated progress before Design Review 1,2 and 3.*

R.I.H.D STAND (TEAM 24)

Team | Allison | Amy | Christian | Lou | Nazli

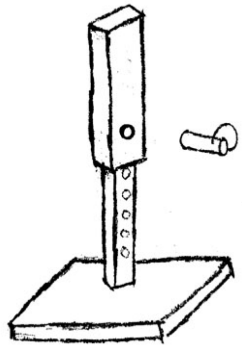
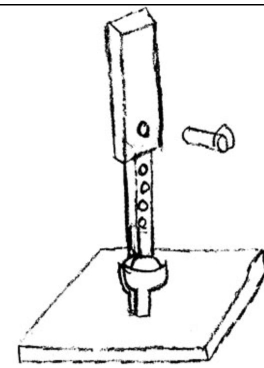
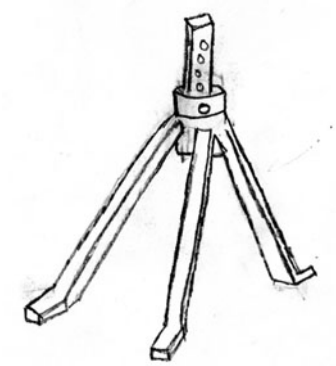
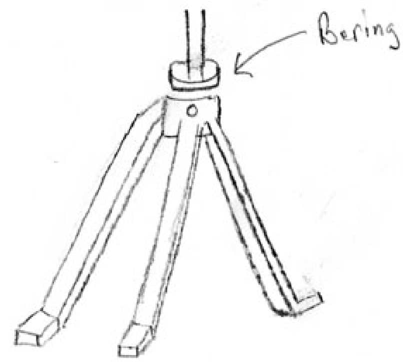
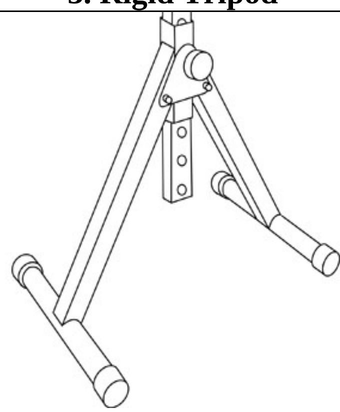
TASKS	17-Jan	18-Jan	19-Jan	20-Jan	21-Jan	22-Jan	23-Jan	24-Jan
Meeting with sponsor								DESIGN REVIEW 1
Research on products (drill w/cluth)								
DESIGN REVIEW 1 (report & presentations)								
Revised Abstract								
Exec. Summary								
Prob Description								
Benchmarks								
Customer Requirements								
Engineering Specifications								
QFD Chart								
Gantt Chart								
Conclusions & References								
Prepare presentations materials								

TASK	25-Jan	27-Jan	29-Jan	31-Jan	2-Feb	4-Feb	6-Feb	8-Feb	10-Feb	12-Feb	14-Feb	16-Feb	18-Feb	20-Feb	21-Feb
DESIGN REVIEW 2															
Visit construction site															DESIGN REVIEW 2
Brainstorming ideas															
Concept generations															
Sketches on concepts															
Choose the prototype															
Preliminary engineering analysis															

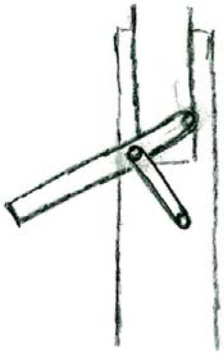
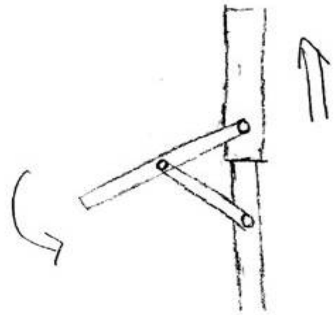
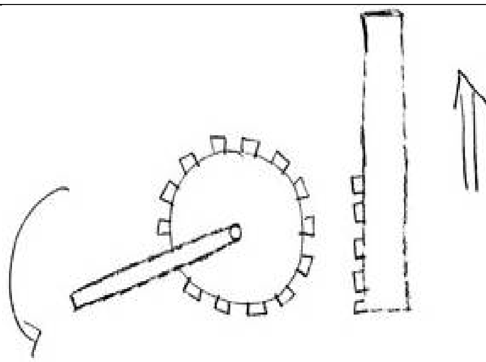
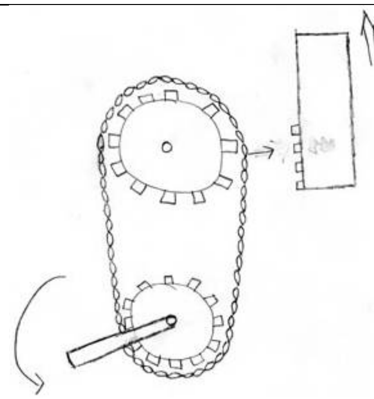
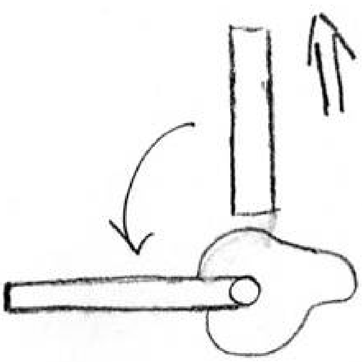
TASK	21-Feb	23-Feb	Spring Break		7-Mar	9-Mar	14-Mar	16-Mar
DESIGN REVIEW 3								
Detailed Engineering Analysis								DESIGN REVIEW 3
specify design dimensions								
choose materials								
CAD Drawings								
Analyze system with ADAMS								
Buy/build parts								
Preliminary Parts Testing								

TASK	20-Mar	25-Mar	28-Mar	9-Apr	10-Apr	12-Apr	13-Apr	17-Apr	18-Apr
DESIGN REVIEW 4 / EXPO / FINAL REPORT				DESIGN REVIEW 4			EXPO		FINAL REPORT
Buy / fabricate parts									
prototype assembly									
prototype review									
prototype testing									
expo materials (poster, video)									
final report									

APPENDIX A: Base Designs

 **1. Pole**	 **2. Ball And Socket**
 **3. Rigid Tripod**	 **4. Tripod with Bearing**
 **5. Bipod**	1. The Pole is steadied by the worker and allows for height adjustability. 2. The Ball and Socket is steadied by the worker and allows for height adjustability and also rotational freedom. 3. The Rigid Tripod is free-standing and allows for height adjustability. 4. The Tripod with Bearing is free-standing, height adjustable and allows rotational freedom of the shaft in the case of drill lock. 5. The Bipod is free-standing with height adjustability.

APPENDIX B: Lifting Motion Mechanisms

 **6. Inside Links**	 **7. Outside Links**
 **8. Rack and Pinion**	 **9. Gear Train System**
 **10. Lever with Cam**	6. The Inside Links allow the center shaft to move the drill vertically by pressing down on the lever. 7. The Outside Links allow the center shaft to move the drill vertically by pressing down on the lever. 8. The Rack and Pinion drives the center shaft upwards by a handle that rotates the gear when pressed. 9. The Gear Train System drives the center shaft upwards through a two gear design. 10. The Lever with a Cam uses a handle attached to a cam whose design drives the shaft upwards when pressed.

APPENDIX C: Debris Deflectors

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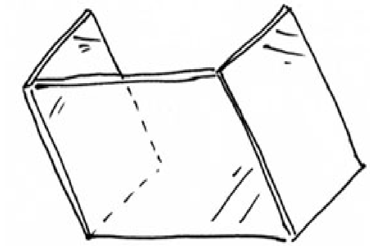
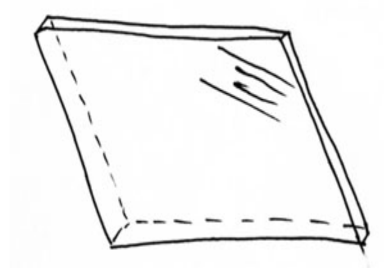
<td>
11. Clear Folded Slanted Slab</td>
<td>
12. Clear Flat Slanted Slab</td>
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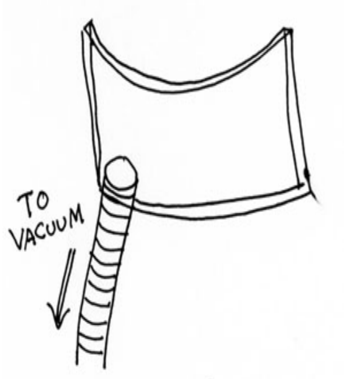
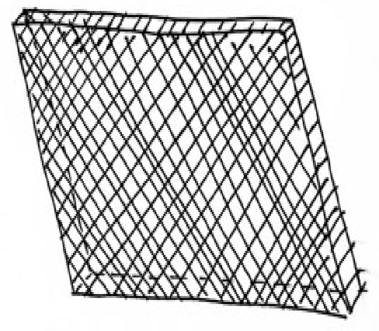
<td>

13. Vacuum</td>
<td>
14. Mesh Collector</td>
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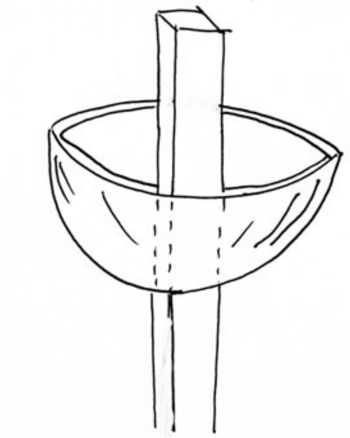
<td>
15. Clear Bowl</td>
<td>11. The Clear Folded Slanted Slab allows for dust and debris falling from the drill to be diverted from the front and the sides to the ground.
12. The Clear Flat Slanted Slab allows for dust and debris falling from the drill to be diverted from the body to the ground.
13. The Vacuum collects dust and debris falling from the drill.
14. The Mesh Collector collects the falling large debris from the drill, but does not collect the dust.
15. The Clear Bowl collects the dust and debris falling from the drill.</td>
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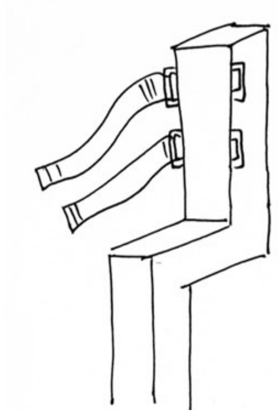
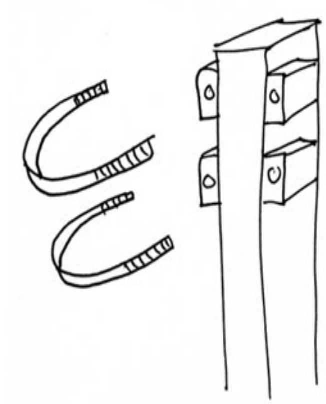
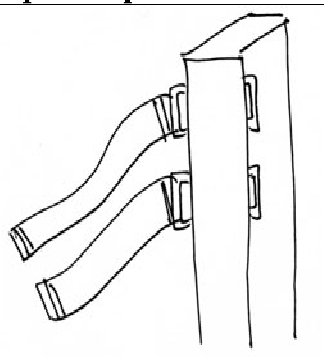
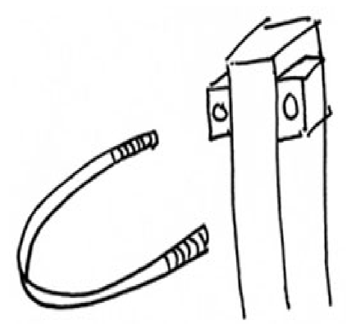
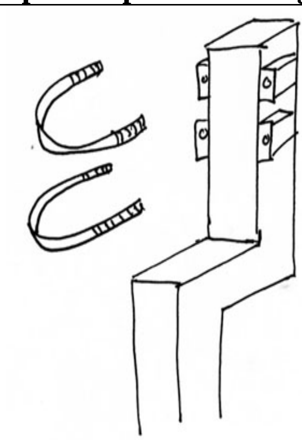
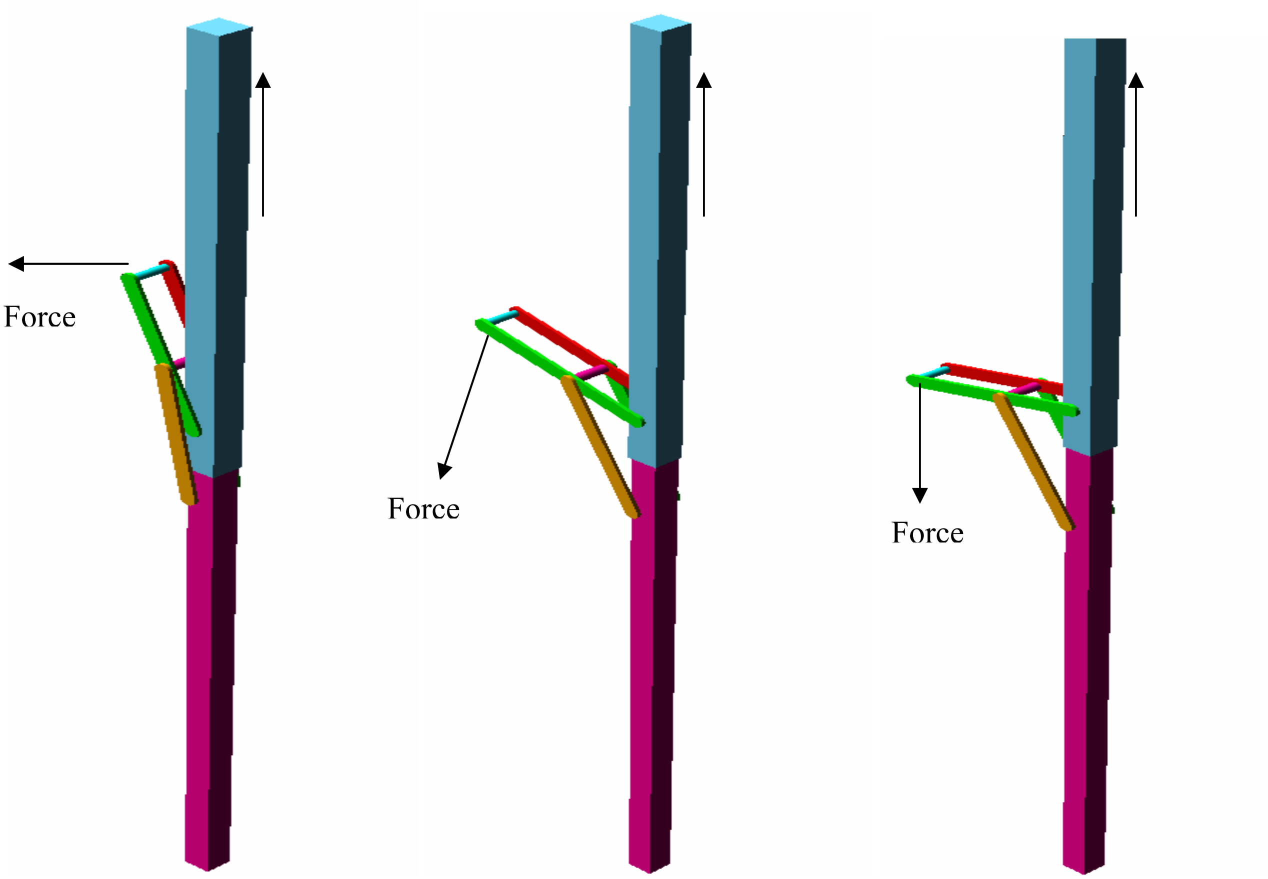
APPENDIX D: Drill Clamping Mechanisms

 **16. 2 Strap Clamps with Crooked Shaft**	 **17. 2 Metal U-Clamps with Straight Shaft**
 **18. 2 Strap Clamps with Straight Shaft**	 **19. 1 Metal U-Clamp**
 **20. 2 Metal U-Clamps with Crooked Shaft**	16. The 2 Strap Clamps with Crooked Shaft hold the drill to the top of the shaft with straps while it rests on the bend in the shaft. 17. The 2 Metal U-Clamps with Straight Shaft affix the drill to the top of the shaft and allow for no rotational freedom in the drill. 18. The 2 Strap Clamps with Straight Shaft hold the drill to the top of the shaft with straps. 19. The 1 Metal U-Clamp holds the drill to the shaft. 20. The 2 Metal U-Clamps with Crooked Shaft allows the drill to rest on the bend in the shaft and affix the drill in two spots to the shaft

APPENDIX E: Linkages Mechanism



APPENDIX F: Pugh Matrices

Legends for Pugh Matrices

Score	Weighted Score
0	0
0	0
9	9
9	6.3
0	0
0	0
9	5.4
9	7.2
9	6.3
	34.2

Score	
0	Low
4	Moderate
9	High

Base Design

Criteria	Weight	Pole		Ball and Socket		Rigid Tripod		Tripod with Bearing		Bipod	
Stand Alone	0.9	0	0	0	0	9	8.1	9	8.1	9	8.1
Rotational Freedom (Supporting)	0.4	0	0	9	3.6	0	0	9	3.6	0	0
Supports Vertical Drilling Force	1.0	9	9	4	4	9	9	9	9	9	9
Lightweight	0.7	9	6.3	9	6.3	4	2.8	4	2.8	4	2.8
Collapsable	0.7	0	0	0	0	4	2.8	4	2.8	4	2.8
Height Adjustable	0.7	0	0	0	0	9	6.3	9	6.3	9	6.3
Inexpensive	0.6	9	5.4	4	2.4	4	2.4	4	2.4	4	2.4
Robust	0.8	9	7.2	4	3.2	4	3.2	4	3.2	9	7.2
Easy to Manufacture	0.8	9	7.2	4	3.2	4	3.2	0	0	9	7.2
Weighted Score Total			**35.1**		**22.7**		**37.8**		**38.2**		**45.8**

Lifting Motion Mechanism

Criteria	Weight	Lever		Gear Train System		Rack & Pinion System		Inside Links		Outside Links	
Able to Raise Drill 6 inches	1.0	0	0	9	9	9	9	4	4	9	9
Robust	0.8	9	7.2	0	0	4	3.2	9	7.2	9	7.2
Easy to Manufacture	0.8	9	7.2	0	0	0	0	4	3.2	9	7.2
Minimize Outer pole Size	0.7	9	6.3	4	2.8	4	2.8	0	0	9	6.3
Inexpensive	0.6	9	5.4	0	0	0	0	9	5.4	9	5.4
Supports Vertical Drilling Force	1.0	9	9	4	4	9	9	9	9	9	9
No Exposed Moving Parts	0.6	0	0	9	5.4	9	5.4	9	5.4	0	0
Weighted Score Total			**35.1**		**21.2**		**29.4**		**34.2**		**44.1**

Debris Deflector

Criteria	Weight	Vacuum		Mesh Collector		Clear Bowl		Clear Folded Slanted Slab		Clear Flat Slanted Slab	
Deflects Large Debris Chunks	1.0	4	4	9	9	9	9	9	9	9	9
Minimizes Dust	0.9	9	8.1	0	0	4	3.6	4	3.6	4	3.6
No Dust Build-Up	0.9	9	8.1	4	3.6	0	0	4	3.6	4	3.6
Inexpensive	0.8	0	0	9	7.2	9	7.2	9	7.2	9	7.2
Lightweight	0.8	0	0	9	7.2	9	7.2	9	7.2	9	7.2
Robust	0.8	4	3.2	9	7.2	9	7.2	9	7.2	9	7.2
Easy to Manufacture	0.7	4	2.8	9	6.3	9	6.3	4	2.8	9	6.3
Weighted Score Total			**26.2**		**40.5**		**40.5**		**40.6**		**44.1**

Drill Clamping Mechanism

Criteria	Weight	1 Metal U-Clamp		2 Strap Clamps Crooked Bar		2 Metal U-Clamps Crooked Bar		2 Strap Clamps Straight Bar		2 Metal U-Clamps Straight Bar	
Secures Drill Well	1.0	4	4	9	9	9	9	9	9	9	9
Easy to Attach/Remove Drill	0.6	9	5.4	4	2.4	4	2.4	4	2.4	4	2.4
Robust	0.8	9	7.2	4	3.2	9	7.2	4	3.2	9	7.2
Easy to Manufacture	0.8	9	7.2	4	3.2	4	3.2	9	7.2	9	7.2
Prevents Rotation of Drill	0.7	4	2.8	9	6.3	9	6.3	9	6.3	9	6.3
Weighted Score Total			**26.6**		**24.1**		**28.1**		**28.1**		**32.1**

APPENDIX G: ADAMS 2005 Plots

Figure G1: *ADAMS 2005 analysis of drill travel and maximum inputted drilling force with safety factor of 1.5*

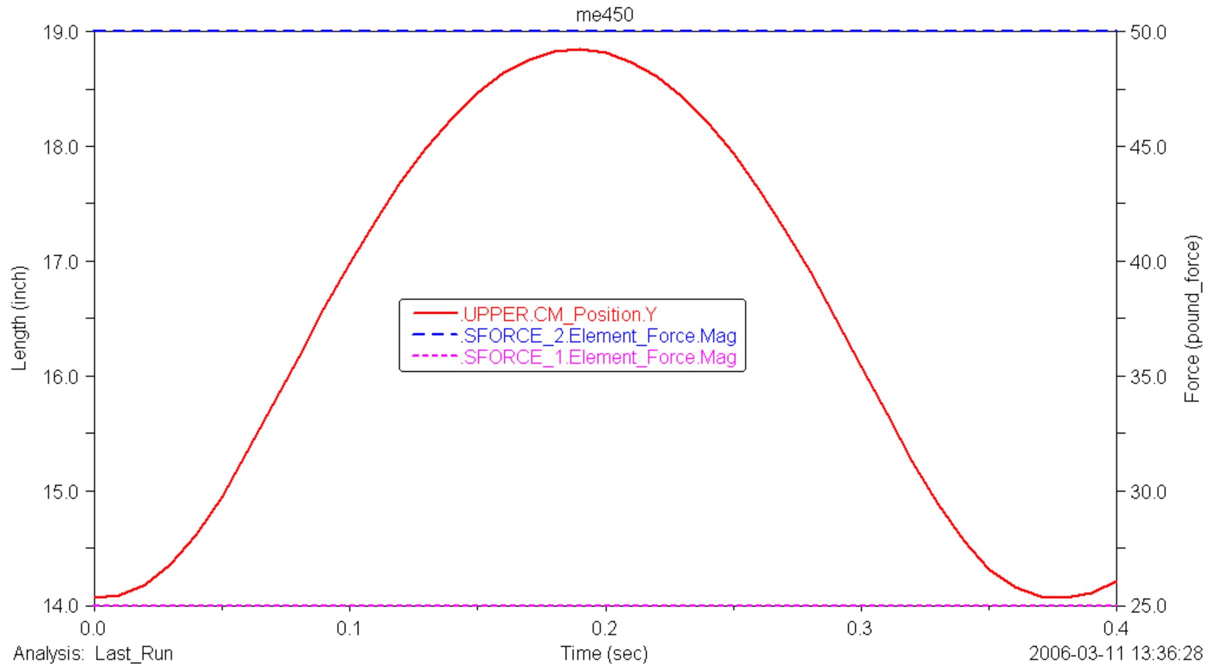


Figure G2: *ADAMS 2005 analysis of maximum inputted drilling force with safety factor of 1.5 as a function of drill travel*

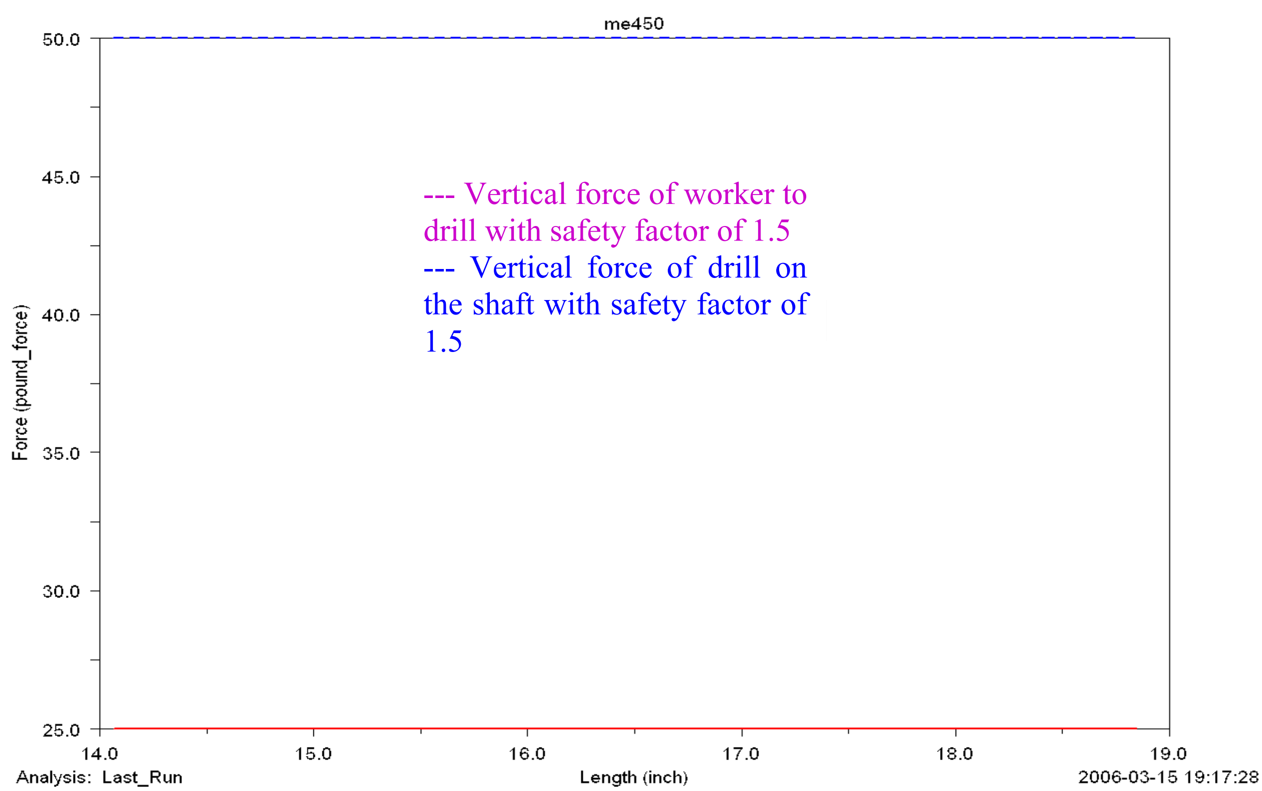
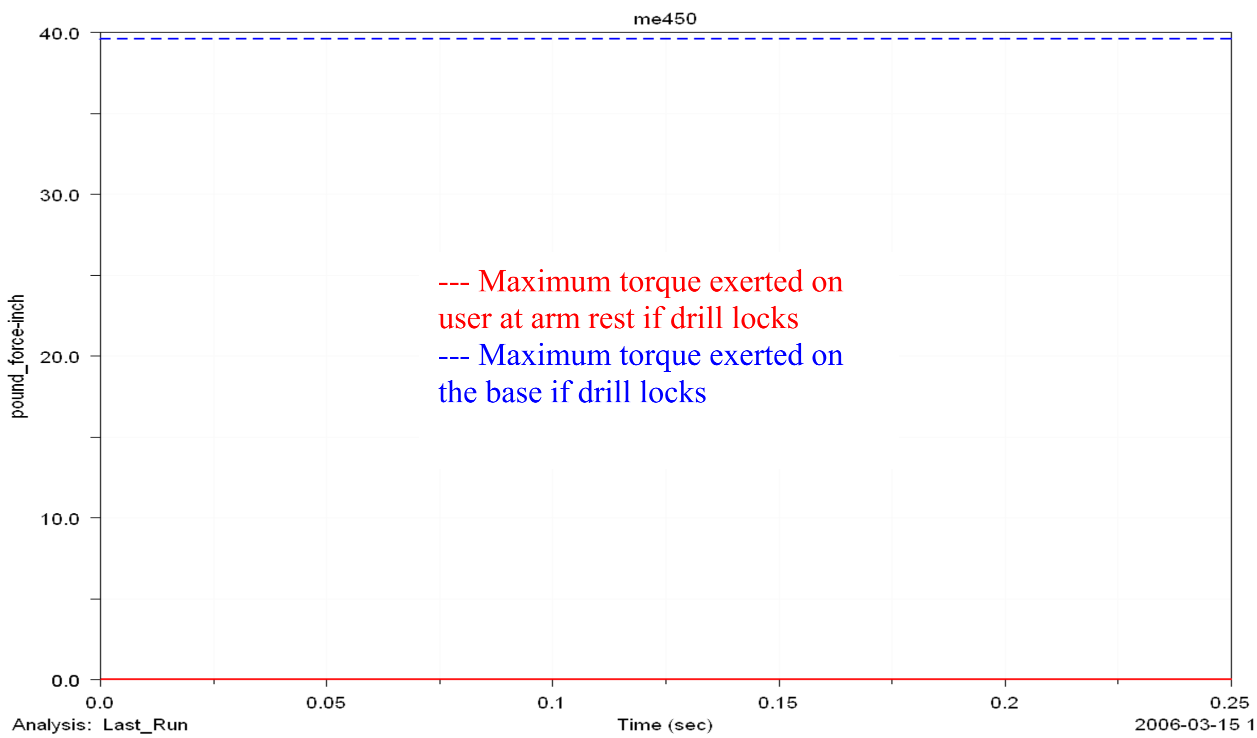


Figure G3*: ADAMS 2005 analysis of torques exerted on the user and the base if drill lock occurs*



APPENDIX H: The following analysis for the height and lengths of tubes for the RIHD stand was performed given the following constraints with a proof of these calculations following. These constraints are:

Constraints:

1) Ceiling height guidelines - a 96" ceiling as our target height. Additionally, the mechanism shall have the capability of drilling to ceiling heights 6" above and below this target height. Thus the range of ceiling heights is 90" to 102".
2) Base constraints - a standard base with a height of 17" above ground level. (The uppermost part of this stand extends 8" above the aforementioned height. This distance is 25" above ground level.)
3) User ergonomics – a maximum height of the lever at rest assigned to be 74" above ground level and a minimum height of the lever at full extension of the drill motion assigned to be 50" above ground level.
4) Drill bit dimensions – the chuck of the drill bit will be flush with the top of the upper tube. The drill bit extends 3" from this flush edge toward the ceiling.
5) Drill bit clearance – the drill bit shall come within 1.5" of the ceiling. The mechanism will cause the drill to travel 4.5" (1.5" to ceiling and 3" into concrete) via operator's use of the lever.
6) Lower tube condition at maximum height of stand – the lower tube shall extend 3" below the standard base height of 17" when the stand is being used for maximum ceiling height of 102".
7) Lever range of motion – the lever will require 11.25" of vertical travel in order to move the drill 4.5" upward.
8) Overlap of tubes – the lower tube shall overlap inside the upper tube 12" after full extension of the lever. Equivalently, the lower tube shall overlap inside the upper tube 16.5" (12" + 4.5" range of motion) at rest.
9) Link angles – the top link will form a 20° with the vertical when the mechanism is at rest and will form a 100° with the vertical when the mechanism is at full extension.

Calculative Proof (Assuming a Ceiling Height of 96"):

1) Measure 8" upward from ground. This is the beginning of the lower tube.
2) Measure 61 ¼" upward from the beginning of the lower tube. This is the end of the lower tube. You are now 69 ¼" above ground.
3) Measure 16.5" downward from the end of the lower tube. You are now at the bottom of the upper tube (lower tube/ upper tube interface) when the mechanism is at rest. This is 52 ¾" above ground level.
4) Measure 4.18" downward from the lower tube/ upper tube interface. This is the location of the pin connecting the lower link to the lower tube. This is 48.57" above ground level.
5) Measure 6.18" upward from the location of the pin connecting the lower link of the lower tube. This is the location of the pin connecting the upper link to the upper tube. This is 54 ¾" above ground level. Call this point "Lever 0,0"
6) Use trigonometry to find that the vertical distance from "Lever 0,0" to the top of the upper link is: 10.25*sin(70°) = 9.63". Therefore, the top of the upper link is 64.38" above ground level.
7) Use trigonometry to find that the vertical distance from the top of the upper link to the top of the handle is: 3.875*sin(70°) = 3.64". Therefore, the top of the handle is 68" above

ground level. Note that handle is therefore always 13.25” above the reference “Lever 0,0” when the mechanism is at rest.

8) Use trigonometry again to find the vertical distance from the top of the handle to the reference “Lever 0,0” when the mechanism is at full extension. This is: (3.875” + 10.25”)*sin(10) = 2.45” below the “Lever 0,0” when the mechanism is at full extension (lever down.) This is 56.8” above ground level. (48.57” + 4.18” + 4.5” + 2” – 2.45” = 56.8”) Note that the handle is therefore always 2.45” below the reference “Lever 0,0” when the mechanism is at full extension (lever down.)
9) Go back to step four (4) where the lower tube/ upper tube interface was defined to be a distance of 52 ¾” above ground level. From this point measure 38 3/4” upward. This is the end of the upper tube. This is 91.5” above the ground.
10) Measure 3” upward from the end of the upper tube. This is the end of the drill bit. This is 94.5” above the ground.
11) Measure 1.5” from the end of the drill bit. This is the ceiling. It is 96” from ground level.
12) The drill travels a distance of 4.5” upward when the operator uses the lever. Thus, the drill bit will engage to a maximum depth of 3” into the concrete.
13) Note that when drilling to a ceiling height of 102” the lever handle will travel from 74” to 62.8” above ground level. When drilling to a ceiling height of 90” the lever handle will travel from 62” to 50.8” above ground level.

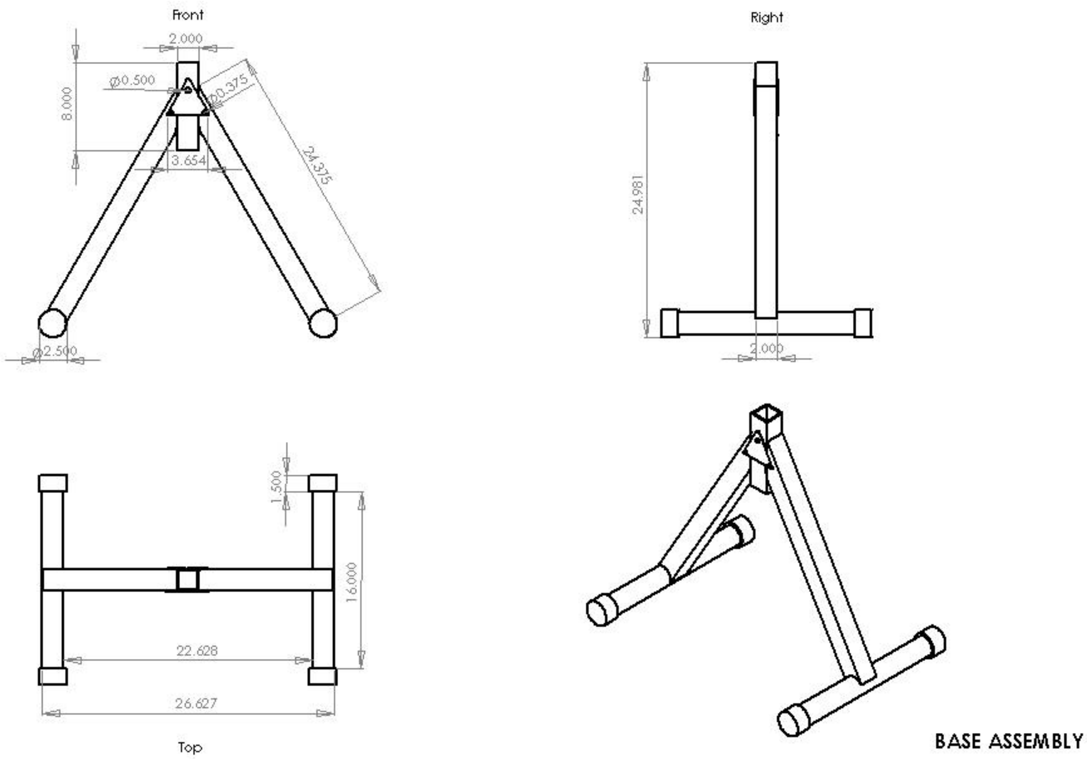
APPENDIX I: Bill of Materials

Part	Description	Picture	Material	Cost	Dimensions	(Inches)
BASE						
Bipod Base		Appendix J pg 32	Steel	$50	Height Collapsed Height Leg Length Spread Collapsed Spread Width Inner Tube Thickness Outer Tube Thickness	24 3/4 27 3/4 24 3/8 27 7/8 5 1/4 18 1/2 1 3/4 2
Large Screw	Secures adjustable tube at desired height (14 threads/in)	Appendix J pg 32	Steel	NA (included in base cost)	Diameter	7/16
Small Screw	Secures adjustable tube at desired height (20 threads/in)	Appendix J pg 32	Steel	NA (included in base cost)	Diameter	5/16
TUBING						
Inner Tube	Adjustable height with 9 holes spaced 1.5 inches apart (5 feet high)	Appendix K pg 34	6063 T5 Aluminum Alloy	$34.10	Height Inner Thickness Outer Thickness Diameter of holes Distance between holes	60 1 1/2 1 3/4 1/2 1 1/2
Outer Tube		Appendix K pg 33	6063 T5 Aluminum Alloy	$34.10	Height Inner Thickness Outer Thickness	38.75 1 3/4 2
LIFTING MECHANISM						
Lower Link	2 links, one on each side.	Appendix L pg 35	6063 T5 Aluminum Alloy	12 inch by 12 inch plate $56.78	Length Width Thickness Pin Diameter	11 1 3/8 3/8
Upper Link	2 links, one on each side.	Appendix L pg 35	6063 T5 Aluminum Alloy	See above	Length Width Thickness Pin Diameter	12 1 3/8 3/8
Handle	Connects both upper links.	Appendix L pg 35	6063 T5 Aluminum Alloy	See above	Length Diameter Handle to link tip dist. Distance between links	5.5 1 3 7/8 2 3/4
Bolts (Upper Links)	2 Total, one connecting upper and lower links. One connecting upper links to upper shaft.	Appendix L pg 35	Steel	$1.00	Diameter	3/8

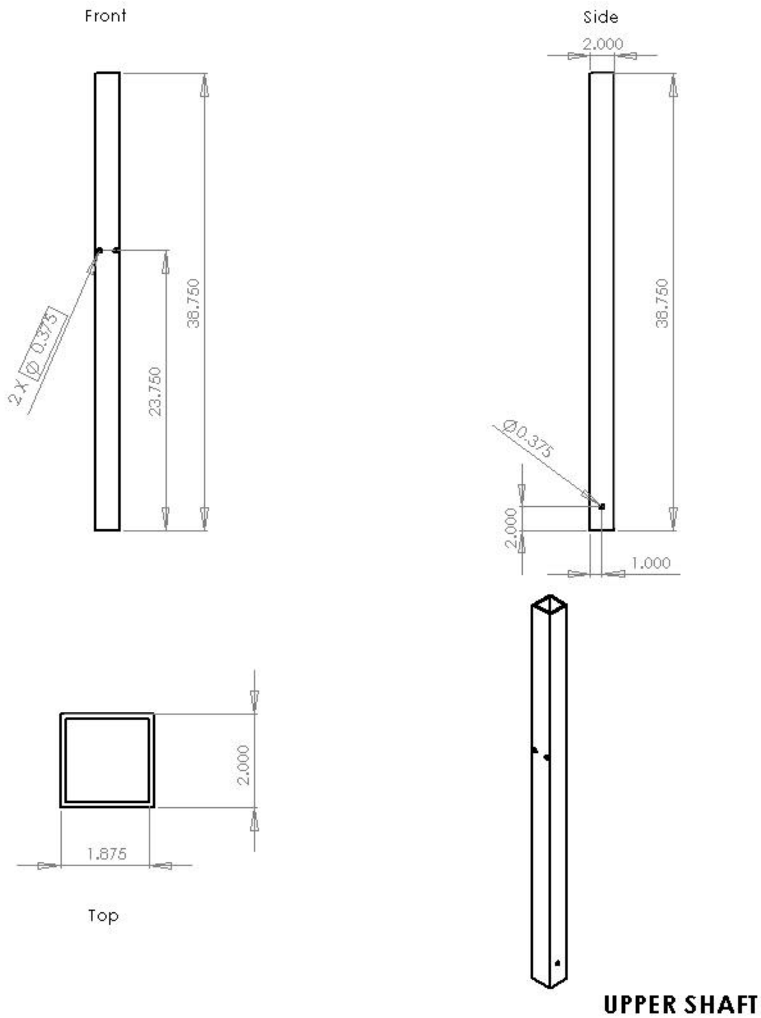
Bolts (Lower Links)	1 Total, connecting lower links to lower shaft	Appendix L pg 35	Steel	$0.50	Length Diameter	3 3/4 3/8
Nuts	3 Total (For Above Pins)	Appendix L pg 35	Steel	$0.25	Length Diameter (Inside)	2 7/8 3/8
STABILIZING HANDLE						
Stabilizing Handle	Connects to inner tube so it is stationary. User braces themselves to prevent the stand from spinning.	Appendix M pg 36	Aluminum		Length - Handle - Threads Diameter - Handle - Threads	 6 2 1/4 1 1/4 1/2
Nut	Attaches arm rest to inner tube	Appendix M pg 36	Steel	$0.25	Diameter (Inside)	1/2
Rubber Grip	Bontrager Bicycle Replacement Grip	Appendix M pg 36	Rubber	$9.00	Length Diameter	6 1 1/4
DEBRIS DEFLECTOR						
Plexiglas sheet		Appendix N pg 37	Plexiglas	24 inch by 48 inch sheet $50.08	Length Height Width	24 18 0.5
Bracket	Attaches the Plexiglas to the stand (2 Symmetric Pcs.)	Appendix N pg 37	Steel	See Lower Link Price	Length Width	2 2
Bolts	2 bolts: connecting bracket to upper shaft	Appendix N pg 37	Steel	$1.00	Diameter Length	3/8 2 1/2
Bolts	2 Bolts: connecting bracket to Plexiglas	Appendix N pg 37	Steel	$1.00	Diameter Length	3/8 7/8
Nuts	4 Nuts	Appendix N pg 37	Steel	$0.25	Diameter (Inside)	3/8
DRILL CLAMP						
Top Clamp	Secures upper section of drill to the stand	Appendix O pg 38	Aluminum		Screw Spacing Length Width Height	3 4 4 1
Bottom Clamp	Secures lower section of drill to the stand. It hooks through the handle	Appendix O pg 39	Aluminum		Screw Spacing Length Width Height	3 4 4 1
Clamp on outer pole	Place were U-clamps connect to	Appendix O pg 38	Aluminum			
Bolts	4 Bolts (2 On each Bracket)	Appendix O pg 38	Steel	$2.00	Length Diameter	4 1/4 3/8

Nuts	4 Nuts (2 On Each Bracket)	Appendix O pg 38	Steel	$0.25	Diameter (Inside)	3/8
DRILL						
Rotary Impact Hammer Drill	Bosch 11255VSR			$200	Height	
ELECTRICAL WIRING						
Power Outlet	Outlet the actual drill cord is plugged into.	Figure 6 pg 12				
Trigger	Controls the power to the drill. Turns the drill on and off.	Figure 6 pg 12				
Power Cord	Provides power from the electrical outlet to the stand. This provides power to the drill which is regulated by the trigger.	Figure 6 pg 12				

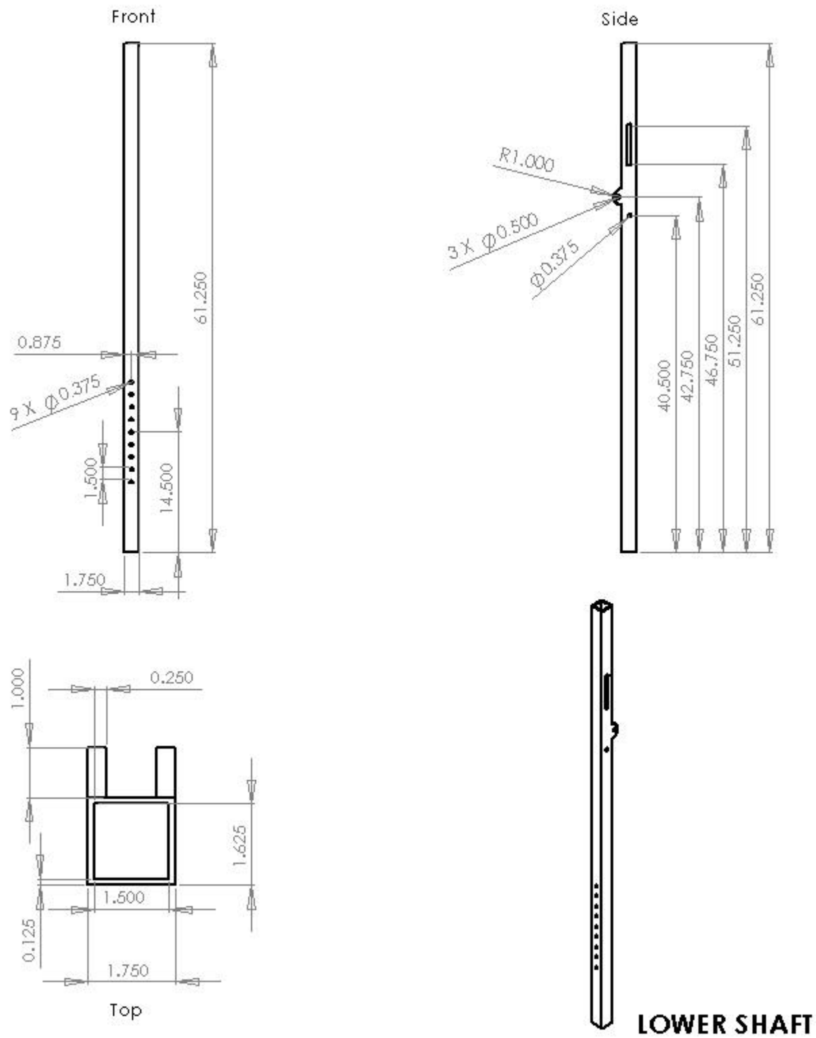
APPENDIX J: Dimensioned Drawing of the Base (all dimensions in inches)



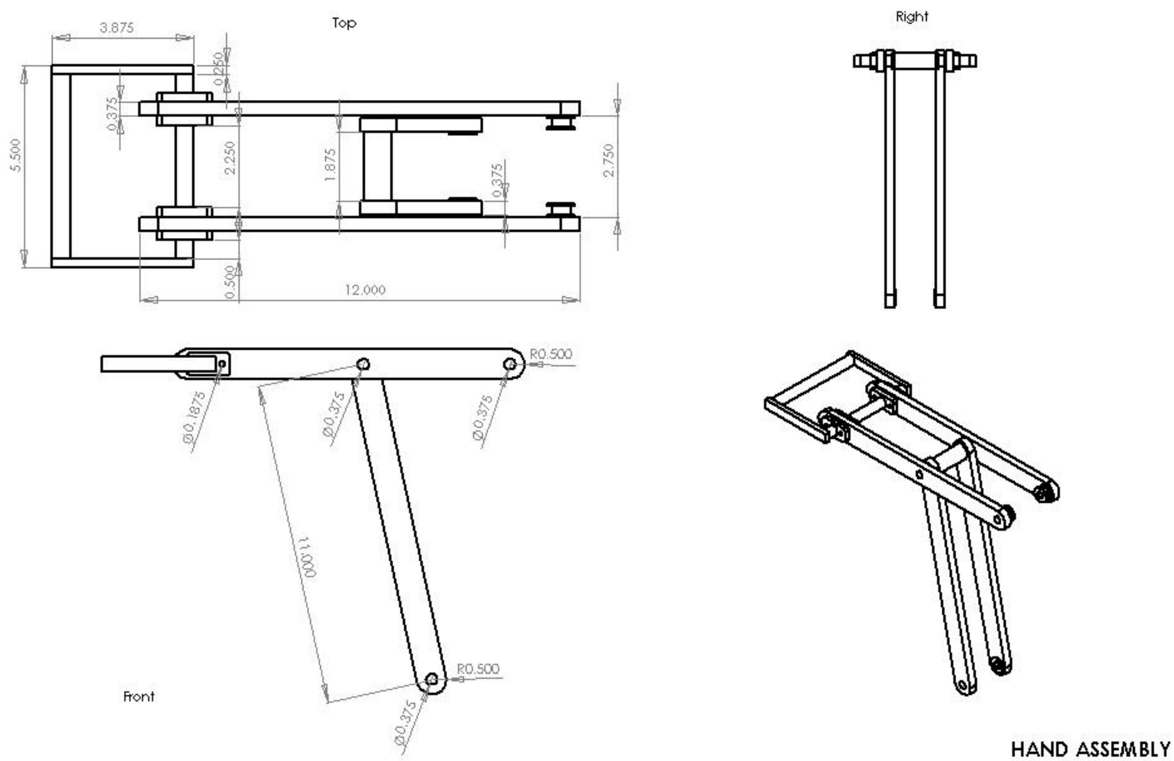
APPENDIX K: Dimensioned Drawing of the Tubing (all dimensions in inches)



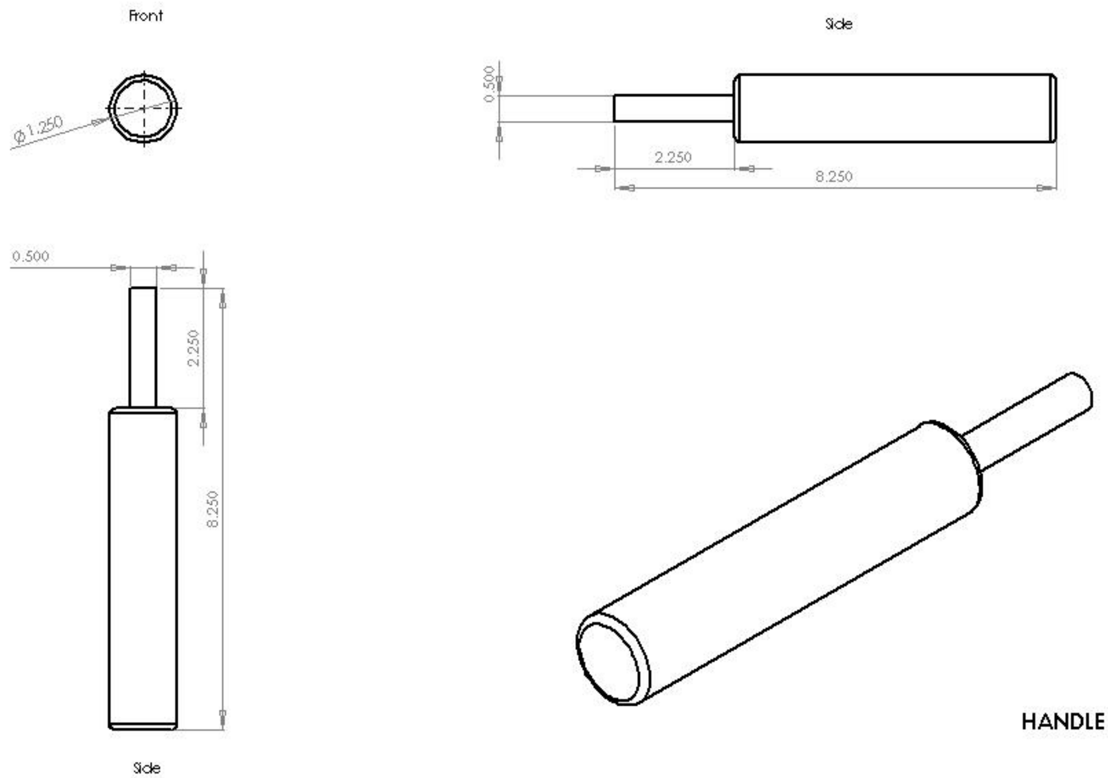
(cont) **APPENDIX K: Dimensioned Drawing of the Tubing (all dimensions in inches)**



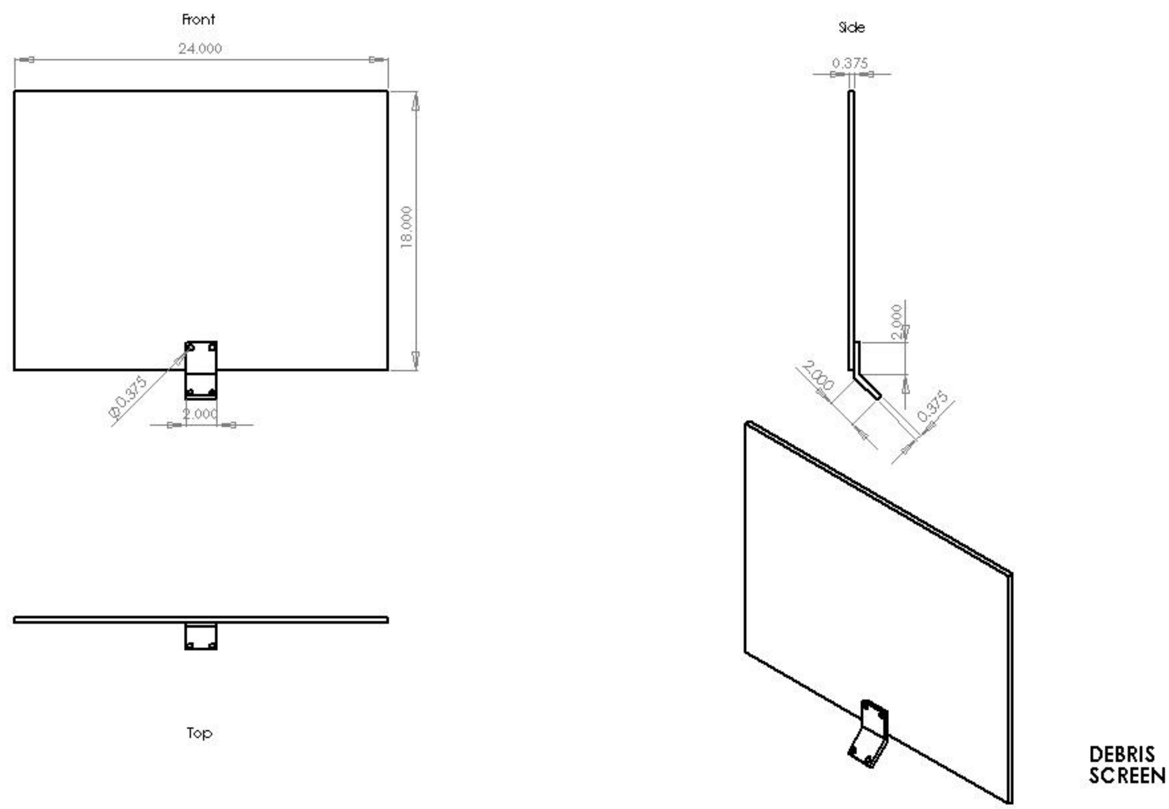
APPENDIX L: Dimensioned Drawing of the Lifting Mechanism (all dimensions in inches)



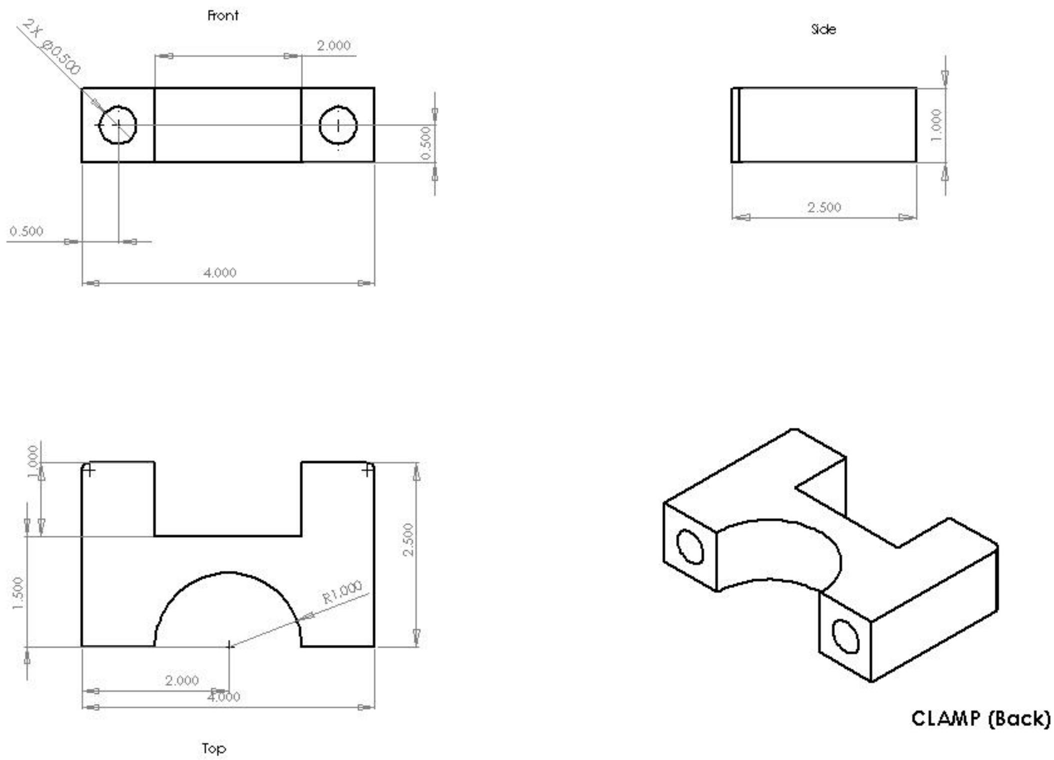
APPENDIX M: Dimensioned Drawing of Stabilizing Handle (all dimensions in inches)



APPENDIX N: Dimensioned Drawing of Plexiglas (all dimensions in inches)



APPENDIX O: Dimensions of Drill Clamps (all dimensions in inches)



(cont) APPENDIX O: Dimensions of Drill Clamps (all dimensions in inches)