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The Poverty Crusher

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I HEREBY RECOMMEND THAT THE THESIS PREPARED
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ENTITLED

THE POVERTY CRUSHER

BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

BACHELOR OF SCIENCE
IN
MECHANICAL ENGINEERING

Thesis Advisor

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THE POVERTY CRUSHER

By

Rob Golterman, Brian Hammond, Ryan Le, and Arvin Lie

THESIS

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ABSTRACT

The Poverty Crusher team built a human-powered rock breaking device for the women in Nepal who make $1.50 - $3 per day crushing rocks. A prototype jaw-type rock crusher was designed and built over a period of several months. However, the device was unable to break rocks due to excessive bending in the connection points of the frame and in the crushing faces. Improvements were suggested for the next prototype, which include increasing the second moment of inertia of the crushing faces, using a welded frame, and generally decreasing the cost and weight of the device.

AC.KNOWLEDGMENTS

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Introduction

In a small community on the outskirts of the city of Birendranagar, Nepal, a group of women and their children painstakingly break rocks with hammers all day to make a living. This work, which barely provides enough money to live on, is arduous, unsafe, and detrimental to the long-term health of the women. In order to produce enough gravel, the children often help, taking away from the time they could spend in school, as shown in Figure 1. Our goal for this project was to create an efficient, safe, low-cost, human-powered rock crusher that was easy on the body. By creating this device and distributing it to the people most in need, the Poverty Crusher team would empower these women so that they can better themselves and their children.

The situation for the poor women of Birendranagar is harsh, but they have few other choices for how to make a living. They often have no husband to help support the family, and women are discriminated against, even at a young age. One survey of 26 districts in Nepal showed that the rate of female child labor is higher than that of males. (Sangroula). The opportunity for education is clearly male dominated, with 61.66% of males receiving some education, and only 38.33% of females (UNICEF). Add to this discrimination the fact that widows are also discriminated against, often treated as subhuman (IrinNews), and it is no surprise that the women in Birendranagar are stuck in an unfortunate situation. They have very little, if any, education, and have no specialized skills. Breaking rocks is often the only way for them to make a living.

Figure 1: A child crushing rocks in Birendranagar, Nepal

The women collect large piles of rocks from the river beds and break them with a hammer, often with the help of their children. Over time, the work takes its toll on the women's bodies and accumulates into problems like health issues with their arms and shoulders, and obvious aging from the bright sun. For this work, they are compensated around $1.50 - $3.00 a day. This money comes from construction contractors who pay the women per sack of gravel. The gravel is then taken to be used for either roads or building material in the town.

The goal of the Poverty Crusher project was to create a human-powered, cost-effective solution for the women of Nepal to be able to break rocks more efficiently, easily, safely, and comfortably. The Poverty Crusher would facilitate a number of beneficial outcomes for the women. First, it was to be able to produce gravel more quickly so that the women can earn more money and spend more time with their families. The extra time and money would allow them to keep their kids in school for longer, which gives hope for the children's future. The device would also be safer than breaking rocks with a hammer and reduce injuries. Similarly, the device should reduce the stress on the women's bodies, allowing them to live healthier lives for longer. Finally, the device will be cost effective, and cost approximately $25 for the final product based on available materials in Nepal as well as the cost of labor.

It was difficult to fathom exactly what life was like in Birendranagar. Brian Hammond and Rob Golterman had the privilege of visiting Nepal for the Poverty Crusher team. Their goal was to determine the best way to introduce the device to the women and discover potential obstacles associated with the different culture and living environment. Cultural boundaries, for example, might prevent certain designs from being successful. The team also had to consider whether individual devices or a community device would best suit the women. Based on their observations, the team needed to answer certain questions concerning this project based in a third-world country. For example, how would the team distribute the device to the women? Should the device be given away or should the women be charged a fee? They had to base their decisions on interviews from the women as well observations about materials and machining capabilities that were available in the town. By travelling to Birendranagar, the team was able to gather research, meet the women, and experience Nepal firsthand. This was extremely important to the long term success of our project.

Overall, the goal of the Poverty Crusher was centered on empowering the poor women in Birendranagar. The overall goal of creating the device was to give the women the opportunity to improve their as well as their children's lives.

Overall System

The Poverty Crusher team's goal was to create an efficient, safe, low-cost, human-powered rock crusher that was easy on the body.

Concept

The rock crusher design was based on a jaw crusher as seen in Figure 2. The crushing mechanism for a jaw crusher takes place between two metal plates, one of which is stationary, and one of which moves back and forth (the fixed jaw and moving jaw). The plates are angled so that, as the rocks fall between the two plates, the moving jaw crushes them into continually smaller pieces. The moving jaw is powered by a rotating flywheel, and an eccentric shaft is utilized to create the back and forth motion. Due to the small diameter of the eccentric shaft and the large diameter of the flywheel, a large amount of force can be imparted by the plates (AGGDesigns).

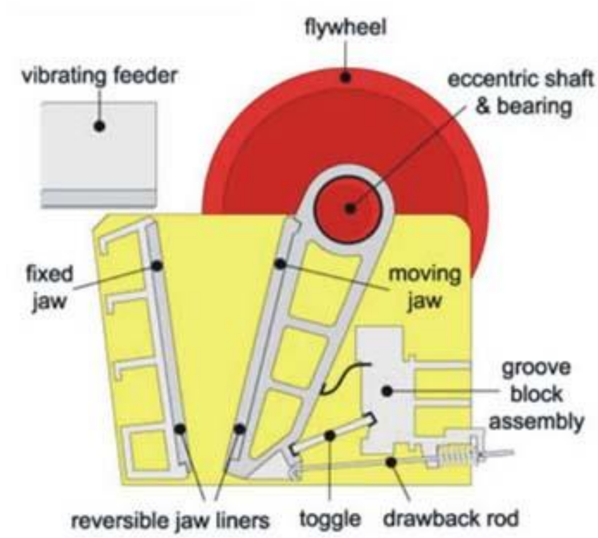

Figure 2: A Jaw Crusher Diagram (Henan)

Our design is a smaller, human-powered version of the jaw crusher, and the basic design can be seen in Figure 3.

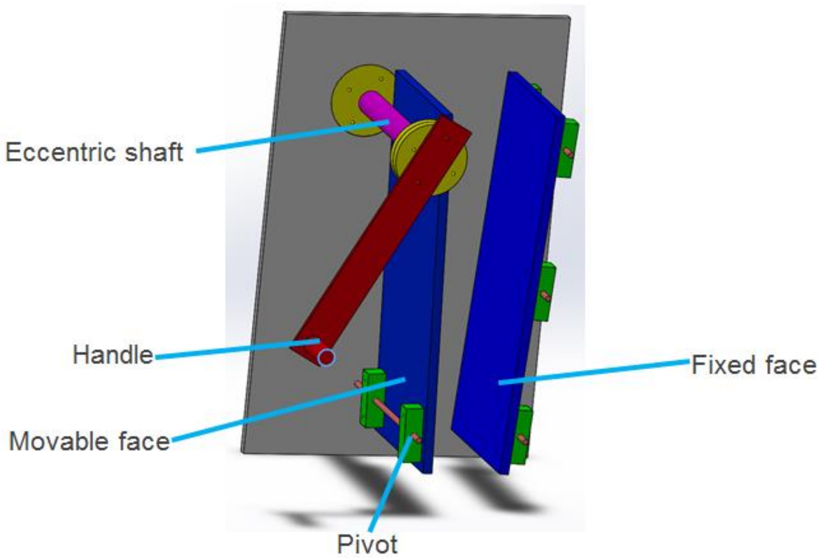

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Figure 3: Basic design of the Poverty Crusher

The device features four main subsystems: the frame, the fixed face, the moving face, and the eccentric shaft and handle. The handle turns an eccentric shaft which is attached to the moving jaw. The eccentric shaft turns within bearings attached to the frame of the device. Since the shaft is off-center, it creates a back and forth motion in the moving face, which is fixed to the frame by a pin connection. The eccentric shaft sits on the back of the moving face and moves freely along the face up and down. The fixed face is connected to the frame and stays stationary as the moving frame pushes rocks against it. The frame essentially holds the system together, but it can also be outfitted with a covering to protect the user from the moving parts and rock shrapnel.

Customer Needs and System Level Requirements

Based on feedback from potential customers, professionals, and non-profit workers, the device needs to fit certain parameters. One of the primary driving parameters was the cost, which was first estimated to be around $25. $25 was chosen because it had to be affordable enough for the women in Nepal to buy while counting in the costs to build and make the device. It is likely that the women would not be able to afford the device's cost upfront, even if it is around $25, so distributing the device by lending it to the women until they can pay it off might be appropriate. Even with a lending plan, the cost is a very important factor in the success of the device.

Another very important parameter is the efficiency of the device. The device must actually be able to improve the gravel output of the women so that they can have a higher amount of revenue. In the early stages of the design, efficiency was not an extremely important criterion. Rather, focus was on maximizing the force output from the device. After receiving a video of the rock breaking in action, it was determined that the women break rocks much more quickly and easily than expected. The design focus changed from high force input to high rock breaking rate. Based on the women's ability to break around 50 pounds of rocks per hour, the device needs to consistently break at least 60 pounds per hour.

The safety of the device has been an important factor in all versions of the design. Injuries can easily occur when breaking rocks with a hammer such a hitting a finger with the hammer or the shrapnel from the gravel can damage the women's eyes. These injuries could put the women out of work for a while leaving the family with little to no income. The moving parts in the device need to be covered, so fingers and clothes will not get caught, and the shrapnel from the broken rocks will be contained and kept away from the eyes. Similarly, the stress the device puts on the user's body is an important factor. The high impact stress imparted on the body from striking a rock with a hammer can accumulate within the women's bodies over time causing chronic pain in the wrists, arms, shoulders, and back. The design should lower the impact stresses imparted to the body, lower the overall input force required, and be a natural, ergonomic motion. Improving the device's ergonomics will reduce the level of impact and the magnitude of the stresses imparted on the woman's body so they can live healthier lives.

While the main driving parameters for the system were cost, efficiency, safety, and stress on the user, there were a number of other design requirements that were kept in mind. Durability was a very important requirement for a successful device. The device would need to last an extended period of time, 2 years or more, in order to continue benefitting the women. In a developing nation, where proper storage might not be available, it is important that the device be developed to resist the elements and handle factors like dust and mud. The device should also be lightweight, so as to be portable, which is important so the women can bring the device home to keep it safe. Another important requirement was that the device could be built and maintained with local materials and resource. Building the device locally not only cuts down on cost, but allows the device to be more easily distributed and repaired. For a summary of the major design criteria, see Table 1 below.

Table 1: Summarized Design Criteria

Efficiency	60 lbs. per hr.
Cost	Under $25
Safety	Covers moving parts
Ergonomics	Reduces strain on body
Reliability/Life Expectancy	2+ years
Weight	Lightweight

Overall, the device had to meet a number of criteria to be successful. The women in Nepal were already using hammers to crush rocks, so an ideal device would increase their efficiency and safety, decrease the stress on their bodies, last a long time, and be made locally, all at an affordable price.

Physical Aspects

The Poverty Crusher was designed to be used by the rock breakers in Birendranagar, most of who are women. The device can be used either at the river where the rocks are collected, or at the houses of the rock breakers. After collecting a number of rocks from the river, the women would load the crusher with a few rocks and turn the handle. The handle would turn the eccentric shaft, which will push the moving jaw into the rock, crushing it against the fixed jaw. As the rocks break, the small pieces will fall out from between the two plates, while larger pieces will travel farther down before getting stuck and crushed between the plates again. Eventually, all the rocks that were placed into the device come out the bottom. Figure 4 below shows the second version of the prototype. The mechanism functions as described, but the device is not stiff enough to break rocks. The bending in the system comes from a combination of factors and is further described in the Subsystems sections.

Figure 4: Second Poverty Crusher prototype

Functional Analysis

The device converts a rotational input force into a back and forth output force. The user turns a handle, which transfers a torque to the eccentric shaft. The torque rotates the eccentric shaft within the bearings, and the eccentric shaft inputs a force onto the moving jaw. The moving jaw and fixed jaw compress the rock, which in turn imparts a force on both jaws.

The handle provides a mechanical advantage because its rotational motion has a larger radius than that of the eccentric shaft. The longer the handle, the greater the advantage is. For the second prototype, the handle shaft was 12 inches long. The eccentric shaft had a radius of 0.5 inches and was offset by 0.3 inches, giving it a rotational radius of 0.8 inches (see Figure 5 below). The mechanical advantage of the system, which can be calculated as the ratio of the handle shaft length to the rotational radius of the eccentric shaft, is 15. This advantage means that a force input at the handle is output 15 times greater at the eccentric shaft.

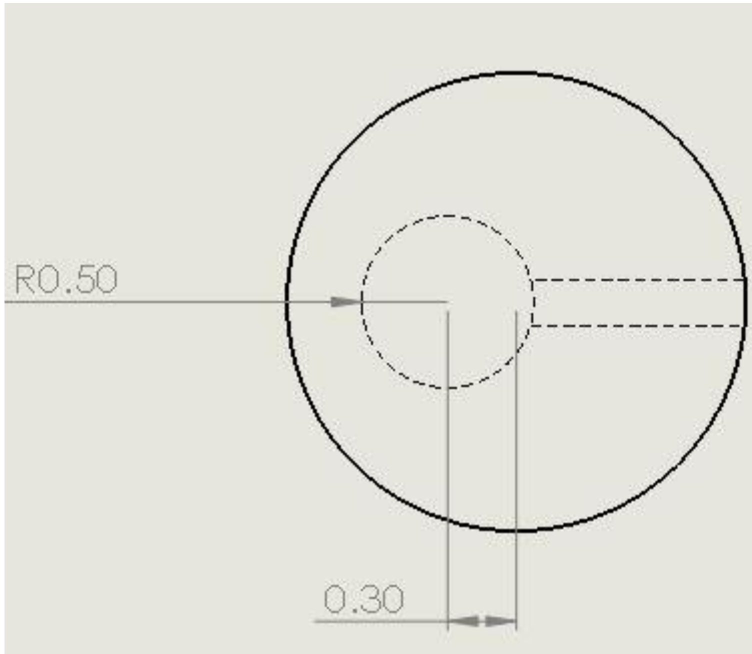

Figure 5: Eccentric Shaft Offset

The connection between the eccentric shaft and moving plate, however, created a mechanical disadvantage because the force from the eccentric shaft was not always directed perpendicular to the moving face. Figures 6, 7, and 8 below demonstrate this mechanical disadvantage. In Figure 6, the eccentric shaft is at the top of its rotation, rotating clockwise. The force it inputs onto the moving face, F, is tangent to its direction of motion, so in this case, the direction of F is horizontal. The moving face is angled, however, so only the perpendicular component of F, F-Perp, does any work in rotating the moving face. F-Perp can be calculated with the following equation:

$$F\_Perp = F * cos\theta \qquad \text{(Equation 1)}$$

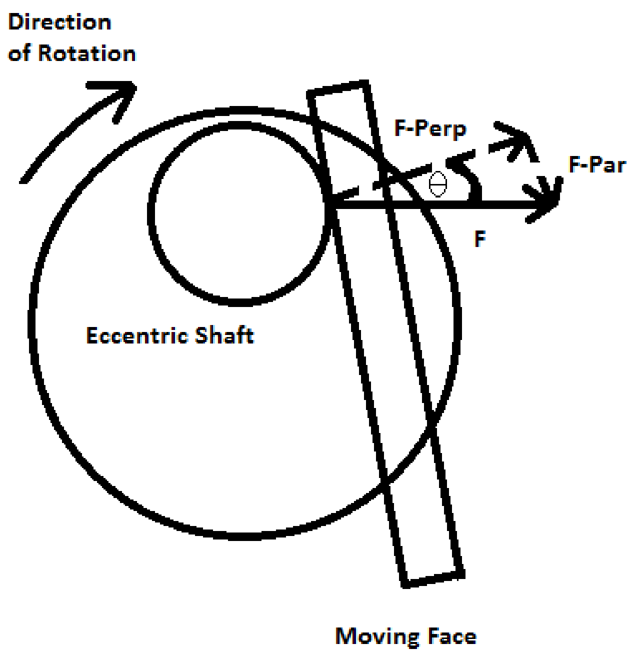

Figure 6: Eccentric Shaft Input Force, Top of Rotation

In Figure 7, the eccentric shaft has rotated clockwise, so its tangent force, F, is now angled downward. Assuming F is constant throughout the rotation, the value of F-Perp decreases as the eccentric shaft rotates from the top position. The parallel component of F, F-Par, has increased between Figures 6 and 7, but since only F-Perp causes the moving face to rotate, the overall force actually input into the moving face has decreased.

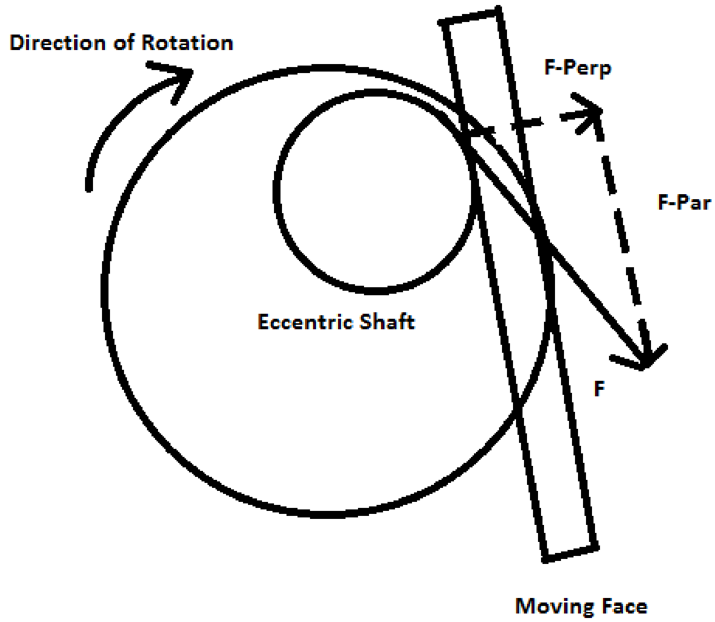

Figure 7: Eccentric Shaft Input Force, Rotated Clockwise

At some point in the rotation, the tangent force from the eccentric shaft, F, is actually perpendicular to the moving face. At this point F = F-Perp, and there is no F-Par component. At this point, all of the force put into the eccentric shaft is translated into the moving plate, so the force output is at its maximum. At all other points along the rotation, however, the system is operating at a mechanical disadvantage.

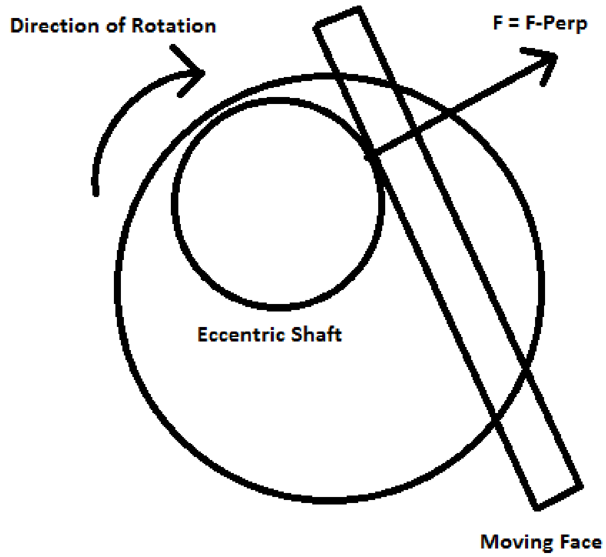

Figure 8: Eccentric Shaft Input Force, Perpendicular to Moving Face

Benchmarking Results

There are devices for crushing rocks already in production. The hammer, for example, is a cheap and robust tool for breaking rocks, which the women currently utilize. However, it is difficult to create gravel quickly with a hammer, and the hammer is unsafe and damaging to the user's body.

There are a few other human-powered rock crushers on the market; in particular, the device created by New Dawn Engineering gave another benchmark for our device. Their product is a hand-powered jaw crusher that increases the user output by about 30 to 50 times compared to using just a hammer. This device breaks rocks efficiently and safely, but is significantly more expensive than the women can afford, costing over $1,000 (New Dawn Engineering) and can be seen in Figure 9.

Figure 9: Rock Crusher Created From New Dawn Engineering (New Dawn Engineering)

Finally, industrial rock crushers are the most efficient and most expensive benchmark available. Not only are they prohibitively expensive, and much larger scale than needed, but they also run on gas or electricity, which would be unavailable to the women in Nepal.

The Poverty Crusher's price would between the cost to afford a hammer and the rock crusher created by New Dawn Engineering. While the device was better in many respects than the hammer, it was neither necessary nor desired to create a device as large and expensive as the one from New Dawn Engineering.

Industrial rock crushers, while clearly inappropriate for women in Nepal, provided insight into efficient mechanisms for breaking rocks and possible ways to design a human powered crusher. The initial ideas for a prototype were inspired by a number of different mechanisms, including a lever system, a kick pedal, and a soil compacter.

The lever system would include a pedal on the left side and a container for rocks on the right side, as seen in Figure 10. As the operator steps on the pedal, the right side of the lever moves up, pushing the bottom plate of the box upward. The bottom plate would force the rocks upward to the top plate which has teeth to break the rocks. This idea was abandoned because it would be difficult to break rocks continuously.

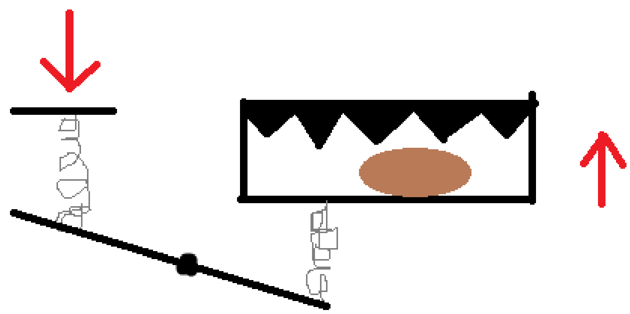

Figure 10: Lever System Idea

The second idea was based on a kick pedal as seen in Figure 11. The user would press down on the pedal which would cause a hammer to turn in rotational motion and crush rocks at its impact point. This option was considered because the team pursued the idea that a device should be built to use something the women already have, the hammer. This would allow the women to use the hammer they own and increased the amount of force they can output. This idea was also abandoned because it would be difficult to crush rocks continuously.

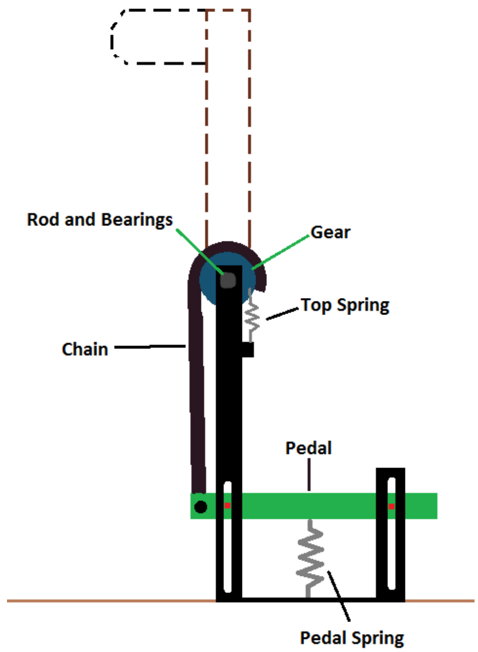

Figure 11: Kick Pedal Idea

Another idea considered was based on a soil compacter, as seen in Figure 12. The soil compacter is used to pack soil by placing soil in the cylinder on the bottom and dropping a weight on the soil. The team would have created a bigger and heavier one so that it was capable of breaking rocks. This idea was disregarded because the manufacturing of a subsystem to hold the weight would cost too much. In addition, a substantial force would be needed to crush rock which meant a heavy weight that would be difficult for the women to lift. In the end, the team decided to create a prototype based on the jaw crusher as it had a seemingly high force output and high production rate.

Figure 12: Soil Compacter (Standard Compaction Test)

Key System Level Issues

The main issue encountered in the design was an abrupt change in the focus of design criteria for the device. At first, the focus was on creating as much crushing force as possible. After seeing a video of the women breaking rocks, however, the focus became rock breaking efficiency. The video showed women breaking rocks more quickly and more easily than previously imagined, so designs that focused on force output at the cost of efficiency were discarded.

Team and Project Management

One of the main issues for the team was budgetary constraints. The initial estimated R&D costs were around $1,400, and travel to Nepal over $3,000. By appealing to the School of Engineering, The Ignatian Center, and some of the team's family members, the Poverty Crusher team was able to raise enough money to not only build the device, but also to travel to Nepal. The final budget for travel and R&D can be found in Tables 2 and 3 below. A more detailed budget can be found in Appendix C.

Table 2: Travel budget

	Cost	**Number**	**Full Cost**
Flight to KTM	$1146	2	$2292
Flight to Nepalgunj (one way)	$165	4	$660
Driver to Birendranagar	$60	2	$120
Hotel per night	$6	14	$84
Food	$10	14	$140
Bus	$13	2	$26
Total Cost			$3296

Table 3: R&D budget

Expense Type	**Cost**	**Number**	**Total**
Wooden Prototype	$50	1	$50
Refined Prototypes	$200	2	$400
Miscellaneous Costs	$75	2	$150
Total			$600

Subsystem 1 – Frame

Introduction to Role/Requirements

Essentially, the Frame is the subsystem that holds all the other subsystems together. A secondary purpose of the frame is to contain moving parts and shrapnel from the broken rocks for the user's protection. The frame must also allow the device to be portable, in that it should be easy to carry or easy to wheel around. A SolidWorks model of the frame can be seen in Figure 13 below.

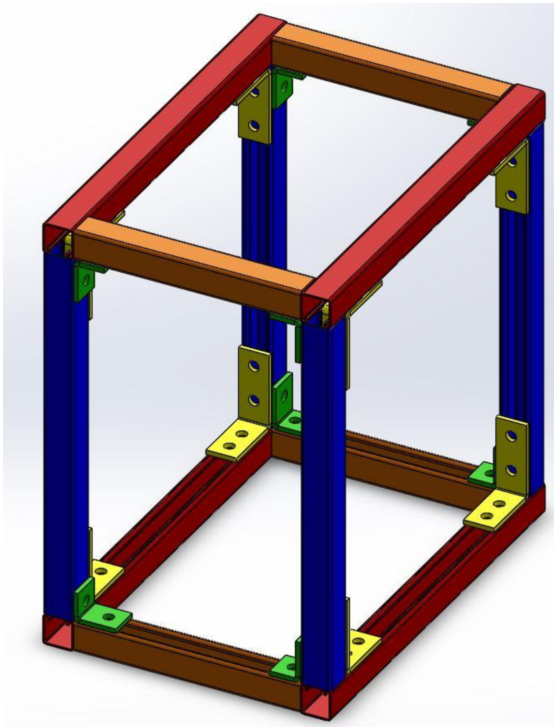

Figure 13: Solidworks Model of Frame Subsystem

The frame must be strong enough not to yield under the stresses it will be experiencing and it must be stiff enough not to bend and take away the force input into the rocks. It also must be durable enough to withstand the elements, especially as the frame will be the part of the system in contact with the ground. A lightweight frame would be ideal, as long as it maintains its stiffness and strength.

Options and Trades

Our initial prototype was designed using a wooden frame. The idea was to create a quick prototype to demonstrate that the dynamics of the device would work. The wooden frame was made out of ½ inch medium-density fiberboard (MDF), which was relatively cheap, less than

$30, and lightweight, less than 20lbs. However, the wooden frame experienced a lot of bending where the fixed and moving jaw were connected. The wooden frame also would not have been a durable option, as pieces of the MDF chipped off easily at connection points, and the wood would have been susceptible to warping or rot when exposed to the elements. Figure 14 below shows the frame of our initial prototype.

Figure 14: Wooden Frame of the Initial Prototype

We recognized the huge amounts of bending in our first prototype, so we wanted to increase the stiffness and strength for all parts of our second prototype. We decided to use Superstrut metal framing to design our frame as it would be stronger than wood and relatively quick to assemble. We used 1-5/8 inch, 12-Gauge galvanized type 304 stainless steel channels, along with a number of 90 degree connectors, cone nuts, bolts, and nuts to assemble the frame. The metal frame, along with the fixed face and eccentric shaft, can be seen in Figure 15 below.

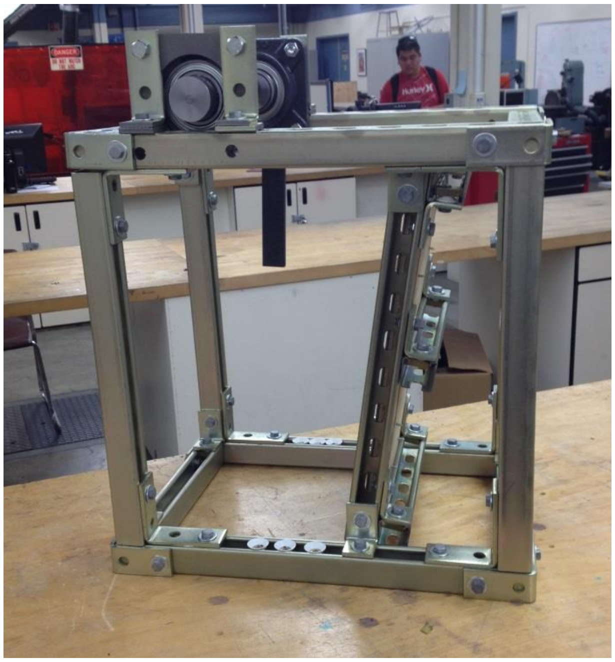

Figure 15: Metal Frame of the Second Prototype

The metal frame had a number of benefits over the wooden frame, including increased strength, stiffness, and durability. As for strength, the yield strength of type 304 steel is around 31.2 ksi (ASM), while the modulus of rupture (analogous to yield strength) of MDF is around 5.2 ksi (Cai 2). Similarly, the modulus of elasticity for the steel is around 28,000 ksi (ASM), while the modulus of elasticity for MDF is around 500 ksi (Cai 2). The galvanized steel would also resist rust, and the steel would not warp if it got wet, like the wood might. However, these benefits come with a few drawbacks. The steel frame was much heavier than the wood, around 70 lbs. The steel frame was also significantly more expensive, around $270. Further, the steel frame left the moving parts and rocks exposed, which could be a safety issue. However, it would be relatively easy to add acrylic glass or wood panels to the side of the frame to contain the moving parts.

Even with the increased strength and stiffness of the metal frame, there was still too much bending in the system to break the rocks. Most of the bending in the frame occurred at the vertices of the frame, where the different channels were connected. The weight of the frame was also too high for it to be easily portable, and the cost would be prohibitively expensive for the women in Nepal. It seems that a welded frame might have fixed a number of these problems.

Square metal tubing would have been much cheaper than the Superstrut, would have been marginally lighter, and would have been much sturdier if welded together. The cost of labor is also very low in Nepal, so a welded frame made of steel tubing would likely be a better option.

Subsystem 2 – Fixed Face

Introduction to Role/Requirements

The fixed face is one of the two metal plates between which the rocks are crushed. As its name suggests, the fixed face is static and connected to the frame. Similar to the frame, the fixed face must be strong enough not to yield, stiff enough not to bend excessively, and durable enough to withstand the elements. Unlike the frame, however, the fixed face must also be hard enough to withstand the stresses exerted by the rocks being broken. Ideally, the fixed face would also be inexpensive and lightweight. A SolidWorks model of the fixed face can be found in Figure 16 below.

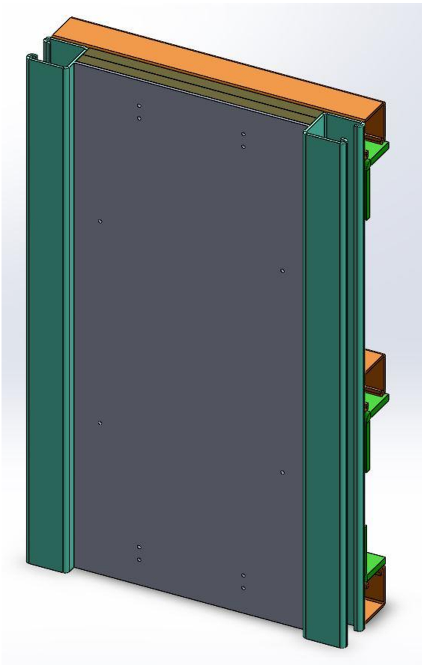

Figure 16: Solidworks Model of the Fixed Face Subsystem

Options and Trades

The original fixed face we designed used 0.1 inch thick, 4130 sheet metal connected to a piece of ½ thick MDF. On the back of the face, wooden blocks were attached to the MDF, and metal rods were run through the wooden blocks. The metal rods were connected to the wooden frame. The initial fixed face was designed to test the mechanism, so it was not expected that it would be able to break rocks. Indeed, there was far too much bending in both the face and the metal rods when the wooden prototype was tested. Though the MDF and metal rods proved inadequate, the sheet metal was chosen so that it could be used in later prototypes. The 4130 sheet metal had the highest hardness and yield strength available, 207 Vickers and 63.1 ksi respectively. A thickness of 0.1 inches was chosen due to its relatively low cost. The purpose of the sheet metal was to provide a layer of hardness, so the thickness was not as important. The thickness of the face could be increased with other material.

The fixed face used in the second prototype was composed of the sheet metal, two pieces of ½ inch plywood, and a number of Superstrut channels and connectors. The Superstrut channels created a backing for the plywood and sheet metal, while simultaneously allowing the fixed face to be connected to the frame. The metal channels also added stiffness and hardness to the fixed face, and allowed for some control of where the stiffness was added. For example, a metal channel was placed across the middle of the fixed face, adding strength where the face would tend to bend the most. Further, the extra piece of plywood increased the area moment of inertia for the face, making it harder to bend (refer to Appendix F)

Compared to the initial fixed face, the one used in the final prototype was stronger, stiffer, heavier, and more expensive. Strictly comparing the plywood to the MDF, the plywood has about the same modulus of rupture (5.5 ksi compared to 5.2 ksi), but a significantly higher modulus of elasticity (1,100 ksi compared to 500 ksi) (Cai 2). Further, adding two pieces of plywood increases the area moment of inertia to resist bending. The final fixed face was also connected to the steel channels, which, as mentioned, have a significantly higher yield strength and modulus of elasticity than either type of wood. As with the frame, these benefits come at the cost of a higher price and a higher weight. The final fixed face weighed around 20 lbs, compared to around 10 for the initial. The final face also cost around $70, compared to around $30 for the initial. As for durability, the galvanized steel of the metal backing would have held up well against the elements, but the plywood used would have been susceptible to rot and warping. However, by using materials other than wood for the fixed face, the durability would increase considerably.

Unfortunately, the fixed face was still too flexible to break rocks. Visible bending could be seen in both the metal plate and the connection within the metal backing. As mentioned for the frame, using a welded backing could decrease some of this bending. Another option, which would decrease the bending in both the plate and the backing, would be to use I-beams instead of the plywood. The I-beams could also potentially be attached directly to the frame, removing the bending that occurred in the metal channel connections. I-beams are specifically designed to have a very high area moment of inertia, so I-beams seem like a natural choice to reduce bending. While I-beams were never tested for the fixed face, they were tested on the moving face, which will be discussed in the next section.

Subsystem 3 – Moving Face

Introduction to Role/Requirements

The moving face is the second of the two faces between which rocks are crushed. The moving face is attached to the frame with a pin connection at the bottom of the plate. The top of the plate is left unattached and is pushed back and forth by the eccentric shaft, causing the moving face to rotate about the pin connection. When a rock is placed in between the two plates, the motion of the moving face crushes the rock into progressively smaller pieces. Similar to the fixed face, the moving face must be strong, stiff, durable, and hard. Ideally the face would also be lightweight and inexpensive. A SolidWorks model of the moving face can be seen in Figure 17 below

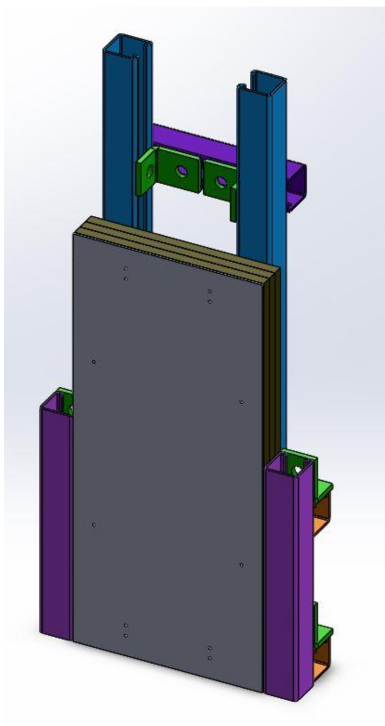

Figure 17: Solidworks Model of the Moving Face Subsystem

Options and Trades

The original moving face was designed almost identical to the original fixed face. The only difference was the number of metal rods on the back of the plate. While the fixed face had three attached rods, the moving face only had one rod at its bottom. This rod was allowed to rotate when attached to the frame. The logic behind the design of the face and the material selection was the same as the original fixed face. In particular, the single layer of MDF and the sheet metal were far too flexible to break rocks. However, the sheet metal was chosen for its strength and hardness and was utilized in the second prototype. In order to decrease bending, the area moment of inertia of the face needed to be increased.

The moving face for the second prototype was made very similar to the fixed face, but with a few differences. Whereas the fixed face has three horizontal Superstrut channels to back it, the moving face only has two, on the bottom and in the middle. The top half of the moving face is backed by two vertical metal channels which extend past the top of the face and rest on the eccentric shaft.
The only other difference is that the moving face was backed with three sheets of plywood to compensate for the lack of the third horizontal metal backing.

Similar to the second fixed face, the second moving face was stronger, stiffer, heavier, and more expensive than the original moving face. The plywood provided more stiffness than the MDF, the thickness of the plywood provided a greater area moment of inertia, and the steel backing provided even more strength and stiffness. The second moving face weighed around 20lbs and cost around $70. The durability of the moving face would have been questionable due to the inclusion of the plywood.

Just as with the fixed face, the moving face was too flexible to break rocks. The bending was even more visible in the moving face than in the fixed face, even with the extra sheet of plywood, likely due to the lack of a third horizontal backing. The vertical channels that extend out to the eccentric shaft also had an impact on the bending of the moving face. The extra length created a longer moment arm, creating more torque in the face and causing it to bend more.

As mentioned, the moving face was also tested using an I-beam to provide more stiffness. The I-beam, composed of A992 Hot Rolled Steel, was 3 inches wide. It was chosen for its relatively low cost, $44 for 6 feet, and for its small size, so that it would fit our device. The plywood and sheet metal was removed from the moving face, and the I-beam was attached to the metal backing. The vertical metal channels were also removed, so the I-beam rested on the eccentric shaft. During testing, the moving face bent much less due to the I-beam, and increased bending could be seen in the fixed face and the connection points of the backing. While using I-beams for the faces decreases bending, the bending in the frame itself is too high for rocks to be crushed. The next version of a prototype should combine a metal frame with faces that use I-beams for support to reduce the bending as much as possible.

Subsystem 4 – Handle and Eccentric Shaft

Introduction to Role/Requirements

The handle and eccentric shaft subsystem takes the input force from the user, and outputs it to the moving face. The subsystem is composed of the handle, the eccentric shaft, and the bearings within which the eccentric shaft rotates. The handle is fixed to the eccentric shaft by two bolts, so when the handle is turned, the eccentric shaft rotates within the bearings, which are attached to the frame. When the eccentric shaft rotates it pushes the moving plate back and forth due to the eccentric motion. A SolidWorks model of the handle and eccentric shaft can be seen in Figure 18 below.

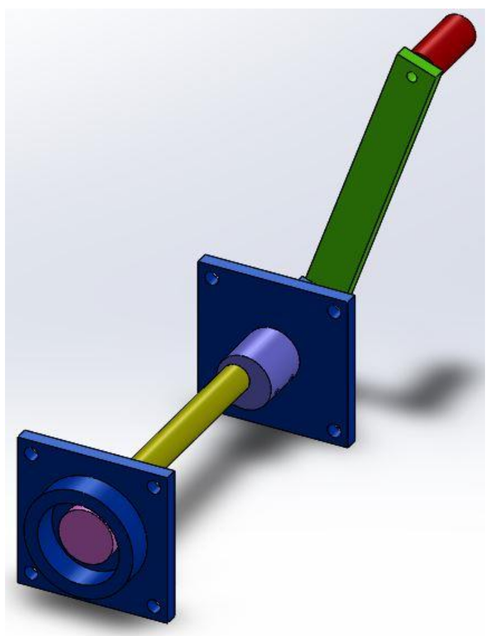

Figure 18: Solidworks Model of the Handle and Eccentric Shaft Subsystem

The handle simply transfers motion into the eccentric shaft, so the main requirements for the handle are that it is strong enough to withstand the loads and that it is comfortable to rotate. The stress on the handle could be relatively high, especially at the connection point with the eccentric shaft, so the materials used have to be strong enough that they do not yield. The handle should also be comfortable to rotate so that it is ergonomic for the user. If the handle is too long, for example, it will be difficult to rotate all the way around. If the handle is not high enough from the ground, the user might have to bend over while using the device, which could hurt the user's back over time.

The eccentric shaft itself needs to be strong and stiff. It needs to be strong so that it will not yield under the high stresses as it pushes the moving face. It needs to be stiff because bending will reduce the amount of force transferred into the rock, so too much bending will keep the rock from breaking.

The bearings house the outer cylinder of the eccentric shaft, so they will experience essentially the same forces. Therefore, the bearings and their connection to the frame need to be strong and stiff as well.

Options and Trades

The original prototype did not have bearings. The handle was made of a thin metal sheet attached to a wooden dowel, and the eccentric shaft was made of PVC pipe (for the offset cylinder) and MDF (for the cylinder that rotates within the frame). Instead of bearings, the eccentric shaft sat directly in the MDF frame. The rotation was not very smooth, and it was decided that bearings would be necessary in the second prototype. The eccentric shaft was also far too flexible, so it was decided that metal would be used in the second prototype.

In the second prototype, the eccentric shaft was fabricated using a 1 inch diameter rod made of 4340 steel, and two 2 inch diameter cylinders made of low carbon steel. The 1 inch diameter rod was reduced to 0.75 inches in diameter on both ends, and the ends were fit into an offset hole drilled into the two 2 inch cylinders. Set screws were utilized to lock the rod into the cylinders. 4340 steel in the rod was chosen for its high yield strength, 103 ksi (ASM). The low carbon steel was chosen for the cylinders because it had a high yield strength, 53.7 ksi (Azom), compared to other cylinders of comparable size. The bearings used were 2 inch flange bearings, chosen for their relatively low cost, about $24 per bearing, their apparent sturdiness, and the way they could be attached to our frame. The handle was similar to the one used in the initial prototype. A wooden dowel was used for the actual handle, a thicker sheet of metal was used for the shaft, and an aluminum spacer was used to connect the handle to the eccentric shaft. In our initial prototype, the handle did not seem to experience high stresses, so our design criteria were not critical and materials were selected due to availability.

Compared to the initial prototype, the eccentric shaft and handle for the second prototype were much stronger, stiffer, durable, heavier, and more expensive. The yield strength and modulus of elasticity for PVC are 5.8 ksi and 435 ksi respectively (pvc.org) and for MDF are 5.2 ksi and 500 ksi respectively. The yield strengths for 4340 steel and low carbon steel are 103 ksi and 53.7 ksi respectively, and both have a modulus of elasticity around 29,500 ksi (ASM, Azom), so the second handle and eccentric shaft were significantly stronger and stiffer than for the initial prototype. By using steel rather than wood, the eccentric shaft is also much more durable and resistant to rot or warping. The wooden dowel used for the handle piece, however, would be susceptible to the elements, and should be replaced with plastic for optimal durability. The whole subsystem weighs around 20 lbs in the second prototype, compared to around 5 lbs in the first prototype. The subsystem costs about $90 in the second prototype, compared to around $15 in the first prototype.

The eccentric shaft and handle was the only subsystem that did not experience noticeable bending during testing. The offset rod of the eccentric shaft has a relatively high diameter, 1 inch, and the connection between the rod and the cylinders is very stable. The bearings also ran very smoothly, with no noticeable deformation or shifting. If bending is reduced in the rest of the system, though, the eccentric shaft and handle will start to experience higher stresses. The connection between the handle and eccentric shaft may be of some concern, but in all tests to date, the stresses between the eccentric shaft and the handle have been relatively low.

System Integration and Testing

Proper testing is critical in order to ensure that the rock crusher is an adequate device to be used in the field. One of the most important conditions that the device needed to meet was to sufficiently break the rocks without failure of the components. This requirement was tested by obtaining rocks found in Nepal and attempting to break them using the rock crusher. Unfortunately, the device was too flexible to break the rocks, but none of the components failed under the stresses applied. Any permanent deformation in the system was considered a failure, because that means further bending will continue to occur.

The device is intended to last at least 2 years while being used every day, so fatigue testing would also be necessary. If the device were able to break rocks, fatigue testing could have been conducted to see how the device will hold up over time. Further testing on the durability of the device could be conducted by exposing it to the elements, like water and dirt. The device needs to work well in harsh conditions over time.

Results

After obtaining rocks found in Nepal, the Poverty Crusher team attempted to break the rocks with our second prototype, but failed to do so. The main problem was that there was significant bending deformation in the system. This bending was caused by high stresses and low stiffness in the faces and frame.

Because bending became a critical issue in the design, calculating the bending within our system was important. The second moment of inertia predicts the resistance to bending for a given object, so second moment of inertia calculations were conducted for the moving face. The first hand calculations were done to determine the area moment of inertia. The dimensions of the face were used, and the calculated area moment of inertia was 1083.33 in^4. The second calculation was to obtain the second moment of inertia. The moving face was assumed to be a simple beam with a single point load in the center of the beam. The results showed that the second moment of inertia for the beam was 0.8359 in^4. The two values from both calculations are vastly different. The difference between the two results lies on how each calculation was done. The first calculation was based solely on the dimensions of the moving face and assuming it was a homogenous material. The moving face is made of a piece of sheet metal with three pieces of plywood on the back. The material is not homogenous which can lead to an error in the result. The second calculation was done accounting each material's properties and thus more accurate at getting a result for the second moment of inertia. See Appendix F for detailed hand calculations.

In order to decrease the bending in the faces, the moment of inertia would have to increase significantly. This could be done by using a material that would be much stiffer and thicker than plywood. Using thicker pieces of plywood, thicker sheet metal, or I-beams are all ways to increase the second moment of inertia. The results of the calculations can be found in Table 4.

Table 4: Calculations for Moment of Inertia in the Moving Face

Calculations	Value (in^4)
Area moment of inertia based on dimensions	1083.33
Second moment of inertia based on beam	0.8359

Rock Identification Key

The rock identification key was made by Don Peck to allow a person to identify a rock based on a series of simple tests. The tests involved looking at the rock grain structure and scratching the rock with certain objects such as a nail or glass. Based on the rock identification key, samples brought back from Nepal were found to be sandstone. Sandstone varies from red to brown and light gray to white in color, and is considered to be hard compared to other types of rocks. Sandstone has a hardness of approximately 7, and Table 5 can be used as a comparison to the levels of hardness for different types of rocks.

Table 5: Mohs Hardness Scale for Rocks (Cordua)

Type	Hardness
Talc	1
Gypsum	2

Calcite	3
Fluorite	4
Apatite	5
Orthoclase	6
Quartz	7
Topaz	8
Corundum	9
Diamond	10

Table 6: Mechanical properties of Rocks (University of Texas)

Rock	UC Strength (MPa)	Tensile Stren (MPa)
Igneous		
Granite	100 – 300	7 – 25
Dolerite	100 – 350	7 – 30
Gabbro	150 – 250	7 – 30
Rhyolite	80 – 160	5 – 10
Andesite	100 – 300	5 – 15
Basalt	100 – 350	10 – 30
Sedimentary		
Conglomerate	30 – 230	3 – 10
Sandstone	20 – 170	4 – 25
Shale	5 – 100	2 – 10
Mudstone	10 – 100	5 – 30

From Table 6, the values for compressive strength were used in determining the amount of load exerted on the beam located in the hand calculations in Appendix F for the Poverty Crusher.

Cost Analysis

The 2nd prototype of the Poverty Crusher has a total count part of 252 parts because it included every piece of material such as nuts, cones, bolts, and screws that were used in the construction of prototype two which led to a total cost of $511.03. To see the material list, go to Appendix C. Table 7 shows how many parts and the total cost for each subsystem was of the 2nd prototype.

Table 7: Cost and Number of Parts for the Poverty Crusher Subsystems

System	Number of Parts	Total
Frame	150	$274.67
Moving Face	40	$73.25
Fixed Face	40	$73.25
Eccentric Shaft	12	$71.55
Handle	10	$18.31
Total	252	$511.03

The original goal of the Poverty Crusher was to have a cost limit of $25. After a prototype was made of wood and PVC, it could be seen that the current design for the Poverty Crusher was going to be above $25, and the limit was pushed to $100. The wooden prototype bent too much due to lack of stiffness in key areas such as the moving and fixed face. The Poverty Crusher would need materials that were much more robust than wood, so the parameter of cost was set aside until after the completion of a working prototype of the Poverty Crusher. Based on Table 5, the total cost was $486.03 above the parameter. Most of the Poverty Crusher was built with Half Slot 12 Gauge Channel Superstrut, chosen for its relatively high strength and stiffness and the ease of assembly. However, the Superstrut cost $74.76 (Appendix C), and the device weighed 134 pounds, which put the goal for a lightweight device out of reach. For a final design, the Poverty Crusher would need to be made much lighter.

The fixed and moving faces were made of sheet metal and plywood. The sheet metal cost a total of $84.14 (Appendix C). The sheet metal was relatively thin, 0.1 inches, to keep costs low. The sheet metal was chosen for its hardness, so the thickness could be increased by other means, such as plywood. The plywood used was 0.5 inches thick, stiffer than MDF, and overall meant to be a cost effective way to increase the thickness of the faces. However, it did not increase stiffness enough.

Another high cost was the combinations of bolts, nuts, washers, and angle brackets used to put the prototype together. The total cost for this combination came out to be $164.80 (Appendix C). This cost was a product of using Superstrut to design the frame and parts of the faces. In the next prototype, a welded frame would be utilized to significantly reduce the connection costs and stiffness of the frame.

The ball bearings, part of the handle and eccentric shaft subsystem, cost $49.58 (Appendix C). In order to reduce cost, the ball bearings could be replaced with a smaller size diameter. In effect, it would also force the rods to be smaller in size and cost. The handle was relatively cheap in comparison to the system and was made of a combination of a dowel, a spacer, and a ½ inch thick metal slab. Refer to Appendix C for the material list.

Business Plan

The Poverty Crusher team wants the device to be sold to as many women as possible in Nepal. The team would advertise the Poverty Crusher to the women as a hand-powered, rock crushing device that can successfully crush rocks into gravel and the income a woman makes would be increased. The advertisement would also demonstrate how simple and reliable the device is as well as the benefits from using it.

Competition

Currently, some companies which sell rock crushers are California Rock Crusher Corp, Construction Equipment Company (CEC) and Mellott Company. These companies' rock crushers can crush large amounts of rocks and have high durability. However, this option was not feasible. CEC sell a 2000 Gator PE 24x36 Jaw Crusher for $150,000 (CEC) and runs on gasoline. The women in Nepal cannot use this device because it is out of their price range as well as they have no way to fuel it. Not to mention, this machine is very bulky and is made to use to crush large pieces of concrete, not small pieces of rock. Their only option is to use a hand – powered device. There are not many hand-powered rock crushers in the market, but one example is the New Dawn Engineering (NDE) rock crusher. The rock crusher from NDE can crush one liter of stone per minute, or more than ½ a cubic meter per day. This device is approximately $1,300 (NDE) which is much cheaper than most industrial rock crushers, but still out of the women's price range.

Sales/Marketing Strategies

The women in Nepal are uneducated which makes most of them unable to read. The best way to advertise our device will be through word of mouth. A salesperson will be assigned to a geographic territory and responsible for sales in that region. They will maintain product lines as well as leasing for the women in Nepal. They will also handle assessments and figuring out which women need the Poverty Crusher the most.

Product Cost and Price

With the current version of the Poverty Crusher, about $500 would be needed to afford the materials for the device in the USA. Further, if the device were to be shipped to Nepal, the cost would increase dramatically. Ideally, local materials and labor would be utilized to construct the device, bringing the price down significantly. To make sure the device is being distributed properly, an additional $250 per month would be needed to maintain a sales representative, based on paying him/her $10 per day. Overall, the Poverty Crusher would be cheaper than the other rock crushers on the market like the rock crusher from NDE, which costs $1300.

Potential Market

Rock crushers are sold commercially in many locations around the world. Rock crushers are used to break up concrete for infrastructure and companies use them to mine for minerals. If the Poverty Crusher were to be commercialized, the Poverty Crusher would need to be leased. To start, the team would work in Birendranagar, Nepal. As the total cost of the Poverty Crusher is higher than what any one woman in Nepal could afford, the Poverty Crusher would need to be leased so that a single woman could afford it. With the estimates that each woman can make $6.40 from one Poverty Crusher from Table 8 and assuming the device was designed to cost $500, the lease could be about $2 per day. The women would have $4.40 a day left over, which is $1.30 increase in revenue instead of using the hammer. Overall, this would be a $374.80 increase in revenue per year for the women. Table 8 shows the amount of money a woman can earn with the lease plan.

Table 8: Revenue Breakdown for Using Poverty Crusher

Revenue	**Total**
Gross Income per Day	$6.40
Cost of Lease	$2.00
Net Income Per Day	$4.40
Revenue per year	$1372.80
Net Gain Over Hammer Per Year	$374.40

Manufacturing Plans

The Poverty Crusher team will commission the machine shops in Nepal to build the device. Each machine shop will have the necessary parts to build it and it should take three days to do it. The shops will have at least three to five extra parts in their inventories to maintain upkeep of the Poverty Crushers. In order to expand the Poverty Crusher, the Poverty Crusher would need to be spread by word of mouth about its existence and its success in crushing rocks. By doing so, women will contact the team's organization for their own Poverty Crushers. As more women demand for the Poverty Crusher, the area of which the Poverty Crusher operates in will expand. More and more people will see the success of this device and will want to take one for their own causing more machine shops to be commission and Poverty Crushers to be built.

Warranties

A salesperson in the area would inspect each Poverty Crusher after it was built by a machine shop. After a successful inspection, the Poverty Crusher can be leased to the women in Nepal. If the Poverty Crusher does not pass inspection, it will be rebuilt. By inspecting the device before it leaves the machine shop, this provides a good level of quality for the women. If the device were to break or be damaged, the salesperson would look at the level of damage and make an assessment. After an assessment is made, the sales person would increase the lease from $2 to $2.25 over a period of time that would cover the charges to fix the Poverty Crusher. For example, if the damage made to the Poverty Crusher was $25, then an increase lease of $2.25 would last 100 days. After 100 days, the women would only have to pay $2 again for the lease. By doing this, the women can still have an increase amount of revenue while paying off the device. If the device is broken and cannot be repaired, a new Poverty Crusher will be given and the full price of the Poverty Crusher will be paid off by the women with an increased lease of $3. This would take the women about 166 days to pay off before returning to a lease of $2. Any repairs are immediately paid by the Poverty Crusher team.

Investor's Return

Potential investors would be people who are interested in helping people in the third world countries. An investor would not see a profit until three years after his initial investment.

Assuming 10 Poverty Crushers and a single salesperson to maintain all ten for a year, the total amount an investor would need to fund $7100. With the leasing proposal, the breakeven point would be 355 days from then. After the breakeven point, the investor would receive an income of $5200 per year assuming the same number of Poverty Crushers and after paying the sales person. In the initial year, the investor would receive no profit, but in the two years afterwards, the investors will make a profit of $3300 and $5200 per year after that.

Engineering Standards and Realistic Constraints

Ethical

The women of Birendranagar, Nepal, are discriminated against harshly, and have little value in their society. Nepal is a male-dominated country where males treat women as they see fit. Once a woman is married, the husband can leave her and marry another woman without prejudice in Nepal. The widowed woman is seen as bad luck and is generally avoided by women who have not been married or are married. The Poverty Crusher was made to empower these widowed women who were to outcast by their society. After interviewing women from Nepal and witnessing the gender gap first hand, many factors were discussed as to whether the Poverty Crusher would actually empower these women. First, if given the Poverty Crusher, the women who use this device could make more money than they had by using a hammer. Some people in the town may get jealous that the women would be making more money, and could possibly try to steal the device. If the women started to make more money than the men in the town, tension could grow between the women who use the Poverty Crusher and the other people around them. These are possible outcomes of implementing the device into Nepal's society and must be taken in account before helping these women.

Health and Safety

Health and Safety was a big parameter of design in the Poverty Crusher. The device had to improve the health standards of the women who operated the device as well as increase their safety. To do this, the design has a frame to protect against the shrapnel produced from the fracture of rock. However, at this time the prototype frame is not covered, and moving parts are exposed to the device operator, which runs the risk of causing injury. In future prototypes, instead of an expose frame, plexiglass could be used to fill the frame, so that the operator can see the rocks being crushed without worrying about shrapnel hitting their bodies.

One important goal was the reduction of health problems. The Ovako Working posture Analysis System, OWAS, was used to estimate if the posture of the operator was improved or degraded (Kumara). OWAS examines the posture of certain body parts (Trunk, Arms, Lower Back, and Neck) during an activity and sees how long that posture is maintained over time. Depending on the posture and degree of time in that posture, the impact can go from neutral to extremely harmful. Table 9 shows the number for each posture in the OWAS system determined by observations. Table 10 shows the resulting degree of harm to the operator. As seen in Table 10 when operating the Poverty Crusher, the degree of harm on the operator is less overall than operating a hammer. This means that the operator would have better posture as well as less strain on the body overall. The Poverty Crusher would satisfy the safety parameter of the project. To see how each body part was scored and the degree of harm, look at Appendix F.

Table 9: Score for each posture for device used from 1 to 6 depending on posture

Posture	Hammer	Poverty Crusher
Trunk	2	1
Arms	1	1
Lower Back	1	1
Neck	2	1

Table 10: Degree of Harm based on numbers in Table 9

Degree of Harm	Hammer	Poverty Crusher
Trunk	Slightly Harmful	Neutral
Arms	Neutral	Neutral
Lower Back	Slightly Harmful	Slightly Harmful
Neck	Distinctly Harmful	Neutral

Economics

The Poverty Crusher was built to increase the amount of gravel produced resulting in a direct increase in the revenue received. Based on observations and firsthand accounts, each woman produces about 400 pounds of gravel per day for about $3.20. Since the device is still going through improvements, it is unknown how much gravel the device could produce in a day. For calculations, it was assumed to that the Poverty Crusher would produce twice the amount of gravel produced per day and in turn the amount of revenue made per day. Table 11 shows the amount of gravel produced per device used. Table 12 shows the amount of revenue per device used. From Table 12 the revenue increase was about $1000 per year.

Table 11: Amount of Gravel produced for each device

	Crushed gravel per day (lb)	Crushed gravel per year (lb)
Hammer	400	124800
Poverty Crusher	800	249600

Table 12: Amount of Revenue produced for each device

	Revenue per day	Revenue per year
Hammer	$3.20	$998.40
Poverty Crusher	$6.40	$1996.80

When these women make around $1000 a year, an extra $1000 boost in their income could have a dramatic effect on their lives. Another impact was the cost of the Poverty Crusher. The original goal of the Poverty Crusher was to be under $25. However, the cost of each part making the five sub-systems exceeded our expected costs.

The total cost, as shown in Table 7, is $511.03, which is much larger than the goal for the cost (Refer to Appendix C for costs). With this high cost, it was obvious that no person in Nepal would be able to afford such an expensive device. Regardless of a device that cost $511.03 or $25, the team would have chosen a leasing option for commercial use. The women could be charged $2 a day to use the device. There are several ways to reduce the overall cost and weigh to the system. The Superstrut can be replaced by a lighter and stronger material. The ball bearings can be smaller in size which would reduce the weight and cost of the Eccentric Shaft Sub-System. The Frame overall could be reduced in size. Instead of having a frame that was 23 in by 21.5 in by 12 in, it could be reduce to half that size. Instead of linking each Sub-Systems with nuts and bolts, they could by welded together. This would increase the sturdiness as well as durable of the device, while lowering the cost and weight. These are all options to consider reducing the cost and weight when building the next prototype.

Manufacturability

We chose materials that were easy to assemble for the design of the Poverty Crusher. This included 4130 Steel, Superstrut, cone nuts, plywood, and metal rods. The device could be easily assembled using a drill press and a lathe with a couple of wrenches. In the trip to Nepal, the team found that the machine shops have lathes and drill presses for fabrication. For materials, they have access to plywood and steel sheet metal; however, Superstrut and cone nuts were not available. In order to make the Poverty Crusher successful, the Superstrut would need to be replaced with a material that could be found in Nepal. In future prototypes, one option would be to use square tubing and weld together the joints rather than using Superstrut. A square tube that was ½ by ½ by 16 GA that was 48 feet long would cost about $31 (MetalsDepot). The square tube is also easy to weld, cut, form, and machine (MetalsDepot). The Superstrut cost about $75 (Appendix C). Further, the connections needed for assembling the Superstrut cost $164. By using welding square tubing, the materials cost would be reduced by $239.

Environmental

Before the women break the rocks, they collect the rocks from a local riverbed. With constant demand for gravel, there was a concern that the removal of material from the river bed would environmental problems in the area. By removing the rocks, the water can more easily seep into the ground, resulting in water level decrease and erosion around the river bank. The erosion could affect people living near the river by increased flooding, and nearby bridges could be affected by the decrease in land near their foundations. Further, a lower water level would have negative effects on communities downstream.

Conclusion

The Poverty Crusher was both a difficult engineering project and an interesting study on the socio-economic environment of Birendranagar, Nepal. Unfortunately, the prototype device was unable to crush rocks due to excessive bending in the system. In order to decrease bending, the stiffness of the device needs to be increased. Using a welded, metal-tube frame would significantly decrease bending in the frame, especially as the connection points of the Superstrut were susceptible to bending. Increasing the second moment of inertia of the faces would also be important. Utilizing I-beams in the faces would acutely increase the stiffness, and attaching the I-beams directly to a welded frame would reduce the bending that occurred in the metal backing of the faces. While the device that was constructed was not able to break rocks, a lot of important information was gathered over the course of the year, and the efforts made were a necessary first step in creating a device that will eventually be distributable to the people of Nepal.

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Appendix A - Detailed Design Definition Information

Luke Metclaf and David Sowerwine were helpful in providing the team with information about Nepal. Luke Metclaf was the team's contact in Nepal and currently working in a non-profit organization building a school in Birendranagar. He helped the team by asking questions to the women there about what they wanted in a rock crushing device. David is an engineer that worked in Nepal before and helped the team get an idea on what society and infrastructure was like in Nepal.

Brian and Luke's Email Correspondence after Skype Call

Brian:

Hello Luke,

Thanks for talking to us about the rock crushing project. We feel that you could greatly help our project be a success. Over our Skype conversation you said you were open to getting some info for us. Below are some things we were wondering you could help us out with.

-Pictures of the following would be great

-The rocks before and after the breaking. (Something like a pen or pencil next to it would be great so we could get an idea of the size of it)

-The tools used to break the rocks

-The usual location the women spend time breaking the rocks

-If you can talk to some of the women that break rocks could you get information on the following topics

-Who they sell the rocks to. Specific company names would be great

-The average daily wage they get

-What they would want in a device that would break rocks. Lightweight, mobile, foot-powered, used sitting down, the ideal price, and fully automatic are some examples.

-If they would use rock breaking device.

It would be awesome if you could help us with any of the above topics. I totally understand your busy lifestyle right now and don't need this need info anytime soon. Let me know if you have any questions about the stuff requested. Hope the school construction is going great.

Thanks

Luke:

Good stuff, Brian.

These are great questions. I actually have to go by that area in the next few days, so I'll gladly talk to the women about this.

-Luke-

Rob and David's Email Correspondence

Rob:

Hi David,

This is Rob Golterman, and I contacted you a few times last year after you spoke at one of our Engineers Without Borders meetings. I'm actually pursuing a senior project centered in Nepal in the town of Birendranagar, and I was hoping we could chat sometime so I could get your input about the project.

In short, my team and I are trying to create a human-powered rock crusher for widowed women in Birendranagar who break rocks by hand to make a living. I'd love to hear your perspective on our project, as well as some of the challenges and victories you've had on your projects.

Just let me know if you think we can work something out. Thanks David!

David:

Hi Rob,

I wouldn't restrict your target to just the widows of Birendranagar. There are a lot of people feeding the concrete craze in Nepal who could benefit from an upgrade from the default ring and hammer technology.

I assume that whatever you come up with, if it works, would be copied overnight by the many small workshops. Anything like that will inevitably be 'open source'. No royalties, sorry.

It would be very surprising if no one before you has attempted some kind of human-powered hammer mill. Do some intensive googling on that issue. If none exist it implies some serious design or operating challenges. It would be thrilling if you could solve this.

I would be happy to talk with you and your team. I'm away however the rest of this week in Colorado (coaching three other teams at CSM which are working on our projects).

So perhaps next week? I may come to SCU next week to meet Megan and her team which is taking up the arsenic prototype challenge. Maybe we could meet before or after her team? Let me know, and thanks for taking on this problem.

David

Table A-1: Customer Analysis Report

Design	Contact	Information
	David	The device needs to cost less than $20
	Luke	The device needs to be easy to be reproduce
	David	If you haven't found any other projects focused towards breaking rocks economically then this may be because it is a tough topic
	Luke	Needs to be easy for a woman to use
Culture		
	David	The device shouldn't just be for the widows but everyone
	Luke	The women spend all day long breaking rocks down
	Luke	Nepalese people do not feel they have the ability to improve their lives
	Luke	Seeing the people break the rocks is depressing
	Luke	The women get around $0.50 to $1 for a day's worth of work
Further Research		
	Luke	I can help you out with getting info from the women and take pictures if you need me to
	David	I am out of town right now but next week I can meet with your team to get a better idea of your project

Email from Luke Metcalf

Brian Hammond <bhammond@scu.edu> Wed, Nov 20, 2013 at 6:42 AM

To: Rob Golterman <rgoltermanjr@gmail.com>, Arvin Lie <alie@scu.edu>, Thien-Ryan Le <tkle@scu.edu>

Got some great info from Luke guys!

---------- Forwarded message ----------

From: C Luke Metcalf <c.luke.metcalf@gmail.com>

Date: Wed, Nov 20, 2013 at 4:17 AM

Subject: Interviews

To: Brian Hammond <bhammond@scu.edu>

Brian,

I went to the river today and spoke with a couple women there. Sorry this took so long to get to you. Nepal just had its parliamentary elections yesterday and the whole country has been largely shut down for the past week.

The first woman I spoke with looked ancient, but was probably 50 or so. The second woman was much younger, probably about 30. There was also a girl, probably about 6 or 7, breaking rocks nearby, but I didn't speak with her.

My questions and their answers:

1) How long do you work each day? What hours do you work?

Woman #1, older: I start around 10 and finish around 4. Sometimes I start after lunch.

Woman #2, younger: I work every day of the week and do about 6 hours each day. From 10-4.

2) Are you tired after every day?

#1: Yes, I'm exhausted.

#2: Yes, I'm very tired.

3) Where are the rocks that you break actually from?

#1 and 2: We go down into the river to collect these stones.

4) Who do you sell your rocks to? How much do you get per bag?

#1: Sometimes we use these stones for our own house. I get 50 rupees for bag when I sell them.

#2: I sell my rocks to construction projects laying roads or making foundations. No company names. 50 rupees per bag.

[My guess is that the bags weigh about 60-80 pounds each. You can see them in some of the photos.]

5) How many bags are you able to fill each day?

#1: A fast worker can do 10 or so. I fill about 4-5 bags each day.

#2: I can do 31 in a day. [I'm assuming this is her record. She was cranking away while I was talking to her though, so I'd assume she average 25 or something].

6) How far away do you live?

#1: I live right here (points to house 10 feet away).

#2: I live over there (points to house 50 feet away, across river).

[I then asked if all the women who work here live right near the river. Woman #2 said yes.]

7) If there were a machine to break rocks for you at a faster rate, would you want to use it?

#1: This makes me so happy. I want to use it.

#2: I would definitely use it; it would make my life much easier.

8) How would you want a machine like this to work? Would it need to be lightweight? Foot powered? Involve sitting? With wheels?

#1: I'd like it to be foot powered and lightweight. [She was just agreeing with anything I said.]

#2: It would be better if it were hand powered. I would want to be able to sit while using it.

9) If it could break four times as many rocks in a day, how much would it be worth to you?

[This was a difficult question to ask without sounding like a salesman. I kind of suggested prices to gauge their reactions. I first asked if they'd buy it for 1000 Rupees (about $10)]

#1: 1000 rupees is so expensive. I cannot afford that.

#2: I would pay 180 Rupees for it.

So, there you go. Here are some photos/videos as well.

As for before/after sizes of the stone: the rocks start anywhere from two inches across up to two fists put together, and end up about the size of your thumbnail.

Also, my guess is that, while they wouldn't just go ahead and commit to spending 1,000 Rupees off the bat on something, once they saw that it worked well and they'd make back their money within a day or two, they'd jump right on board. You could also consider, if your best design seems prohibitively expensive, a loan program where they pay back a few hundred Rupees per week. If I were you, I'd try hard to keep the cost under $20 with economies of scale taken into account, but you can probably work around having a higher price. If this helps, there are plenty of welders in town, and you can find gears of all shapes and sizes. Also, I'd think you'll struggle to make it lightweight and mobile unless you have some large lever instead of a flywheel (my assumption), but it may not matter since all of the women live so close-by.

Anyway, I'm interested in what you guys come up with! Let me know how the project is going and if you need more info. It was great talking to these women and hearing what they had to say. The older one seemed absolutely enchanted with the idea of a machine to make her work go faster.

Table A-2: PDS

Characteristic / Parameter	Parameter Units	Design Criticality	Design Target	Benchmark 1 Range (hammer)	Benchmark 2 Range (NDE human powered jaw crusher)
Force Output	N	High	600+ N	600 N	600+ N
Device life expectancy		low to high	2 years	2+ years	probably 2 years
Max diameter rock size	in	high	12 in	any size	6 in
Necessary user height	ft	medium to high	3 - 4 ft. tall	usable for all	4 - 5 ft.
Necessary Input force	N	low to high	300 N	600 N	< 400 N
Weight	lb	high	25 lb.	2 - 5 lb	100+ lb
Unwieldiness		medium	Not unwieldy	Not unwieldy	
Safety		high	contain shrapnel, cover moving parts	not safe	safe
Smooth operation		medium to high	can be used continuously without setup in between impact	Yes	Needs rocks broken in multiple batches
Ergonomic device		high	Device is easy on the user's body	No	Yes
Cost	$	high	ideally $50	< $50	$1000.00 +
Rock breaking efficiency	m/s	low to medium	how fast gravel is produced	1 sack per day	30 to 50 sacks a day
Maintenance		medium to high	simple, easy maintenance	No maintenance	check every week
Strength of materials		medium to high	Materials need to be strong enough to handle stresses	Adequate material strength	Adequate material strength
Comfort		low to medium	customer satisfaction using the product	Comfortable for short term	Pretty good comfort
Reliability		medium to high	how reliable the product use in long term	It likely won't break	Reliable, but has some moving parts
Ruggedness		low to high	maintenance check once a month	Doesn't really need maintenance	May need maintenance
Weather resistant		medium to high	it can resist any kinds of weather	Fairly weather resistant	not sure
Water and corrosion resistant		medium to high	materials won't corrode in wet condition	Corrosion could be an issue	not sure
Abrasive resistant		medium to high	Material won't degrade too quickly from the rocks	Good abrasive resistance	probably good abrasive resistance

Appendix B - Detailed Analysis Results

The images below show the very beginning SolidWorks prototypes that were considered and the FEA analysis of the moving face. Unfortunately, the FEA analysis was deemed too simple to be useful in analyzing our device.

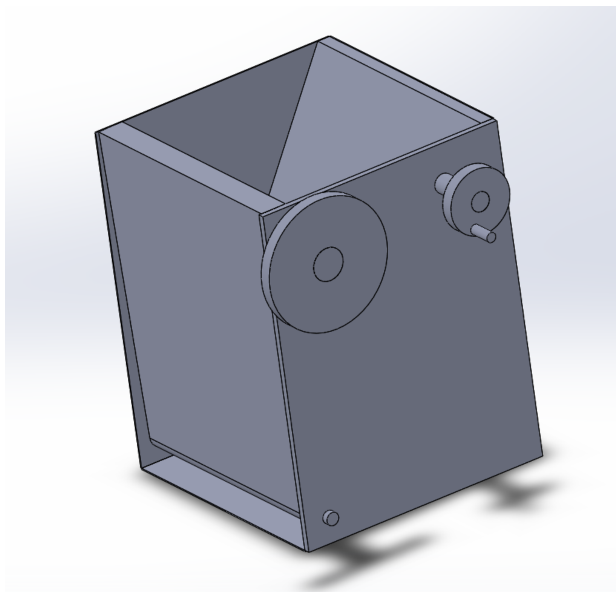


Figure B-1: SolidWorks of the Poverty Crusher prototype

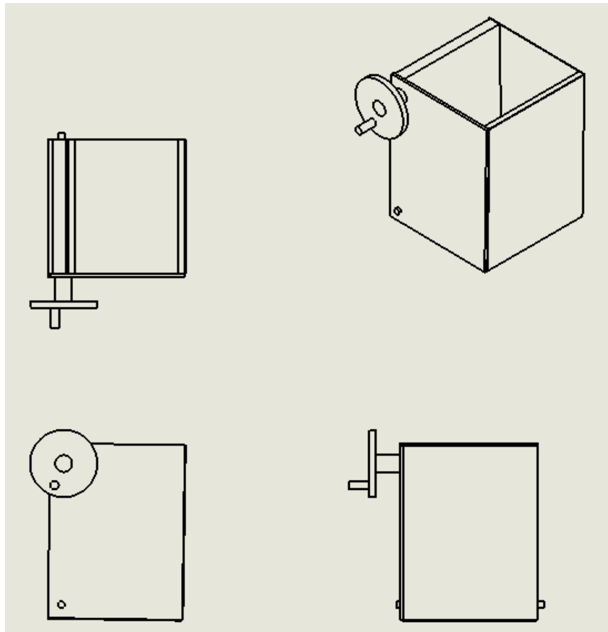


Figure B-2: Top, Front, Rear Side, and Isometric View of the Poverty Crusher prototype starting the top left and moving counter-clockwise

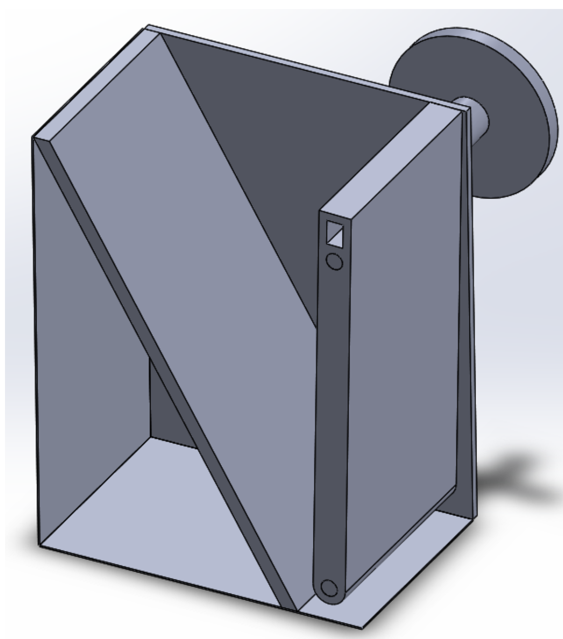


Figure B-3: Internal View of the SolidWorks Prototype

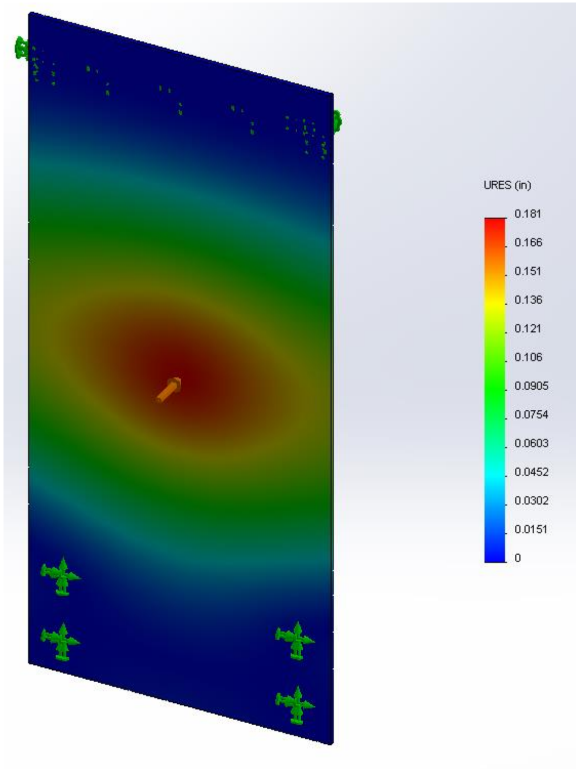


Figure B-4: Finite Element Analysis of the Moving Face where a point load was applied to the center to show the deformation experienced in the part

Appendix C - Project Management Data

Budget

Table C-1: Detailed R&D Budget

Project	**Poverty Crusher**					
Version 3						
Subsystem	Component Description	Sub-Component	# of items	Vendor	Cost / part	Cost Total Per Part
Wooden Prototype - Frame						
	Frame - MDF		1	Southern Lumber	$10	$10
		Wheel Side Frame	2			
		Base Frame Piece	1			
	Sub System Totals		3			
Wooden Prototype - Jaws						
	Jaws - MDF		1	Southern Lumber	$10	$10
		Swinging Jaw	1			
		Fixed Jaw	1			
	Eccentric Shaft		1	Southern Lumber		
		4" wooden disc, MDF	3		$5.29	$15.87
		1.25" PVC	1		$0.86	$0.86
	Sub System Totals		4			
Possible Final - Frame						
	Frame - 2x4 wood		1	Southern Lumber	$2	$2
		Front Structure	6			
		Wheel Side Structure	6			
		Other Side Structure	6			
		Back Structure	6			
		Base Structure	6			
	Plywood		2	Southern Lumber	$11	$22
	2 in. Ball Bearing		2	vxb.com	$8	$16

	Sub System Totals		35			**$76**
Possible Final - Jaws						
	Jaws - 4130 Steel Sheet Metal (8"x24"x.1")		2	Online metals	$41	$82.54
		Swing Jaw				
		Fixed Jaw				
	Die - A36 Steel U Channels		4	Metal Depot	$2	$7.84
	Eccentric Shaft					
		4 in. diameter wooden (MDF)	2		$3	$6.00
		Steel Rod 4140 steel	1	McMaster	$43	$43.34
	Pivot Shaft - 4140 Steel Rod (1" dia x 1')		1	McMaster	$14	$13.55
	Mounted Bearings		2	McMaster	$13	$25.38
	Sliders - Polycarbonate Square Tube		1	McMaster	$23	$23.00
	Unforeseen Costs				$50	$50.00
	Sub System Totals					**$251.65**
	Number of Devices		2		**$251.65**	**$503**
Project Totals						**$580**

Table C-4: Material List of 2nd Prototype

Size (in)	Type	Quantity	Price	Total
3/8	Bolts	50	$0.36	$18.00
3/8	Nuts	30	$0.11	$3.30
3/8	Cone Nuts	30	$0.86	$25.92
3/8	Washers	30	$0.14	$4.20
1/2	Bolts	10	$0.20	$2.00
1/2	Washers	10	$0.48	$4.80
1/2	Nuts	10	$0.30	$3.00
1/2	90 Angle Bracket 4 Hole	22	$3.26	$71.72
1/2	90 Angle Bracket 2 Hole	18	$1.77	$31.86
1 (dia) x 1	High-Strength Impact Resistant 4340 Alloy Steel Rod	1	$27.17	$27.17
2 (dia) x6	Low Carbon Steel Rod	1	$19.47	$19.47
	Ball Bearings	2	$24.79	$49.58
2 (dia)	Wooden Dowel	1	$2.00	$2.00
1x1/4	Wood Screws	12	$0.28	$3.36
1/2	Machine Screws	12	$0.65	$7.84
2x1.5x2	Spacer (Steel)	1	$5.00	$5.00
12x1.5x0.5	Handle (Steel)	1	$5.00	$5.00
120	Half Slot 12 Gauge Channel Superstruts	4	$18.69	$74.76
0.125x20x9	Metal Sheet	2	$42.12	$84.24
3/4x2x4	Multifiber	2	$10.37	$20.74
1/2x2x4	Multifiber	2	$9.32	$18.64
1/2x1/2x72	High-Strength 1045 Carbon Steel	1	$28.43	$28.43
	Total	252		$511.03

Funding

Sources of Funding

Santa Clara University School of Engineering: $2856.00

Santa Clara University Ignatian Center: $788.00

Rob and Anne Golterman: $500.00

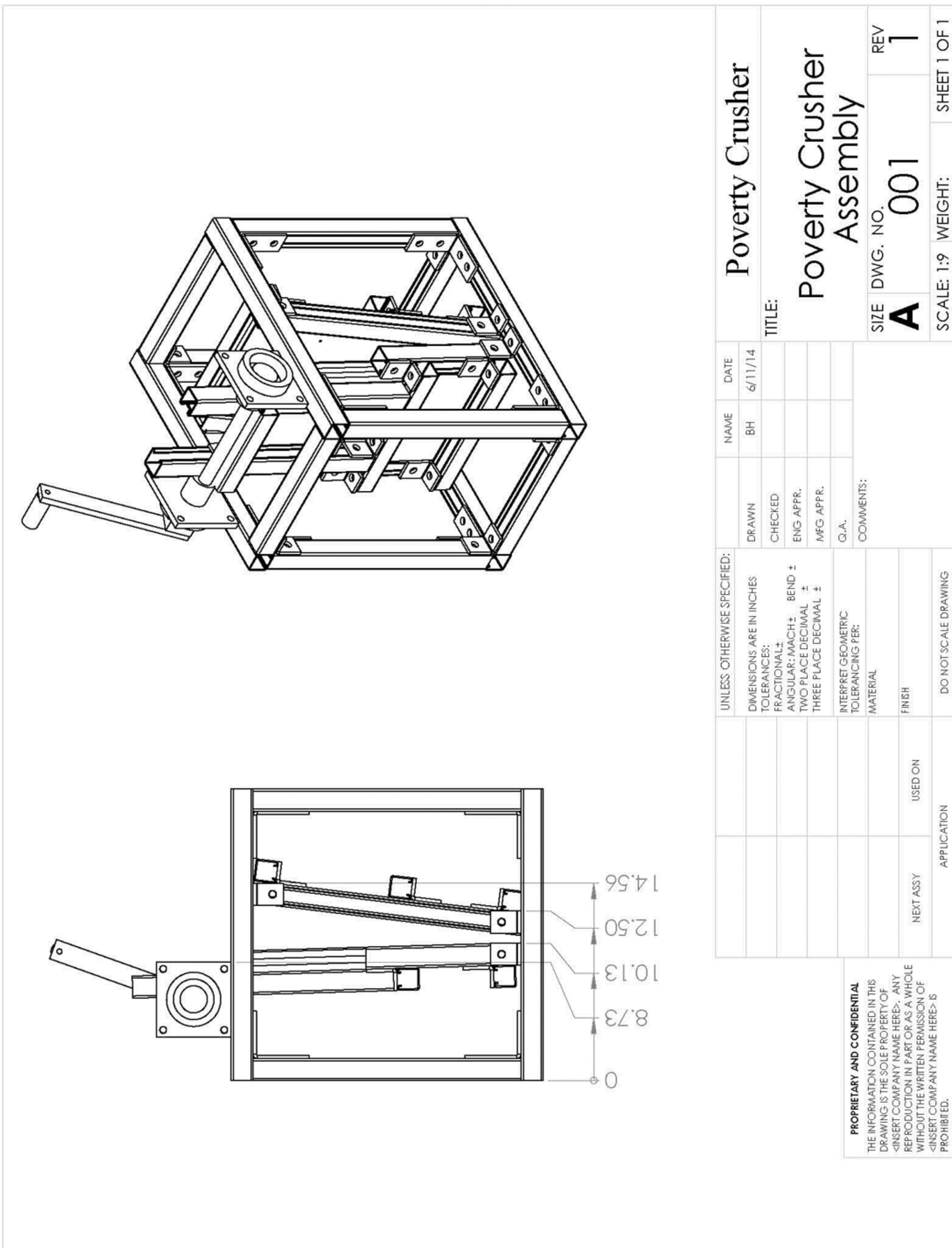
Roelandts Grant: Denied

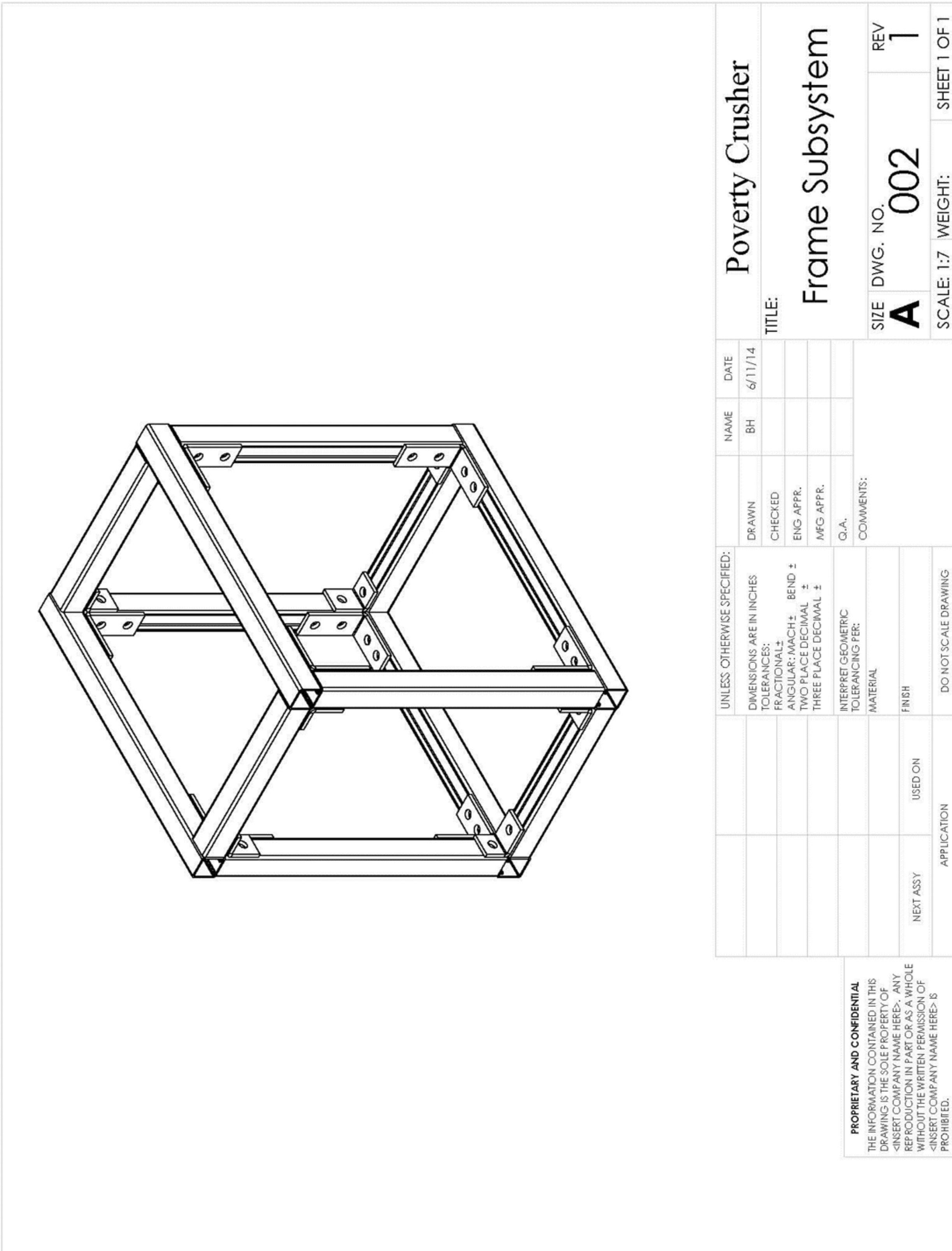
Hackworth Fellowship: Denied

Private donors: iDE, Room to Read, VillageTech Solutions, Alan Gianotti

Appendix D - SolidWorks

The following pictures are the CAD drawings of the second Poverty Crusher prototype. It includes the sub-systems as well as the individual pieces that make each sub-system.

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MFG APPR.
Q.A.
COMMENTS:
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TOLERANCES:
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ANGULAR: MACH± BEND ±
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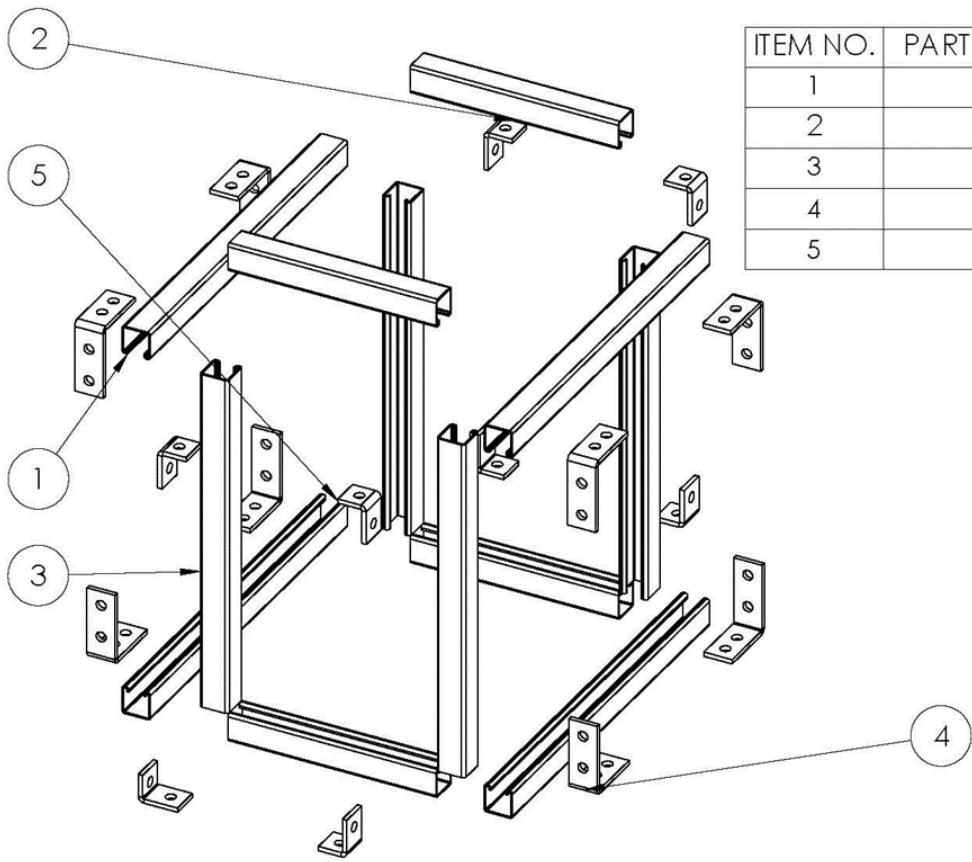

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1	029	21.5" Superstrut	4
2	024	12" Superstrut	4
3	027	19.75" Superstrut	4
4	009	4 hole bracket	8
5	020	2 hole bracket	8

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MFG APPR.		
Q.A.		

COMMENTS:

Poverty Crusher

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Frame Subsystem

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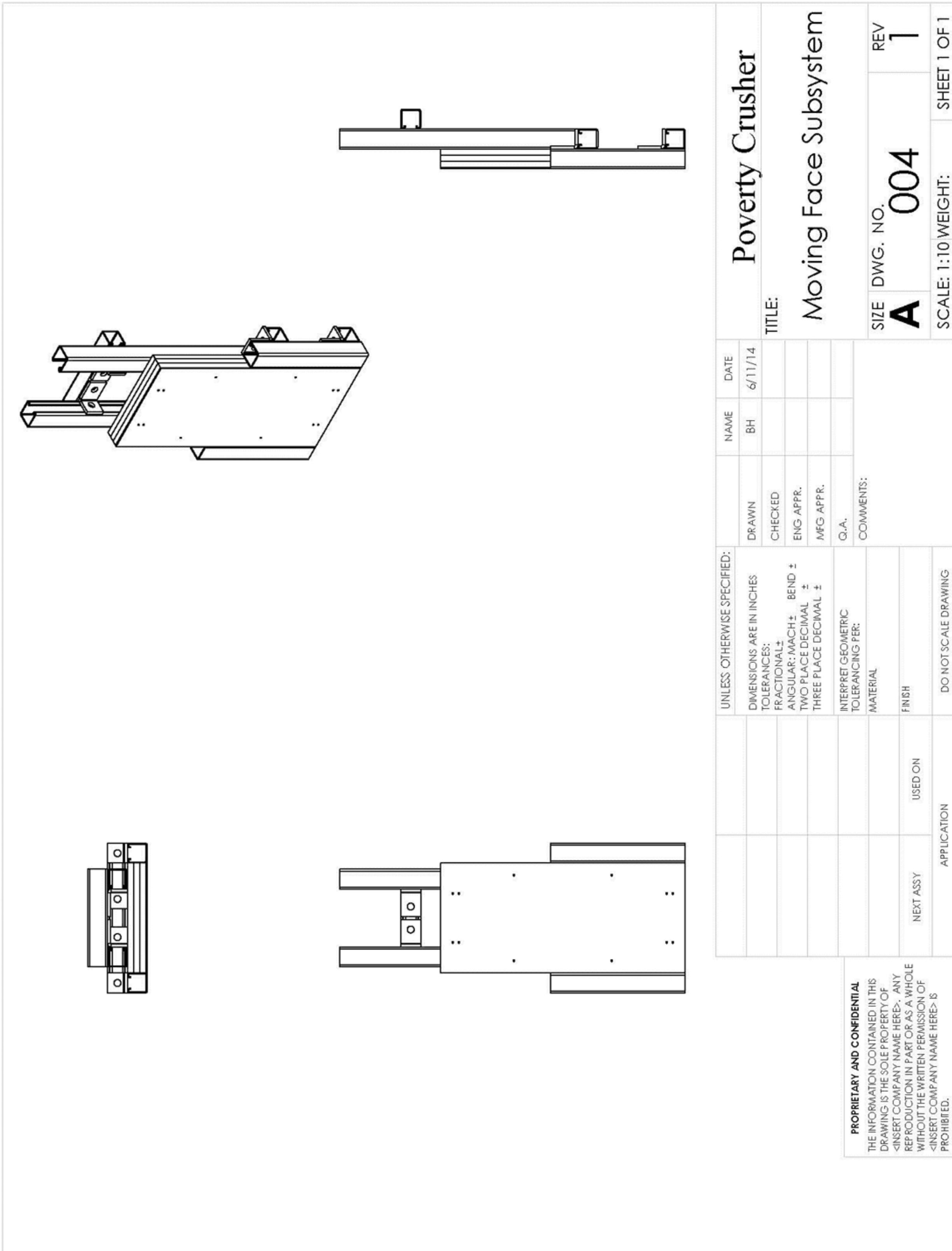
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Moving Face Subsystem
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DWG. NO.
004
REV
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WEIGHT:
SHEET 1 OF 1
NAME
DATE
DRAWN
BH
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MFG APPR.
Q.A.
COMMENTS:
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ANGULAR: MACH ± BEND ±
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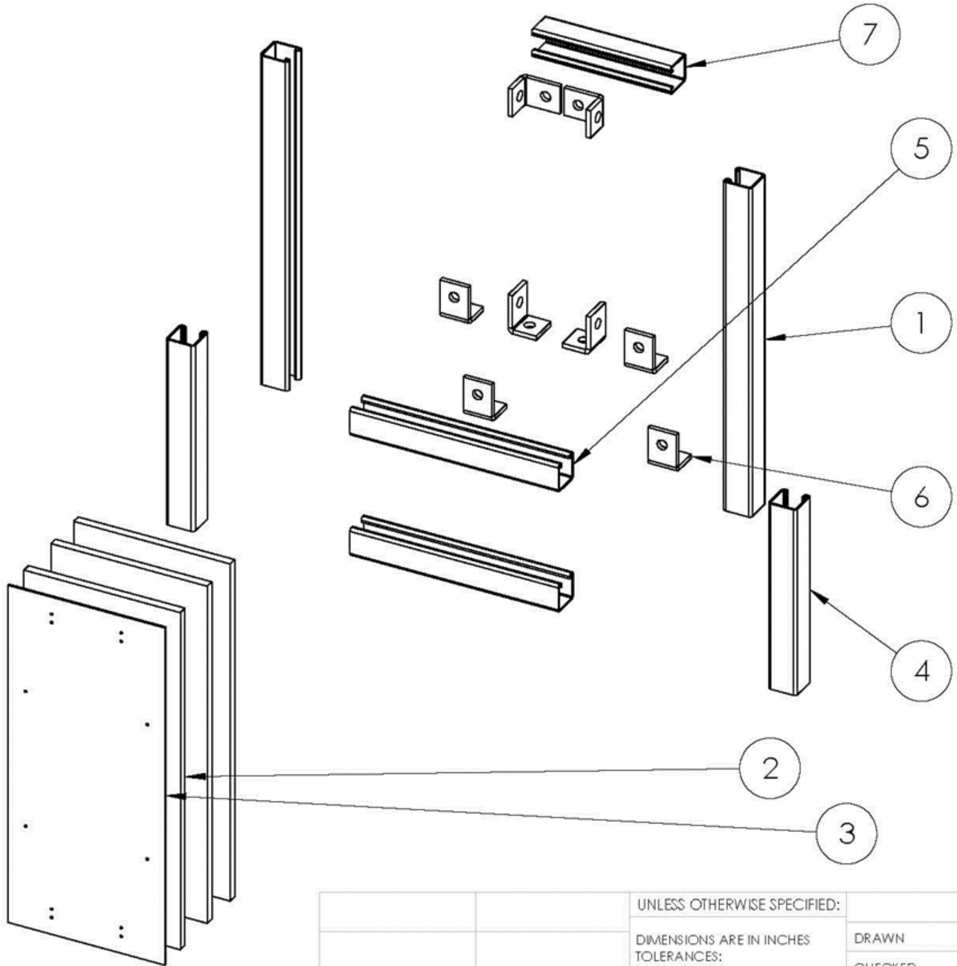

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3	018	Sheet metal face	1
4	023	11 inch Superstrut	2
5	024	12 inch Superstrut	2
6	020	2 hole bracket	8
7	022	9 inch Superstrut	1

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THREE PLACE DECIMAL ±

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COMMENTS:

Poverty Crusher

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Moving Face Subsystem

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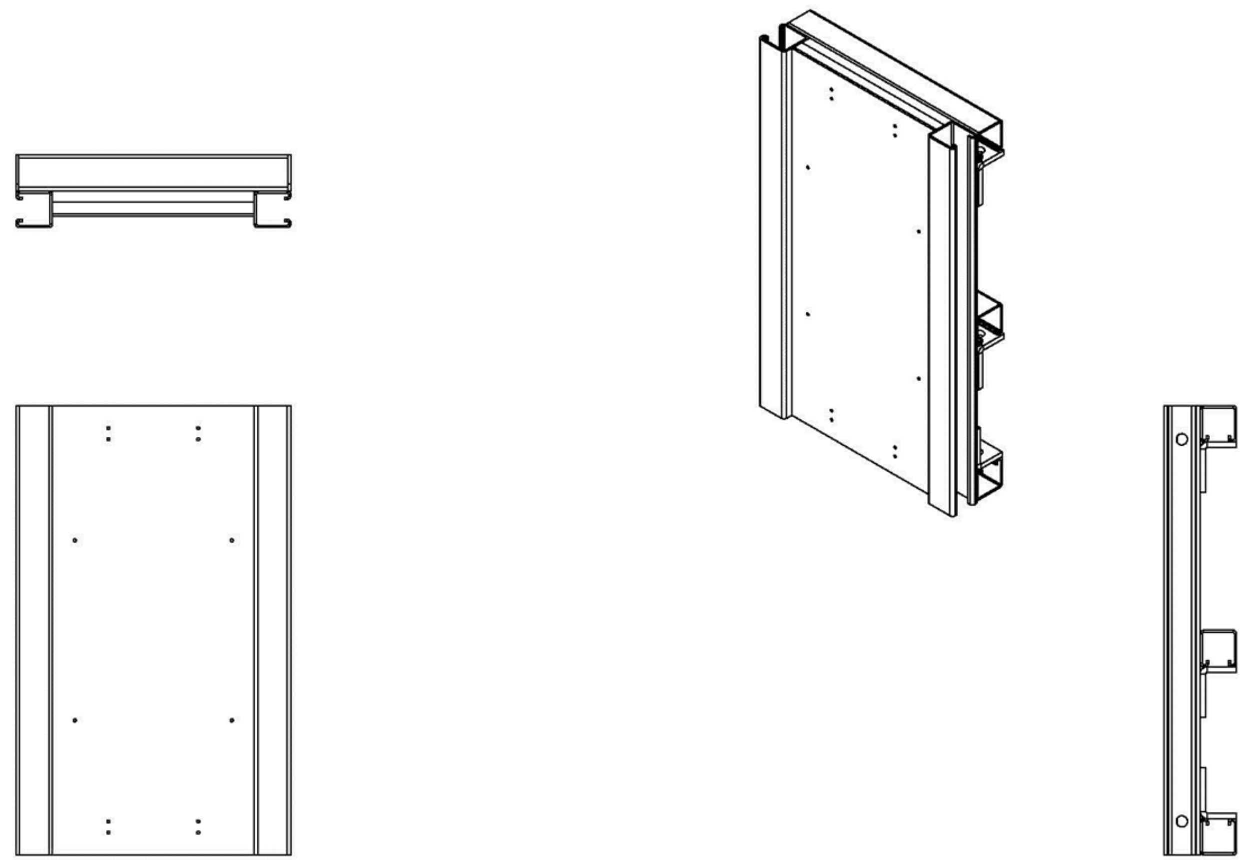

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Poverty Crusher

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Fixed Face

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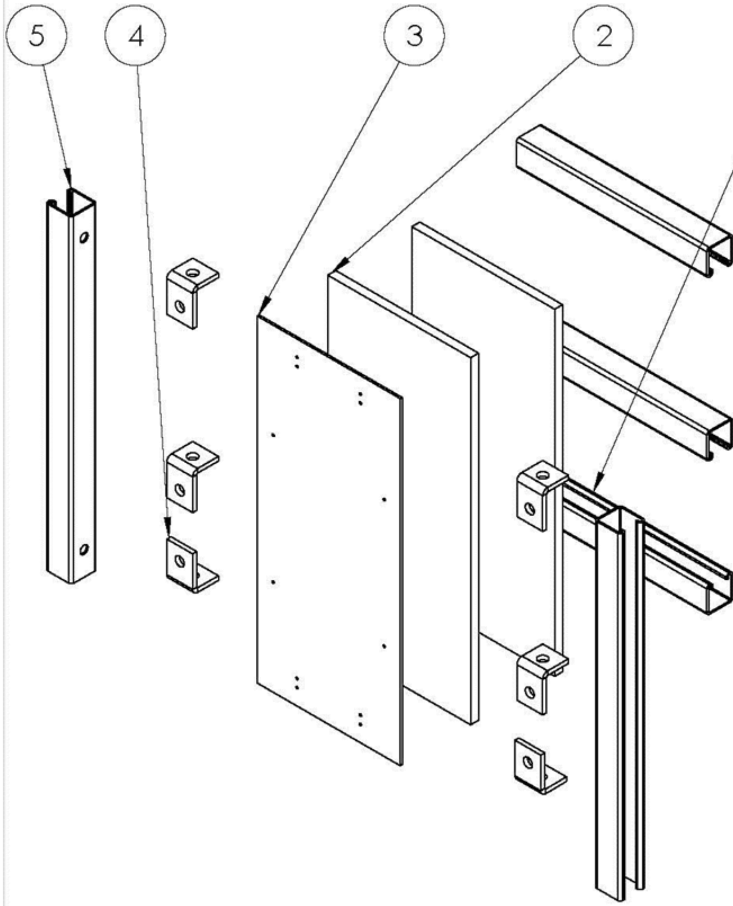

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3	018	Sheet metal face	1
4	020	2 hole bracket	6
5	028	20" Superstrut	2

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ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

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MFG APPR.		
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COMMENTS:

Poverty Crusher

TITLE:

Fixed Face Subassembly

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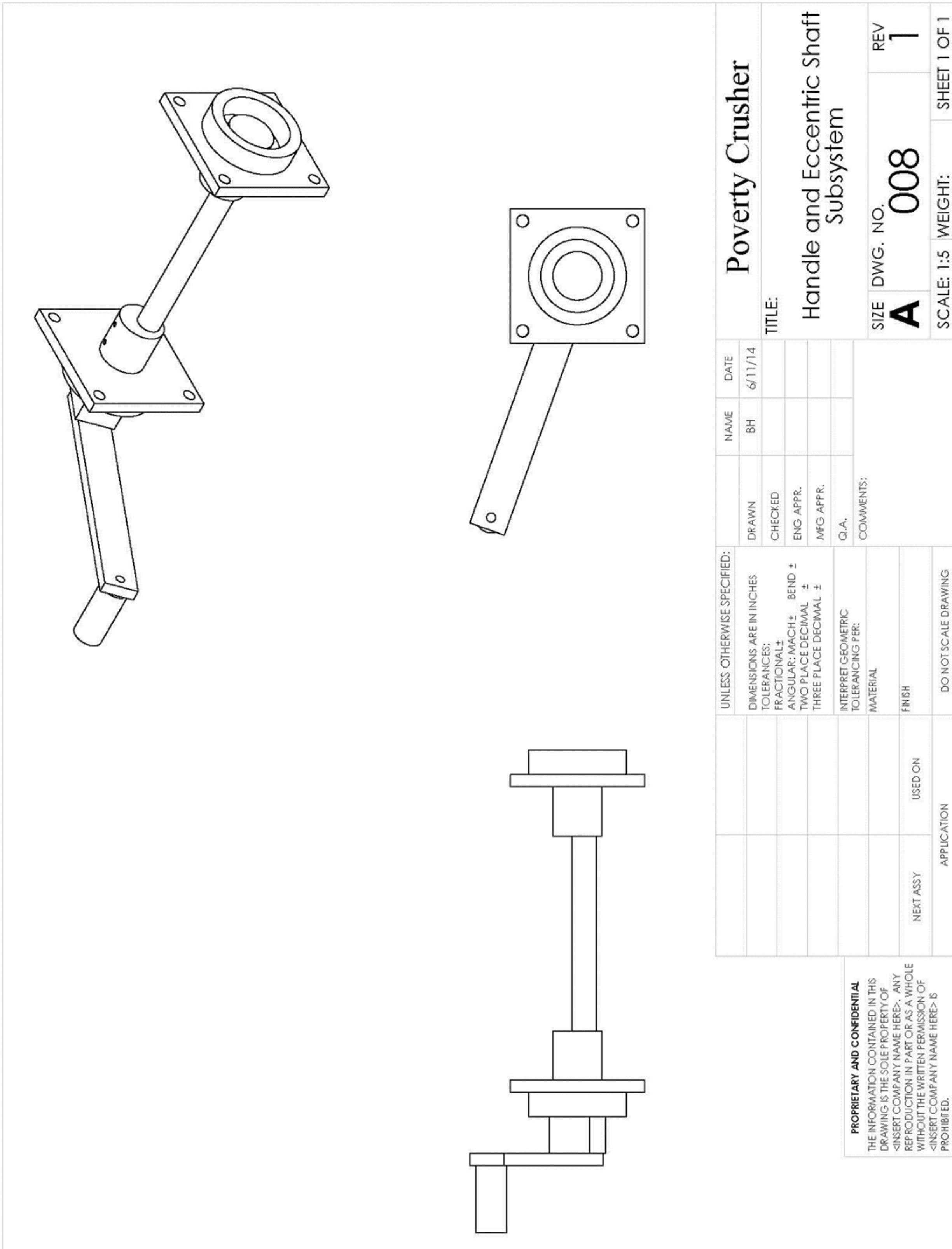
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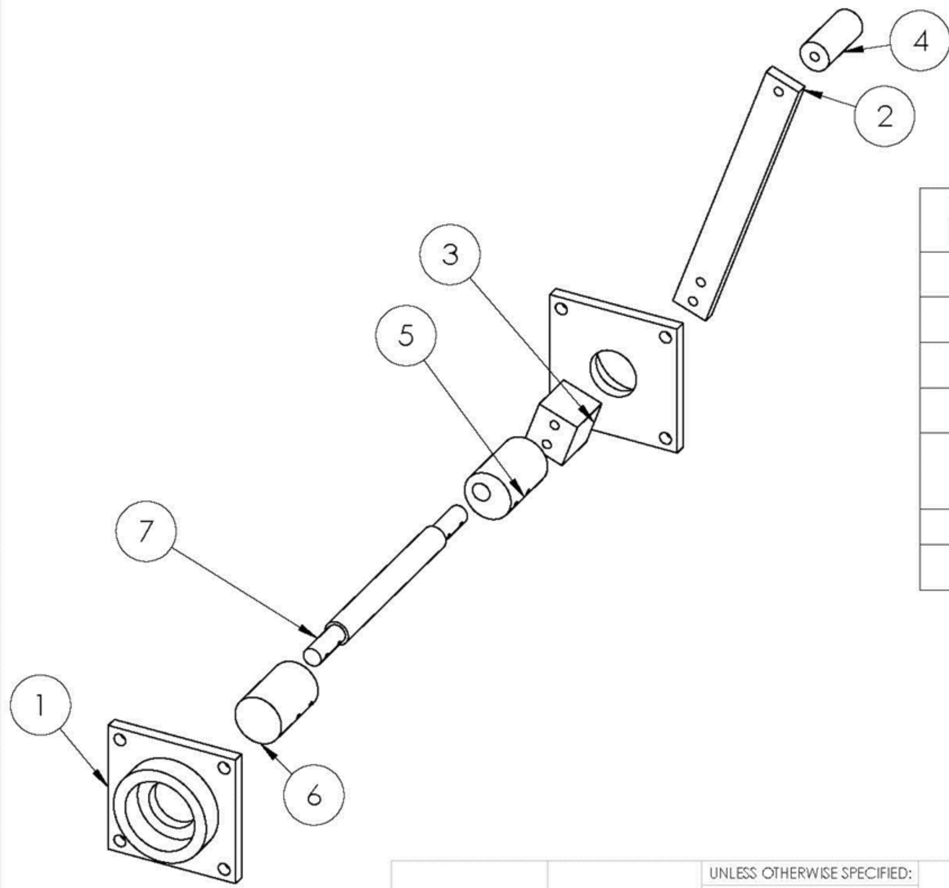

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3	014	Metal spacer	1
4	016	Dowel	1
5	011	Handle side eccentric end	1
6	010	Eccentric end	1
7	012	Metal driveshaft	1

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TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	BH	6/4/14
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

Poverty Crusher

TITLE:

Handle and Eccentric Shaft Subsystem

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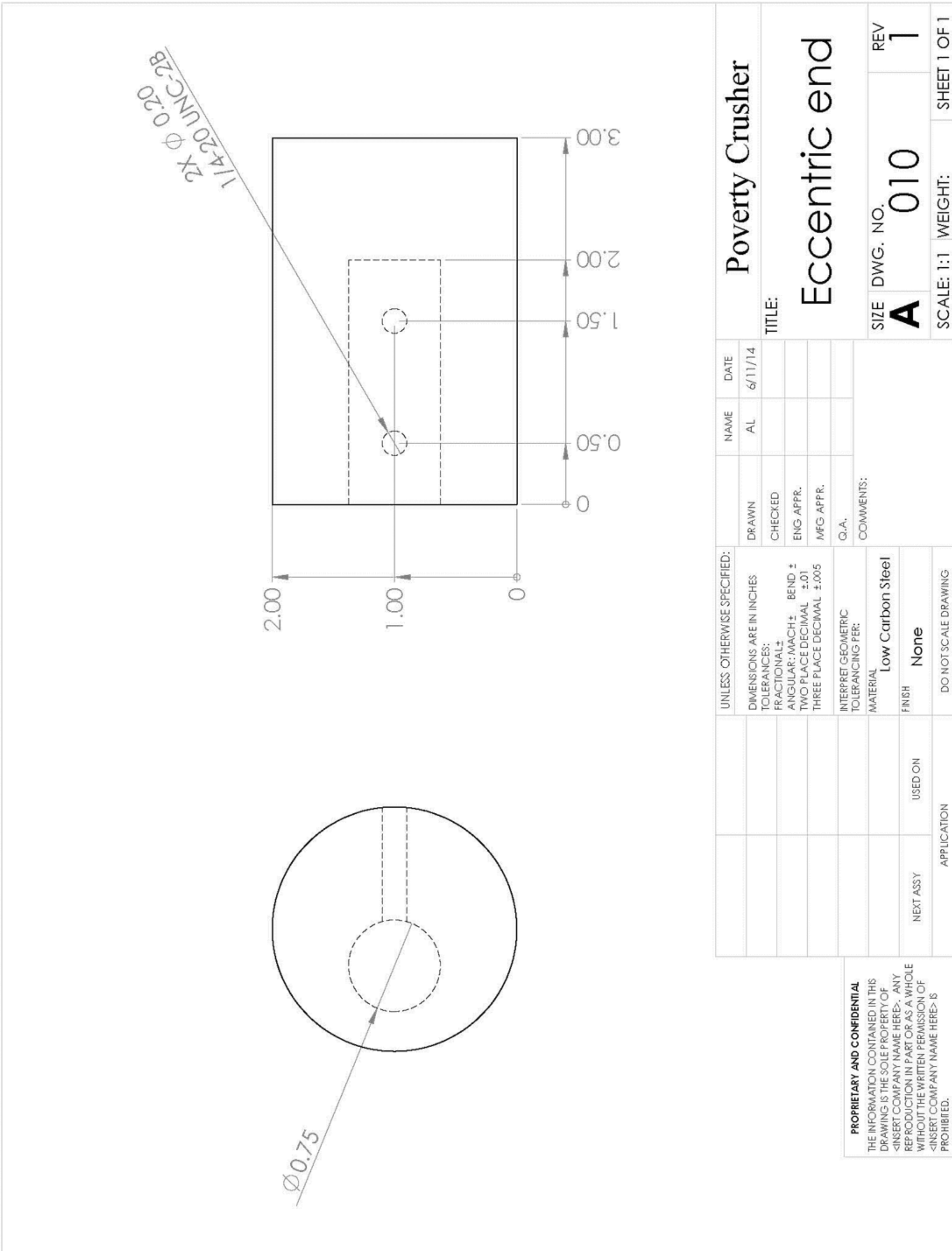

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Poverty Crusher
TITLE:
Eccentric end
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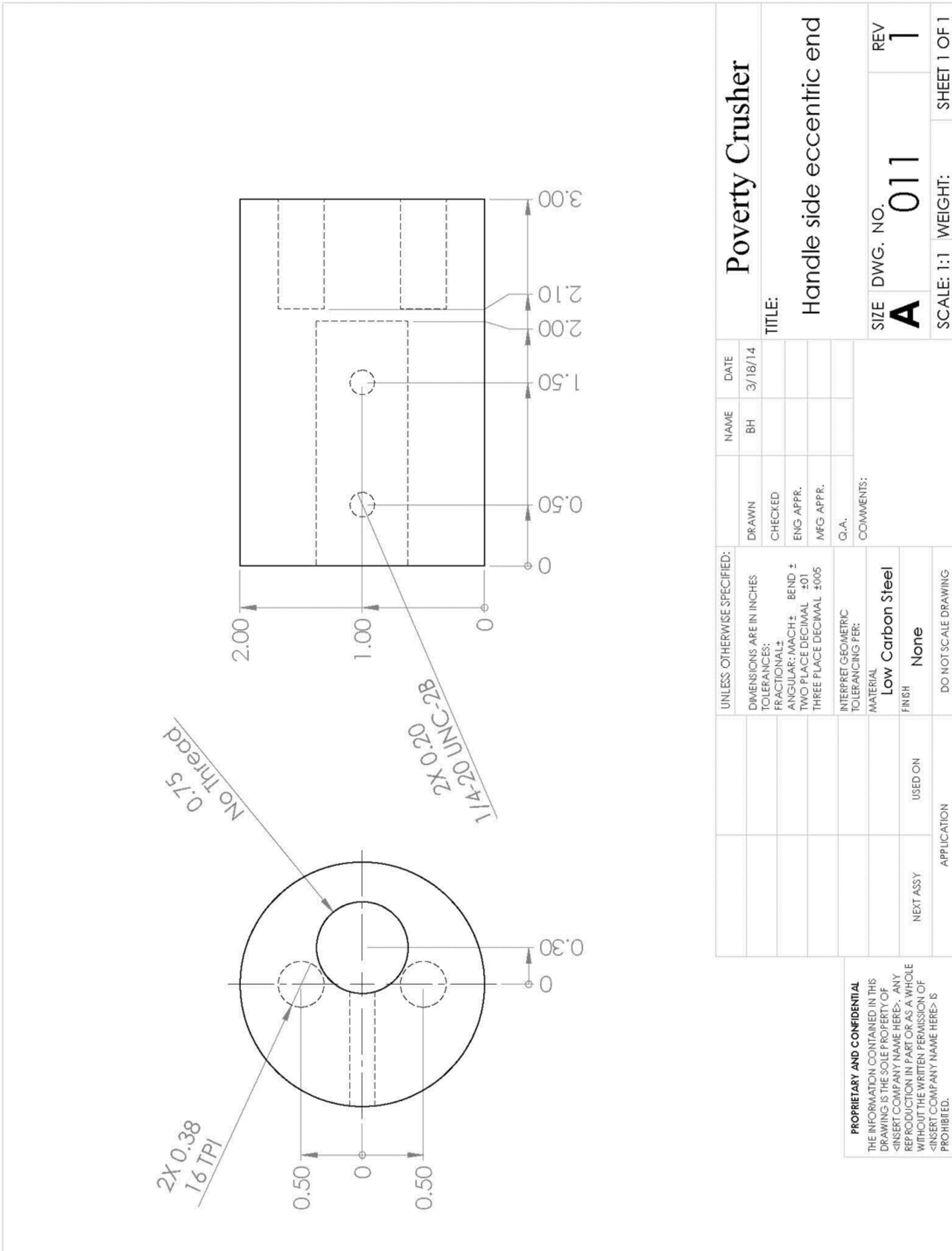
REV 1
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
NAME
DATE
DRAWN
AL
6/11/14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Low Carbon Steel
FINISH
None
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.


Poverty Crusher
TITLE:
Handle side eccentric end
SIZE
A
DWG. NO.
011
REV
1
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±01
THREE PLACE DECIMAL ±005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Low Carbon Steel
FINISH
None
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
BH
3/18/14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
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THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
2X 0.20
1/4-20 UNC-2B
0.75
No Thread
2X 0.38
16 TPI
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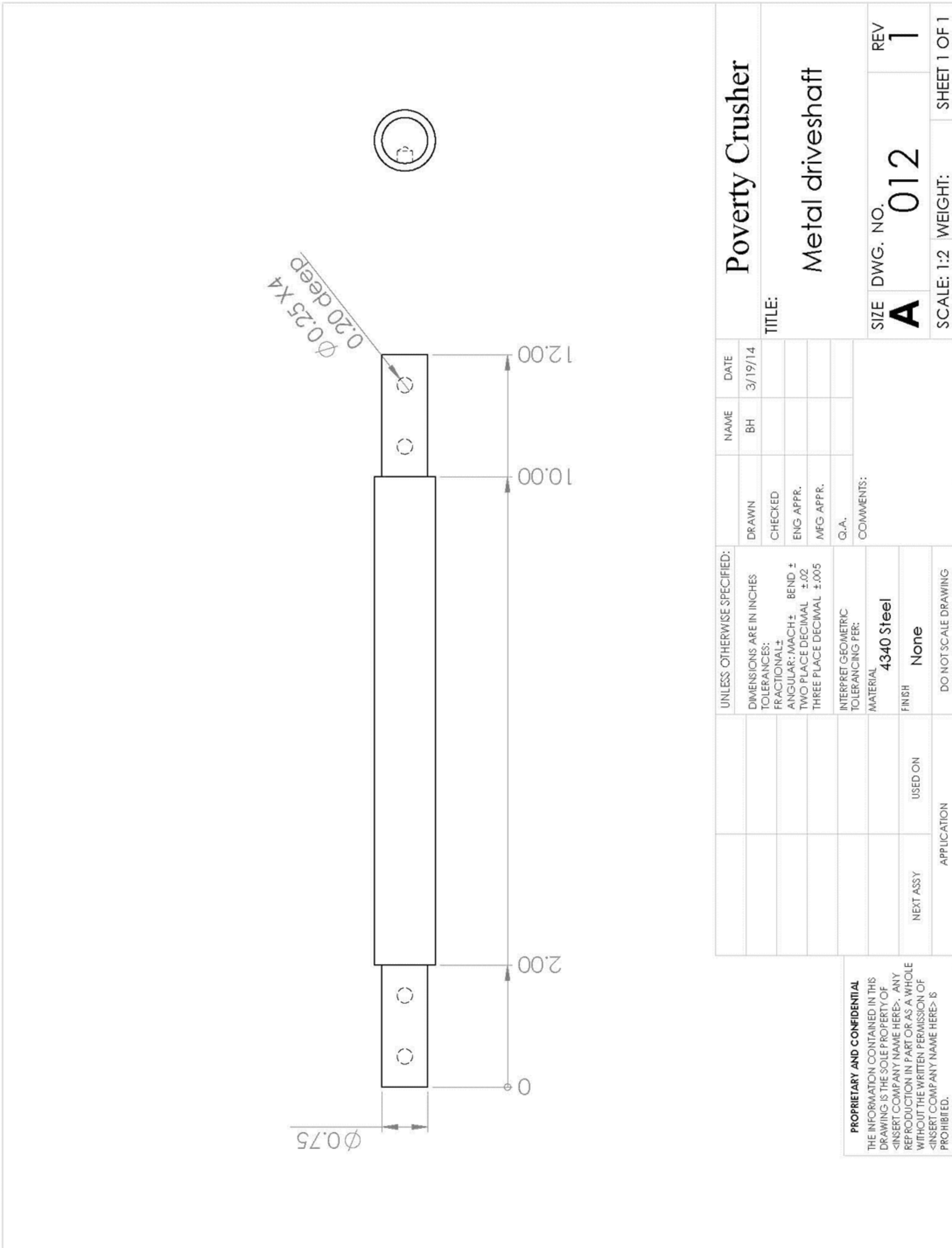
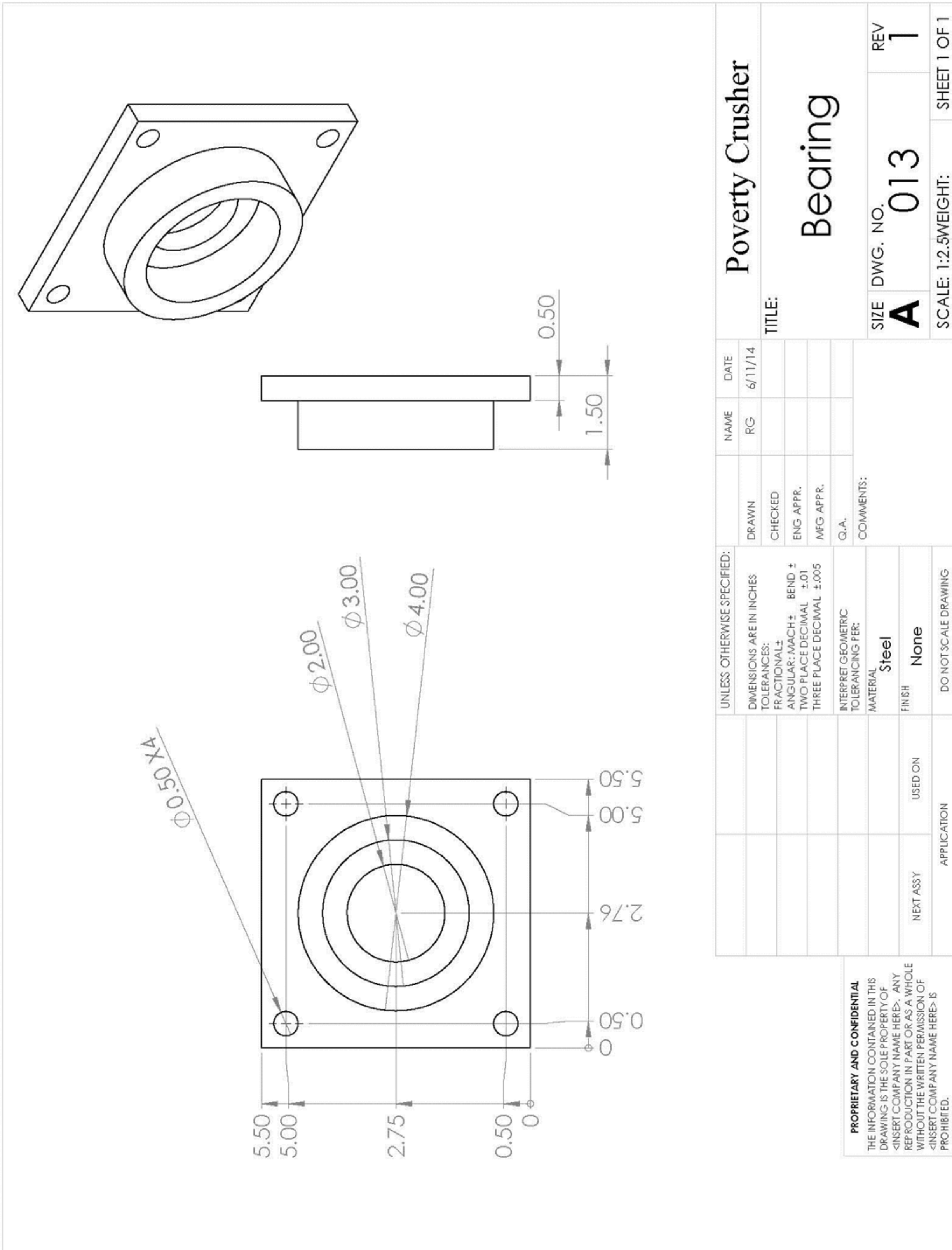
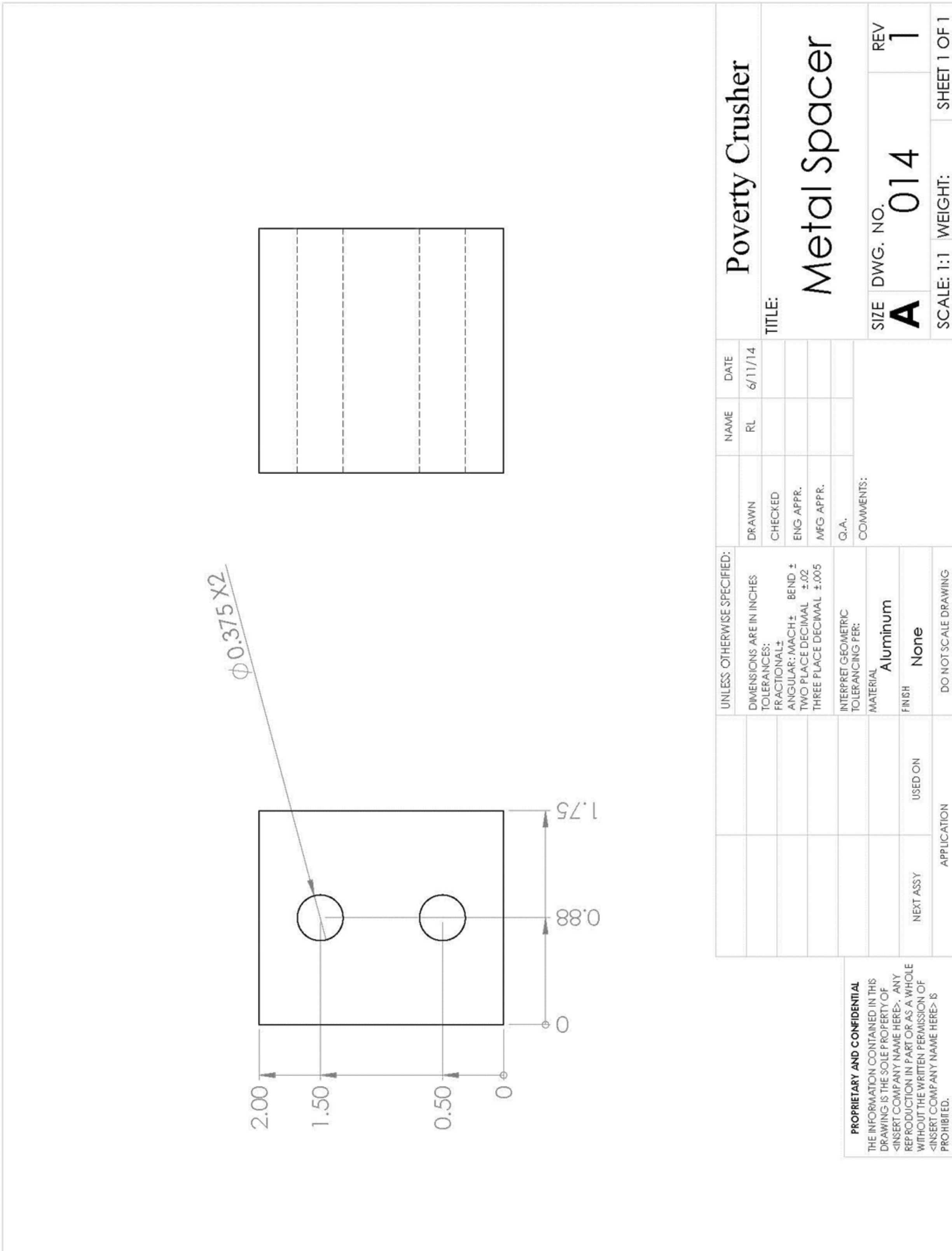
0.50
1.50
2.00
2.10
3.00
1.00
0.30

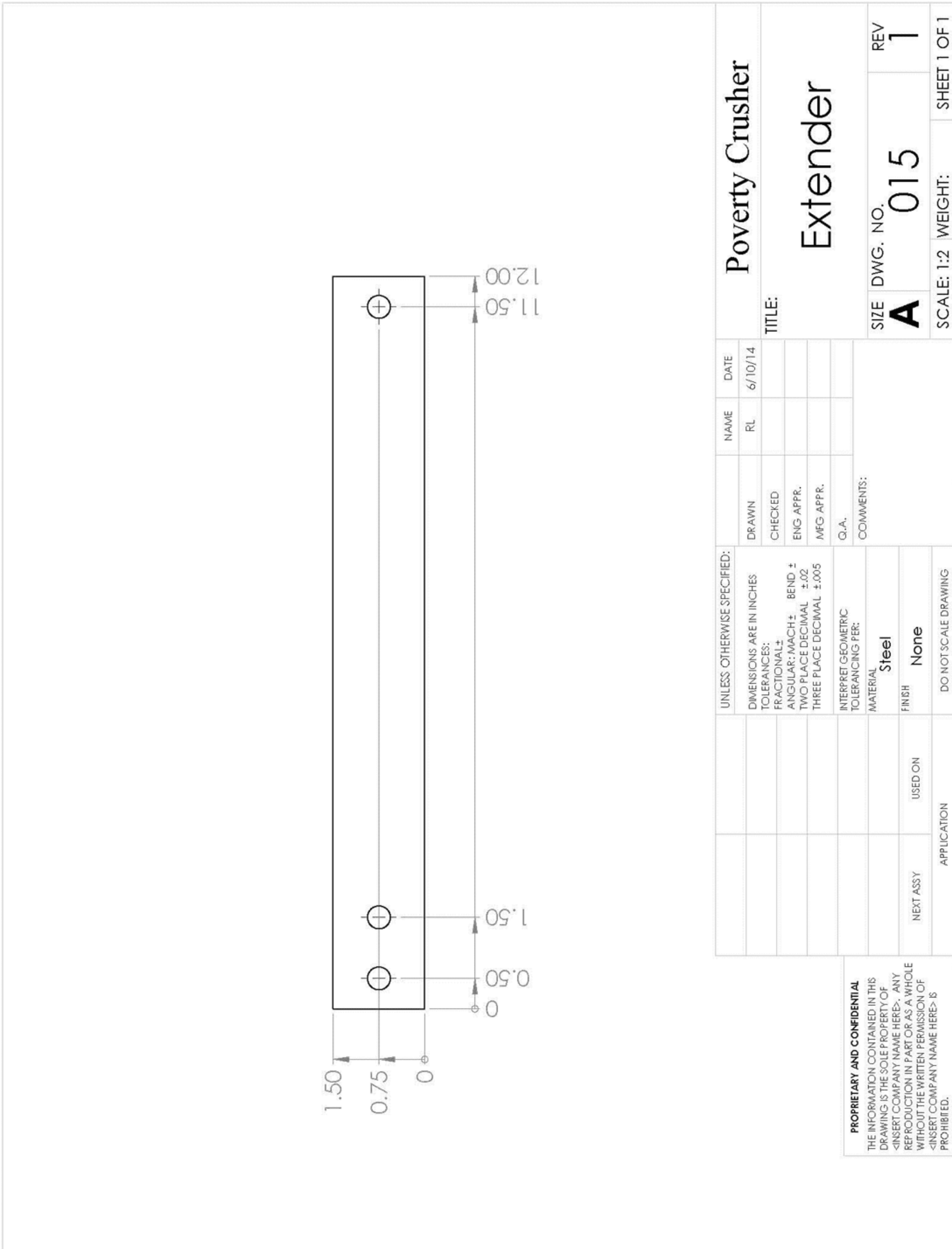


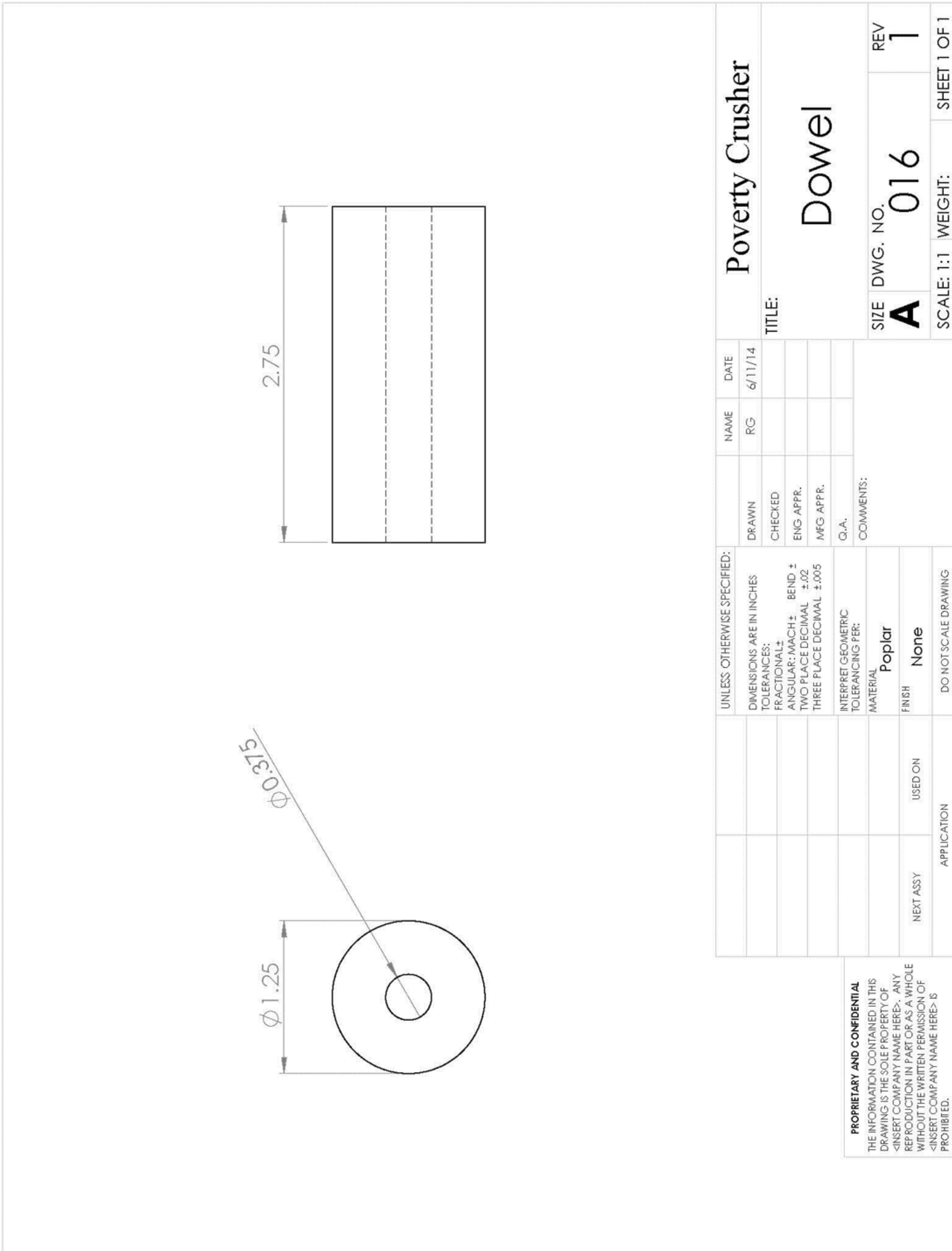
Poverty Crusher
TITLE:
Metal driveshaft
SIZE A
DWG. NO. 012
REV 1
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
NAME
DATE
DRAWN
BH
3/19/14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
4340 Steel
FINISH
None
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
Ø0.25 X 4
0.20 deep
Ø0.75
0
2.00
10.00
12.00


Poverty Crusher
TITLE:
Bearing
SIZE
A
DWG. NO.
013
REV
1
SCALE: 1:2.5
WEIGHT:
SHEET 1 OF 1
NAME
DATE
DRAWN
RG
6/11/14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Steel
FINISH
None
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
Ø0.50 X4
Ø2.00
Ø3.00
Ø4.00
0.50
1.50
5.50
5.00
2.76
0.50
0
5.50
5.00
2.75
0.50
0

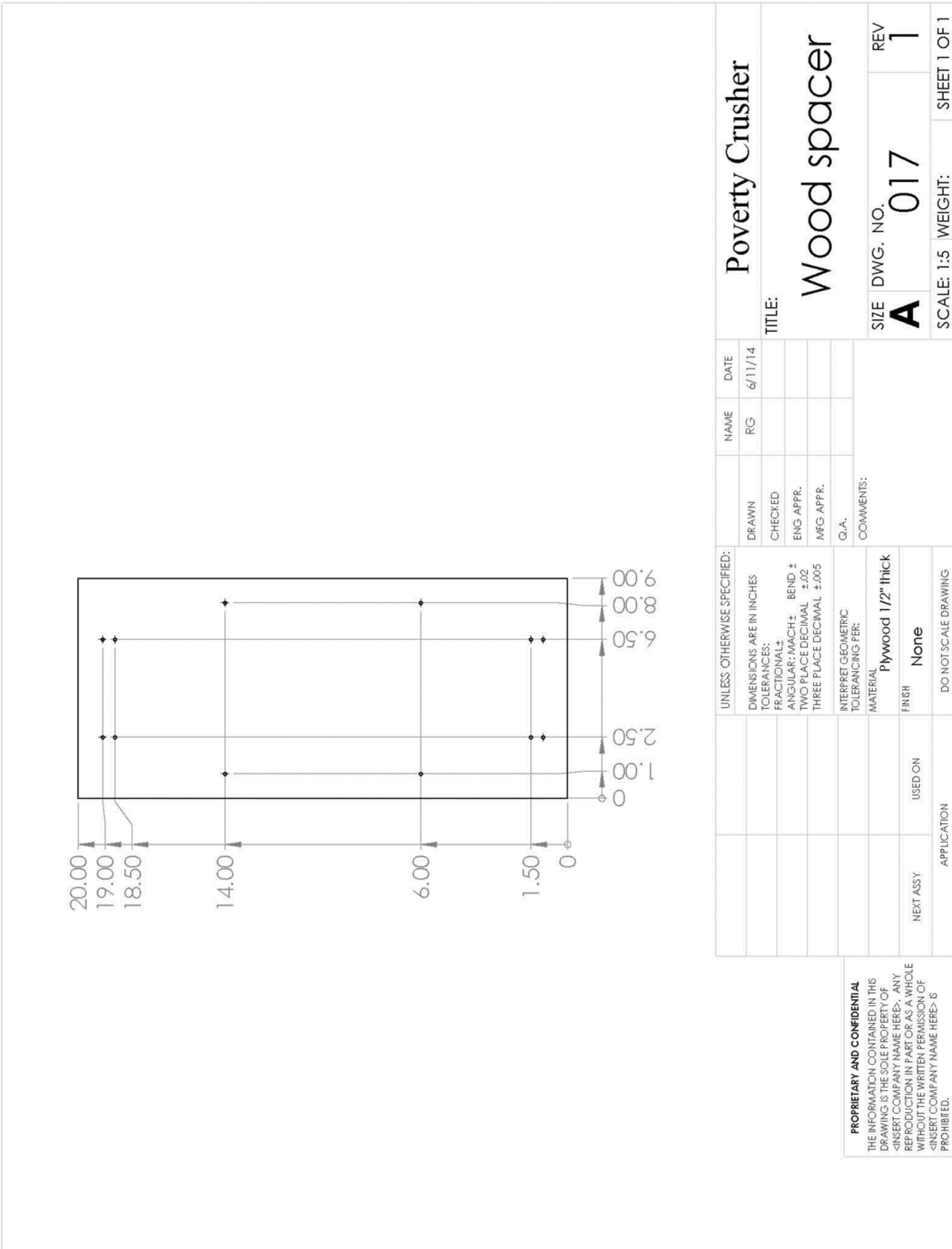


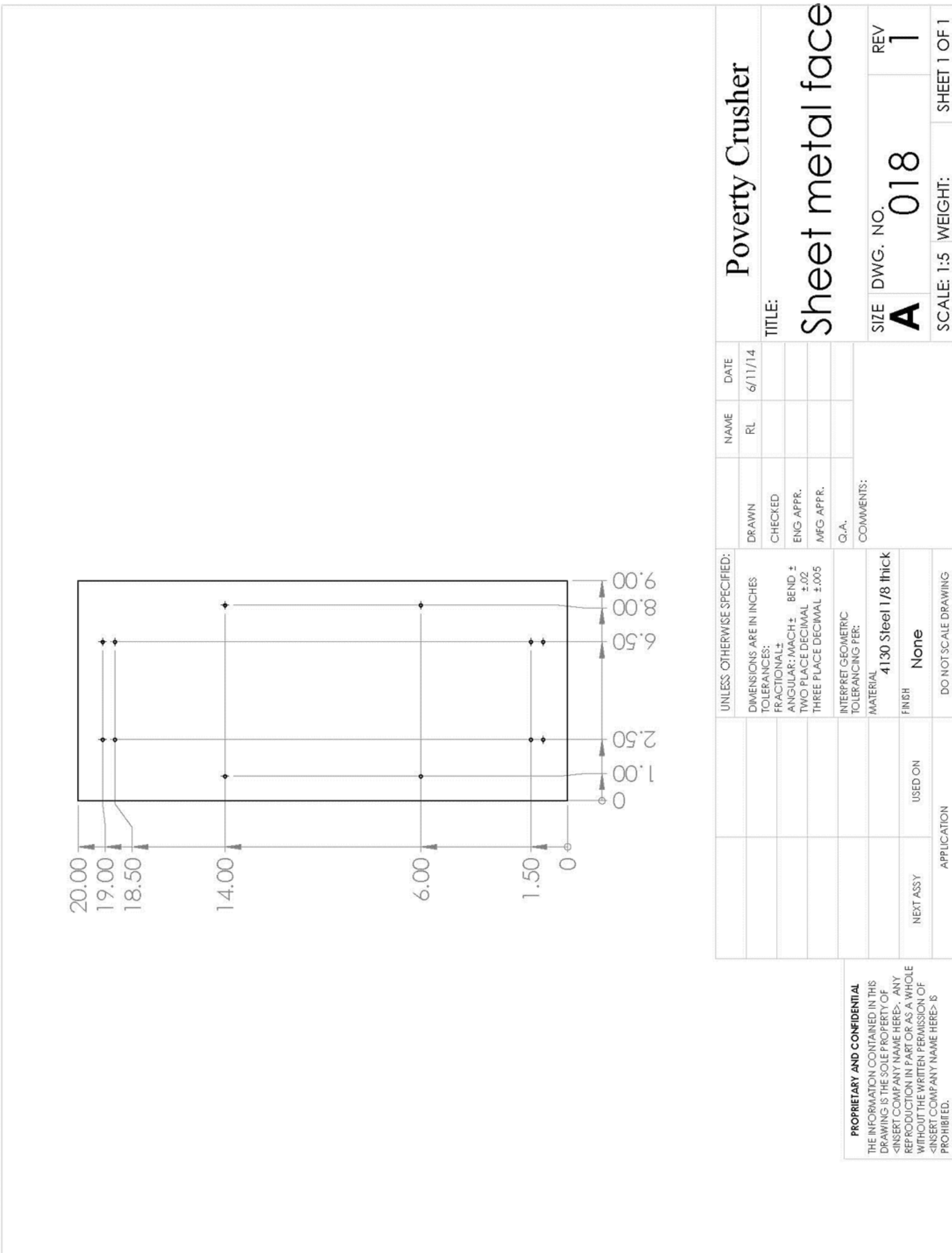
ϕ0.375 X2
2.00
1.50
0.50
0
0
0.88
1.75
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Aluminum
FINISH
None
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
RL
6/11/14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Poverty Crusher
TITLE:
Metal Spacer
SIZE
A
DWG. NO.
014
REV
1
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
5
4
3
2
1

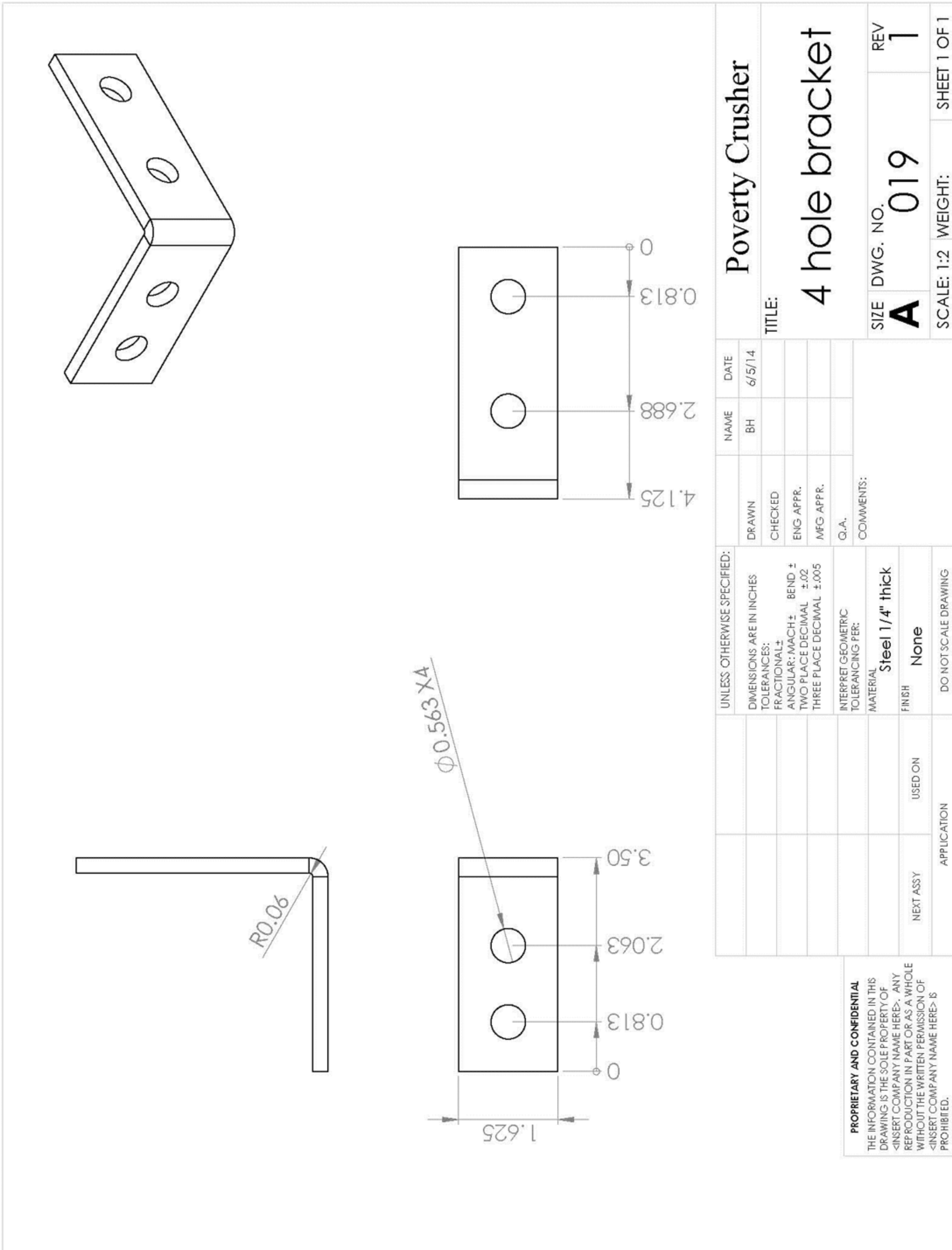

12.00
11.50
1.50
0.50
0
1.50
0.75
0
Poverty Crusher
TITLE:
Extender
SIZE
A
DWG. NO.
015
REV
1
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
NAME
DATE
DRAWN
RL
6/10/14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Steel
FINISH
None
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
5
4
3
2
1

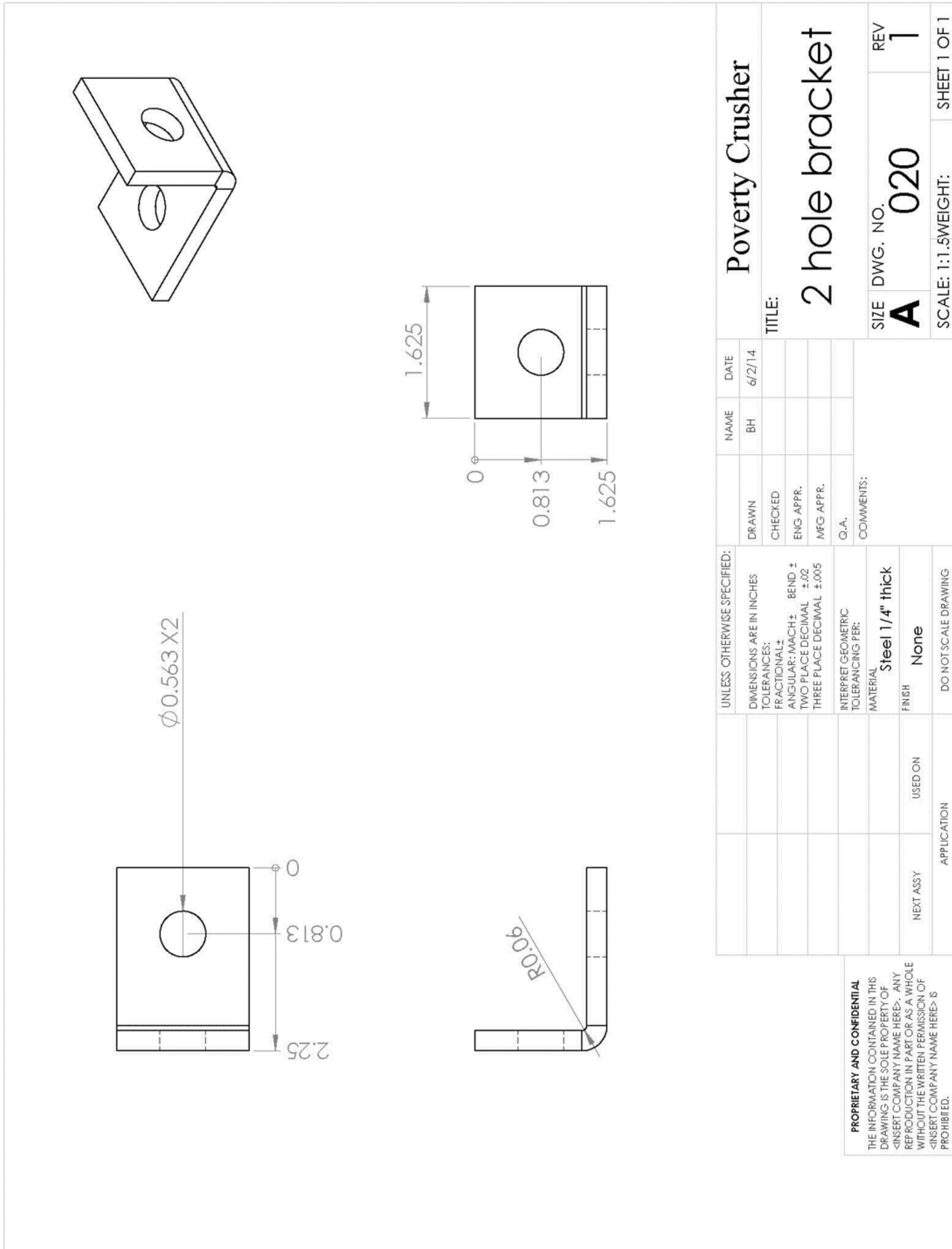


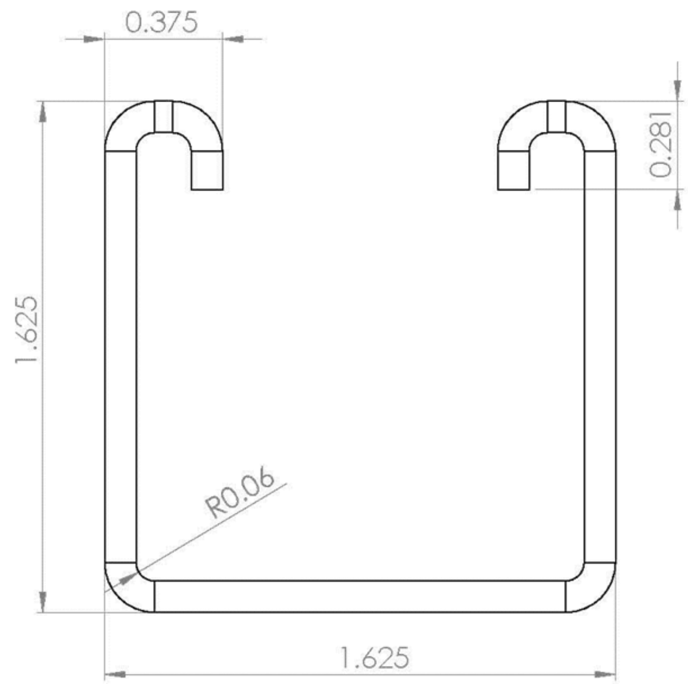
Poverty Crusher
TITLE:
Dowel
SIZE
A
DWG. NO.
016
REV
1
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
NAME
DATE
DRAWN
RG
6/11/14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Poplar
FINISH
None
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
2.75
ϕ1.25
ϕ0.375
5
4
3
2
1

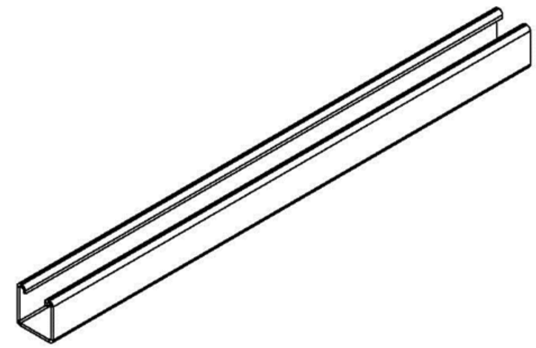

20.00
19.00
18.50
14.00
6.00
1.50
0
0
1.00
2.50
6.50
8.00
9.00
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Plywood 1/2" thick
FINISH
None
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
RG
6/11/14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Poverty Crusher
TITLE:
Wood spacer
SIZE
A
DWG. NO.
017
REV
1
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1
1
2
3
4
5


Poverty Crusher
TITLE:
Sheet metal face
SIZE
A
DWG. NO.
018
REV
1
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1
DRAWN
RL
6/11/14
NAME
DATE
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
4130 Steel 1/8 thick
FINISH
None
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
20.00
19.00
18.50
14.00
6.00
1.50
0
9.00
8.00
6.50
2.50
1.00
0


R0.06
⌀0.563 X4
1.625
0
0.813
2.063
3.50
0
0.813
2.688
4.125
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Steel 1/4" thick
FINISH
None
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
BH
6/5/14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Poverty Crusher
TITLE:
4 hole bracket
SIZE
A
DWG. NO.
019
REV
1
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
1
2
3
4
5


Poverty Crusher
TITLE:
2 hole bracket
SIZE A
DWG. NO. 020
REV 1
SCALE: 1:1.5
WEIGHT:
SHEET 1 OF 1
NAME
DATE
DRAWN BH 6/2/14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Steel 1/4" thick
FINISH
None
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
Ø0.563 X2
0
0.813
2.25
R0.06
1.625
0
0.813
1.625
1
2
3
4
5





PART NUMBER	LENGTHS	QTY
022	9"	1
023	11"	2
024	12"	9
026	19.5"	2
027	19.75"	4
028	20"	2
029	21.5	4

NEXT ASSY	USED ON	
APPLICATION		DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL Steel 12 Gauge
FINISH

	NAME	DATE
DRAWN	BH	6/2/14
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

Poverty Crusher

TITLE: Superstrut Channel

SIZE A DWG. NO. 021 REV 1

SCALE: 1:0.5 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

Appendix E – OWAS Method

The following figures show the OWAS method to determine the levels of harm for certain body postures over a certain period of time.

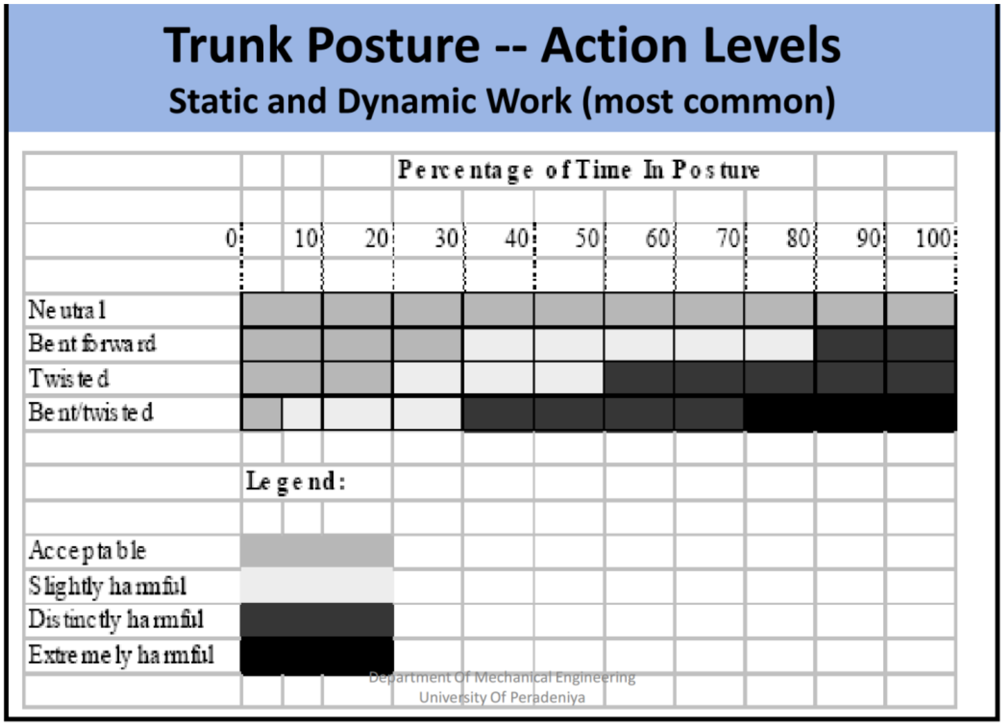


Figure F-1: Degree of Harm for Trunk Posture in OWAS system (Kumara)

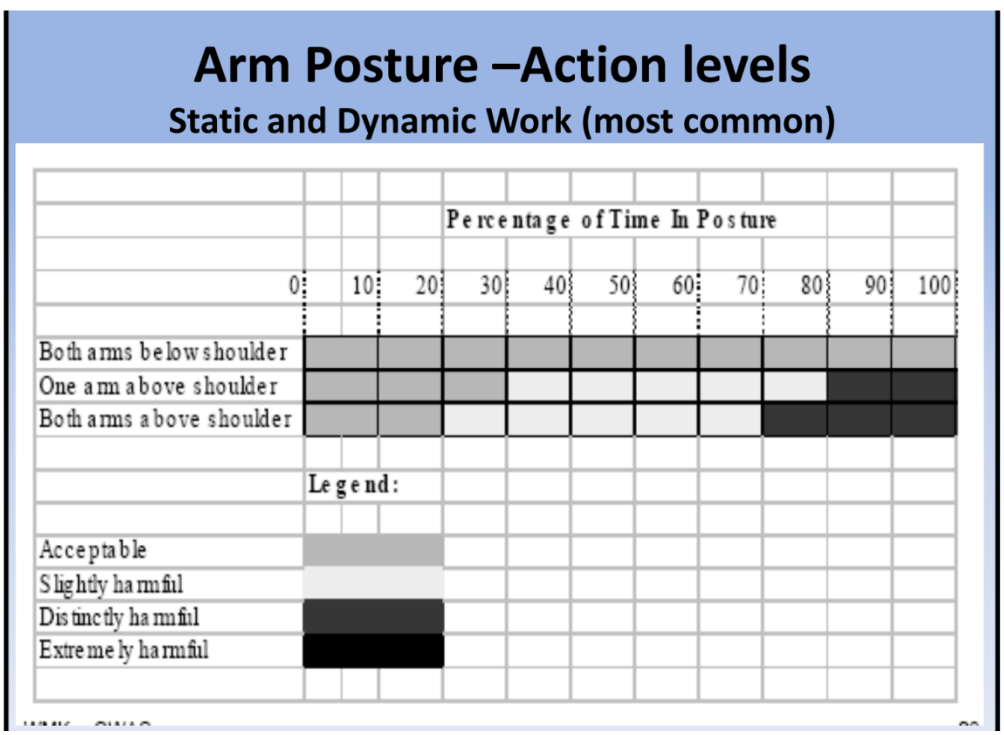


Figure F-2: Degree of Harm for Arm Posture in OWAS system (Kumara)

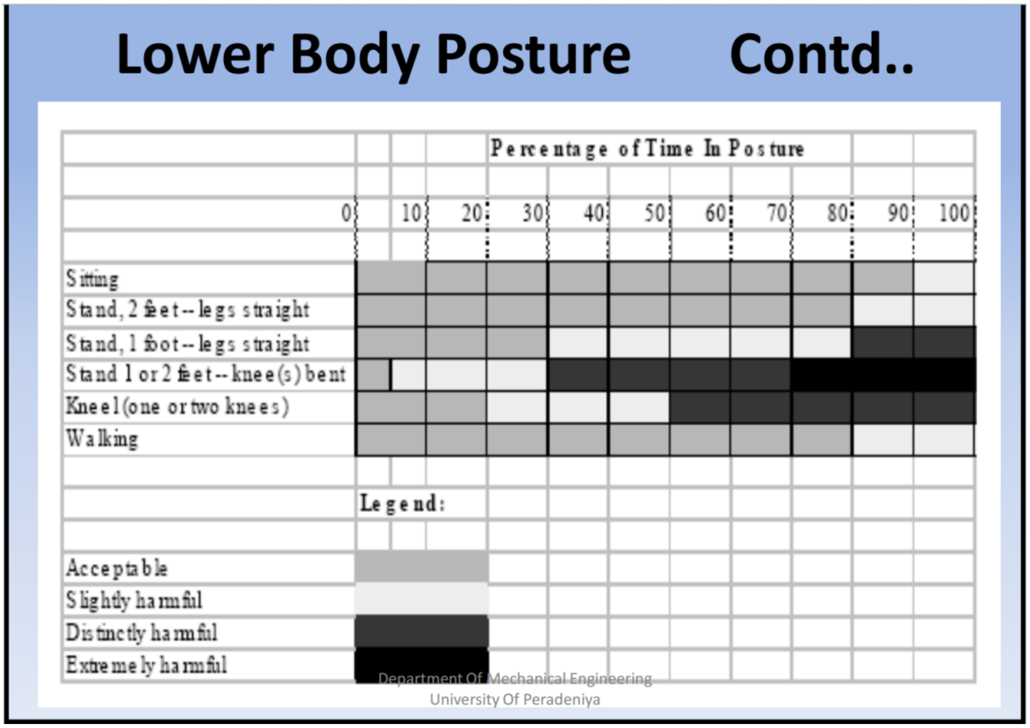


Figure F-3: Degree of Harm for Lower Body Posture in OWAS system (Kumara)

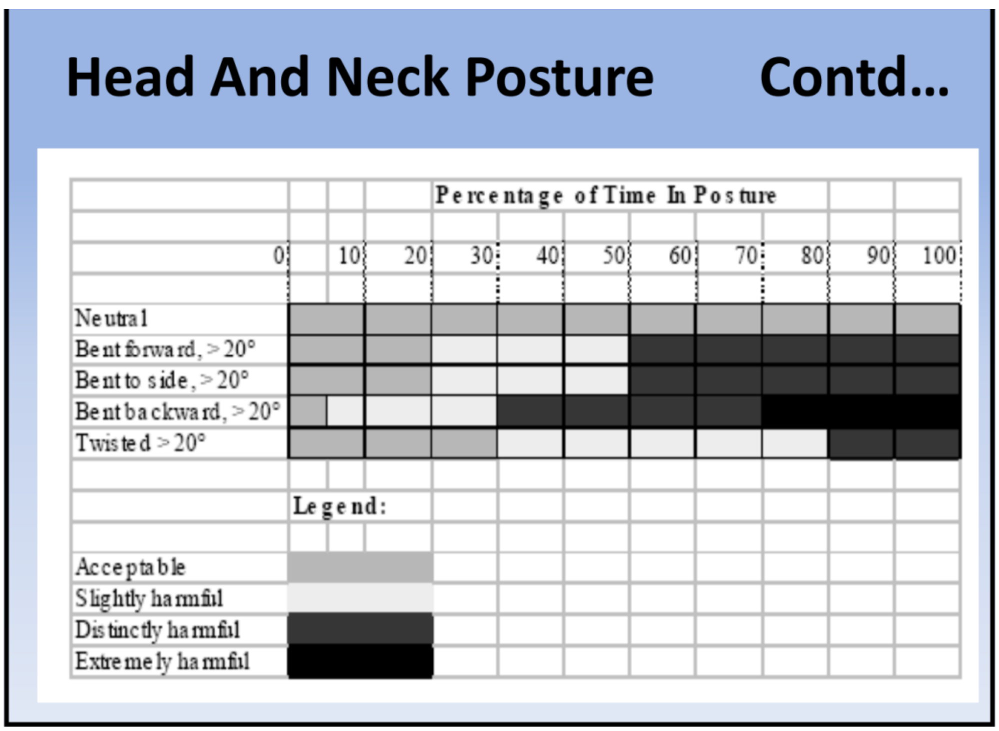


Figure F-4: Degree of Harm for Head and Neck Posture in OWAS system (Kumara)

Appendix F – Hand Calculations

The following pages show the hand calculations to solve the second moment of inertia in the moving face.

Moment of Inertia Calculated by a Simple Beam

Modulus of Elasticity (E)

Sheet Metal = 29700000 psi

Plywood = 1125000 psi

Volume

Sheet Metal = $0.125 \cdot 20 \cdot 9 = 22.5\ in^3$

Plywood = $0.5 \cdot 20 \cdot 9 = 90\ in^3$

Volume = $22.5 + 3(90) = 292.5\ in^3$

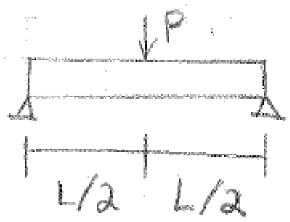
Rules of Mixtures

$E_{TOT} = E_A V_A + E_B V_B (3)$

$= (2.97 \cdot 10^7)(22.5/292.5) + (1.125 \cdot 10^6)(90/292.5)3$

$= 3.323 \cdot 10^7$ psi

Beam Type



$$\delta_{MAX} = \frac{PL^3}{48EI}$$

$$I_{MAX} = \frac{PL^3}{48E\delta}$$

$$I_{MAX} = \frac{10000(20^3)}{48(3.323 \cdot 10^7)0.6}$$

$$I_{MAX} = 0.8359\ in^4$$

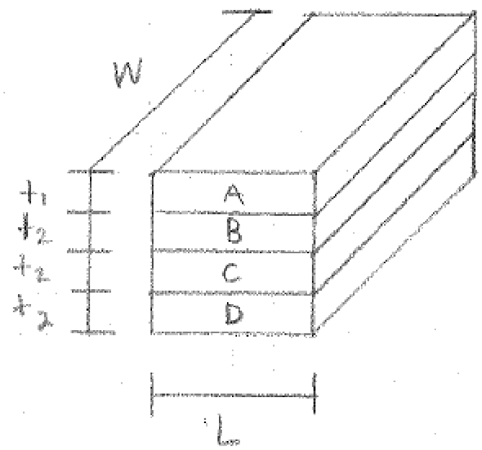
P = 10000 lb

(force to break a rock)

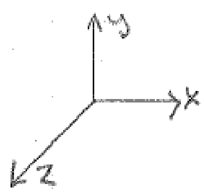
$\delta = 0.6$ in

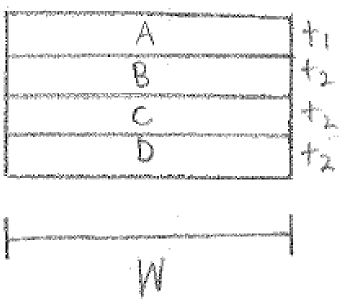
Amount of deflection produced due 0.3 in offset in eccentric shaft

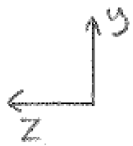
Moment of Inertia Calculated with Area



$W = 20$ in
$t_1 = 0.125$ in
$t_2 = 0.5$ in
$L = 9$ in







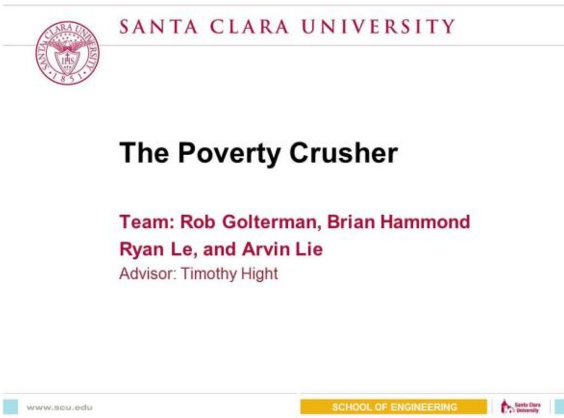
$$I_{yA} = \frac{b^3h}{12} = \frac{w^3t_1}{12} = 83.33 \text{ in}^4 \qquad I_{yB} = \frac{b^3h}{12} = \frac{w^3t_2}{12} = 333.33 \text{ in}^4$$

$$I_{yB} = I_{yC} = I_{yD}$$

$$I_y = \Sigma I_y + Ad = [83.33 + 0.125(20 \cdot 9)0] + [333.33 + 0.5(20 \cdot 9)0]$$
$$= 1083.33 \text{ in}^4$$

Appendix G – Senior Design Presentation Powerpoint

The following slides are what were used during the senior design conference in spring of 2014.



SANTA CLARA UNIVERSITY

Rock Breaking Life

Groups of women breaking rocks at the river

A woman carrying her rocks

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Rock Usage

Construction workers dropping off gravel

Newly constructed concrete house

Rocks used for roads

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Project Statement

Our goal is to design and build a human powered rock crusher that is safe, efficient, ergonomic, and affordable. The purpose of the device is to improve the lives of widowed women in Birendranagar, Nepal, who make a living through grueling rock crushing work.

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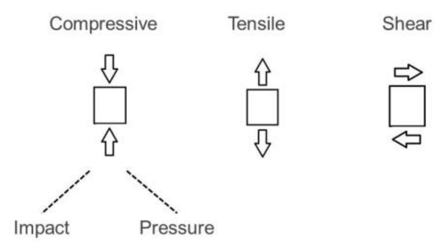
SANTA CLARA UNIVERSITY

Rock Mechanics



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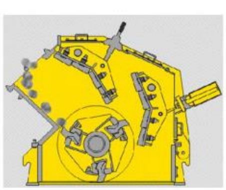
Industrial Crushers

Impact Crusher



Impact crusher animation

Industrial impact crusher

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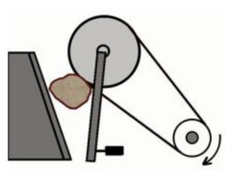
Industrial Crushers Cont.

Jaw Crusher



Jaw crusher animation

Industrial jaw crusher

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Product Comparison

	Impact Crusher	Jaw Crusher	New Dawn Jaw Crusher	Basic hammer
Max feed size	11"	7"	1.5"	NA
Output (lbs/hr)	45,000	13,000	660	55
Weight (lbs)	16,000	2,000	440	1
Cost	$26,400	$3,149	$1,700	$4

Rocks in Nepal

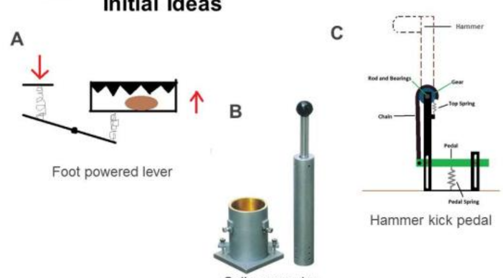
- Sandstone (Rock Identification Key)
  - Compressive strength: 50-100Mpa
  - Mohs hardness: 6.5 - 7

Typical rock crushed by one of the women

Crusher Design Criteria

Efficiency	60 lbs per hr
Cost	Under $25
Safety	Covers moving parts
Ergonomics	Reduce strain on body
Reliability/Life Expectancy	2+ years
Portability	Easy to transport

Initial Ideas



Foot powered lever

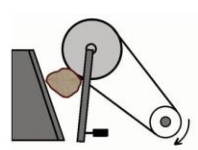
Soil compactor

Hammer kick pedal

Video of Rock Breaking

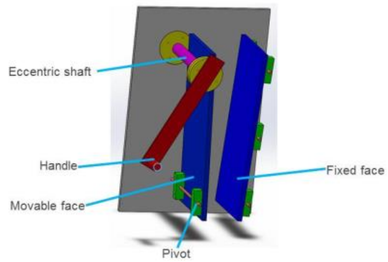
Jaw crusher design

- Advantages
  - High output
  - Simple design
  - Potentially low cost
- Disadvantages
  - Undergoes high stresses
  - Getting jammed



Jaw crusher animation

Jaw Crusher CAD design



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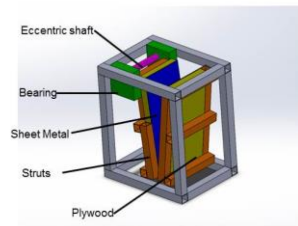
Current Prototype



Solidworks design


Jaw crusher prototype

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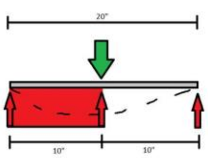
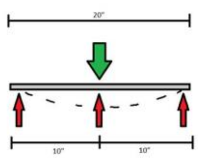
Free Body Diagrams



Movable face



Fixed face

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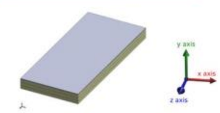
Moment of Inertia Calculations

- $I_x = \frac{1}{12}m(b^2 + c^2)$
- $I_y = \frac{1}{12}m(c^2 + a^2)$
- $I_z = \frac{1}{12}m(a^2 + b^2)$
- $I = \sum_1^n I_n + A_n d_n$

Moment of Inertia	Total (lbs*in^2)
X	28.90
Y	22.72
Z	8.33



Sample face made of sheet metal and wood

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Material List

- **4130 steel**
  - High yield strength
  - Very hard
- **Superstrut**
  - Easy to assemble
- **Weight: 135 lbs**

System	Number of Parts	Price
Frame	150	$275
Moving Face	40	$73
Fixed Face	40	$73
Eccentric Shaft	12	$22
Handle	10	$18
Total	**252**	**$461**

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Testing our Device

- Rate of gravel production
- Fatigue test
- Ergonomics analysis

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Travel to Nepal

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Getting to Know the Women

Interviewing women by the river

Interviews at the Women's Center

A young girl who crushes rocks

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Machine Shops

Drill press

Laithe

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What We Learned

Hanging out with the kids

Little tyke breaking rocks

Breaking rocks in the shade

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Quote from *Banker to the Poor*

"In the world of development, if one mixes the poor and the nonpoor in a program, the nonpoor will always drive out the poor, and the less poor will drive out the more poor, unless protective measures are instituted right at the beginning."

Muhammad Yunus

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Environmental Impact

Large channels dug by women

Brian in a hole

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Future Plans

- Pass the device on
- Make design improvements
  - Reduce cost
  - Reduce weight
  - Use local materials
  - Conduct further ergonomic study
- Look into impact crusher
- Give the design to Nepali machine shops

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Conclusion

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Questions?

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Thank You!

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