13 May 2005
Team 11: Sow What?

Kristin De Groot
Brian Katerberg
Dan Schrik
Andy Vander Moren
Executive Summary

This report summarizes the Senior Design Project of Team 11: Sow What? The team members are Kristin De Groot, Brian Katerberg, Dan Schrik, and Andy Vander Moren. The main objective was to design, build, and test an amaranth seed processor to be used by farmers in Kenya and other Developing Countries. This project was completed in conjunction with the Christian Reformed World Relief Committee (CRWRC) and Hillcrest Christian Reformed Church (CRC). It is hoped that this device, an improvement on current methods of cleaning the valuable amaranth seed, will aid in the economic development of poorer countries such as Kenya, Uganda, Mexico, and Belize. The main design issues were fan speed, efficiency in cleaning, ease of seed processing, and final seed cleanliness.

Two main deliverables were completed. A final working prototype was constructed; along with all the parts necessary to construct another machine. The second deliverable was a kit which includes the prototype parts, an assembly manual, and the necessary tools. Volunteers from Hillcrest CRC will reproduce the device components. CRWRC will then distribute these machines throughout Africa and parts of Central and South America. As of the publication date, 11 mills have already been ordered for delivery around the world. While the project has been continually growing, the main focus of our team has been on villages in Eastern Kenya. For the remainder of this report, Kenyan farmers will be assumed to be the end users of our final project.

The final cost of the prototype was $295.74. However, the team at Hillcrest CRC will likely reproduce this device at a lower cost due to larger quantity orders and industry connections.
# Table of Contents

1. Introduction 5  
2. Objective 5  
3. Scope 6  
4. Design Considerations 7  
5. Research 8  
6. Method of Approach 9  
   6.1. Testing 9  
      6.1.1. Winnowing 9  
      6.1.2. Thresher 10  
      6.1.3. Debris Separation 10  
      6.1.4. Integration 11  
   6.2. Tweaking 11  
   6.3. Final Design Decisions 12  
7. Final Design Proposal by Components 12  
   7.1. Thresher 13  
   7.2. Debris Separation 14  
   7.3. Chaff/Seed Separator 14  
   7.4. Power Train 14  
   7.5. Hopper 15  
   7.6. Frame 15  
8. Kit 16  
9. Manual 16  
10. Project Management 17  
   10.1. Team Organization 17  
   10.2. Schedule 17  
   10.3. Budget 17  
      10.3.1. Mechanical Component Cost Estimate 18  
      10.3.2. Manual Labor Costs 19  
      10.3.3. Total Cost 19  
11. Ethics 19
Appendices

Appendix

Design Alternatives
A
Design Calculations
B
Testing & Redesign Discussion
C
Amaranth Data
D
Final Design Specifications
E
Assembly Manual
F
Works Cited
G

Figures and Tables

Page

Figure 3.1: Project Flow Diagram 6
Figure 6.1: Air Chute Setup 9
Figure 6.2: Triangular Belt Setup 10
Figure 6.3: First Prototype 11
Figure 7.1: Final Components Diagram 13
Figure 7.2: CNC Cutout Design 15
Figure 8.1: Kit Parts 16
Figure 9.1: Assembly Manual Sample 16
Figure 10.1: Schedule 17
Table 10.1: Bill of Materials 18
1. Introduction

In Eastern Africa, a seed known as amaranth is emerging as a strong cash crop. Amaranth has very high nutritional value and grows quickly and easily while requiring little water. Hillcrest Christian Reformed Church, in affiliation with Christian Reformed World Relief Committee, asked the team to provide a simple and efficient way for Kenyan farmers to process this seed. Currently there are a few operational Clipper 1B and 2B fanning mills which are being used to process amaranth in Kenya. The mills are extremely run down and are insufficient for the quantity and quality of amaranth the Kenyans would like to grow and sell. Most Kenyans do not have access to these machines due to there high cost and low portability, and therefore thresh and winnow the amaranth seed by hand.

Designing a machine that can effectively clean amaranth seed can encourage economic growth in an extremely poor area of the world. Amaranth seed sells for three times the amount corn sells for on the current market, and thus can provide increased income for needy families. This nutritional seed can also be used to boost the physical health of the villagers. This is especially important for Kenya, an area where malnutrition is a concern for approximately 40% of the population.

The group is working directly with Bob Beute, the ministry and outreach coordinator at Hillcrest Christian Reformed Church in Hudsonville, Michigan to design a prototype amaranth seed cleaning mill. Mr. Beute and his team of craftsmen from the Hillcrest CRC congregation will then finance the mass production of eleven devices modeled after the prototype. The mills will then be given to CRWRC for shipment and distribution to the farmers in Kenya and other parts of the world.

2. Objective

The goal of this project was to design a small, hand powered machine that is able to thresh and winnow amaranth seed for farmers in Kenya. That is, the machine separates the seed and chaff from the stem (threshing), and then separates the seed from the chaff (winnowing). The parts for the machine will be built in Hudsonville, Michigan by the Hillcrest CRC team and then shipped as an all inclusive kit to Kenya for assembly. This small, economic device will allow more individuals to own the mills, eliminates the tedious and labor intensive process of beating
the seed from the stem by hand, and provides a cleaner product than what is currently being produced in Kenya.

3. **Scope**

![Project Flow Diagram](image)

There are four main deliverables that constitute this project:

The first is a working prototype. A final prototype was built after numerous design alternatives were considered and testing was performed. Testing was conducted to prove that the machine met the project expectations and requirements. This included 1) The performance of the machine (quality of processed seed), 2) The effectiveness of the assembly manual, and 3) The maintenance required.

Much was discovered during the building and testing of the machine. Using this information, the team authored an assembly manual tailored to the needs of the Kenyan people. This assembly manual was constructed without the use of words to prevent the language barrier from being a limiting factor for the delivery of these mills. Instead of words, the manual uses pictorial representations of the machine. This was done to allow the machine to be shipped to many different countries without any need for translation. Testing of this manual was conducted by allowing individuals with no prior knowledge of our machine to assemble the machine using only the assembly manual. This manual was the second deliverable.
The third deliverable was a set of mechanical drawings and manufacturing instructions for the craftsmen from Hillcrest CRC. These instructions included a detailed bill of materials, including part numbers and vendors.

Finally, the fourth deliverable was this compilation: a final report documenting all work completed throughout the year.

Additional responsibilities included maintaining communication between the contacts at Hillcrest CRC and CRWRC. The team also researched the capabilities and resources of the craftsmen from Hillcrest CRC so as to design parts that could be reproduced using machines available to the Hillcrest craftsmen.

It was not the responsibility of this project to ship the mills from the United States to Kenya. Hillcrest CRC will be in charge of crating the kit and CRWRC will take care of the shipping aspect of the process.

4. Design Considerations

The circumstances and location of the customer drove many of the design decisions. The parts for the mill must be built in the United States; and the machine can not be assembled until the parts arrive in Kenya.

The parts for the machine must be constructed in the United States because the manufacturing capability in many Kenyan cities is very limited. Very few Kenyans possess the skills and/or tools necessary to produce the parts that comprise the mill.

The processor must be broken down for shipment for a variety of reasons. First, complete machines cannot be sent into the country because of international customs laws. If, however, the machine is sent in pieces, the parts may enter the country without any major difficulties. The second reason the device will be shipped in parts is to minimize cost. Breaking the mill into smaller pieces enables the kit to be shipped in a smaller container, reducing shipping costs.

Sow What’s device will be reassembled in Kenya. All necessary tools are supplied for the assembly of the mill as tool suppliers in Kenya are rare. This provided an incentive to make the mill easy to assemble with as few tools as possible. Another reason for a straightforward assembly was because of the inability of many Kenyans to read any type of language. Easy-to-understand pictographic instructions were the most logical way to get around this difficulty. A hard to understand assembly and design will mostly likely reduce the machine parts to a useless
pile of scrap.

The scale of the machine depended on the desired amount of seed output. The goal of this project was to produce a machine that would process seed faster than current methods used by Kenyan farmers. It was estimated that our mill would be twice as efficient as current techniques.

In addition to these guidelines, there were less concrete, yet still important, considerations that were taken into account.

The first of these considerations were the culture and situation of the Kenyan farmers. The device was designed to produce acceptable, repeatable results with few difficulties and few complexities. The machine was designed to be lightweight, and handles were added to make it easily portable. This will allow farmers to share the machine within the community. Due to the lack of machining technology, required machine maintenance was minimized. Finally, tools needed for the assembly were included in the kit. Also included in the kit were extra parts, as some of the device parts are not easily obtained in Kenya.

Aside from the considerations resulting from the culture and situation of the Kenyan farmers, the burden on the manufacturers of the equipment was also considered. The design minimized material and labor costs, reducing the financial burden on Hillcrest CRC. The design was kept as simple as possible so that Hillcrest’s manufacturing team could build the device quickly and easily. Finally, the machine was designed to be small and lightweight to cut down on shipment costs.

5. Research

Two main areas were researched. First, it was necessary to understand the need of the customers. Most of this research was done through talking to members of Hillcrest CRC who had been to Kenya and seen the conditions to which our machine would be subjected. Tom Post of CRWRC was another source of information. Mr. Post helped us understand the way amaranth seed is impacting communities in Kenya and around the world. Having this knowledge helped us to see the importance of our machine more clearly.

The second area of research was the nature of the amaranth plant. This research gave us a more complete understanding of the amaranth plant itself and allowed us to become more familiar with current harvesting and processing techniques.
6. Method of Approach

6.1 Testing

The following outlines the process through which the final design was chosen. Research and testing required an extensive amount of time, and is briefly described here. For specific test procedures, see Appendix C.

6.1.1 Winnowing (Appendix C)

The goal of winnowing is to separate the chaff from the seed. Under current methods, the winnowing step is the most labor intensive. A variety of methods were discussed and explored. The most promising methods were a trough design and a fan/air chute design. Ultimately, as the following pages discuss, the air chute design was chosen as the optimal design. Tests were completed that 1) Determined an acceptable air chute design (angle, size, and length) 2) Explored air intake regulation techniques, and 3) Quantified an acceptable operational air speed interval.

Certain conclusions were made concerning length, width, and incline angle. The length, or height, of the chute was chosen to be equal to the height of the fan, not only for effectiveness but also for aesthetic appeal. It was found that the chaff, once airborne, is able to follow the air path, even for a substantially long chute. An ideal incline angle was among the hardest things to determine. It was found early on that sharp bends in the air chute severely hinder the success of separation. A smooth, radial chute will work better than a chute with sharp turns. Later it was observed that too shallow of an incline caused the seeds to ride up the slope and be pinned to the chute instead of sliding down the incline.

The decision was made to abandon air regulators such as mechanical governors, due to the added complexity for both builders and users alike. Currently Kenyans are taught to count out a beat while they turn the crank to ensure the fan is turned at a constant speed. This has proven to
be effective, and the simplest solution to this difficulty.

Finally, acceptable results were obtained with crank speeds ranging between 30rpm to 120rpm (revolutions per minute) with the ideal being closer to 90rpm.

### 6.1.2 Thresher (Appendix C)

![Triangular Belt Setup](image)

Figure 6.2: Triangular Belt Setup

Although the original request from CRWRC only asked for a mechanical winnowing device, the team decided to incorporate a threshing device into the design. Currently, most Kenyan farmers beat the seed heads with a stick to separate the seed and chaff from the stem of the head. Although this addition of a thresher will increase the cost and complexity of the design, our team, with the approval of Hillcrest CRC, felt that the addition of the thresher will make the machine even more useful and will allow the Kenyan farmers to process seed much faster than they would if they still had to do the threshing by hand. Upon completion of the preliminary testing of the threshing device (Appendix C), it was decided that further testing would be beneficial. The thresher belt system was incorporated in the rough prototype design, and belts were chosen that would experience a small amount of wear over time. It is anticipated that the most amount of wear will take place on the edges of the rotating belt and near the center of the stationary belt.

### 6.1.3 Debris Separation (Appendix C)

The bulk of the seed cleaning for the Clipper fanning mill was achieved using a set of screens located right at the beginning of the operation. However, these screens were an extremely expensive part of the final design. While the final design does require some screening, it was a project goal to reduce the use of screens in order to minimize costs. The design uses two screens, one to separate the large debris from the seed and chaff and another to separate the medium sized stems from the clean seed. These screens were moved further back in the seed cleaning process allowing them to be much smaller than the screen used in the Clipper fanning mills and can be purchased for a much lower price than the screens from the original Clipper. Various screen sizes were tested by hand for effectiveness. The final design used a screen with
3/8” diameter holes to filter the large debris. The screen used for filtering the medium sized stems used 1/16” holes. Also, testing was carried out to determine the orientation of the screen for effective debris separation.

6.1.4 Integration

The third main test completed was the integration of the thresher and winnower. A full prototype was completed with all parts incorporated. The machine, though not exact, confirmed the compatibility of the components. Furthermore, the sturdiness of the machine and optimal gear ratio could also be explored. The fan and thresher were at first run by two different handles to determine the difference in speed requirements.

6.2 Tweaking

After building the first prototype, the device was presented to the primary contacts: Bob Beute from Hillcrest CRC and Tom Post from CRWRC. Also, the team met with Chuck Spoelhof, an industrial consultant. They gave valuable insight into potential difficulties that might be encountered in the future along with feedback pertinent to the Kenyan culture.

Two additional components were added to the original prototype. A hopper was added for ease of use and safety, and to allow more heads to be put into the machine at once. Also, a seed tray was added to effectively catch the seed falling off the incline plane. This was later altered in size (larger) and complexity (a fine screen was added to further clean the seed from debris).

The thresher was also tweaked in the redesign process. The belt orientation was changed slightly to be more effective, and the tensioning system set up so that everything would be better aligned.

The side panel/frame design was significantly altered. The first prototype had two side panels with holes cut out for air intake to the fan and for large debris exit. Holes were also drilled to accommodate the shafts and the bolts for the tensioning brackets. The sheet metal pieces were mounted to the side frames via mounting brackets that were small, required a number of parts, and consumed a lot of time in assembly. For the final side panels, ¾ ” thick sheets of plywood
were used with ¼” deep grooves machined by a CNC machine. The cutouts were made to allow the edges of the sheet metal parts to seat inside the side panels. The mounting brackets were replaced with long threaded rods spanning the width of the mill. This design helps us to minimize the amount of parts needed and may make assembly much easier.

Once the final prototype was built and testing proved that the machine produced good results, work was able to begin on the assembly manual. Also, the drawings for the manufactured parts could be reviewed to confirm that they reflect the approved final design.

**6.3 Final Design Decisions**

Final design decisions were categorized into three main areas. First there needed to be decisions regarding which parts to custom machine and which parts to purchase. The side panel material was another area of concern. The final decision would be based on a trade-off between cost and effectiveness. The initial prototype used particle wood, a cheap and easy material to test on, but not a very durable material, especially in the presence of moisture. The use of plastic side panels with CNC cutouts was explored, but the cost of using a plastic side panel strong enough (that is, thick enough) for this application was not feasible: $400 for a 4’x 8’ sheet. Thus, the final material chosen was strong, thick 9 ply birch plywood, provided by Lorik Tool. The panels were finished with a stain and two coats of weather proofing sealer to protect it from the elements. The third and final area for decisions concerned safety. The cross bar pattern at the air inlet sufficiently blocks easy access to the fan without hindering the air intake. A gear cover was added to prevent any injury to children with the moving chain and sprocket.

**7. Final Design Proposal by Component**

(See Appendix E for design prints)

The final design proposal is best described on a component-by-component basis. Six main components are implemented in the machine, shown in Figure 7.1, below:
Figure 7.1: Final Design Components Diagram

The components will be discussed in the order they were designed:

1. Thresher
2. Debris Screen
3. Winnower
4. Power Train
5. Hopper
6. Frame

The following pages present descriptions of the components. For a full description of how they were tested and verified, please see Appendix C.

7.1 Thresher

The design of the thresher was composed of a conveyor belt system that essentially “shears” the harvested heads via friction.

This design uses one belt rubbing against a separate fixed belt to thresh the amaranth heads. A food-grade belt supplied by Mol Belting is mounted on the curved perimeter of the fan housing. This belt has a “half-moon” raised profile which provides an effective surface to shear the heads and also allows the seeds to easily roll off the belt. The rotating belt, also a food-grade
belt from Mol Belting has smaller dimples which help grab the amaranth and pull them through the thresher without damaging them. Further testing results can be found in Appendix C.

7.2 Debris Screen

The purpose of this component is to separate the sheared stalks and leaves from the seed and chaff. After the harvested head has passed through the thresher, the threshed debris falls onto an inclined screen. The screen hole-size was chosen to allow for the seed and chaff to fall through to the air chute while prohibiting the large debris from entering this chute. The debris sits on this screen until an operator reaches through the debris holes in the side panel and removes the accumulating debris.

As the seed and chaff are separated in the fan chute, the seed (which is heavier than the chaff) follows the incline of the chute and falls into a catch pan. The seed falls into the catch pan and onto a fine screen which filters out most of the remaining particles. The back of the catch pan is much higher than the front, to ensure that no airborne seeds will miss the pan.

7.3 Winnower

The fan separates the seed and the chaff by taking advantage of the mass and drag differences of the seed and chaff. The seed and chaff fall down a sloped path while a fan produces a constant stream of air flowing up the path. The larger mass of the seed allows it to continue its descent to the bottom of the slope, while the chaff is picked up by the stream of air and blown out of the machine. As mentioned earlier, the optimal speed of the hand-crank is around 90rpm.

This method of cleaning the seed has been proven to be successful. The current machine used in Kenya uses this fan system to separate the seed and chaff with minimal problems. The disadvantage of the current system in Kenya is that the mill is large and cumbersome. The blower in the new design was selected such that it could generate a constant, fast air stream while being small enough for easy shipping but large enough that an extreme gear ratio was not needed to provide the necessary rotational velocity.

7.4 Power Train

In compliance with the Kenyan work ethic, the processor is hand-powered. The operator is the feedback loop in determining whether to speed up or slow down the input cranking speed.
While this design is cost effective, the design’s weakness is its lack of repeatability. Due to the addition of the thresher on the system; there is a potentially higher risk of system speed fluctuations, especially concerning the speed of the fan. Because of this fluctuation problem, adding some sort of flywheel to the system was seriously considered. However, the cost and simplicity of the design must be kept in mind, and this endeavor was abandoned (Appendix C). Additionally, for safety reasons it is better for the moving parts to move only when someone is physically turning the hand crank.

The power train was built using parts similar to bike parts. This is advantageous because many Kenyans are familiar with bikes as it is one of their primary forms of transportation. The gear-to-gear ratio is 48/14.

### 7.5 Hopper

The hopper was designed for three reasons. First, it was to protect customers from getting their hands caught in the belt system and other moving parts. Second, it was to enable the heads to enter the thresher more easily. Third, it was to allow the user to put more heads into the machine at once.

While there is not a large risk of injury caused by appropriately using this mill, there is a risk if someone pushes their hand most of the way into the mill or along the inside edges of the mill. These are the areas that the hopper provides increased protection.

### 7.6 Frame

The overall frame design depended largely on the integration of the chosen components. Thus, as the design of the components was completed, great care was taken to allow for a simple frame design.

The frame consists of two rectangular sides of plywood. Cutouts for the fan, debris exits, bushings and handles are visible in Figure 7.2, left. This frame design is simple to manufacture using a CNC machine, is robust, and promotes a uniform and aesthetically pleasing look.
The materials considered for the side panel were aluminum, strong plastic, or plywood. Thin aluminum is cheaper to buy, but more expensive to ship. Strong plastic reduces the shipment costs significantly, but the price of the plastic is much higher. Plywood is cheap and light, but would not have the weather resistance of the others. For the final prototype, birch plywood was chosen because of its sturdiness and relatively low price. It is suggested that for further production, a higher-quality material be used.

8. Kit

The kit was the second deliverable of our project. Figure 8.1 shows every part that goes into the proposed device. The formed sheet metal parts are located along the top, the side panels can be seen on the left, and the thresher and winnower components are located in the lower right area.


An example of the assembly manual can be seen in Figure 9.1. One of the main objectives of this project was to provide a universal, easy-to-understand manual for assembly of the seed processor. Most farmers in Kenya are illiterate, even in their native Swahili. By not using any words, the machine can be easily distributed in various developing countries around the world without having to spend any extra time or money to have the entire manual translated.
10. Project Management

10.1 Team Organization

During a given work day the team tends to break up the tasks so that we get more accomplished instead of all of us working on the same thing. Kristin De Groot did a lot of work updating our report. She also does a good job at making sure we stay organized and on track. She was also responsible for developing and giving the final presentation. Brian Katerberg was our Autodesk Inventor specialist. He created an entire assembly video in Inventor, with Dan Schrik responsible for keeping the part designs updated. Brian also spent time building different prototype ideas for testing. Dan Schrik did most of the work to help ensure that the manufacturing print manual was ready for the Hillcrest craftsmen. In addition to this Dan managed the budget for our group. Andy Vander Moren has a good mechanical background and tended to do a lot of work on the prototype building. Additionally, Andy was the main communication link between our group and our contact people. He also kept track of the purchased parts and budgeting. Although we each do work on these respective items, we all share the total workload so that no one is doing too much of the work by themselves. Our different preferences complement each other, and when it all comes together, our separate parts make the overall picture complete.

10.2 Schedule

The most effective way of scheduling was to use the Dry-Erase board and prioritize the listings. Next to each item, the date for completion was listed, as well as the initials of the responsible person(s) to complete the task. Also, monthly to-do lists were made and can be found in the Senior Design Folder.

10.3 Budget

Financial resources for this project came from many different organizations. In addition to the $300 available to us from the Calvin College Engineering Department, we had generous financial support from Hudsonville CRC, Lorik Tool, and Haworth Furniture. This additional funding gave us freedom to experiment with different parts and components that would not have otherwise been available, helping us to better optimize our machine.
While we were not confined to a strict budget, it was still an important goal for us to keep the total cost of the machine within a reasonable price range. By doing so, we can help minimize the cost for Hillcrest CRC to reproduce the machine. This allows for more machines to be built and more farmers to be helped.

### 10.3.1 Mechanical Component Cost Estimate

Based upon the finalized design, the following bill of materials has been constructed:

Table 10.1 – Bill of Materials

<table>
<thead>
<tr>
<th>Component</th>
<th>Use/Function</th>
<th>Quantity</th>
<th>Cost</th>
<th>Total Cost</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan Shroud</td>
<td></td>
<td>1</td>
<td>$50.00</td>
<td>$50.00</td>
<td>Genzink</td>
</tr>
<tr>
<td>Screen</td>
<td>filtering the stems</td>
<td>1</td>
<td>$10.00</td>
<td>$10.00</td>
<td>McNichols</td>
</tr>
<tr>
<td><strong>Fan Assembly</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bronze Flanged Bearings</td>
<td>bearings for fan shaft</td>
<td>2</td>
<td>$0.81</td>
<td>$1.62</td>
<td>McMaster</td>
</tr>
<tr>
<td>Precision Ground Shaft</td>
<td>shaft for squirrel cage 15&quot;</td>
<td>1</td>
<td>$6.00</td>
<td>$6.00</td>
<td>McMaster</td>
</tr>
<tr>
<td>Fan</td>
<td>for winnowing operation</td>
<td>1</td>
<td>$31.45</td>
<td>$31.45</td>
<td>Grainger</td>
</tr>
<tr>
<td>Shaft Collar</td>
<td>shaft positioning</td>
<td>1</td>
<td>$2.09</td>
<td>$2.09</td>
<td>McMaster</td>
</tr>
<tr>
<td><strong>Thrasher Assembly</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belt</td>
<td>thrashing</td>
<td>1</td>
<td>$3.50</td>
<td>$3.50</td>
<td>Mol Belting</td>
</tr>
<tr>
<td>Belt</td>
<td>thrashing</td>
<td>1</td>
<td>$48.48</td>
<td>$48.48</td>
<td>Mol Belting</td>
</tr>
<tr>
<td><strong>Drive Roller</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bronze Flanged Bearings</td>
<td>bearings for thrasher drive roller</td>
<td>2</td>
<td>$0.81</td>
<td>$1.62</td>
<td>McMaster</td>
</tr>
<tr>
<td>Precision Ground Shaft</td>
<td>shaft for thrasher drive roller 15&quot;</td>
<td>1</td>
<td>$6.00</td>
<td>$6.00</td>
<td>McMaster</td>
</tr>
<tr>
<td>1.5in Dia. black pipe</td>
<td>pipe for drive roller</td>
<td>1</td>
<td>$4.00</td>
<td>$4.00</td>
<td>Godwin Plumbing</td>
</tr>
<tr>
<td>Crank Handle</td>
<td>driving the roller</td>
<td>1</td>
<td>$12.62</td>
<td>$12.62</td>
<td>McMaster</td>
</tr>
<tr>
<td><strong>Idler Roller</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel Conveyor Roller</td>
<td>1.9&quot;Dia, 12&quot; between frame</td>
<td>1</td>
<td>$7.27</td>
<td>$7.27</td>
<td>McMaster</td>
</tr>
<tr>
<td>Angle Iron</td>
<td>Bracket for tensioning system</td>
<td>2</td>
<td>$0.25</td>
<td>$0.50</td>
<td>Genzink</td>
</tr>
<tr>
<td><strong>Gearing Mechanism</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 tooth roller chain sprocket</td>
<td>small gear to drive fan</td>
<td>1</td>
<td>$5.83</td>
<td>$5.83</td>
<td>McMaster</td>
</tr>
<tr>
<td>48 tooth roller chain sprocket</td>
<td>large gear to drive fan</td>
<td>1</td>
<td>$12.48</td>
<td>$12.48</td>
<td>McMaster</td>
</tr>
<tr>
<td>#25 steel roller chain</td>
<td>chain for drive sprockets ($3.19/ft.)</td>
<td>4</td>
<td>$3.19</td>
<td>$12.76</td>
<td>McMaster</td>
</tr>
<tr>
<td><strong>Frame Assembly</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conduit</td>
<td>Frame Spacing</td>
<td>1</td>
<td>$2.98</td>
<td>$2.98</td>
<td>Lowe’s</td>
</tr>
<tr>
<td>Threaded Rod</td>
<td>Frame Spacing</td>
<td>2</td>
<td>$5.00</td>
<td>$10.00</td>
<td>Mol Belting</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubber Edge Trim</td>
<td>safety</td>
<td>4</td>
<td>$0.47</td>
<td>$1.88</td>
<td>McMaster</td>
</tr>
<tr>
<td>Misc. Steel</td>
<td>for crank arm, drive roller ends, idler ext.</td>
<td>1</td>
<td>$10.00</td>
<td>$10.00</td>
<td>Genzink</td>
</tr>
<tr>
<td>Misc. Hardware</td>
<td>for fastening</td>
<td>1</td>
<td>$5.00</td>
<td>$5.00</td>
<td>Lowe’s</td>
</tr>
<tr>
<td>Tools</td>
<td>for assembly and maintenance</td>
<td>1</td>
<td>$25.00</td>
<td>$25.00</td>
<td>Lowe’s</td>
</tr>
<tr>
<td><strong>Side Plates (24&quot; X 32&quot;)</strong></td>
<td></td>
<td>2</td>
<td>$12.33</td>
<td>$24.66</td>
<td>Home Depot</td>
</tr>
</tbody>
</table>

Total Cost: $295.74
10.3.2 **Manual Labor Costs**

Now that the design has been finalized and the prototype has been built, the plans were handed off to a team of craftsmen from Hillcrest CRC for continued production. In Michigan, the average Tool and Die Shop rate is $60/hour. Because of this cost, the design must be kept simple to minimize the time and therefore money it takes to reproduce the mills.

10.3.3 **Total Cost**

The total cost for reproduction of our mills will be a combination of raw materials cost and shipping costs. Hillcrest CRC volunteers will be responsible for the raw material. It is likely that these costs will be lower than our estimates due to bulk ordering and/or donations. Once the mills are complete, it will be CRWRC’s task to distribute them in the developing countries. It is our understanding that many will be shipped in CRWRC’s bi-annual crate to Africa. If they are not, shipping will become a significant cost as our machine weighs nearly 60lbs.

11. **Ethics**

While Christ says, “You will always have the poor among you,” in John 12:3; our Senior Design team does not feel that this is a command not to try to help the poor by providing them with money, food, or clothing. Instead was a statement for the moment as he was forewarning them of his death. With this in mind we feel that it is part of our duty as Christians and more specifically as Christian engineers to do what we can to help those in need. As we work through our designs we are making every effort to keep those people who have the obvious need in mind, but are also trying to design for the people at Hillcrest CRC and CRWRC who will be building and distributing the mills. Through the mindset that we have been blessed with much and therefore will have much required of us, we intend to do our best in the design and construction of this project, but also in representing Christ through our actions.

The focus of the design is to meet the needs of Kenyan farmers. It is necessary to aid the farmers, not replace them. A fully automated grain sorting mill is easier to control: one could use electronic sensors and an electrically powered fan, and fuel all by a photovoltaic panel. However, a mill like this would take away all of the harvesting work from a farmer instead of helping them to do their work. Also, there is an abundance of available workers in Eastern
Kenya, and using manual labor proves to be more cost-effective than using expensive new technology. The tendency of Americans is to prefer things that are fully automated, giving them more time to relax; however, the Kenyan’s have a different culture and a different way of life. Instead of feeling frustrated by the amount of work that they have to do, many Kenyan farmers are pleased by the work they put into their farm and are given a sense of ownership through it. This is the case with the Kenyan villages being focused on in this outreach ministry of Hillcrest CRC, although it is not a universally accepted Kenyan way of life. While people from this village feel that the amaranth grain is easy, although time consuming to work with, others from different villages get frustrated from working with this tiny grain.

In contrast to Americans, who delight in any device that makes life easier and allows them to do less, the Kenyans take an ownership in the work they do. There exists a certain advantage of the dirt-screener container, one that is particular to this project. According to Bob Beute, working gives the Kenyans a feeling of self-worth. The addition of this container would allow another person to have a part in the seed processing and promote this sentiment. The realization of the Kenyan attitude toward work has spurred reconsiderations on all aspects of the design. The entire machine is run by a hand crank. A motor could have easily been implemented to make the machine work with the “push of a button.” This was difficult to step out of the American mindset to perceive what the best design could be, but it was an important step.
Appendix A

Overall Design Options
Design progression
Additional Component Ideas
A.1 Overall Design Ideas

A.1.1 Clipper Fanning Mill Design

It is important to be familiar with the original design, so that when a new overall design is being considered, one can compare it to the original.

Currently there are a few antique fanning mills in operation in Kenya. These fanning mills have been retrofitted with steel gears and all bearings have been replaced with improved sealed bearings. It was also desired to have sealed bearings on the new mill to eliminate the need for maintenance.

Thresher

The original fanning mill does not include a thresher in its design. Currently, the technique for threshing the crop is to beat the heads of amaranth on a tarp. Whatever is beaten out is collected and brought to the fanning mill. Using this original idea, the final threshing concept was designed.

Separating Large Debris and Dirt Particles

The original fanning mill separates large debris and dirt particles by utilizing two sets of screen to filter the seed by size. The chaff and seed is dumped on the screen with a larger set of holes. This screen allows the seed and any particles smaller than the seed to pass through. The second screen holds back the seed and allows all the smaller particles to pass through. To cause the seed to pass through the screens more easily, the screens are vibrated using a hand crank and a cam/pitman arm setup. The chaff and dirt are directed out of the machine while the seed along with chaff of similar size are allowed to fall down a chute.

Chaff/Seed Separator
A fan at the bottom of the chute creates airflow through this duct to separate the chaff and seed by weight. The seed, due to its larger mass, continues to fall to the bottom of the machine while the chaff is blown out of the machine.

Advantages/Disadvantages

The advantages of this design are that it has been used in the past and worked, is easy to operate, and reasonably acceptable results can be achieved. However, with the amount of moving parts, a lot of wear occurs. Fan speed is critical to obtaining acceptable results. The overall device is large and heavy, increasing shipping costs and making it less portable between amaranth fields. Finally, because of the size, the price of a single fanning mill is unfavorably high.

A.1.2 Clipper Fanning Mill Design

The seed cleaner shown in Figure A.2 has several adjustments to help improve the quality of the sorting. The amount of dirty seed entering the chute is controlled by a gate at the bottom of a hopper. Another adjustment is the speed of the fan which in this case is controlled by the motor, but in the case of the actual design would be controlled by the operator as it is hand powered. One other adjustment is the amount of air entering into the fan. By limiting the amount of air entering into the fan, the volumetric flow rate of the exit air can be easily adjusted. Testing was performed with a similar system to further explore how effective the system operates. One additional variable that Agriculex seems to have zeroed in on is the angle of the chute. While the slope was variable for this test, the final design will likely have a fixed slope.
A.2 Design Progression

One of our first designs can be seen in Figure A.3, left. The hopper can be seen in green, the threshing belt in blue, and the winnower/chute in red. This design had a large frame and would not have been very portable.

The next design (Figure A.4, below left) incorporated the outside of the fan box as the stationary surface for the thresher to run against. This eliminated a lot of space, and allowed the components to be integrated in a small, compact frame.

Separation of Dirt Particles

To catch the large debris, our team considered placing small catch pans under the openings for the debris exit. However, for the application of the machine, these catch pans were not necessary, as the debris was biodegradable and the machine operated in a rural area. If the user would like to re-run the debris, these small catch pans might be an option.

A.3 Additional Component Ideas

A.3.1 Mechanical Governor

A mechanical governor was considered to help limit the speed, or possibly even actively adjust the ratio between the input and output speeds.

However, because this adds complexity, weight, and cost to the system, as well as well as higher potential repair costs, it is a technology whose effectiveness was outweighed by simplicity and cost. A short discussion will be presented that summarizes the considerations made.
In terms of mechanical governors, there are several types that seemed like feasible options. Because of the high bicycle use in Kenya it would seem that a bicycle chain, gears, and derailleur could be set up to adjust the gearing on the system. The gearing adjustments could be made manually or even automatically through an automatic derailleur such as the Di2 (http://www.popularmechanics.com/outdoors/bicycles/2002/3/bike_with_brains/index2.phtml). Details of the bike situation in Kenya were not known, namely whether or not these are single or multi-gear bikes. If they do use just single gear bikes, using multi-gear bike parts would not provide the desired ease of replacement that would be obtained if they were used to multi-gear bicycles.

An alternative approach to the bicycle derailleur is using a mechanical governor. This governor could be used in several different ways. One way of using it is to create a ceiling (maximum) for the speed of the fan. This could be done by creating extra drag on the flyballs of the mechanical governor, which would either run up against a solid plate or the inside edge of a cylinder when the angle (θ) becomes too large. Because of all the gearing that the system goes through before reaching this stage, the small amount of friction on the governor would equate to a large frictional force on the input. This could easily be used to slow the operator down; the sound of the flyballs rubbing up against the solid shell would also alert the operator that they are going too fast.

A second method of using governors would be to use the governor to adjust the gearing of the system. By setting up the governor properly it could be used to scale up the rotational speed by different ratios based on the angle θ at which the governors come to rest. One way that this could possibly be done would be through friction drives. This works well with the governor as the governor will shift the driving friction plate to one extreme or the other pressing it into one of the two friction gears that in turn get geared up or down to provide the desired air speed.

While this could be built into the kit as a solid mass, the kit could instead be included with some sort of hollow drum into which soil could be packed. This drum could then be attached to the fan, thresher, or the input shaft causing the system to stay more consistent.

Due to the addition of the thresher on the system there is a higher risk of system speed fluctuations, especially concerning the speed of the fan. Because of this adding some sort of flywheel to the system was seriously considered. However, the cost and simplicity of the design must be kept to a minimum, and this endeavor was abandoned.
A.3.2 Hopper

A constant seed-feeding device was also considered. This would allow us to design a system based on a constant, known flow rate of seed. If there is too much seed, or too little seed, the mill will not process the seed efficiently. A hopper could be attached to the mill, which would scoop out a given amount of un-threshed grain and send it through the cleaning device. This could be something as simple as a cylinder with a “scoop” cut into it that rotates under the large hopper and is filled up and then emptied with each rotation.

A.3.3 Seed Entry Controller

A potential problem that may be encountered during the testing of the mill would be that the seed and chaff will not fall evenly from the hopper. This may necessitate some sort of redesign of the hopper or a type of agitator to help the seed to enter the wind tunnel more evenly. Ideally, the vibration due to the movement of the rest of the system will be enough to cause the seed to fall through the hopper without much difficulty.

A.3.4 Sorting Containers

Two types of debris need to be dealt with: the large stems from the first screen, and the chaff from the winnower. For customer comfort, it is recommended that the debris be controlled as it exits the device. The current application is designed for a rural setting where the following described apparatus would not be necessary.

One solution to control the chaff is a cloth chute, which encloses the metal chute opening. The chaff falls out of the cloth chute into one area on the ground (or into a wheelbarrow, if the user so desires). The cloth chute does not permit the chaff to fly into the air and bother the user, and guides all debris into one central location. The shape of the chute can easily be manipulated. It can be compacted/put away when moving the machine, and the output of the chute (where the debris lands) can be changed easily by manipulating the cloth shape and/or direction. Also, being light and easily compactable, it is easy to ship.
Appendix B
Calculations

Critical Air Speed
Bike Gear Power Train
Side Panel FEA Analysis
B.1 Calculations

B.1.1 Critical Air Speed

**Seed Free-Fall Velocity**

**Seed Characteristics**

\[ \text{diam}_{\text{seed}} = 0.01 \text{m} \]
\[ \text{Vol}_{\text{seed}} = \frac{4}{3} \pi \left( \frac{\text{diam}_{\text{seed}}}{2} \right)^2 \]
\[ \text{m}_{\text{seed}} = 8 \times 10^{-7} \text{kg} \]
\[ \text{area}_{\text{seed}} = \pi \left( \frac{\text{diam}_{\text{seed}}}{2} \right)^2 \]

**Force of Gravity**

\[ \text{grav} = 9.81 \frac{\text{m}}{s^2} \]
\[ f_{\text{grav}} = m_{\text{seed}} \cdot \text{grav} \]
\[ f_{\text{grav}} = 7.848 \times 10^{-6} \text{N} \]

**Force of Air Drag**

\[ C_d = 0.5 \]
\[ \rho_{\text{air}} = 1.25 \frac{\text{kg}}{\text{m}^3} \]
\[ f_{\text{drag}} = f_{\text{grav}} \]

**Air Speed Calculations**

\[ v_{\text{el,air}} = \sqrt{\frac{f_{\text{drag}}}{\frac{1}{2} C_d \rho_{\text{air}} \text{area}_{\text{seed}}}} \]
\[ v_{\text{el,air}} = 5.655 \frac{\text{m}}{s} \]
Mechanical Governor

Constants of Governor, etc.

\[ \text{grav} = 9.81 \, \frac{m}{s^2} \quad \rho_{\text{steel}} = 8000 \, \frac{\text{kg}}{\text{m}^3} \]

\[ r_{\text{ball}} = .01 \text{m} \]

\[ m_{\text{ball}} = \left( \frac{4}{3} \pi r_{\text{ball}}^3 \right) \rho_{\text{steel}} \quad m_{\text{ball}} = 0.034 \text{kg} \]

\[ l_{\text{arm}} = 0.5 \text{m} \]

\[ r_{\text{rod}} = 0.025 \text{m} \]

\[ l_{\text{rod}} = .125 \text{m} \]

\[ m_{\text{rod}} = \left( \pi r_{\text{rod}}^2 l_{\text{rod}} \right) \rho_{\text{steel}} \quad m_{\text{rod}} = 0.02 \text{kg} \]

Variable Input

\[ \omega = 0 \text{Hz, } 2 \text{Hz, } 180 \text{Hz} \]

Velocity / Angle Relationship

\[ \theta(\omega) = \acos \left( \frac{\text{grav}}{\omega^2 l_{\text{arm}}} \right) \]

Minimum Physically Possible Angle \( \theta \) Based on Governor Size

\[ \theta_{\text{min}} = \tan \left( \frac{r_{\text{ball}} + r_{\text{rod}}}{l_{\text{arm}}} \right) \quad \theta_{\text{min}} = 0.245 \]

Critical Velocity from Ideal Point Mass Simulation

\[ \omega_{\text{crit}} = \sqrt{\frac{\text{grav}}{l_{\text{arm}}}} \]

\[ \omega_{\text{crit}} = 14.007 \text{ Hz} \]

Minimum Velocity for a Real Governor

\[ \omega_{\text{min}} = \sqrt{\frac{\text{grav}}{\cos(\theta_{\text{min}}) l_{\text{arm}}}} \]

\[ \omega_{\text{min}} = 14.221 \text{ Hz} \]

Equilibrium Positions of Mechanical Governor with Specific Inputs

\[ \theta_{\text{gov}}(\omega) = \begin{cases} \omega > \omega_{\text{min}} & \theta(\omega), \theta_{\text{min}} \end{cases} \]

\[ r(\omega) = \sin(\theta_{\text{gov}}(\omega) \cdot \text{deg}) l_{\text{arm}} \]
\begin{table}
\centering
\begin{tabular}{|c|c|c|c|}
\hline
$\omega$ (Hz) & $\varphi_{gov}(\omega)$ (deg) & $\psi(\omega)$ (m) \\
\hline
0 & 14.036 & 2.138 \times 10^{-4} \\
2 & 14.036 & 2.138 \times 10^{-4} \\
4 & 14.036 & 2.138 \times 10^{-4} \\
6 & 14.036 & 2.138 \times 10^{-4} \\
8 & 14.036 & 2.138 \times 10^{-4} \\
10 & 14.036 & 2.138 \times 10^{-4} \\
12 & 14.036 & 2.138 \times 10^{-4} \\
14 & 14.036 & 2.138 \times 10^{-4} \\
16 & 59.868 & 6.087 \times 10^{-4} \\
18 & 92.731 & 8.031 \times 10^{-4} \\
20 & 170.627 & 9.233 \times 10^{-4} \\
22 & 266.066 & 1.006 \times 10^{-3} \\
24 & 370.085 & 1.067 \times 10^{-3} \\
26 & 573.128 & 1.148 \times 10^{-3} \\
28 & 755.207 & 1.150 \times 10^{-3} \\
30 & 774.408 & 1.179 \times 10^{-3} \\
32 & 789.954 & 1.201 \times 10^{-3} \\
34 & 802.228 & 1.222 \times 10^{-3} \\
36 & 812.933 & 1.238 \times 10^{-3} \\
38 & 821.91 & 1.252 \times 10^{-3} \\
40 & 829.566 & 1.263 \times 10^{-3} \\
42 & 836.14 & 1.273 \times 10^{-3} \\
44 & 84.183 & 1.282 \times 10^{-3} \\
\hline
\end{tabular}
\end{table}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{chart.png}
\end{figure}
B.1.2 Finite Element Analysis

In order to verify the strength of our side panels, a Finite Element Analysis was performed using the Finite Element program Algor. Nodal loads were estimated for the weight of the two shafts, the roller chain tension, and the rotating belt tension. The bottom edge of the plate was modeled as fixed nodes. The results are presented below.

Results

Figure B.1: Stress Calculations for current side panel
Figure B.2: Deflection Calculations for current side panel

Figure B.3: Stress calculations for proposed 3-prong design
The results verify our assumption that we have ample strength in our side panels to sustain the given loads. The highest stress achieved is around 330psi, which is well below the tensile strength of wood, estimate at 5000psi. The deflection that is calculated is also negligible.
Appendix C

Testing and Verification of Components
All six main components were tested:

1. Threshing device (conveyer belt)
2. Debris separation (screen)
3. Seed/chaff separator (fan)
4. Frame
5. Sorting Containers (catch pan, chaff bag)
6. Power Train (gear system)

C.1 Thresher

Although the original request from CRWRC only asked for a mechanical winnowing device, the team decided to incorporate a threshing machine into the design. Currently, most Kenyan farmers beat the seed heads with a stick to separate the seed and chaff from the stem of the head, and winnow the seed by tossing it in the air (to blow away the chaff) and catching it in a basket. Upon completion of the preliminary testing of the threshing device it was decided that further testing would be beneficial. The thresher belt system was incorporated in the rough prototype design. Through this machine testing, it was determined that the thresher was indeed an effective and suitable addition to the seed processor.

If mass production is considered, it is recommended that various tests be done to prove the performance and durability of the thresher.

One test could involve replacing the hand crank with a motor and gearing it down to simulate the hand crank speed. A 100 hour test could be performed to detect weak spots of the device. Predicted areas are: 1) The edges of the belt wearing as it rubs against the washers on the drive shaft, 2) Wear on the half-moons, 3) Loosening of the chain, and 4) Loosening of the set screws.

Another test to be done would be to run amaranth—or a similar rough material, such as wheat—through the belt. This test could determine the amount of wear the belt experiences over a certain amount of time. The most wear would occur in the center, where most of the shearing and friction occurs.

Test 1
The earliest investigation for how to thresh the seed was done by hand. Taking the heads of seed in one’s hand, it was easy to see and “feel” what kind of force was needed for the shearing action. This observation led to the first test, which mimicked the shearing action with a conveyor belt.

The original design included two belts that threshed the seed. One belt ran significantly faster than the other belt to produce a shearing action, and the belts themselves were textured to promote better threshing. This threshing idea has been implemented in many current machines, and has produced very satisfactory results.

Test 2

However, through advice by Chuck Spoelhof, another design was tested and chosen, one that substantially simplified the process. This option used only one belt running against a fixed, rough surface (with matching dimensions) to thresh the crop heads. The curved perimeter of the fan box was used as the fixed surface, which magnified the force between the belt and the fan surface.

The first test performed to analyze the effectiveness of the belt thresher was conducted in December 2004. Extol Inc. donated a belt for this procedure. The belt was used inside out, as the inside of the belt had a rougher surface than the outside of the belt. The testing suggested that most of the shearing took place at the top of the raised stationary surface. After passing the top of the raised portion, the seed and chaff were sheared to a greater extent before exiting the thresher, allowing for more separation.

The first time this device was tested, too much of a gap existed between the belt and the stationary surface. The device did not pull the head through the thresher. It was helped through and when it exited the thresher the seed head was only compressed, not sheared as was hoped.

The belt was adjusted so that it was tighter and closer to the stationary surface. This test yielded much better results. It was more difficult to get the seed head into the thresher, but once
it entered, it moved along without any assistance. It was desired that the head moved much faster through the thresher. After the head passed through the thresher, the product consisted of the seed and chaff and an almost completely bare stem. It was estimated that less than five percent of the total seed on the head was left on the head after the threshing process.

To improve on the thresher design, the height of the raised surface of the stationary belt was raised, and the gap at the opening of the thresher was increased to allow the heads to enter the thresher effortlessly. A rougher belt would also help do a better job shearing the heads while also decreasing the need for as much tension in the belt to provide extra contact force.

Another problem existed within this testing device. Although the “inside-out” effect gave a better shearing motion, the smooth side on the inside slipped on the drive roller. Thus, it was necessary to pull the belt along as the drive roller was turned. Also, it was determined that the belt’s roughness did not provide enough friction for the project’s expectations. Extol’s belt seems to slide over the seed head without effectively grabbing it. A rougher, rubber-based belt seemed to be a better option.

**Test 3**

Bob Beute, one of the contacts, set up a meeting with an employee at Mol Belting, a company that distributes food quality belts. Team 11 attended a meeting with a Mol Belting employee, Dan Prewitt, in which textured belting options were discussed. Dan Prewitt generously gave Team 11 several samples to take back to the Engineering Building to conduct testing. The most favorable ones were found to be made of Polyurethane, a flexible, durable, and inexpensive material.

When the rough prototype was built, one of Polyurethane belts was chosen to be the stationary surface. The raised belt profile was in the form of half-circles, which were oriented down, to promote friction and also movement of the seed down the slope. This was mounted on the fan surface. With the addition of the other components, including the conveyer belt and the screen, the effectiveness of this belt was tested. The orientation of the conveyer belt had to be adjusted numerous times, but overall this rougher belt seemed satisfactory for this machine.

The amount of force was critical to monitor and check for two main reasons. First, a large force (implying a tiny entry gap) would require extensive design of a hopper. Secondly, too much force would cause damage to the seeds, such as cracking or crushing.
C.2 Debris Separation

The bulk of the seed cleaning for the Clipper fanning mill was achieved using a set of screens. However, these screens were an extremely expensive part of the final design. It was a project goal to minimize the use of screens in the design to minimize costs. The final design did require some screening. The prototype uses only one screen, to separate the large debris from the seed and chaff. It was approximately half the size of the one currently used on the Clipper fanning mill. Various screen sizes were tested by hand for effectiveness. A screen with holes 3/8” diameter was finally chosen. Also, the orientation of the screen was tested for optimal debris separation.

In the original prototype, the screen at the bottom of the thresher was crowned, having a slight lift in the middle of the screen so that the debris would more easily fall to the side outlets. However, the added complexity of this did not balance out the effectiveness of the crown, and was taken out of the final design.

With the debris screen holes relatively large, some heavier particles were able to make it into the air chute. Thus, a smaller screen in catch pan was added to further clean the seed from the foreign particles. This addition of a screen in the catch pan was a tradeoff between additional cost and improved first run recovery rates.

C.3 Seed/Chaff Separator (Winnowing)

The goal of winnowing was to separate the chaff from the seed. Under current methods, the winnowing step is the most labor intensive. A variety of methods were discussed and explored. The most promising methods were a trough design and a fan/air chute design. Ultimately, as the following pages discuss, the air chute design was chosen as the optimal design. Tests were completed that 1) Determined an acceptable air chute design (angle, size, length) 2) Explored air intake regulation techniques, and 3) Quantified an acceptable operational air speed interval.

Certain conclusions were made concerning length, width, and incline angle. The length, or height, of the chute was chosen to be equal to the height of the fan, not only for effectiveness but also for aesthetic appeal. It was found that the chaff, once airborne, has a high consistency to follow the air path, even for a substantially long chute. As the cross-sectional area increased, the effectiveness of the separation also seemed to increase. The incline angle was the hardest to
determine. It was found that bends in the air chute severely hinder the success of separation. A smooth, radial chute will work better than a chute with turns.

The decision was made to abandon air regulations, due to the added complexity for both builders and users alike. Currently Kenyans are taught to count out a beat while they turn the crank to ensure the fan is turned at a constant speed. This has proven to be effective, and the simplest solution to this difficulty.

Finally, the speed interval of the hand crank was found to be 30rpm-120rpm to obtain acceptable air speed through the chute. This was done using an RPM gauge while continuously feeding harvested amaranth heads.

Research

Before the team had even left the fields in Hudsonville, testing had already begun for different cleaning methods. The first method consisted of simply rubbing one’s hands together with some of the small heads of grain in between them. When this was done, the seed and chaff would quite easily pop off of the stems. Once this was done a soft blow of air would blow the chaff out of the person’s hand leaving only the seed.

Some ideas for removing chaff included such things as electrostatics to attract the chaff while not having a strong enough attraction to lift the seed. Another idea was to shoot the seed and chaff mixture against a solid surface with the assumption that the seeds would rebound with a much higher velocity than the chaff thus helping to sort the two. These ideas were both seen to be less than desirable for various reasons. The electrostatics seemed dangerous considering that the winnowing involves dry chaff in a very dry environment thus having a high risk for fire. The impact method would be hard to do as it would require a very strong and consistent air stream which would be hard to duplicate with a hand powered system.

Test 1

With the simplistic method of blowing at a pile of seed in one’s hand seeming more feasible than the more complex methods, the strategy was to go to the drawing board with simplicity in mind. In doing this, it was found that the seed and chaff were effectively separated by placing the chaff in a small trough and then blowing at the back wall of the trough. This process allowed the chaff to be blown out of the trough while not moving any significant amount of seed.
To help make this process more continuous, the consideration was made to slope the trough so that over time the seed would work its way from the high side to the low side and then into a container of clean seed. As the seed rolls down the slope, the chaff works its way to the top where it will be picked up by the wind and blown away.

While these trough methods seem to clean the seed effectively, they don’t have the preferable high volume capabilities. For high volumes, it seems optimal to have a system somewhat like the winnower in the original Clipper fanning mill.

Test 2

Upon deciding on the air chute separation method, a simple test was performed. A small air chute was built and attached to a blower outlet (See Figure C.3, below). The objectives of this lab were to 1) Determine an acceptable air chute design (angle, size, length) and 2) Explore air intake regulation techniques. The electrical fan was much too powerful for the experimental setup. Although the air intake was minimized, acceptable—but not precise—results were obtained.
First, certain conclusions were made concerning length, width, and incline angle. The length, or height, of the chute was chosen to be equal to the height of the fan, not only for effectiveness but also for aesthetic appeal. It was found that the chaff, once airborne, has a high consistency to follow the air path, even for a substantially long chute. As the cross-sectional area increased, the effectiveness of the separation also seemed to increase. The incline angle was the hardest to determine. It was found that bends in the air chute severely hinder the success of separation. A smooth, radial chute will work better than a chute with turns.

Test 3

Air speed, or fan speed, was critical to obtaining acceptable results. The fan speed was dependent on the crank speed. Calculations with the first prototype’s gear ratios show the average air velocity generated by the fan was around 4.22 m/s, a safe cushion below 5.01 m/s, the terminal velocity of air required to pick up the seed. For the final prototype, testing results gave a generous interval for acceptable operational speed: 30 rpm-120 rpm.

Test 4

While using a wind tunnel is effective for cleaning the amaranth seed, there are a number of variables that can affect the quality of the cleaned seed. The first, and most critical, is the speed of the air through the wind tunnel. There is a finite range of air speeds through which the seed cleaner is effective: a hand crank speed of 30rpm to 120 rpm. If the air speeds fall below this acceptable range, the seed and chaff both fall through the air tunnel which results in dirty seed. This seed would sell for a low price or would have to be rerun through the machine, costing the operator time and money. If the air speeds are too high, both the seed and the chaff blow out of the wind tunnel. This results in wasted seed that may not be recovered.

It would be simple if the mill could be wired up to a constant speed motor, but the requirement that the machine be hand powered implies a type of governor system as the next best
option for regulating air flow. Research has been done concerning this difficulty with minimal success. Most modern governor systems are electrical and require a processor type unit. This would not fit the simplicity requirement of the project. The other option would be to devise some sort of mechanical governor to control the air flow. Research has shown that the simplest mechanical governor is a flyball governor. These governors were first used on steam engines to automatically adjust for load changes on the engine. To use this type of device for the project, a linkage would need to be designed that will adjust the air speed according to the input.

When using electrically powered fans to do testing, it was found that limiting the air intake to the fan worked well to control the air speed. If the flyball governor were to work, it seems the best way to control the air flow would be to have the governor control some sort of intake control gate. If the fan were turning too fast, the governor would close the intake control gate, which would limit the supply of air to be pushed through the wind tunnel. The opposite would take place when the fan turns too slow.

Theoretically, this idea would be satisfactory for controlling the air speed. However, it may be very difficult to calibrate the governor to work throughout a large range of fan speeds. Also, the device and controller linkage would add a considerable amount of complexity and weight to the design.

A potential alternative to a mechanical governor would be to install a differential pressure gauge to the outlet of the fan. This gauge must be easily readable by the operator of the mill. The pressure difference caused by the fan would give a reading. Testing would determine the acceptable range through which the fan may be operated. The operator would then need to watch the pressure gauge while turning the fan to verify that the machine is operating within an acceptable range. Unfortunately this is not an automatic way of controlling the fan speed since it requires that the operator pay close attention to the pressure gauge reading. Also, not much air movement is needed to achieve adequate filtering. It is still questionable whether a differential pressure gauge can be obtained that can detect small enough changes in pressure and still be able to easily show the change to the operator of the machine.

Currently Kenyans are taught to count out a beat while they turn the crank to ensure the fan is turned at a constant speed. This has proven to be effective, and the simplest solution to this difficulty. In fact, as mentioned earlier, the performance of the rough prototype under different crank speeds was tested. This test showed that not only was it easy to “get a feeling” for the
optimal speed, but fluctuations in this speed did not affect the quality of the seed output as much as expected. Thus, the simplicity this solution offered for both builders and users alike influenced the final design decision to have manual air speed regulation.

C.4 Frame

The main design decisions of the frame were in terms of cost and simplicity, or a balance between the two. The frame side panels were designed to be easy to machine and ship. The material of the frame was a large issue, as discussed earlier. Testing played a key role in the final material decision. Plastic side panels were cut and used, but were not stiff enough for our purposes. The birch side panels in the final prototype were extremely sturdy, and offered a robust design that was also cost effective.

C.5 Integration Testing

As outlined earlier, a rough prototype was built to test various portions of the project, namely the threshing and winnowing. This was built off of the original idea for the configuration, shown below. Through testing, the optimum belt size and type was determined. It was decided that the belt width would be nearly equal to that of the blower cage, to optimize the amount of surface contact for the thresher. Furthermore, the original setup was verified as the best configuration for the system. Although it was small and compact, it was surprisingly efficient for the size of the machine, and intelligently combined the threshing and winnowing into one device.
To obtain accurate ratios for the power train, the first prototype incorporated two handles: one to turn the blower and one to turn the thresher. When two members ran the machine together, a third could determine the speed ratio between the two, and a first-cut ratio was determined.

C.6 Performance Testing

To quantify the performance of the machine, tests were run to determine the amount of total seed recovered after one, two, and three runs. To carry out this test, a seed head was weighed before it was run through the machine. The floor around the machine was swept and the machine was cleaned as well as possible. The weighed seed head was then run through the machine and the amount of seed recovered was weighed. The chaff and debris from the seed head was swept up and then rerun through the machine a second time. The seed from this second run was weighed and the debris and chaff was swept up again and run a third time. After running the seed for a third time, it was assumed that all recoverable seed had been collected. From these measurements we were able to determine the percent of total seed recovered per run. This test was carried out numerous times with consistent results. Testing showed that our mill was able to recover approximately 80% of the total seed after the first run. Two runs allow the farmer to recover closer to 90% of the total seed.

These tests were not exact due to various reasons. First, some of the seed from the seed heads were lodged in the machine and never were recovered and measured as part of the total seed weight. This was determined to be insignificant and was ignored. The second reason was due to the fact that the seed we tested with was very dry. The seed the Kenyan farmers will process will be fresh and have higher moisture content therefore changing the weight ratios. The following table shows the test results from the aforementioned tests.
<table>
<thead>
<tr>
<th>Initial Wt. Heads</th>
<th>Wt. Seeds 1st Run</th>
<th>Wt. Seed 2nd Run</th>
<th>Wt. Seed 3rd Run</th>
<th>% on first Run</th>
<th>% of Seed from Head</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 grams</td>
<td>12.89 grams</td>
<td>3.7 grams</td>
<td>grams</td>
<td>78%</td>
<td>37%</td>
</tr>
<tr>
<td>43.7 grams</td>
<td>11.3 grams</td>
<td>3.4 grams</td>
<td>grams</td>
<td>77%</td>
<td>34%</td>
</tr>
<tr>
<td>59.2 grams</td>
<td>9.5 grams</td>
<td>2.57 grams</td>
<td>grams</td>
<td>79%</td>
<td>20%</td>
</tr>
<tr>
<td>41 grams</td>
<td>7.2 grams</td>
<td>2.6 grams</td>
<td>grams</td>
<td>73%</td>
<td>24%</td>
</tr>
<tr>
<td>47.95 grams</td>
<td>9.1 grams</td>
<td>2.93 grams</td>
<td>grams</td>
<td>76%</td>
<td>25%</td>
</tr>
<tr>
<td>46.32 grams</td>
<td>16.04 grams</td>
<td>2.6 grams</td>
<td>1.11 grams</td>
<td>81%</td>
<td>43%</td>
</tr>
<tr>
<td>40.77 grams</td>
<td>13 grams</td>
<td>3 grams</td>
<td>1.22 grams</td>
<td>75%</td>
<td>42%</td>
</tr>
</tbody>
</table>

**Figure C6: Seed Recovery Data**
Appendix D

Amaranth Data
Amaranth Research

1.1. Our Testing

1.2. Overview of Amaranth
   1.2.1. Introduction
   1.2.2. Plant Characteristics
   1.2.3. Uses of Amaranth
   1.2.4. Amaranth Economics
   1.2.5. Planting
   1.2.6. Harvesting
   1.2.7. Project Relevance
1.1 Growth Attempts

The team attempted to grow amaranth in the Calvin College greenhouse on Lake Drive. The experimentation consisted of different watering methods and soil types. It was found that the plants did not grow as well as hoped. Additional seed was planted, and the seed was not watered until the leaves began to wilt. It was possible that the seeds were over-watered. It was also possible that there was not enough sunlight. Some of the planted seed was brought to the Engineering Building with hopes that the seed could be more closely monitored and exposed to more light. Amaranth was planted at consistent intervals throughout second semester to show the stages of growth at the Senior Design Presentation, but to no success. A larger amount of seed was planted at the beginning of second semester to have fresh seed for testing the prototype. This would have also allowed for experimentation with different drying times after harvest.

Different recipes for amaranth were tested. A few good recipes were found, and products of these will be shared with visitors to the presentation. A missionary with CRWRC in Kenya has been contacted, and he has sent a few recipes that he uses while in Kenya. Popping the amaranth like popcorn was attempted, but it burned instead of popping.

Other ideas for the promotion of amaranth included the following:
- Produce a 1 page flyer highlighting the health benefits of amaranth to be at the presentation table
- Supply baked goods, recipe books, and resources for those who would like to purchase amaranth products

1.1 Introduction

To be able to effectively design a device to clean amaranth seed, it is important to have a good understanding of the amaranth seed itself. The following discussion will highlight characteristics and qualities of the seed, uses for amaranth, as well as planting and harvesting instructions for the grower.

Amaranth is a plant that looks much like soybeans early in its development. It is a broadleaf plant that can eventually grow to be anywhere from two to eight feet tall. Not much Amaranth is grown in the United States because of low demand for the seed and rather high yields to most farmers who grow amaranth. Amaranth is often most recognized for the bright colored head of seed that forms shortly before harvest. Each head of seed is full of thousands of tiny seeds that
can be saved for replanting or can be ground and used in food products. In the United States, the seed is the only part of the plant which is used, however, in an increasing number of third world countries, the leaves of the plant are also used for human and animal consumption.

Amaranth was an important food source to early American cultures, especially the Aztec Indians. Amaranth is rather tasteless but yet it has a high nutritional value. The seeds of the amaranth plant are 14 to 16 percent protein which is relatively high for most naturally grown food sources. Corn, for example, has roughly 10 percent protein at maturity. Additionally, the seeds have an exceptionally well balanced amount of amino acids which is very uncommon in most grains. Amaranth can now be easily found in the health food section of most grocery stores. Amaranth has the potential to be used in more food items but its comparatively high price discourages most food preparers from including it in their products.

1.2 Plant Characteristics

While amaranth may be a healthy alternative to most grains, many of its 50 species are considered to be weeds in the United States. There are three main species of amaranth that are grown for grain purposes. The most common species grown in the United States is Amaranthus hypochondriacus. A similar type, A. cruentus has also been grown, but in smaller quantities. The last main species is A. caudatus. These types of amaranth are unique in the stem color, leaf size, and flower type but each have a deep red color that they all hold in common. Other varieties might have a greener colored head while some are more of a golden brown.

Much of the United States’ supply of amaranth is grown in Missouri. Farmers in Missouri tend to grow a variety of amaranth called Plainsman. This variety of amaranth can grow between two and eight feet tall. The amaranth plant consists of a sturdy stem with a large seed filled head at the top. This head is usually a deep red color and can range from four to twelve inches in length. The seed head is usually rather slender in comparison to the rest of the plant, only two to six inches wide. The seeds found in the head are extremely small. These seeds are spherical in shape and are approximately 1/25” in diameter. A fully developed head can yield thousands of amaranth seeds.

A characteristic that is unique to amaranth is its high tolerance to drought. This is one of the reasons why amaranth is an attractive crop to farmers in Kenya. Kenya has a very dry climate and has only two very short rainy seasons per year. The drought resistance of amaranth allows
high yields to be achieved without significant moisture. The ability of amaranth to tolerate
drought is something that is not completely understood. One characteristic of amaranth that
plays a role in its drought resistance is its ability to wilt for a short time and then resume growing
once moisture is available.

1.3 Uses of Amaranth

Amaranth is used in a variety of ways depending mostly on the region in which it is used.
For example, in the United States, amaranth is grown only for its seed. However, in places such
as Africa and the Caribbean, the leaves are the main food product. There are reports from China
indicating that over one hundred thousand acres of amaranth is being grown as forage for hogs.

Amaranth is a desirable health food product for its high amounts of protein and also for its
high amount of fiber. There are a variety of ways amaranth can be used. The most common way
is to grind the amaranth seeds into flour and use it for baking purposes. However, amaranth can
also be popped, flaked, and extruded. Amaranth is sometimes seen as a “pseudo cereal” because
of its similarities to the grains used in many cereal products. Amaranth has been tried as a
healthier alternative to the regular flour used in many baked goods. Results of these tests show
that amaranth flour can be blended with other flours at 50 and even up to 75 percent levels
without any noticeable difference in taste.

Other less developed yet potentially useful uses include the relatively high amount of
squalene found in the oil of the seeds. Squalene is a substance used in skin treatment products
and can sell for thousands of dollars per pound. Another use is that the reddish pigment in the
flour and vegetation of the amaranth plant could potentially compete with sugar beets as a source
for non-toxic red dye. Amaranth is also a welcomed alternative to people who are allergic to the
gluten found in conventional baking flour.

1.4 Amaranth Economics

There are many advantages to growing and using amaranth for consumption. One of these
advantages is the ability to make a profit. Currently farmers are receiving $0.40 per pound for
their amaranth seed. While this price is sufficient enough to make a good profit, it is difficult to
sell large quantities of this seed to a small yet growing health food market. Amaranth yields vary
between 1000 and 2000 pounds per acre, compared to 130 pounds per acre for wheat. This shows that it does not take much land to produce a large amount of seed.

The small amaranth market consists of three main buyers: Arrowhead Mills from Texas, Health Valley in California, and Illinois based Nu-World Amaranth. Most of the amaranth grown in the United States comes from the Midwest states therefore making transportation costs for the seed very high. To avoid these costs, some farmers sell their seed to smaller companies.

1.5 Planting

Amaranth is a robust plant that can be grown in a variety of soil types and climates. However, there are certain conditions in which amaranth is able to thrive and produce its highest yields.

Amaranth grows best in fertile, well drained soils. While many plants thrive only with large amounts of nitrogen in the soil, the amaranth seed does not require an excess of nitrogen in the soil. It is recommended that if nitrogen must be applied, it should only be applied at a rate of 40 to 80 pounds per acre. There is also no indication that amaranth significantly depletes the soil of minerals and nutrients. Regarding the pH of the soil, no extensive tests have been conducted but it has been reported that amaranth is able to grow well in soils with a pH as acidic as 5.6.

Planting times and harvest are very similar to that of sorghum. In the United States, amaranth is often used as a double crop after wheat or canola. When amaranth is in the early stages of its development, the seedlings are rather fragile and can be blocked from emergence by a crust of soil usually caused by rain. Planting in soils that are low in clay along with tending to the seedbed can help avoid any crusting problems. If problems do occur, there are often so many seedlings that a large number can be lost without affecting yields. It is recommended that two pounds of amaranth seed should be planted for every acre, however, studies have shown that a wide range of planting rates usually show very similar yields. For example, studies show that yields were very similar for planting rates ranging between one fourth and four pounds of seed per acre.

Planting times vary greatly depending on the climate of the region in which the seed is being planted. Using Missouri as an example, the best time to plant is in early June. Nevertheless, this date is very flexible. Amaranth can be planted anywhere from mid May to mid June without much difference in yield. Amaranth should be planted a half inch deep in rows 30 inches wide.
This makes it simple to tend to the seedbed while still providing adequate shade to discourage weed growth. If amaranth is planted in rows narrower than 30 inches, studies have shown that the plants compete with each other excessively and therefore are much shorter and produce lower yields.

Weed control is an issue for amaranth early on in its development. Amaranth grows slowly at first and can easily be overtaken by other weeds. Once the plants are about eight inches tall, the amaranth grows much more rapidly and weeds are no longer a problem due to the shading of the ground. Therefore, the recommended approach is to till between the rows until the plant growth takes over. As far as herbicides are concerned, there are no recommended sprays for amaranth; however as the market for amaranth increases, it is likely that herbicides will be developed.

The large leaves of the amaranth plants are very inviting for many insects, the most common being blister beetles and alfalfa webworm. Fortunately amaranth can tolerate a relatively large amount of leaf feeding before realizing a significant loss in seed yield. There are no insecticides labeled for use on amaranth, but organic insecticides have proven to be effective. The most destructive insect to amaranth is the tarnished plant bug. This brown, lady bug sized insect infests the flowers and seeds of the amaranth head. Sometimes it is difficult to diagnose when this insect is present but the affect this insect has had will be seen in seed yield losses.

Amaranth has high resistance to diseases. There are no known bacterial or viral diseases known to affect amaranth. The only diseases that have affected amaranth are fungal diseases. Unfortunately there are no fungicides labeled for use with amaranth. Most of the fungal diseases are caused by excessively wet soil.

1.6 Harvesting

It is very difficult to prescribe an exact time when it is best to harvest grain amaranth. There are three main varieties of amaranth. There are 45, 60 and 90 day crops. The number of days gives an approximate amount of time that the seed takes to grow to full maturation under ideal conditions. However, much of the harvesting timing is dependent on the weather during the growth period and the overall climate of the region. For example, in the northern states, growers usually wait a week after the first hard frost to harvest the amaranth seed. This causes the plant to be drier and more easily harvested. In the southern states, it is slightly more difficult to
prescribe a harvesting time. It is important to allow the seed to dry in the field without the seed becoming too mature and shattering during harvest.

Cleaning the seed either during or shortly after harvest is essential to achieving the highest possible price for the seed. Most of the commercially grown and processed seed is cleaned using sophisticated equipment. When storing the amaranth, the seed must be kept at 10 to 12 percent moisture content. Driers can be used to achieve the desired moisture content.

1.7 Project Relevance

The most important aspect of amaranth pertaining to the design of this mill is found in the characteristics of the seed. One of the leading issues in the cleaning process for amaranth is the speed of the air stream used for sorting the seed and chaff. Due to the small size, and consequently low weight of amaranth seed, there is a tight tolerance in terms of air speed required to effectively sort the seed from the chaff. By calculating the terminal velocity of amaranth seeds, the size and power requirements of the system can be better approximated. Because of the given amount of variability in the size of the seeds, the system will be sized so that it will be able to collect the large majority of the seed, while still effectively separating most of the chaff from the seed.
Appendix E

Design Specifications
<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>DESCRIPTION</th>
<th>MANUFACTURER</th>
<th>PART NO./DWG NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
<td>1</td>
<td>Fan Housing</td>
<td>In House</td>
<td>A03</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>Bottom Hopper</td>
<td>In House</td>
<td>A06</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>Lower Chute</td>
<td>In House</td>
<td>A05</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>Filter Screen</td>
<td>In House</td>
<td>A02</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>Upper Chute</td>
<td>In House</td>
<td>A04</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>Upper Hopper</td>
<td>In House</td>
<td>A07</td>
</tr>
<tr>
<td>42</td>
<td>1</td>
<td>Stationary Belt</td>
<td>Mol Belting</td>
<td>1W120-COS-CP</td>
</tr>
<tr>
<td>19</td>
<td>1</td>
<td>Blower Fan</td>
<td>Grainger</td>
<td>4C712</td>
</tr>
<tr>
<td>21</td>
<td>1</td>
<td>0.5 DIA. Steel Shaft</td>
<td>In House</td>
<td>A11</td>
</tr>
<tr>
<td>29</td>
<td>1</td>
<td>Shaft Collar</td>
<td>McMaster-Carr</td>
<td>6435 K14</td>
</tr>
<tr>
<td>30</td>
<td>3</td>
<td>Edge Guard</td>
<td>McMaster-Carr</td>
<td>8507 K721</td>
</tr>
<tr>
<td>37</td>
<td>6</td>
<td>1/4 inch Washer</td>
<td>Lowe's</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>14</td>
<td>1/4-20 SHCS</td>
<td>Lowe's</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>14</td>
<td>1/4-20 Nut</td>
<td>Lowe's</td>
<td></td>
</tr>
<tr>
<td>ITEM</td>
<td>QTY</td>
<td>DESCRIPTION</td>
<td>MANUFACTURER</td>
<td>PART NO./DWG NO.</td>
</tr>
<tr>
<td>------</td>
<td>-----</td>
<td>-------------------------</td>
<td>--------------</td>
<td>------------------</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Revolving Handle</td>
<td>McMaster-Carr</td>
<td>64425 K75</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>Spacer Tube</td>
<td>In-House</td>
<td>A12</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>5/16 Threaded Rod</td>
<td>In-House</td>
<td>A13</td>
</tr>
<tr>
<td>14</td>
<td>34</td>
<td>5/16 Washer</td>
<td>Lowe's</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>28</td>
<td>5/16 Nut</td>
<td>Lowe's</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>Angle Bracket</td>
<td>In-House</td>
<td>A09</td>
</tr>
<tr>
<td>17</td>
<td>2</td>
<td>5/16-18 Bolt</td>
<td>Lowe's</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>4</td>
<td>Bronze Flange Bearing</td>
<td>McMaster-Carr</td>
<td>6338 K423</td>
</tr>
<tr>
<td>27</td>
<td>2</td>
<td>5/16-18 Bolt, 4&quot; Length</td>
<td>Lowe's</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>5</td>
<td>1/2 Washer</td>
<td>Lowe's</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>1</td>
<td>Crank Arm</td>
<td>In-House</td>
<td>A01</td>
</tr>
</tbody>
</table>
Parts List

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>DESCRIPTION</th>
<th>MANUFACTURER</th>
<th>PART NO./DWG NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
<td>Catch Screen Assembly</td>
<td>In House</td>
<td>A26</td>
</tr>
<tr>
<td>35</td>
<td>1</td>
<td>Catch Pan</td>
<td>In House</td>
<td>A18</td>
</tr>
<tr>
<td>37</td>
<td>14</td>
<td>10-32 SHCS</td>
<td>Lowe's</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>14</td>
<td>10-32 Hex Flange Nut</td>
<td>Lowe's</td>
<td></td>
</tr>
</tbody>
</table>
### Crank Arm

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>Quantity</th>
<th>Finish</th>
<th>Size</th>
<th>DRWG NO</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Steel</td>
<td>1</td>
<td></td>
<td></td>
<td>A01</td>
<td></td>
</tr>
</tbody>
</table>

**Dimensions:**

- **Drill and Tap for 1/4-20 set screws (2 places)**
- **Drill and Tap 1/2-13**

**Clearance for 0.5 in. Shaft**

<table>
<thead>
<tr>
<th>Dia.</th>
<th>.000</th>
<th>.113</th>
<th>.300</th>
<th>.488</th>
<th>.600</th>
<th>1.738</th>
<th>2.113</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>.000</td>
<td>.113</td>
<td>.300</td>
<td>.488</td>
<td>.600</td>
<td>1.738</td>
<td>2.113</td>
</tr>
<tr>
<td>0.375</td>
<td>.000</td>
<td>.113</td>
<td>.300</td>
<td>.488</td>
<td>.600</td>
<td>1.738</td>
<td>2.113</td>
</tr>
<tr>
<td>0.750</td>
<td>.000</td>
<td>.113</td>
<td>.300</td>
<td>.488</td>
<td>.600</td>
<td>1.738</td>
<td>2.113</td>
</tr>
<tr>
<td>1.125</td>
<td>.000</td>
<td>.113</td>
<td>.300</td>
<td>.488</td>
<td>.600</td>
<td>1.738</td>
<td>2.113</td>
</tr>
<tr>
<td>1.500</td>
<td>.000</td>
<td>.113</td>
<td>.300</td>
<td>.488</td>
<td>.600</td>
<td>1.738</td>
<td>2.113</td>
</tr>
<tr>
<td>2</td>
<td>.000</td>
<td>.113</td>
<td>.300</td>
<td>.488</td>
<td>.600</td>
<td>1.738</td>
<td>2.113</td>
</tr>
<tr>
<td>2.500</td>
<td>.000</td>
<td>.113</td>
<td>.300</td>
<td>.488</td>
<td>.600</td>
<td>1.738</td>
<td>2.113</td>
</tr>
<tr>
<td>3</td>
<td>.000</td>
<td>.113</td>
<td>.300</td>
<td>.488</td>
<td>.600</td>
<td>1.738</td>
<td>2.113</td>
</tr>
</tbody>
</table>

**Drill and Tap for 1/4-20 set screws (2 places)**

**Drill and Tap 1/2-13**
Screen

MATERIAL: 20 Gauge Perforated Sheet Metal

QUANTITY: 1

FINISH: C

SIZE: A02

DRAW NO: A02

REV: A

DATE: 5/2/06

NOTE: The diagram shows a design for a screen with specified dimensions and tolerances. The drawing includes detailed measurements, such as distances and angles, which are critical for fabrication. The material is specified as 20 Gauge Perforated Sheet Metal, indicating the thickness and surface treatment of the material. The drawing is labeled as Sheet 1 of 1, implying it is part of a set of drawings for a project.
Clearance for 1/4-20 Cap Screw (3 Places)

13/64\(\beta\) (4 Places)
Upper Chute

MATERIAL: 24 Gauge Sheet Metal

4/11/2005

QUANTITY: 1

FINISH: C

DRAWING NO: A04

Clearance for 1/4-20 Cap Screw (3 Places)
Drive Roller End Cap

MATERIAL: Cold Rolled Steel

QUANTITY: 1

FINISH: 1

SIZE: 427/2005

DRAW NO: A08

SCALE: 1

SHEET 1 OF 1
Drill Clearance for 5/16 Threaded Bolt (2 Places)
Drive Shaft

MATERIAL: Cold Rolled Steel

4/20/2005

QUANTITY: 1

FINISH:

SIZE: C

DRAW NO: A10

REV: 1

Sheet 1 of 1
Fan Shaft

MATERIAL
Cold Rolled Steel

QUANTITY
1

FINISH
1

SIZE
C

DRAW NO
A11

REV
1

SHEET
1

OF
1

0.000
0.050
0.050
1.000
7.875
8.625
14.875
15.875
**Title:** Spacer Tube

**Material:** 0.75 in. Steel Conduit

**Size:** 11.90

**Finish:** B

**Quantity:** 8

**Drawing Date:** 4/19/2005
Threaded Rod

5/16 Threaded Rod

4/20/2005

8

A13

0.313

14.250

 ø0.313

Threaded Rod

MATERIAL

5/16 Threaded Rod

4/20/2005

QUANTITY

8

FINISH

Threaded Rod

SIZE

C

DRAW NO

A13

REV

1
Drill and Tap 5/16 - 18

Cold Rolled Steel

Drill and Tap 5/16 - 18

0.500

0.000

1.200
Close Pan

522/505

Catch Pan

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>FINISH</th>
<th>QUANTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 Gauge Sheet Metal</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Clearance for 10-32 Screw (4 Places)
Metal Chain Guard

MATERIAL
24 Gauge Sheet Metal

QUANTITY
1

FINISH
C

DRAW NO
A19

TITLE
Metal Chain Guard

SIZE
C

DRAWN BY

REVISION

SCALE
1

SHEET
1 OF 1
Drive Roller

MATERIAL: 2.005 Steel Pipe

QUANTITY: 1

FINISH:

SIZE: C

DRAW NO: A21

REV:

DATE: 5/5/2005
Screen Border
24 Gauge Sheet Metal

Screen Handles
24 Gauge Sheet Metal
Appendix F

Assembly Manual
International Assembly Manual
Step #1

x 4
Step #3

x 8
Step #10
Step #11
Step #12
Step #13
Step #15

x 8
Step #16
Step #18

x 3
Step #20

x 1

x 3

20
Step #21

1 x 1
4 x 4
Agriculux Inc. (Seed Cleaning Techniques)
http://www.agriculex.guelph.org/

http://www.itdg.org/?id=food_chain

“All About Amaranth;” Agricultural Marketing Resource Center.
http://www.agmrc.org/speccrops/amaranthmain.html

http://www.asareca.org/agriforum/articles18/g-nut%20tech.htm

“Bulk Cleaning;” Reso Seeds—Mobile Seed Cleaning and Processing Specialists.
http://www.resoseeds.co.uk/bcleaning.htm

Ferrell and Co (Saginaw, MI). Screen research and information.


USPTO Full-text and Image Database.
http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2Fsearch-bool.html&r=0&f=S&s=50&TERM1=seed&FIELD1=&co1=AND&TERM2=thrashing&FIELD2=&d=ptxt

http://www.asareca.org/agriforum/articles18/bookshelf18.htm

“Threshing techniques;” International Maize and Wheat Improvement Center.
http://www.cimmyt.org

http://www.bagelhole.org/article.php/food/147/