Design Report: Rotary Arm for Use in U.S. Roaster Corp. Coffee Roasting Machine Cooling Bins

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Table of Contents

List of Figures

List of Tables

Executive Summary

A few years ago, the U.S. Roaster Corp conducted a customer survey about their current coffee roaster machines, in which they asked their customers about which aspect of their coffee machines could be improved. According to their clientele, their current coffee bean cooling system was the aspect that could use the most improvement. Thus, the Coolroast design group was tasked to construct a new rotary arm design for the U.S. Roaster Corp's coffee bean roaster machines. This rotary arm mixes the beans as they empty into a cooling bin after being roasted. The necessary design specifications for the rotary arm were set forth in a meeting with the U.S. Roaster Corp on September 9, 2012, and are as follows: the rotary arm that the Coolroast design group should perform better than the current rotary arm design in several key criteria in order to improve the cooling process. The new arm design should improve airflow within the coffee bean cooling bin, which can improve the rate of cooling. It should also mix the coffee beans in such a way so that the beans cool more uniformly. The effect that the rotary arms have on the cooling speed of the beans in the cooling bin should also be investigated. The arm should also empty out the cooling bin in a timely fashion, and minimize the amount of coffee beans that are broken while the beans vacate the bin. The new rotary arm should also not deviate too far from the aesthetics of the rotary arms commonly used in other coffee roasters.

Statement of Problem

The need for this design was made apparent to the U.S. Roaster Corp after they assigned a previous engineering group from Oklahoma State University to discover which aspect of their coffee roaster machines needed the most improvement. According to a survey conducted by this group, the U.S. Roaster Corp's clientele described that they thought that the cooling mechanism in the coffee roaster machines could be improved. This presents a bit of a unique problem: in a meeting between the Coolroast design group and the U.S. Roaster Corp that occurred on September 19, 2012, it was said that the consumers in the coffee roaster machine industry tend to shy away from purchasing roasters that stray too far from the traditional roaster look. Thus, the U.S. Roaster Corp cannot drastically change the design or aesthetics of the current cooling system, even if it does end up significantly improving the cooling aspect of their machines. It was decided that the rotary arm that mixes the coffee beans in the cooling bin attached to the roaster machine was the component that could be safely modified without breaking conventional roaster aesthetics. By improving the design of the rotary arm, it may become possible to improve the cooling rate of the coffee beans as they fill the cooling bin while cutting down on production costs of the coffee roaster machine. In addition, designing the arm to adhere to NSF standards could offer a unique distinction to the U.S. Roaster Corp's machine over its competitors.

Statement of Work

Scope of Work

The goal of our project is to improve the design of the U.S. Roaster Corp rotary arm that is currently used in their cooling bin designs. The type of work that we would need to do to accomplish this would involve:

- Drawing preliminary sketches/concept sketches of new rotary arm designs.
- Testing the current rotary arm design that the U.S. Roaster Corp uses in their cooling bin and gathering data from those tests. We will also need to do the same for our own rotary arm designs.
- Researching NSF International guidelines as well as consulting professors within OSU to determine how the rotary arm can be designed to adhere to NSF standards.
- Creating CAD models of preliminary sketches of prototype rotary arm designs.
- Testing these prototype rotary arms using heated coffee beans and analyzing the rate of cooling using an infrared thermal imaging camera.
- Creating a suitable mixing test by modifying an ASABE mixing assessment protocol to gauge the mixing strength of the rotary arms.
- Determining how well the beans are being mixed using a mixing test using spray-painted beans as a visual tracer.
- Testing and collecting data from our final design model using the thermal imaging camera, visual area evaluation method, and comparing it to the default rotary arm included with the cooling bin.
- Comparing data gathered from testing rotary arm designs and judging which design is best suited for the cooling bin according to cost, bean cooling uniformity, bean cooling speed, bean mixing capability, and bean vacating speed.
- Determining which rotary arm prototype is the most practical/efficient design.
- Creating a final prototype from the best design model in the appropriate final material.
- Presenting our final design to U.S. Roaster Corp.

Location of Work

The mixing capability tests and vacating tests conducted for this project were carried out in the Robert M. Kerr Food and Agricultural Products (FAPC) Wet Processing labs, which is where the cooling bin model was delivered after its completion. The construction of the prototype was carried out by the U.S. Roaster Corp's fabrication professionals. CAD work and other composition work will be done in the BAE computer labs in the Agriculture Hall buildings in room 208 and/or room 210; the Agricultural Hall building and the computer labs housed within are located within the bounds of the Oklahoma State University campus. Any modifications to the roasted coffee beans (such as spray-painting) will also be carried out in the

FAPC or in one of the team member's residences. The cooling tests were carried out at the U.S. Roaster Corp's headquarters in Oklahoma City.

Period of Performance

1/14/2013 - 1/18/2013

- Consultation with U.S. Roaster Corp about prototype concept selection and prototype fabrication.

1/21/2013 - 2/18/2013

- Design rotary arm prototype.
- Modify existing ASABE mixing ability protocol to work with coffee beans and cooling bin.

2/4/2013 - 3/4/2013

- Test mixing capability of default rotary arm.
- Record and compile data from mixing capability test.

3/4/2013 - 4/9/2013

- Construction of prototype by U.S. Roaster Corp.

4/10/2013 - 4/19/2013

- Cooling test performed on default rotary arm and prototype arm.
- Mixing capability of prototype arm tested.
- Data consolidated and prepared for final design report.

4/19/2013 - 4/24/2013

- CAD drawings of selected prototype, performance summary of selected prototype, modified ASABE mixing protocol, and other requested materials prepared for consolidation in final design report.
- Work on design presentation begins.

4/25/2013

- Present design process and findings via design presentation.

4/29/2013 - 5/2/2013

- Final revisions to design report made.
- Send final design report to U.S. Roaster Corp.

Acceptance Criteria

The cost of materials budget and cost of labor to manufacture the rotary arm should not exceed $650. The rotary arms should also be optimally designed to fit within the 12 kg coffee bean roaster cooling bin. The cooling bin itself has an inner diameter of 25.313 inches. According to the 12 kilogram coffee roaster AutoCAD drawings, the rotary arms need to be approximately 12.00” long. In addition, the new prototype design should mix the coffee beans more thoroughly than the default rotary arm. The criteria for the mixing capability tests are detailed in the mixing capability protocol that was derived from the ASABE mixing ability protocol.

Special Requirements

An infrared thermal imaging camera will also be needed to measure how uniformly the beans are cooling. The CAD software known as “Solidworks” will be utilized to draw up schematics for the rotary arm designs, and will be required by the machinery staff at the Oklahoma State University BAE lab and at the U.S. Roaster Corp in order to construct the rotary arm prototype. Solidworks designs will also be needed to create the final prototype, which will be made of stainless steel. In addition, the mixing tests devised by the Coolroast group require the use of spray paint and roasted coffee beans in order to create the tracer material.

Required Resources

- U.S. Roaster Corp 12 kilogram cooling bin with current stirrer arm design installed.
- Roasted coffee beans.
- Testing Materials for Mixing Tests: includes spray paint and roasted coffee beans.
- Solidworks software.
- Infrared Thermal imaging camera.
- Ovens capable of heating coffee beans up to 450 degrees Fahrenheit, or access to a fully functional U.S. Roaster Corp 12 kilogram roaster machine.
- Metal material for prototype fabrication and final prototype fabrication from BAE lab
- Allocated time from BAE lab machinists and U.S. Roaster Corp machinists.
- Additional resources as testing protocols are developed

Task List (2013)

- Research information on how to make sure the design is NSF approved.
- Develop prototype rotary arm design and write justification for prototype design.
- Modify existing ASABE mixing test protocol to work with coffee beans.
- Test bean cooling rate and uniformity of bean cooling capability of the default rotary arm included with the model cooling bin using infrared camera.
- Evaluate mixing capability of default rotary arm included with model cooling bin using spray-painted coffee beans and modified ASABE mixing test protocol.
- Evaluate possible designs on basis of ease of fabrication and design aesthetic.
- Draw rotary arm schematics in Solidworks CAD program.
- Consult U.S. Roaster Corp on the features of prototype rotary arms.
- Adjust rotary arm features as needed according to U.S. Roaster Corp.
- Decide what type of metal(s) to use for constructing our prototype designs.
- Seek out parts supplier to provide materials for prototype rotary mixing arm parts.
- Collect information on shipping delay for needed parts.
- Acquire cost estimates for fabricating rotary arm prototypes from said metal; modify designs if design cost exceeds $650.
- Fabricate prototype rotary arm designs via BAE machine shop and U.S. Roaster Corp.
- Test bean cooling rate and uniformity of bean cooling capability of prototype rotary arms using infrared camera.
- Evaluate mixing capability of prototype rotary arms using spray-painted coffee beans and modified ASABE mixing test protocol.
- Compile prototype performance reports from testing data.
- Compare uniformity of cooling and mixing capability of prototype arms to that of the default rotary arm included with the cooling bin.
- Discard prototypes that perform worse than the default rotary arm design.
- Deliver prototype performance reports to U.S. Roaster Corp.
- Decide upon final design using gathered data from testing and input from U.S. Roaster Corp.
- Construct final rotary arm design.
- Deliver modified ASABE mixing test protocol to U.S. Roaster Corp. for use in future arm design projects.
- Deliver final rotary arm design by April 2013.
- Organize data into coherent document and select data for May product presentation.
- Create presentation for May product presentation.

Patent Search

A search on patents relating to coffee roaster machines and rotary arms was conducted using the "Google Patent" search engine. This was done to ensure that the rotary arm designs that the Coolroast design group created would not infringe on any active patents. Four patents were found that pertain specifically to coffee roaster machine design. One design was patented by an Isaac M. Ginn in January 1894, and another design was patented by an H.L. Smith Jr. in July 1967. The third design was patented by three people in April 2011: Masanori Kando, Akira Kishimoto, and Tasutaka Katsuragi. The fourth design was patented in January 2011 by a Eugene Song.

Ginn's coffee roaster machine involved a hand-crank mechanism to turn a mounted pan that contains roasted coffee beans; the design does not appear to include any sort of rotary arm device for cooling the coffee beans. Similarly, H.L. Smith Jr.'s design involves dropping roasted coffee beans down a series of conical bins, and does not involve any sort of rotary arm to stir the beans with the intent of cooling said beans. The design patented by Kando et al. appears to use an air-exchange method for cooling the roasted coffee beans and shows no evidence of using a rotary arm to aid this process. The coffee roaster machine designed by Eugene Song, however, does include a rotary arm (referred to as a "stirring rotator" in the patent) that is intended to stir roasted coffee beans after the beans enter a cooling bin. A review of the claims section of this patent reveals that the heating system and the control system for said heating system are the items being patented, while the rotary arm is not. Nonetheless, it may be safer to create prototype rotary arms that are distinct from Song's design. The rotary arm in Song's design can be seen in Figure 1 (parts 92, 92-2 through 92-5):

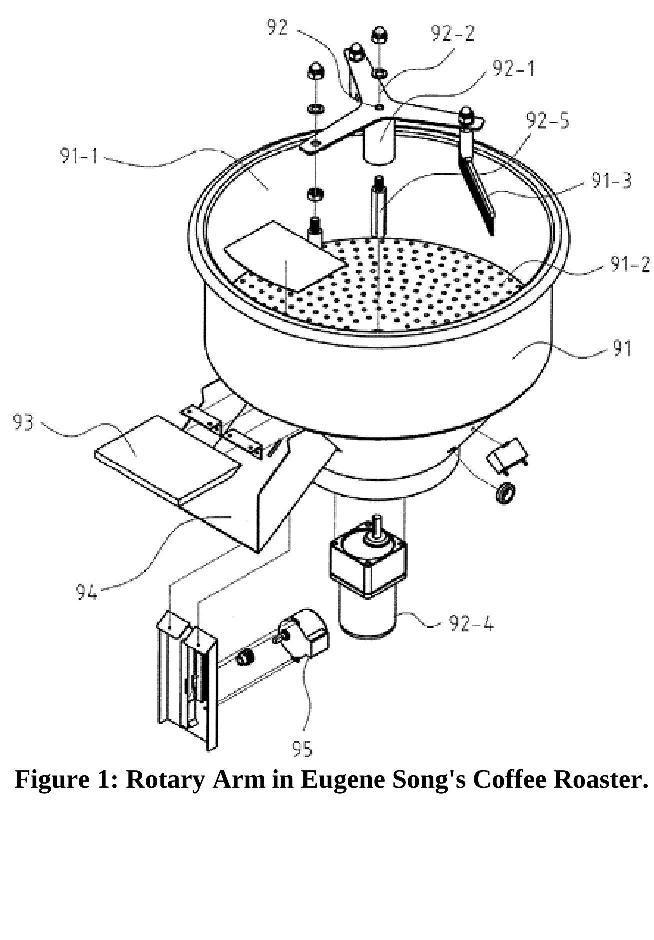

Figure 1: Rotary Arm in Eugene Song's Coffee Roaster.

Design Objectives

This document proposes several designs for a new rotary cooling arm design for use in the cooling bins of the U.S. Roaster Corp's coffee bean roasting machines. In order to create a satisfactory design for our client, the Coolroast design team has several design objectives to fulfill:

1.) Improve the uniformity of cooling for the roasted coffee beans after they are deposited in the cooling bin of the coffee roasting machines.

2.) Investigate the effect that the rotary arms have on the cooling speed of roasted coffee beans as they cool within the cooling bin.

3.) Minimize the amount of coffee beans that are destroyed (i.e. crushed or ground) by the rotary arm in the cooling bin.

4.) The rotary arm design should also adhere to NSF standards, if at all possible.

The first objective is necessary due to it being a key demand of our client. If the uniformity of cooling for the roasted coffee beans is improved significantly, then it is believed that the taste of the coffee will be better. If the second objective is successfully fulfilled, then discovering the effect that the rotary arms have on the coffee bean cooling speed may lead to better rotary arm design concepts in the future. As such, the fulfillment of this objective could positively affect company efficiency and profits. It is worth noting that this objective was formerly "Improve the rate of cooling of coffee beans within the cooling bin”. This was changed after consulting with Dr. Hardin (a professor at OSU) regarding the factors that influence the cooling speed of the coffee beans; the reasoning behind this change is described in the later section titled “Development of Engineering Specifications”.

The realization of the fourth objective would improve the appeal of the machine. While a few broken coffee beans may not have a lasting impact on the taste of the coffee, it could negatively influence potential buyers' perception of the machine. If we minimize this risk, then there is less chance that the U.S. Roaster Corp's coffee roasters will be passed up by potential customers. In addition, if the rotary arm design fulfills NSF requirements, then that is another positive quality that can be assigned to the machine, which in turn could possibly boost sales.

In order to accomplish these objectives, we will need to analyze how the rotating arm attachments that we design will interact with the coffee beans. These interactions include: how well the arms stir the beans, whether the arms damage the beans or not, and how well the arm design improves the flow of air in the cooling bin. Our group will also need to analyze the uniformity of cooling in the bin by measuring how evenly the heat dissipates from the coffee beans. U.S. Roaster Corp. is willing to construct a cooling bin for us to utilize throughout the course of the project.

Technical Approach

Based on designs we observed while at U.S. Roaster we will be able to develop our own design concepts, as well as determine the ease of fabrication for these designs. Our team will then take these concepts and develop designs within the Solidworks program that can then be fabricated by the U.S. Roaster Corp machinists. Once we have our rotating arm designs constructed, we will conduct experiments to see how well the beans are being mixed and screen the bean mixture for any damaged beans.

Identifying Customer Needs

Our customer and sponsor for this senior design project is U.S. Roaster Corp, which is based in Oklahoma City. We were tasked by them to create a new rotary arm design for use in their coffee bean roasters. Ideally, the new stirring arm will improve the uniformity of cooling within the roasted coffee beans after the beans have entered the cooling bin of the roaster. The new arm design should also improve the flow of air through the cooling bin. If the arm is designed and implemented properly, then it may be possible to use lower-power fans to cool the coffee beans, which could reduce the cost of building the coffee bean roasters. The stirrer arm design should minimize the amount of coffee beans that are broken or warped as it rotates, as broken beans may negatively impact sales and customer satisfaction. Our design concept should also ensure that coffee beans or other debris does not get stuck along the walls of the cooling bin during the coffee bean cooling process. The design should be able to fully vacate the cooling bin of cooled coffee beans in a reasonable amount of time.

U.S. Roaster Corp insisted that our final stirring arm design should be made from stainless steel. Their reasoning for this requirement is that stainless steel does not retain the flavor of previous coffee bean batches; this ensures that the distinct flavor and quality of each batch of coffee beans is preserved. U.S. Roaster Corp. also expressed interest in our design obtaining NSF certification, which could improve the reputation and marketability of the coffee roasters that use our design. U.S. Roaster Corp also stated that spending time and money on designing an aesthetically pleasing rotary arm design may be worthwhile, as it could potentially boost sales.

Identifying Target Specifications

The rotary arm should ensure that the coffee beans in the cooling bin cool from a temperature of 450 degrees Fahrenheit to 90 degrees Fahrenheit, assuming that the cooling bin fan is working properly. Any effect that the rotary arms have on the cooling speed of the coffee beans should also be recorded. When the cooling process is complete and the cooling bin exit hatch is opened, the rotary arms should help the cooled coffee beans vacate the cooling bin in less than 5 minutes. Our group was also given a cost of materials budget of approximately $650. The rotary arms should also be optimally designed to fit within the 12 kg coffee bean roaster cooling bin. The cooling bin itself has an inner diameter of 25.313 inches. According to the 12 kilogram coffee roaster AutoCAD drawings, the rotary arms need to be approximately 12.00” long.

In addition, the prototype rotary arm design that will be created by our group should show a stronger mixing capability and better mixing uniformity than the rotary arm created by the U.S. Roaster Corp. The criteria for mixing capability and mixing uniformity is quantified by using the mixing capability protocol that the Coolroast design group derived from an ASABE mixing ability protocol. The details of both the mixing capability protocol and the ASABE protocol are outlined in the section of the document titled “Design Testing”.

Generating Design Concepts

The various rotary arm designs that the Coolroast group generated were done after observing how the U.S. Roaster Corp's initial rotary arm design performed in several criteria, as listed below:

- The first criterion was the uniformity of the heat dissipation, which was a key customer requirement. By observing the pattern of the heat dissipation by using an infrared camera, it became possible to quantify the uniformity of the heat dissipation by assigning different numerical weights to the colors displayed by the camera.
- The second criterion was the speed at which the rotary arms could vacate the coffee beans from the cooling bin. After the exit hatch door is open, the vast majority of the coffee beans should vacate the cooling bin in less than 5 minutes.
- The last criteria were the mixing capability and the mixing uniformity of the rotary arms. If the rotary arm design is able to mix the beans thoroughly then it could be surmised that more beans will be exposed to the air that is being pulled by the cooling bin’s fan, resulting in a faster cooling rate. The uniformity of the mixing may result in more uniform cooling, as the roasted beans are being more evenly dispersed throughout the cooling bin (and thus being more evenly cooled by the air being pulled by the cooling bin fan).

Development of Engineering Specifications

An engineering analysis was conducted on the current rotary arm so that the Coolroast design group could get a better idea of the parameters that we would need to analyze in the rotary arm. Firstly, the default rotary was disassembled, and the individual pieces weighed on a scale located in the FAPC lab that the model cooling bin was contained in. A free-body diagram was drawn in order to quantify the forces and moments that were acting on the rotary arm assembly; from there, shear and moment diagrams were constructed to find the maximum shear and maximum moment acting on the rotary arm. These shear and moment calculations were then used to perform a weld analysis, which was used to calculate a factor of safety for the current rotary arm design. The factor of safety is a quantity that defines how “reliable” the device being analyzed is; in the context of welding, the factor of safety defines how reliable the welding is (the higher the safety factor on the weld, the less likely the weld is going to break/crack/warp). This analysis will be performed on the prototype rotary arms as well.

The mixing capability of the rotary arms needs to be quantified so that the mixing capabilities of the default rotary arm and that of the prototype rotary arms can be compared objectively. After consulting with several professors at Oklahoma State University, Dr. Timothy Bowser referred the Coolroast design group to an ASABE testing protocol. This ASABE protocol was created in order to gauge the ability of a portable farm batch mixer to mix granular materials, such as finely ground corn. Thus, the Coolroast group worked with Dr. Bowser to modify the protocol to work with coffee beans.

For the airflow assessment, the Coolroast group consulted Dr. Hardin about how the rotary arm designs could affect the airflow within the cooling bin. It was said that the design and the power of the fan used in the cooling bin would be the foremost factor in altering the amount of air being pulled through the bin, and ergo the most important component of the cooling bin's airflow. It was also pointed out that the airflow may have a significant effect on the cooling speed of the roasted coffee beans as they cooled within the cooling bin. As such, the Coolroast group modified the design objectives and criteria; it decided that it might be best to investigate how the rotary arm designs affected the cooling speed of the coffee beans, rather than to design a rotary arm without fully understanding how the rotary arm's design would influence the cooling speed. In addition, the objective and criteria relating to airflow were removed, seeing as how the cooling bin fan would have the greatest effect on qualities relating to airflow.

Selecting Design Concepts

The generation of the design concepts started with observing the rotary arms installed on coffee roasters stored at the U.S. Roaster Corp's facilities. From these roasters, several designs concepts were then sketched by the individual members of the Coolroast design group and evaluated by the rest of the group as a whole. The group discussed the advantages and disadvantages of the individual designs, and selected traits from each concept that were favorable. These selected traits were used to generate a final design concept. In the end, it was decided to go with a rotary arm design that possessed three arms, each of which was used to support a different mixing attachment that would fulfill a specific function. The CAD figure of the initial prototype assembly can be seen below, along with that of the final prototype:

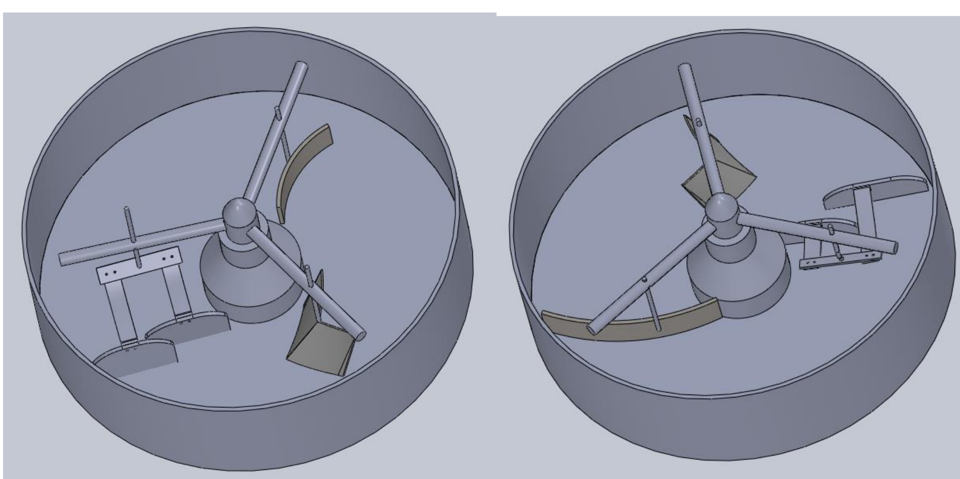

Figure 2: Initial Prototype Rotary Arm Assembly (left) and Final Assembly (right).

The first attachment was based off the design and functional capabilities of a train snow plow and a tillage blade. This attachment will raise coffee beans from the bottom of the bin to the surface of the cooling bin, where the ambient air temperature will cool the roasted beans. The plow will also move the beans to the outer and inner edge of the bin. The plow was designed to be constructed out of a single piece of metal that can be bent and curved into a plow shape. The figure below shows the CAD representation of the plow attachment.

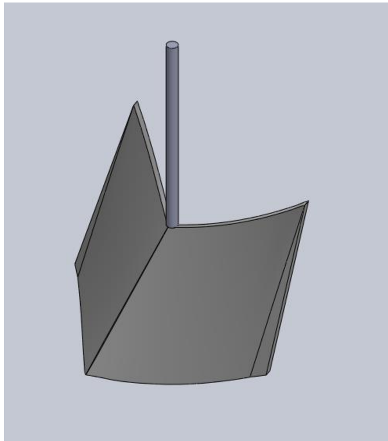

Figure 3: Plow Attachment.

The attachment following the plow was a piece of curved metal, which was dubbed the "leveler" attachment. This attachment was meant to evenly distribute the coffee beans across the bin after they have been displaced by the plow. This is a concept that we saw in larger scale roasters made by other roaster manufacturers. The leveler is connected to the arm by a screw, and its height can be adjusted if needed. Our design has the leveler attachment supported by only one arm, since the 12-kg roaster that our group is working on is used mainly for small-scale batch roasting. The leveler attachment was initially designed to be short, but was later revised to be made from a longer piece of metal so it could distribute the beans more effectively and pull beans from the edge to the center of the bin, allowing more beans to be plowed. The following figures show the design of the initial and final leveler attachment:

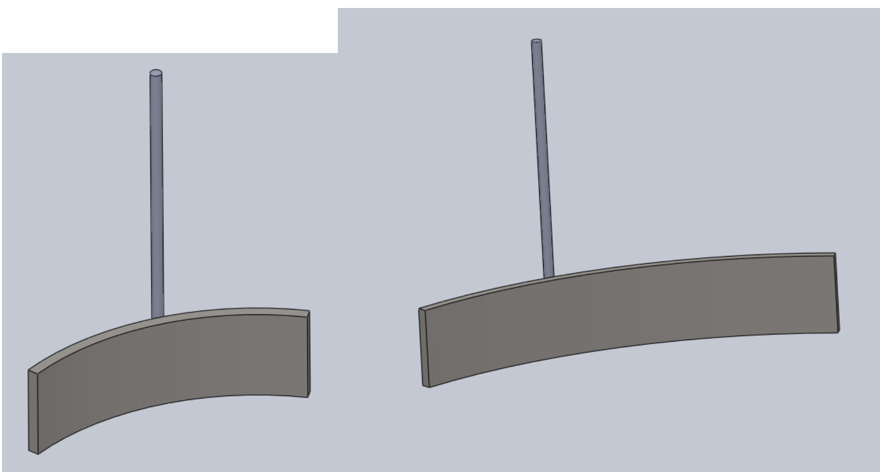

Figure 4: Leveler Attachment. Initial design on left, final design on right.

The final attachment was connected to the third arm, and consisted a pair of draggers that utilize spring steel to hold them against the bottom of the bin. This attachment is referred to as the “dragger” attachment. The Coolroast design group also saw this concept in action while observing the roasters in storage at the U.S. Roaster Corp. The draggers consist of a metal blade that is held against the bottom of the cooling bin; as the prototype arm rotates, the dragger attachment moves the beans around the bin. The draggers serve to push the coffee beans towards the exit hatch after they have been cooled. The spring steel was used to help prevent bean breakage by allowing some give within the design in case a coffee bean becomes jammed underneath the dragger. The dragger attachment can be seen in differing orientations in the figures below:

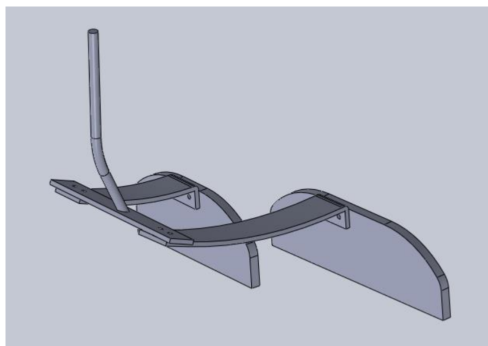

Figure 5: Dragger Attachment, front view.

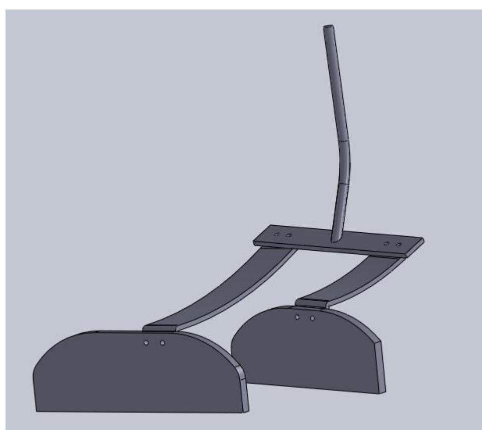

Figure 6: Dragger Attachment, back view.

Environmental, Societal, and Global Impacts of Design Concept

The main environmental impact that the new rotary arm design could have on the environment is mainly tied with its construction. The metal that it will be constructed from will need to be mined from the Earth; in turn, that metal will need to be refined, shaped, and shipped. In addition, the rotary arm may boost sales of the U.S. Roaster Corp's coffee roasting machines, which will probably incur an expenditure of electricity and fossil fuels. But aside from the fuel expenditure for its production, the rotary arm itself does not appear to directly influence the state of the environment. Similarly, the production of the prototype rotary arm may not have many sociological consequences. If the arm design boosts the U.S. Roaster Corp's coffee roaster machine sales significantly, it may be possible that competing roaster machine companies will lose significant numbers of customers.

Design Testing

In order to properly gauge the performance of the prototype rotary arm against the default rotary arm, it is necessary to have testing methods in place that can objectively measure the performance of each rotary arm in terms of bean mixing or cooling the coffee beans deposited in the cooling bin. To accomplish this, the Coolroast group created testing protocols that could quantify the mixing capability and cooling capability of both the prototype rotary arm and the default rotary arm. The mixing capability test created by the Coolroast design group was derived from a mixing ability protocol developed by the ASABE (Standard 380), which was intended to measure how well a portable farm mixer could mix granular material such as ground corn. After extensive consultation with Dr. Timothy Bowser, our group adapted the ASABE protocol to work with roasted coffee beans. This involved using spray-painted roasted coffee beans as a tracer material (which helps to gauge how well the rotary arm mixes the beans), and using mass percentage composition of tracer beans in each sample along with standard deviation as a metric for mixing capability. The protocol for this test is described in the section titled "Mixing Capability Test Summary", and is also attached to this report in the appendix.

The cooling capability test required the use of a U.S. Roaster Corp. 12-kilogram roaster. The Coolroast group opted to travel to the U.S. Roaster Corp's headquarters in Oklahoma City to carry out this testing on a spare 12-kilogram roaster, rather than purchasing one or using industrial ovens to heat the beans. This was done due to the fact that purchasing a 12-kilogram roaster would be considered expensive relative to the Oklahoma State University Senior Design Budget; also, it was found that the ovens that were housed in the FAPC were unable to heat enough beans at the same time, which would have confounded the results of the cooling tests. It was thusly decided that testing the cooling capability of both the default arm and the prototype arm on a genuine 12-kilogram roaster would result in the most accurate findings. The details of the cooling test are described in greater detail in the section titled "Cooling Test Summary".

In addition, the Coolroast group also conducted a vacating test for the default rotary arm and the prototype rotary arm. This test was designed to gauge how quickly a rotary arm design could vacate the cooling bin of any roasted coffee beans. The details of this test are described in the section labeled “Vacating Test Summary”.

Mixing Capability Test Summary

The mixing capability test calls for using 10% of the coffee bean mass roasted per roasting batch operation as tracer materials. Since the Coolroast group was assigned to work on a roaster that roasts approximately 12 kg of coffee beans per batch, approximately 1.2 kg of the batch consisted of “tracer” beans, while the remaining 10.8 kg was made of unpainted “stock” beans. This means that for each mixing capability test, a grand total of 10% of the total mass of each batch was composed of tracer beans, with the remaining 90% being unpainted stock beans. The tracer beans were spray-painted over the span of 2 days. The first day consisted of spray-painting one side of the beans and allowing the paint to dry for the rest of the day; the second day was spent spray-painting the other side of the beans and allowing the paint to dry for the remainder of the second day. After the tracer beans were prepared, 1.2 kg of the tracer beans were weighed, and 10.8 kg of the stock beans were weighed. The stock beans were then deposited into the cooling bin, and the tracer beans were evenly distributed across the surface of the stock beans. Our group then took a picture of the mass of beans within the cooling bin to use as a visual reference. This part of the procedure was repeated seven times over the span of the design project.

The Coolroast group then set the cooling bin to operate at 100% fan power and 100% mixing speed, and ran the rotary arm for 3 minutes. This time limit was set to see which rotary arm design could mix the beans more uniformly within a short time span; it was also thought that both rotary arms would eventually disperse the beans evenly throughout the coffee bean mix if allowed to mix the coffee beans for too long, which would defeat the purpose of the mixing capability test. The mixing of the beans during these 3 minutes was recorded via video camera for reference purposes. After the 3 minute mark was reached, the fan and rotary arm motor were deactivated using the control console on the cooling bin. Six cups were then placed on the bean mixture; one was placed near the cooling bin walls, another was placed near the rotary arm spool (in the center of the cooling bin), and the rest were dispersed throughout the cooling bin. A picture was taken of the cups to reference their position on the beans. The cups were then used to scoop up the layer of beans directly under their position, and collected for tallying. The weight and number of tracer beans in each cup was measured and recorded, as was the weight of the stock beans in each cup. The data was then compiled in a table and several calculations for different values were calculated. The detailed results can be seen in Appendix D. The arrangement of the cups can be seen in the figures below:

Figure 7: Arrangement of Sampling Cups, Prototype Arm.

Figure 8: Arrangement of Sampling Cups, Default Arm.

Cooling Test Summary

The cooling tests involved the use of one of the U.S. Roaster Corp's previously fabricated 12-kilogram coffee roasters, both the prototype arm that was fabricated for the Coolroast group and the default arm on the 12-kilogram roaster, and an infrared thermal imaging camera lent to the Coolroast group by Dr. Frazer (a professor employed by Oklahoma State University). The infrared camera was set to recognize temperatures on a fixed interval of 70 degrees Fahrenheit to 510 degrees Fahrenheit; this would ensure that the color/temperature scale of the infrared camera would remain static, ensuring a more intuitive display of color and temperature within the snapshots taken by the camera. An appropriate amount of unroasted coffee beans (about 20 lbs) were loaded into the 12-kilogram roaster, and was roasted until the beans reached 450 degrees Fahrenheit; the temperature of the beans within the roaster were measured and controlled through a mechanism that comes included with the 12-kilogram roaster. The beans were then emptied into the cooling bin after reaching 450 degrees Fahrenheit, after which the cooling bin fans and the mixing mechanism via the rotary arm were both activated to 100% capacity. The thermal imaging camera was then used to take snapshots of the coffee beans from a static orientation every 30 seconds until they reached around 77 degrees Fahrenheit. This procedure was carried out for the default rotary arm included with the 12-kilogram roaster, and was repeated when the prototype rotary arm was installed on the roaster. This repetition ensured that the cooling profile of the prototype rotary arm would be recorded.

Vacating Test Summary

This test consisted of filling the cooling bin with 12 kg of roasted coffee beans, letting the arm mix the beans for 10 seconds, and then opening the exit hatch of the cooling bin. The vacating of the beans was recorded via video camera. The cooling bin was defined as “vacated” when there were no beans left within the cooling bin, or if a trace amount of beans remaining in the cooling bin were not able to be pushed out of the cooling bin via the exit hatch by the rotary arm. Six videos of the vacating process (three for the default arm, three for the prototype arm) were used to ascertain the time needed for each rotary arm to vacate a load of 12 kg of roasted coffee beans.

Testing Results: Mixing Capability Tests

The detailed results of the mixing capability test for the prototype rotary arm and the default rotary arm can be seen in the excel sheet in Appendix D. An abridged form of the results can be seen in the table and figure below:

Table 1: Table of Mixing Capability Results (Abridged)

Mixing Tests	Mixing Arm Type	Average Mass % of Tracers (%)	Lowest Standard Deviation (Best-Case)	Highest Standard Deviation (Worst-Case)	Average Standard Deviation
1-6	Default	12.95	1.213	4.713	2.760
7-10	**Prototype**	**10.23**	**1.240**	**2.863**	**1.926**

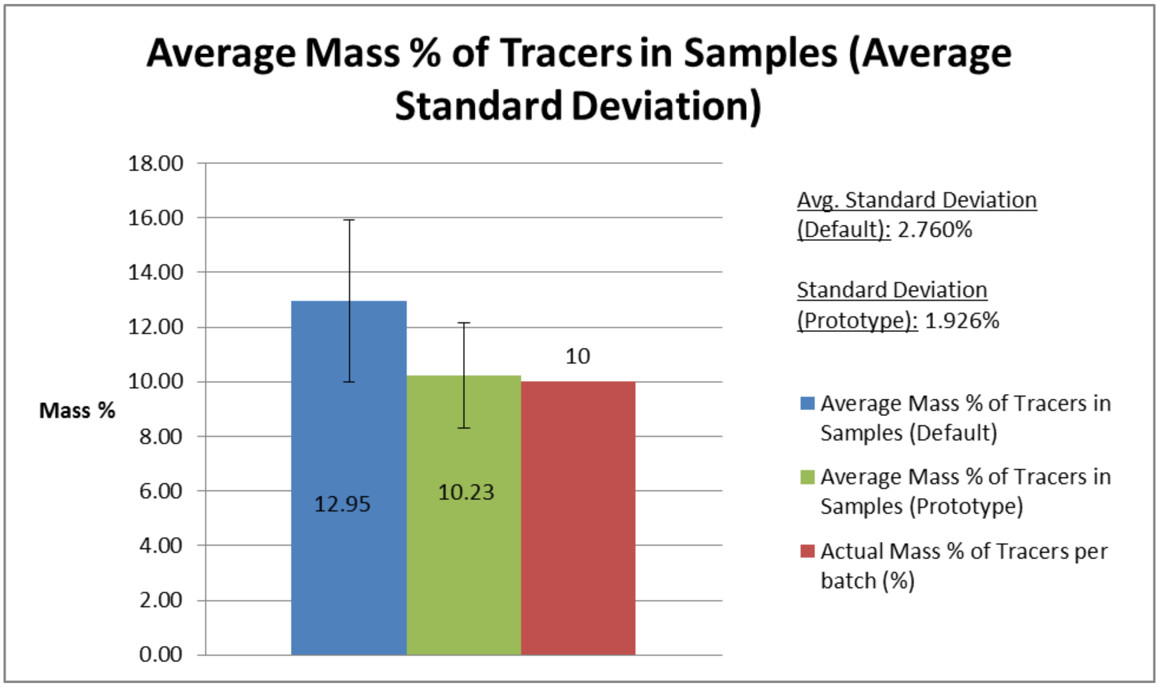

Figure 9: Average Mass Percentage of Tracers in Samples (Average Standard Deviation).

The data from the table and figure mean that each sample taken from the coffee mixed by default rotary arms contained 12.95% tracers by mass on average, and each sample taken from the coffee mixed by the prototype rotary arms were composed of 10.23% tracers by mass on average. The standard deviation of the default arm samples was 2.760% tracers, whereas the standard deviation for the prototype arm samples was 1.926% tracers. In addition, graphs that include cases for the best-case standard deviation and worst-case standard deviation for the default arm and prototype arm were constructed. The purpose of these graphs was to show the extremes of the variability of tracer composition that could occur for each rotary arm design. The figure on the following page shows a graph of the worst-case standard deviation.

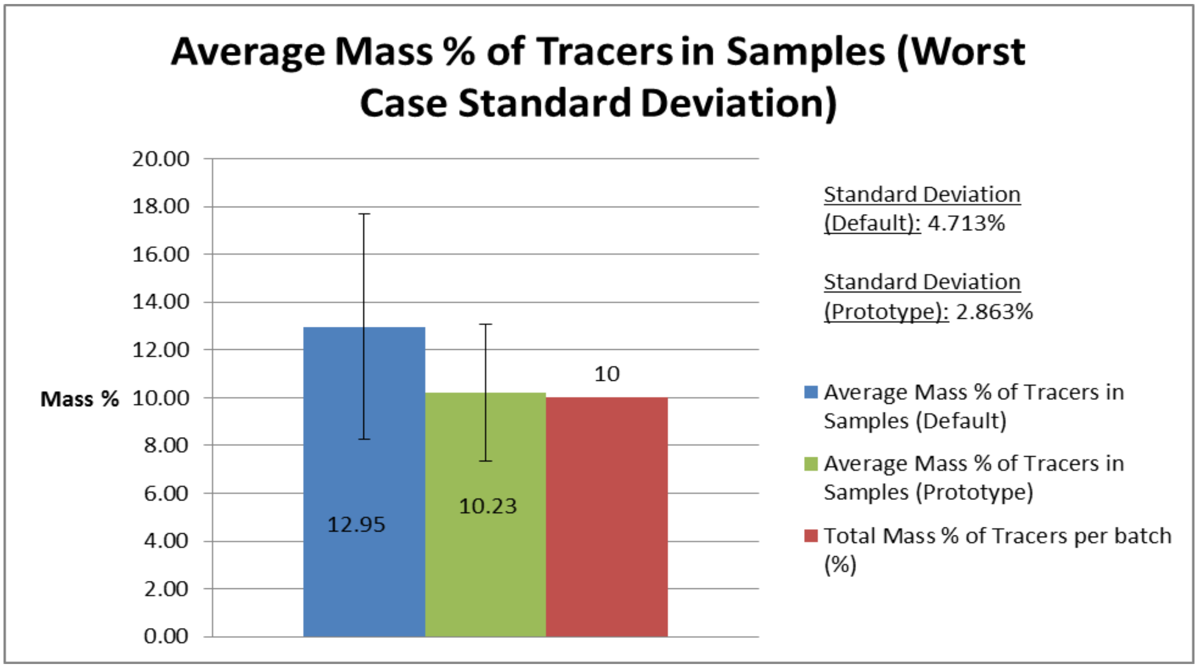

Figure 10: Average Mass Percentage of Tracers in Samples (Worst Case Standard Deviation)

As is displayed above, the range of variance due to the standard deviation is substantial. The average mass percentage value for tracers found in the default arm test samples can now actually be any value in between 8.237% (12.95% - 4.713%) and 17.663% (12.95% + 4.713%). In addition, the average mass percentage value for the tracers found in the prototype arm test samples could actually be any value in between 7.367% (12.23% - 2.863%) and 13.093% (10.23% + 2.863%). In this worst-case standard deviation scenario, there may be a substantial overlap between the average mass percentage values for the prototype arm samples and default arm samples. For this particular scenario, this can mean that there could be no significant difference between the two values, which could mean that the prototype arm and default arm do not have any real difference in mixing capability. The best-case standard deviation can be seen below:

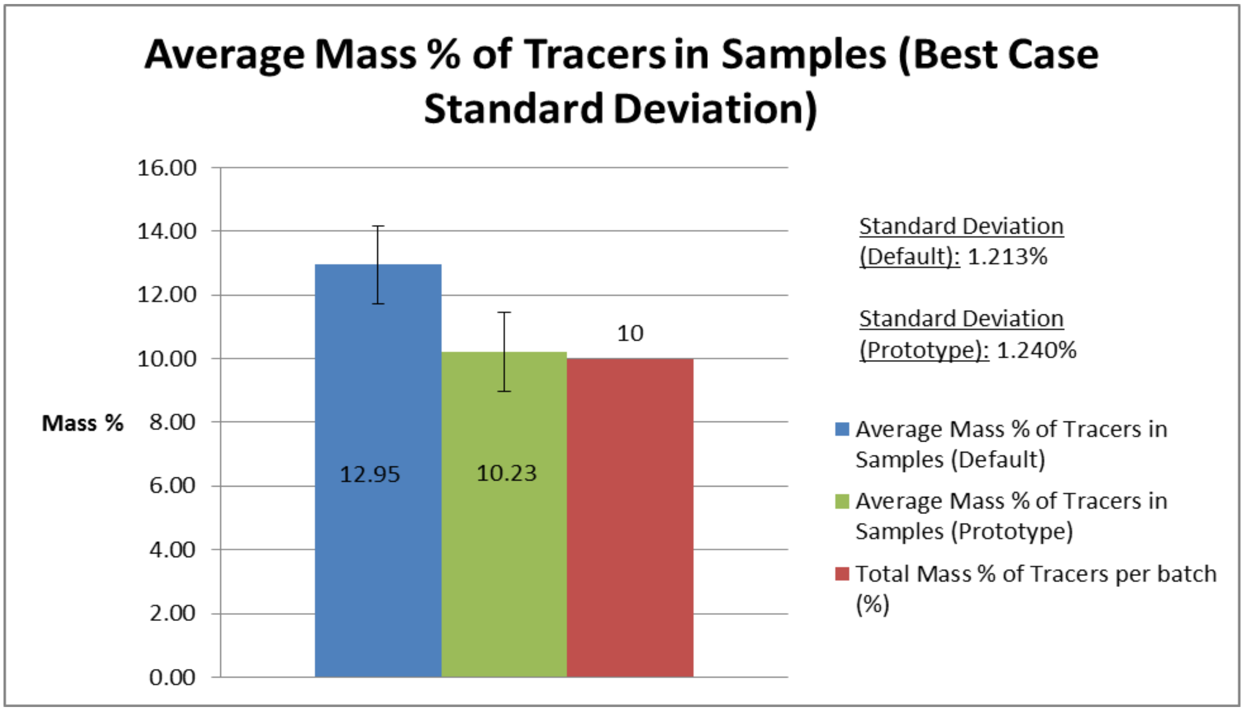

Figure 11: Average Mass Percentage of Tracers in Samples, Best Case Standard Deviation.

As can be seen in the above figure, the best-case standard deviation adds a range of variance for the average mass percentage of tracers. Thus, the 12.95% mass percentage value for the default arm could actually be any value in between 11.737% (12.95% - 1.213%) and 14.163% (12.95% + 1.213%). Similarly, the average mass percentage value of 10.23% for the prototype arm has some variance, and in practice could fall in between the values of 8.99% (10.23% - 1.240%) and 11.47% (10.23% + 1.240%). In this best-case scenario, none of the possible values for the average mass percentage for either the prototype arm or the default arm overlap; this could mean that both values are distinct from each other.

Testing Results: Cooling Tests

The infrared thermal images taken by the camera can be seen in Appendix E. The images show that the default rotary arm cools the beans to 90 degrees Fahrenheit in a timespan between five and six minutes, whereas the prototype rotary arm cools the beans to 90 degrees Fahrenheit in about six minutes. Though the beans were heated to 450 degrees within the 12-kilogram roaster, they appear to cool down extremely rapidly upon being released; thus, the default beans start at 430 degrees Fahrenheit, while the prototype beans appear to start at around 408 degrees Fahrenheit. However, the prototype picture shows that the majority of the beans are around the reticule 420 degrees Fahrenheit, and the reticule is settled on a spot where the temperature is 408 degrees Fahrenheit.

Testing Results: Vacating Tests

The results of the Vacating Test show that the default rotary arm was able to vacate 12 kg of roasted coffee beans from the cooling bin within a time span of 1 minute, 20 seconds. The prototype arm vacated 12 kg of roasted coffee beans from the cooling bin within 1 minute, 37 seconds.

Discussion: Mixing Capability Tests

The results of the mixing capability tests show that, on average, the samples taken from the coffee mixed by the default rotary arm contain more tracers than the samples taken from the coffee mixed by the prototype rotary arm. For ease of reference, Table 2 below summarizes this combination of results:

Table 2: Summary of Mixing Capability Test Results

Mixing Tests	Mixing Arm Type	Average Mass % of Tracers (%) in Samples	Actual Mass % of Tracers per Batch (%)	Average Mass % Difference	Lowest Standard Deviation (Best-Case)	Highest Standard Deviation (Worst-Case)	Average Standard Deviation
1-6	Default	12.95	10	2.95	1.213	4.713	2.760
7-10	**Prototype**	**10.23**	**10**	**0.23**	**1.240**	**2.863**	**1.926**

As can be seen above, Table 2 shows that the mass percentage difference for the prototype arm samples is less than that of the mass percentage difference for the default arm (0.225% vs. 2.952%). Since each batch was composed of 12 kg of beans, and 10% of those 12 kg were composed of tracers (1.2 kg), the ACTUAL mass percentage of tracers for each mixing capability test was 10%. Since the default arm's average mass percentage of tracers was 12.95% (2.95% greater than the ACTUAL mass percentage value), this implies that the default arm was concentrating beans in certain areas in the bin as it mixed. As the prototype arm's average mass percentage of tracers was 10.23% (only 0.23% greater than the ACTUAL mass percentage value), it could be said that the prototype arm was better at uniformly mixing the beans than the default arm was. In addition, the average standard deviation of the prototype arm was less than the average standard deviation of the default arm. This means that the range of standard deviations for the prototype arm is less than that of the default arm. As such, the prototype arm mixes more consistently than the default arm. From these results, it could be inferred that the prototype arm mixes the beans more uniformly or thoroughly than the default arm within a 3-minute time span.

However, the Coolroast group noted that the dragger attachment on the prototype arm tended to arrest a number mass of beans as it rotated around the bin, limiting circulation for those mass of beans. Even then, it would appear that the plow attachment and the leveler attachment can compensate for any potential limiting effects that the dragger attachment creates as far as mixing capabilities are concerned.

Discussion: Vacating Tests

The vacating test results show that the default arm was able to vacate the cooling bin of 12 kg of roasted coffee beans within 1 minute and 20 seconds, while the prototype arm vacated the cooling bin of 12 kg of coffee beans within 1 minute and 37 seconds. The chief cause for this difference in vacating speed was probably the orientation of the dragger arms, as can be seen in the following figure:

Figure 12: Default Rotary Arm in Model Cooling Bin. Exit hatch (circled in green) is in "closed" position.

As can be seen in the above figure, the default rotary arm has two dragger attachments dedicated to shuffling coffee beans out of the cooling bin. Each of these draggers is secured to each of the two shafts of the default rotary arm via screws. As the default arm rotates, the centermost dragger (outlined in a red circle) is angled in such a way that coffee beans from the center of the bin are pushed to the outer edges of the bin. The second dragger acts in tandem with the first dragger, collecting the coffee beans pushed to outer edges, and carting them to the exit hatch of the cooling bin (circled in green). The dragger attachment for the prototype arm can be seen in the figures below:

Figure 13: Prototype Rotary Arm in Model Cooling Bin

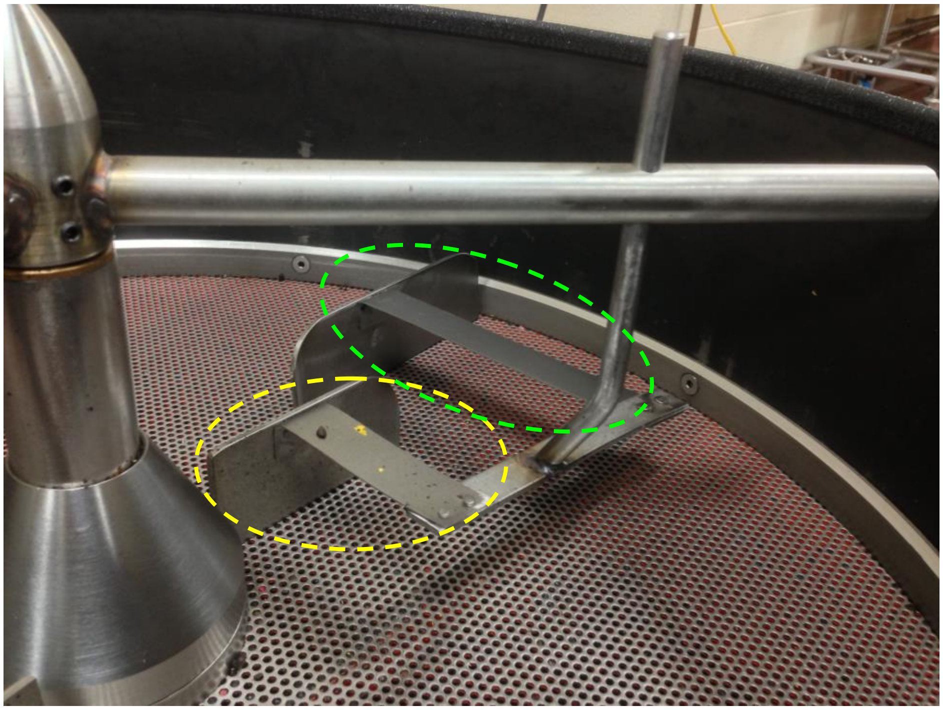

Figure 14: Dragger Arm Attachment of Prototype Rotary Arm

The singular dragger attachment on the prototype arm attempts to replicate this effect with two draggers located on one shaft of the prototype rotary arm. However, the prototype arm's inner dragger (circled in yellow) does not appear to shuffle beans to the outer edges of the bin quite as well as the default arm's dragger does. In addition, the outermost dragger on the dragger attachment (circled in green) appears to "jump" as it passes over certain areas of the cooling bin, resulting in some coffee beans not being pushed as it rotates. However, this problem becomes a non-factor once enough coffee beans are vacated from the bin. In addition, the prototype rotary arm is capable of vacating the cooling bin in less than 2 minutes. Thus, the prototype rotary arm meets the design criteria set forth for the vacating speed (bin emptied/vacated within 5 minutes).

Discussion: Cooling Tests

For the cooling test, the thermal images show that the default arm cooled the beans to 90 degrees Fahrenheit after the 5-minute mark, whereas the prototype arm cooled the coffee beans to 90 degrees Fahrenheit after the 5-minute and 30-second mark. During the cooling test for the prototype arm, there was a bit of confounding for the thermal images due to a particular region of beans that were observed to retain higher temperatures than the rest of the bean mass. It is thought that this region of beans corresponds to the "clump" created by the dragger attachment, in which a substantial pile of beans accumulates around the dragger. If the dragger arm does not allow beans to mix, then it may be reasonable to infer that these beans in the middle of the clump receive less exposure to the ambient air and the air being pulled into the bin by the fan. Thus, those "clumped" beans cool at a slower rate than the rest of the coffee beans.

Alternatively, the slower cooling speed of the prototype arm could also be due to the fact that the prototype arm may be circulating roasted coffee beans to the surface of the bean mix to a greater degree than the default arm. It may be reasonable to assume that the temperature of the "core" beans located below the surface of the bean mix retain heat better than the beans located at the surface of the bean mix. If the prototype arm is circulating beans to a greater degree than the default arm, then the infrared thermal imaging camera would observe more "core" beans in the prototype arm cooling tests. Thus, it may be possible to say that the coffee beans being mixed by the prototype arm aren't cooling slower than the beans being mixed by the default arm.

Instead, it could be said that the beans being observed in the cooling test for the default arm are mostly beans which stay at the top surface layer and don't circulate well. Since these beans are constantly exposed to air, they would cool faster than the beans below the surface layer. This could create a confounding effect in the cooling test, since the beans being measured in the cooling tests are only the beans that can be observed at the surface of the bean mix. Thus, if the prototype arm exposes more "core" beans to the surface (which may be hotter than surface beans) as it mixes, then the infrared camera would naturally record higher temperatures than the temperature values for the default arm. It may be possible that the hotter "core" beans in the default arm cooling tests are merely not being exposed as frequently as the hotter "core" beans in the prototype arm cooling tests, creating the impression of a faster cooling speed for the default arm.

Regardless, the cooling uniformity of the beans in both sets of images appears to be similar. It would seem that both arms perform similarly as far as cooling speed and cooling uniformity are concerned. As was said earlier, the Coolroast group consulted with Dr. Hardin, who said may be that the cooling speed of the beans is more heavily influenced by other factors, such as the amount of air being pulled through the cooling bin by the cooling bin fan. Since only one cooling test for was conducted for each rotary arm design, there is not a large pool of results to draw from; more cooling tests may need to be conducted before a definitive conclusion can be drawn about the effects that rotary arm design has on bean cooling speed.

Recommendations

Based on the results of both the mixing capability test, the cooling test, and the vacating test, we believe that the overall design of the prototype is solid. The plow appeared to push beans and encourage a forward-tumbling motion of the beans it displaces, and the leveler caused beans to tumble across it as it moved forward. However, some modifications need to be made to the dragger arm to correct the “clumping” issue. It is thought that lowering the height of the two dragger plates on the dragger attachment (outlined in yellow in the figure below) that contact the bottom of the bin would lower the height of the clump. Alternatively, the flex-steel strips that are used in the attachment could be made narrower to allow beans to pass over the dragger plates, and also made thicker to ensure that the tension does not change; these strips can be seen in the following figure, and are outlined in green. If the clump issue is resolved, then the prototype arm may be used without fear of overflowing the cooling bin, and it may also serve to decrease the cooling time of the beans that the prototype arm stirs.

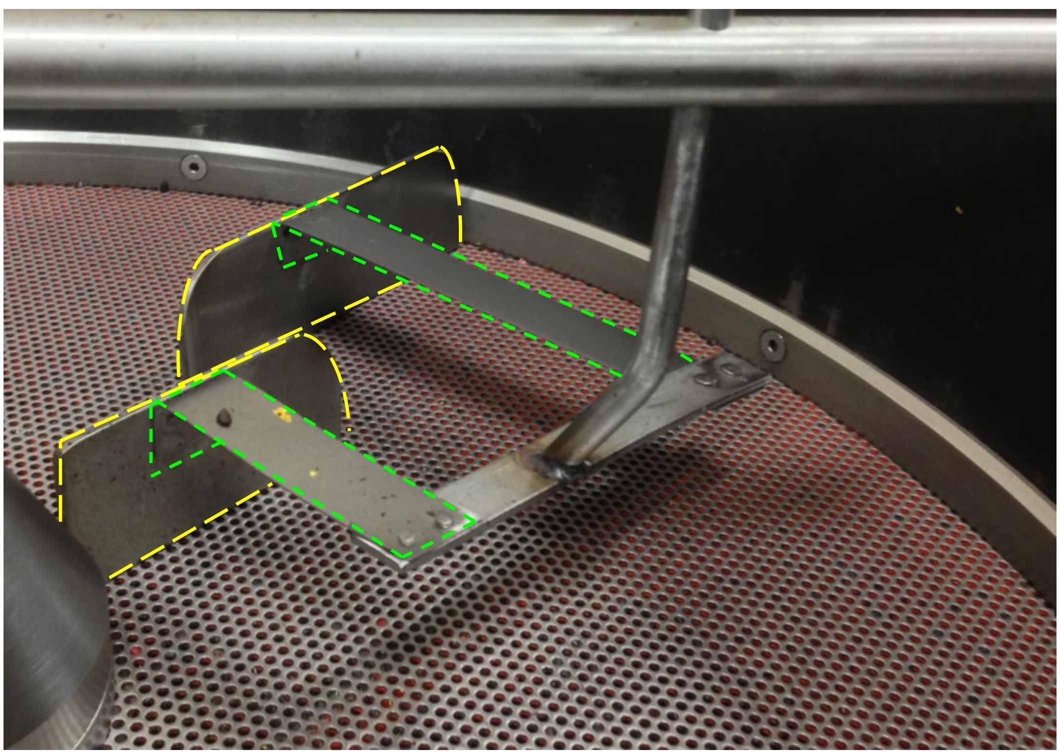

Figure 15: Dragger Attachment.

Project Management

The timeframe for this design project can be seen in the Gantt chart below:

	Task Mode	Task Name	Duration	Start	Finish	Pr
1		Consult with U.S. Roaster Corp. about Prototype Rotary Arm design concepts.	5 days	Mon 1/14/13	Fri 1/18/13	
2		Design Prototype Rotary Arm in Solidworks.	10 days	Mon 1/21/13	Fri 2/1/13	1
3		Prototype Arm Design Selected.	0 days	Mon 2/4/13	Mon 2/4/13	2
4		Send Prototype Design to U.S. Roaster Corp. for fabrication.	0 days	Mon 2/4/13	Mon 2/4/13	3
5		Fabrication of Prototype Rotary Arm by U.S. Roaster Corp.	39 days	Mon 2/4/13	Thu 3/28/13	4
6		Mixing capability test created from ASABE protocol.	2 days	Thu 1/31/13	Fri 2/1/13	
7		Conduct Mixing Capability Tests on Default Arm	21 days	Mon 2/4/13	Mon 3/4/13	6
8		Conduct Mixing Capability Tests on Prototype Arm.	1 day	Tue 4/9/13	Tue 4/9/13	6
9		Conduct Cooling Tests on both rotary arms.	1 day	Wed 4/10/13	Wed 4/10/13	
10		Consolidate data for presentation and design report.	4 days	Fri 4/19/13	Wed 4/24/13	
11		Consult videos for Vacating Speed Tests	1 day	Fri 4/19/13	Fri 4/19/13	
12		Design Presentation	1 day	Thu 4/25/13	Thu 4/25/13	
13		Final Revisions to Design Report	3 days	Mon 4/29/13	Wed 5/1/13	
14		Design Report completed and sent to U.S. Roaster Corp.	0 days	Thu 5/2/13	Thu 5/2/13	13

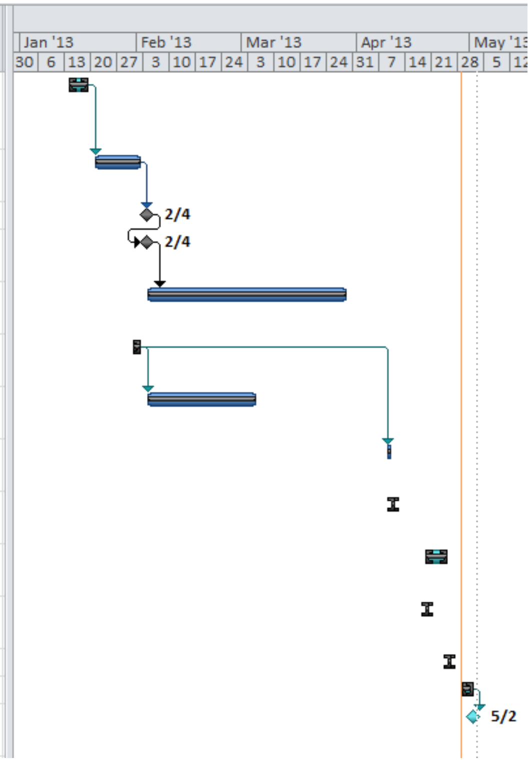

Figure 16: Gantt chart of Coolroast Design Project.

Deliverables

The deliverables that will be given to the U.S. Roaster Corp will include several items. The first item is the technical analyses of the prototype rotary arms that were tested in the model cooling bin, located in Appendix D. The analyses will contain the detailed results of the mixing capability test, cooling test and vacating test. The Coolroast team will also include the estimated cost of labor required to fabricate the design and any possible quirks in the design that may require special equipment to replicate. The CAD drawings of the final rotary arm design will also be delivered to the U.S. Roaster Corp, and will be created in Solidworks. The final item to deliver will be the mixing capability protocol that the Coolroast group derived from the ASABE mixing ability protocol.

Budget

The Coolroast design team was allocated a design budget of $650 by the U.S. Roaster Corp. This means that the overall cost of producing the final product should not exceed $650. This budget does not include the cost of construction of prototypes or the acquisition of materials needed for the testing process; that cost is already covered by the Oklahoma State University funds set aside for the Senior Design course. Ideally, the cost that the U.S. Roaster Corp. should incur for producing this rotary arm design should be under $650. NSF standards dictate that metal items must be constructed from 304 Stainless Steel, which can impact the price of the prototypes. The following table shows the actual cost of producing the final prototype arm:

Table 3: Cost of Prototype

Prototype Arm Costs	
Item	**Cost (U.S. Dollars)**
Materials	$36
Labor	$315
Mixing Test Materials	$59
Total Cost:	$410
Design Budget:	$650
Difference:	($240)

As can be seen from the table, the cost of the actual materials needed to create the prototype rotary arm constitute is only about $36. The majority of the cost comes from labor, which costs approximately $315. Other costs incurred include the purchase of materials needed for the mixing capability test, which includes: differing colors of spray paint for the tracer beans, wooden beads (purchased during the first semester as a possible tracer material), and other stuff. The total cost of the prototype arm plus the testing was about $410, which falls well within the desired $650 design budget set forth by the U.S. Roaster Corp.

Communication and Coordination with Sponsor

The Coolroast design group first met with the U.S. Roaster Corp through a formal meeting between the team members and Dan Jolliff at the company headquarters, located in Oklahoma City, Oklahoma. During that time, the scope of the project was explained and the Coolroast team was given a tour of the U.S. Roaster Corp facilities. The Coolroast team was also shown functional rotary arms that were mounted on the cooling bins that the U.S. Roaster Corp had in storage. The team was also able to see the machining capabilities that the shop mechanics had at their disposal during the construction process.

After the initial meeting with Dan at the U.S. Roaster Corp headquarters, correspondence with the client was carried out via email through the team leader, Drew Sutterfield. By contacting Dan at U.S. Roaster Corp, Drew was able to communicate with Dan as the project progressed. The contact with Dan was consisted primarily of follow-up questions pertaining to the project in general, as the team worked to define the problem in greater detail. As the conversations continued, they shifted more on how construction of the cooling bin was progressing and about details that the business team required from Dan for completion of their analysis. It also included information about of the end of fall semester project presentation.

Team Qualifications

Drew Sutterfield is currently enrolled as a senior undergraduate at Oklahoma State University in Biosystems Engineering, with options in biomechanical and food process engineering. Having been involved with many projects throughout college has observed and developed the personal and technical skills that are required to coordinate a team of engineers effectively throughout a project. Having worked at the Food and Agriculture Products Center under Jake Nelson and Kyle Flynn for the past three years, he has a general knowledge of how the equipment needed for experiments at the Food and Agriculture Products Center operate. During high school welding and shop construction classes Drew developed a sensible view of how difficult or easy a part could be constructed in a shop setting.

Jonathan Lim is an undergraduate student who is currently enrolled at Oklahoma State University. He is currently a senior majoring in Biosystems Engineering (Food Processing option) and is also pursuing a degree in Human Nutrition (Pre-med option). He has worked on several research projects on finding renewable sources of ethanol fuel, and has written a scientific paper on the subject that is currently in the reviewing process. As a Biosystems Engineering students enrolled at OSU, he has a strong background in mechanical engineering subjects and has taken several courses that specifically deal with solving agricultural and environmental engineering problems. He also has learned how to present information to the public through his nutritional science education, and has strong technical writing skills due to the research projects and project reports he has created over the span of his education.

Sibongile Hlatywayo is a senior in Biosystems engineering at Oklahoma State University. She is pursuing a degree option in Bio-Mechanical engineering due to strong interest in mechanical engineering. She has worked under Dr. Marek a professor at Oklahoma state university on plant pathology research giving her a strong background research and project building. Having taken the majority of her core classes in Mechanical engineering she has a strong understanding of mechanical design and problem solving.

Cameron Buswell is a senior Biosystems Engineering (Biomechanical option) student at Oklahoma State University. Having been a part of several design projects throughout college that required CAD, programming, electronics, and fatigue analysis. He understands the steps necessary to complete a successful project and enjoys coming up with creative solutions to problems.

References

1.) Ginn, I. M. 1984. COFFEE-STIRRER. U.S. Patent No. 513,179.

2.) Kando, M., Kishimoto, A., Katsuragi, Y. 2011. METHOD AND DEVICE FOR ROASTING/COOLING BEAN. U.S. Patent No. 2011/0081467A1 .

3.) Smith JR., H.L. 1967. METHOD FOR COOLING ROASTED COFFEE. U.S. Patent No. 3332780.

4.) Song, E. 2011. Coffee Roaster and Controlling Method of Same. U.S. Patent No. 7875833B2.

Appendix A: Résumés of Team Members

Drew Sutterfield

drew.h.sutterfield@okstate.edu
(918) 348-4713

Permanent	Local
1609 Bluestem Rd.	209 1/2 South Duck Street
Fort Gibson, Oklahoma 74434	Stillwater, Oklahoma 74074

OBJECTIVE:

To secure a position within a reputable engineering company as an entry-level engineer that challenges me to incorporate the knowledge and work ethic that I have developed throughout my life, as well as allowing me to expand my field of experience and learn new material.

SUMMARY:

A Biosystems and Agricultural Engineering senior that has worked diligently to complete my degree within four years, with an above average grade point average. While developing relationships and friendships in college I have succeeded greatly and have had an enjoyable experience. I am extremely proud of my influential work during each of the past four summers to take time out of my schedule to be a counselor at Oklahoma Boys State; where high school seniors learn how our government and politics operate, as well as what patriotism truly is. I have had the privilege to work with approximately two hundred students through this program.

Skills and Accomplishments

- Acting as a Senior Counselor at Oklahoma Boys State in 2012
- Funding my college career by working on campus at the Food and Ag Products Center and through scholarships and other financial aid.
- Extensive knowledge of computers and intuitive ability to utilize them

Education:

Oklahoma State University	Stillwater, Oklahoma
Candidate for Bachelor of Science in Biosystems and Agricultural Engineering	August 2009-Present
	G.P.A. 3.43

Specific in Biomechanical Engineering and Food Engineering

Professional Experience:

Oklahoma State University Food and Agricultural Products Center, Stillwater, Oklahoma, Summer 2010-Present

-Harvesting meat from beef, swine, and lambs on the harvest floor
-Gaining experience in working with a supervisor and other students
-Incorporating Agricultural Engineering within a meat processing plant
-Working first-hand with a Suspentech/Cozzini Fat Injection System

Drew.Sutterfield's Auto Detailing, Fort Gibson, Oklahoma, Summer 2009
- Learned how to financially manage a self-employed business

JONATHAN C. LIM

jclim@ostatemail.okstate.edu **4005 W 32nd Avenue**
(405) 269-2137 **Stillwater, OK 74074**

EDUCATION

Bachelor of Science in Biosystems Engineering, Food Processing Option (Expected: 2013)
Bachelor of Science in Human Nutritional Sciences (Expected: 2012)
Oklahoma State University, Stillwater, OK
GPA: 3.315/4.000

Oklahoma Regents Scholarship, 2005 – 2009

SELECTED SKILLS AND ACCOMPLISHMENTS

- Created an electronic control system that regulated humidity, moisture, and temperature for a model-scale greenhouse.
- Experienced with using Arduino Pro Mini microcontrollers and Arduino programming language.
- Completed NIH Web-based training course "Protecting Human Research Participants".

PROFESSIONAL EXPERIENCE

Undergraduate Researcher ***MAY 2012 – SEPTEMBER 2012***
Oklahoma State University **Stillwater, OK**

- Performed enzymatic assay experiments to ascertain the amount of starch in Sweet Sorghum samples.
- Studied technical literature to understand the workings of sugarbeet and sugarcane extraction facilities in the United States and overseas.
- Communicated with different companies to find and purchase a suitable assay kit for the research project.
- Created experimental samples as directed by the assay protocol.

Undergraduate Researcher ***MAY 2010 – AUGUST 2010***
Oklahoma State University **Stillwater, OK**

- Designed and performed experiments to discover the viability of using soft drinks as a source of ethanol fuel.
- Wrote a scientific paper detailing the methodology of the research project and results of the research project.
- Worked with a university professor to assess the importance of each experiment.
- Created Excel spreadsheets and graphs with appropriate functions and equations to consolidate the relevant experimental data.

Cameron Mancill Buswell
cameron.buswell@okstate.edu | (405)-416-0547
409 ½ South Duncan Apt. A, Stillwater, OK 74074

SKILLS AND ACCOMPLISHMENTS

Familiar with MS Word, Excel, Visual Basic, Pro-Engineer, and Solid Works.

Raced in the 2009 and 2010 Mountain Bike National Championships in Granby, CO.

Former Vice President and Mountain Bike Officer of the Oklahoma State University Cycling Club.

Have a Cat. 1 USA Cycling Mountain Bike License and race for Schlegel Bicycles and OSU Cycling.

Eagle Scout-Troop 117

EDUCATION

Oklahoma State University| Stillwater, OK Projected May 2013
Bachelor of Science: Biosystems Engineering - Biomechanical Engineering Option

EXPERIENCE

District Bicycles | Stillwater, OK Summer 2012
Mechanic

- Performed repairs, built new bikes, and helped customers with questions.

Oklahoma State University| Stillwater, OK Summer 2011
Carpentry Department

- Assisted with various projects throughout campus, primarily in the student housing complexes.

YMCA of the Rockies | Estes Park, CO
Building and Grounds/ Food Service Summer 2010

- Being a third-year staff member, I took on a more supervisory role for the AM kitchen crew and delegated instructions to newer employees.

Food Service Summer 2009

- As a returning staff member I was given additional responsibilities in the kitchen.

Food Service Summer 2008

- Learned how a large scale kitchen operates and basic cooking skills.

D-TABB & Associates | Oklahoma City, OK Summer 2006
Modular Furniture Mover and Installer

Sibongile Faith Hlatywayo

89 S University Place apt. 3 *405-880-5292*
Stillwater OK 74075 *sibongile.hlatwayo@okstate.edu*

Bachelor of Science in Bio-Mechanical Engineering
Oklahoma State University, Stillwater, Oklahoma

Professional Experience
Technician
Oklahoma State University, Stillwater OK, *May 2011-May 2012*

- Activate data control rooms
- Troubleshoot internet outages
- Install wireless internet coverage

Library Associate
Oklahoma State University, Stillwater, Oklahoma, August 2008-August 2009

- Serviced students by checking out items using computer system voyage
- Shelved books using numeric number system

Lab assistant
Plant Pathology Dept., Oklahoma State University, Stillwater, Oklahoma, *August 2005- May 2007*

- Assisted graduate students with research
- Autoclaved material, kept the research area sterile
- Watered and planted researched plants in the green house
- Prepared algae for the testing of Medicago truncatula mutants

TECHNICAL SKILLS

- Visual Basic
- Proficient with Microsoft Office programs, including MS Word, MS Excel, MS Power Point, MS Outlook
- Solid Works

LEADERSHIP
Internship
Heifer International Ranch, Perryville, Arkansas, May 2007- August 2007

- Proved experiential education to the visitors
- Taught a class about promoting sustainable solutions to global hunger and poverty

Student Organizations
Cultural Coordinator of African students Organization, Oklahoma state university, Stillwater Oklahoma, *May 2011-May 2012*

Appendix B: Detailed Protocol – Mixing Capability Test

This protocol was created by modifying the ASABE Standard 380 (December 1995).
NOTE: This protocol was intended to work with the 12-kg model coffee roaster machines manufactured by the U.S. Roaster Corp, and is described as such. The method behind the protocol may allow it to be applied to other machines of similar make and size, but it has so far been untested on anything smaller or larger than a 12-kg coffee roaster cooling bin.

REQUIRED MATERIALS

- **COOLING BIN COMPONENT OF COFFEE ROASTER MACHINE**
  - Protocol assumes that the cooling bin is the approximate size of the cooling bin that is attached to the 12-kg model of the coffee roaster machine manufactured by the U.S. Roaster Corp.
- **LARGE WEIGHING SCALE**
  - Should be capable of measuring weights up to a minimum of 30 kilograms // 66 pounds, and within two or more decimal places.
- **SMALL WEIGHING SCALE**
  - Should be capable of measuring weights up to a minimum of 200g within two or more decimal places.
- **12 (TWELVE) KILOGRAMS // 26.46 POUNDS OF ROASTED COFFEE BEANS**
- **SPRAY PAINT, NON-BROWN COLOR**
- **STOPWATCH, OR OTHER TIMING DEVICE**
- **OPTIONAL: RECORDING DEVICE**
  - Video cameras, cellphone cameras, etc.
- **6 (SIX) CYLINDRICAL SAMPLING CONTAINERS OF THE SAME SIZE/VOLUME**
  - Containers should hold approximately 8 ounces of fluid.
  - Approximate Diameter: 4-5 inches.
  - Approximate Height: 4-5 inches.

TRACER MATERIAL PREPARATION

1. Weigh out and record the total mass of coffee beans used in the mixing test (12 kg).

2. Measure out 10% of the total mass of roasted coffee beans that are being used for this protocol (1.2kg // 2.65 lbs.). This particular mass of coffee beans will now be known as the **"tracer beans"**, or **"tracers"**.

3. Set aside the remaining 90% of roasted coffee beans in a separate container. This mass of coffee beans will now be known as the **"stock beans"**, or **"stock material"**.

4. Prepare an area for spray-painting.
   a. ***Ensure that proper overspray measures are taken so that the spray paint will not stain anything that was not intended to be painted!!!***

   b. Ensure that proper protective gear is worn by the person/people handling the spray paint and/or working around the area in which the spray-painting will occur.

5. Evenly distribute the tracer beans across a surface that is prepared to receive spray-paint. This surface should be covered with a disposable material, such as a sheet of plastic or a disposable trash bag.

6. Coat the tracer beans with a layer of spray-paint; ensure that all the beans are painted.

7. Allow the spray-painted beans to dry for approximately 1 day.

8. After drying, flip over the tracer beans to expose the unpainted side of the tracer beans and coat the other side of the tracer beans with a layer of spray-paint.

9. Allow the spray-painted beans to dry for approximately 1 day.

10. After drying, remove the spray-painted tracer beans from the prepared surface, making sure that none of the tracers have stuck to the surface on which they were painted on.

11. Weigh out the spray-painted tracer beans. The added weight of the paint should not exceed 20% of the unpainted tracer bean weight.

12. Store the tracer beans in a proper container; a disposable trash bag should suffice.

MIXING CAPABILITY TEST PROCEDURE

1. Ensure that cooling bin is able to function and is connected to an appropriate power source.

2. Set cooling bin fan capacity to 100% and mixing speed to 100%.

3. Deposit stock beans evenly in cooling bin. The surface of the stock beans should be as level as possible.

4. Deposit tracer beans evenly across the surface of the stock beans (see picture below).
    a. *Optional: ensure that recording media (i.e. video cameras, cellphones) are prepared to record mixing capability test.*

5. Ensure that the fan capacity for the bin is set to 100%, and activate the fan for the cooling bin.

(continued on next page)

6. Ensure that the mixing speed of the cooling bin is set to 100% speed, and activate the stirring mechanism.

   a. *Optional: begin recording of mixing capability test.*

7. Allow the tracer beans to mix with the stock beans for 3 minutes.

8. After 3 minutes, de-activate the cooling bin's stirring mechanism and fan.

   a. *Optional: stop recording of mixing capability test.*

9. Collect sampling containers, and label containers distinctly. Each container should be recognizable from the other containers.

10. Distribute sampling containers throughout the bean mixture; each container should be placed so that it can represent a certain area of the cooling bin. See the below picture for an example of this distribution. **Note and record the placement of the containers for later reference.**

(continued on next page)

11. Collect bean samples from the places where the sampling containers were placed. The total amount of beans in each container should be roughly equal.

12. Activate the small weighing scale. Adjust the weight scale to grams, and the amount of decimal places to two or more.

NOTE: ***The following steps are easier to perform with a premade datasheet. See Appendix C for example datasheets with instructions that can be used for recording and data and making the necessary calculations.***

13. Locate notebook or other media that can be used to record data, or use the example datasheets provided. Write down the current date.

14. Get one of the full sample containers, and record the labeling of the container.

15. Deposit the contents of the container on a nearby surface. **Do not throw away the beans.**

16. Separate all of the tracer beans from the stock beans.

17. Put the empty container on the small weighing scale. When the weight settles, press the “tare” or “zero” button. This ensures that the weight of the sampling container will be taken into account for each of the sample measurements.

18. Deposit the stock beans into the empty container on the scale. Read and record the weight displayed by the scale. This value is known as the **“Mass of Stock Beans”**.

19. Empty out the container of the stock beans, and put the empty container on the scale. When the weight settles, press the “tare” or “zero” button to zero out the weight.

20. Deposit the tracer beans into the empty container on the scale. Read and record the weight displayed by the scale. This value is known as the **“Mass of Tracer Beans”**.

21. Repeat steps 13-20 for all sample containers.

22. Record all data on a sheet or in a notebook, or on the example datasheets provided after these instructions.

23. Calculate the Mass Percentage of Tracer in each sample. See example datasheets for calculation information.

24. Calculate the Average Mass Percentage of Tracer for the mixing capability test. See example datasheets for calculation information.

25. Calculate the Sample Standard Deviation for the mixing capability test. See example datasheets for calculation information.

26. If another mixing capability test is desired, repeat steps 1-25 for another batch of beans.

   a. The **Tracer Material Preparation** procedure will need to be carried out again. At this point, all of the beans used in the last test can be discarded and the procedure for **Tracer Material Preparation** can be performed once more.

27. Once all of the desired mixing capability tests have been carried out, record the values for the **Average Mass % Tracer** for each mixing capability test and the **Standard Deviation** values for each mixing capability test.

28. Following the example datasheet, calculate the **Average Mass % Tracer** for ALL of the mixing tests performed and the **Average Standard Deviation** values for ALL of the mixing tests performed.

29. Repeat steps 1-26, and steps 27-28 for any additional rotary arm designs.

Appendix C: Mixing Capability Test Datasheets

ARM TYPE: *DEFAULT*	**MIXING CAPABILITY TEST:** *EXAMPLE*		**DATE:** *5/3/2015*	**TRACER COLOR:** *YELLOW*
SAMPLE CONTAINER LABEL	**MASS OF TRACER BEANS (g)**	**MASS OF STOCK BEANS (g)**	**MASS % TRACER**	**AVERAGE % TRACER FOR THIS TEST**
EXAMPLE #1	13.45	63.44	$(100) \times \frac{13.45}{13.45 + 63.44}$ = 17.49	$= \frac{SUM\ OF\ MASS\ \%\ TRACER}{NUMBER\ OF\ SAMPLES}$ $= \frac{17.49 + 16.95 + 18.01 + 13.75 + 14.31 + 16.91}{6}$ $=$ 16.24
EXAMPLE #2	12.33	60.42	16.95	
EXAMPLE #3	15.24	69.13	18.01	
EXAMPLE #4	10.58	66.39	13.75	
EXAMPLE #5	11.37	68.11	14.31	
EXAMPLE #6	13.71	67.38	16.91	

ARM TYPE: *DEFAULT*	**MIXING CAPABILITY TEST:** *EXAMPLE* STANDARD DEVIATION CALCULATIONS	**DATE:** *5/3/2015*	**TRACER COLOR:** *YELLOW*

% TRACER	AVERAGE % TRACER	(% TRACER – AVERAGE % TRACER)^2	STANDARD SAMPLE DEVIATION FOR THIS MIXING CAPABILITY TEST
17.49	16.24	$= (16.24 - 17.49) \times (16.24 - 17.49)$ $= 1.56$	$= \sqrt{\frac{1}{\# \, Samples - 1} \times (1.56 + 0.50 + 3.31 + 6.20 + 3.73 + 0.45)}$
16.95	16.24	$= 0.50$	$= \sqrt{\frac{1}{6 - 1} \times (1.56 + 0.50 + 3.31 + 6.20 + 3.73 + 0.45)}$
18.01	16.24	$= 3.31$	$= \sqrt{\frac{1}{5} \times (15.65)}$
13.75	16.24	$= 6.20$	$= \mathbf{1.77}$
14.31	16.24	$= 3.73$	
16.91	16.24	$= 0.45$	

ARM TYPE: *DEFAULT*	**MIXING CAPABILITY TEST:** EXAMPLE SUMMARY OF MIXING TESTS			**DATE:** *5/3/2015*	**TRACER COLOR:** *YELLOW*
MIXING TEST	**AVERAGE % TRACER (%)**	**TOTAL % TRACER PER TEST**	**STANDARD DEVIATION**	**AVERAGE % TRACER FOR MIXING TESTS #1-6**	**AVERAGE STANDARD DEVIATION FOR MIXING TESTS #1-6**
1	16.24	10	1.77	=(16.24 + 15.24 + 14.28 + 12.56 + 16.01+ 15.75) x (1/6) **= 15.01**	= (1.77+1.65+1.52+ 1.38 + 1.62+1.57) X (1/6) **= 1.59**
2	15.24	10	1.65		
3	14.28	10	1.52		
4	12.56	10	1.38		
5	16.01	10	1.62		
6	15.75	10	1.57		

ARM TYPE:	MIXING CAPABILITY TEST:			DATE:	TRACER COLOR:
SAMPLE CONTAINER LABEL	MASS OF TRACER BEANS (g)	MASS OF STOCK BEANS (g)	MASS % TRACER	AVERAGE % TRACER FOR THIS TEST	

<table>
<tr><td><u>ARM TYPE:</u></td><td colspan="2"><u>MIXING CAPABILITY TEST:</u>

STANDARD DEVIATION CALCULATIONS</td><td><u>DATE:</u></td><td><u>TRACER COLOR:</u></td></tr>
<tr><td><u>% TRACER</u></td><td><u>AVERAGE % TRACER</u></td><td><u>(% TRACER – AVERAGE % TRACER)^2</u></td><td colspan="2"><u>STANDARD SAMPLE DEVIATION
FOR THIS MIXING CAPABILITY TEST</u></td></tr>
<tr><td></td><td></td><td></td><td colspan="2" rowspan="6"></td></tr>
<tr><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

ARM TYPE:	**MIXING CAPABILITY TEST:** SUMMARY OF MIXING TESTS			**DATE:**	**TRACER COLOR:**
MIXING TEST	**AVERAGE % TRACER (%)**	**TOTAL % TRACER PER TEST**	**STANDARD DEVIATION**	**AVERAGE % TRACER FOR MIXING TESTS #1-6**	**AVERAGE STANDARD DEVIATION FOR MIXING TESTS #1-6**

Appendix D: Detailed Results – Mixing Capability Test

-	*Tracer Color: White*	**Mixing Test #1 (2/4/2013)**	*Default Arm*		-
CUP	**MASS OF TRACER BEANS (g)**	**TOTAL MASS OF BEANS (g)**	**% TRACER**	**AVERAGE % TRACER IN SAMPLES**	**Standard Deviation**
6-3	10.4	63.5	16.38	12.01	2.59
6-6	7.2	76.9	9.363		
6-7	8.3	64.4	12.89		
6-9	8.5	69.6	12.21		
6-11	8.7	74.2	11.73		
6-15	7.3	77.1	9.468		

-	*Tracer Color: White*	**Mixing Test #2 (2/13/2013)**	*Default Arm*	-	-
CUP	**MASS OF TRACER BEANS (g)**	**TOTAL MASS OF BEANS (g)**	**% TRACER**	**AVERAGE % TRACER IN SAMPLES**	**Standard Deviation**
6-3	12.86	76.64	16.78	13.18	3.19
6-6	9.38	59.43	15.78		-
6-7	6.99	60.25	11.60		
6-9	8.23	56.97	14.45		
6-11	5.14	64.03	8.027		
6-15	7.54	60.61	12.44		

-	*Tracer Color: White*	**Mixing Test #3 (2/18/2013)**	*Default Arm*		
CUP	**MASS OF TRACER BEANS (g)**	**TOTAL MASS OF BEANS (g)**	**% TRACER**	**AVERAGE % TRACER IN SAMPLES**	**Standard Deviation**
6-3	7.8	61.4	12.70	13.13	1.79
6-6	8.3	60	13.83		
6-7	6.8	56	12.14		
6-9	9.5	58.4	16.27		
6-11	6.4	58.1	11.02		
6-15	7.9	61.6	12.82		

-	*Tracer Color: Yellow*	**Mixing Test #4 (3/4/2013)**	*Default Arm*		
CUP	**MASS OF TRACER BEANS (g)**	**TOTAL MASS OF BEANS (g)**	**% TRACER**	**AVERAGE % TRACER IN SAMPLES**	**Standard Deviation**
6-3	8.4	67.6	12.43	14.15	1.21
6-6	8.3	61.9	13.41		
6-7	9.6	62.1	15.46		
6-9	8.9	63.7	13.97		
6-11	8.4	59.9	14.02		
6-15	9.4	60.3	15.59		

-	*Tracer Color: Red*	**Mixing Test #5 (3/4/2013)**	*Default Arm*		
CUP	**MASS OF TRACER BEANS (g)**	**TOTAL MASS OF BEANS (g)**	**% TRACER**	**AVERAGE % TRACER IN SAMPLES**	**Standard Deviation**
6-3	7.16	60.06	11.92	11.73	3.07
6-6	10.3	59.4	17.34		
6-7	6.4	60.4	10.60		
6-9	5.5	62.3	8.828		
6-11	6.9	56.1	12.30		
6-15	5	53.3	9.381		

-	*Tracer Color: Green*	**Mixing Test #6 (3/4/2013)**	*Default Arm*		-
CUP	**MASS OF TRACER BEANS (g)**	**TOTAL MASS OF BEANS (g)**	**% TRACER**	**AVERAGE % TRACER IN SAMPLES**	**Standard Deviation**
6-3	7.3	62.4	11.70	13.51	4.71
6-6	12.5	58.4	21.40		
6-7	5.8	61.5	9.431		
6-9	5.3	57.4	9.233		
6-11	6.9	54.6	12.64		
6-15	8.9	53.5	16.64		

-	*Tracer Color: White*	**Mixing Test #7 (4/10/2013)**	*Prototype Arm*		
CUP	**MASS OF TRACER BEANS (g)**	**MASS OF NON-TRACER BEANS (g)**	**TOTAL MASS OF BEANS (g)**	**% TRACER**	**Standard Deviation**
6-3	4.76	48.93	53.69	8.866	2.8626
6-6	8.39	48.22	56.61	14.821	
6-7	5.42	50.02	55.44	9.776	
6-9	3.47	52.17	55.64	6.237	
6-11	6.28	47.94	54.22	11.582	
6-15	5.22	47.01	52.23	9.994	

-	*Tracer Color: Red*	**Mixing Test #8 (4/10/2013)**	*Prototype Arm*		
CUP	**MASS OF TRACER BEANS (g)**	**MASS OF NON-TRACER BEANS (g)**	**TOTAL MASS OF BEANS (g)**	**% TRACER**	**Standard Deviation**
6-3	6.03	51.74	57.77	10.438	1.2401
6-6	5.81	49.64	55.45	10.478	
6-7	6.91	49.69	56.6	12.208	
6-9	5.29	51.86	57.15	9.256	
6-11	6.55	45.41	51.96	12.606	
6-15	6.15	48.97	55.12	11.157	

-	*Tracer Color: Blue*	**Mixing Test #9 (4/10/2013)**	*Prototype Arm*		
CUP	MASS OF TRACER BEANS (g)	MASS OF NON-TRACER BEANS (g)	TOTAL MASS OF BEANS (g)	% TRACER	Standard Deviation
6-3	6.47	45.57	52.04	12.433	1.4815
6-6	4.79	48.64	53.43	8.965	
6-7	4.49	51.24	55.73	8.057	
6-9	5.63	52.45	58.08	9.694	
6-11	4.83	44.25	49.08	9.841	
6-15	5.84	50.36	56.2	10.391	

-	*Tracer Color: Yellow*	**Mixing Test #10 (4/10/2013)**	*Prototype Arm*		
CUP	MASS OF TRACER BEANS (g)	MASS OF NON-TRACER BEANS (g)	TOTAL MASS OF BEANS (g)	% TRACER	Standard Deviation
6-3	6.71	47.25	53.96	12.435	2.1182
6-6	4.01	44.14	48.15	8.328	
6-7	5.28	49.95	55.23	9.560	
6-9	3.36	46.05	49.41	6.800	
6-11	5.4	50.65	56.05	9.634	
6-15	6.21	46.15	52.36	11.860	

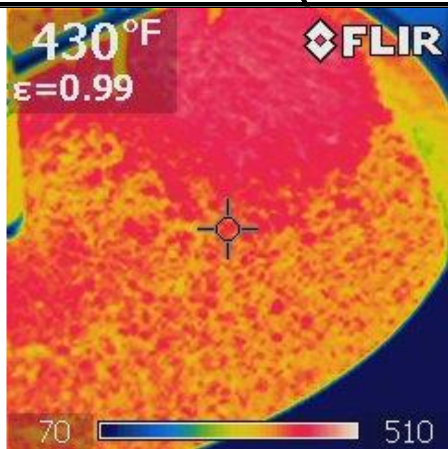
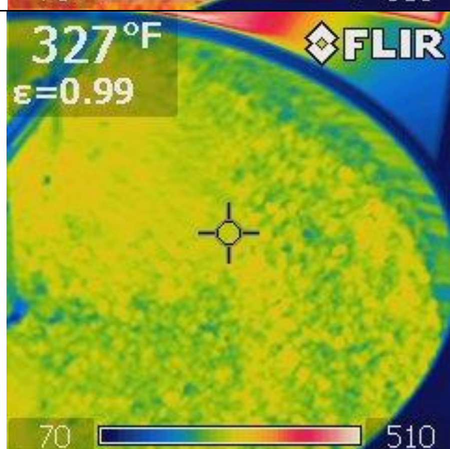
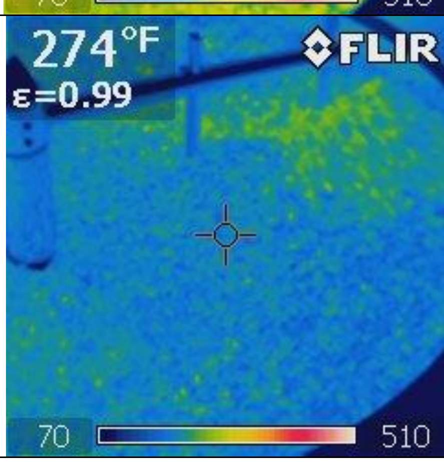
Mixing Test	**Mixing Arm Type**	**Tracer Color**	**Average Mass % of Tracers (%)**	**Standard Deviation (%)**
1	Default	White	12.01	2.586
2	Default	White	13.18	3.191
3	Default	White	13.13	1.792
4	Default	Yellow	14.15	1.213
5	Default	Red	11.73	3.068
6	Default	Green	13.51	4.713
7	**Prototype**	**White**	**10.21**	**2.863**
8	**Prototype**	**Red**	**11.02**	**1.240**
9	**Prototype**	**Blue**	**9.90**	**1.482**
10	**Prototype**	**Yellow**	**9.77**	**2.118**

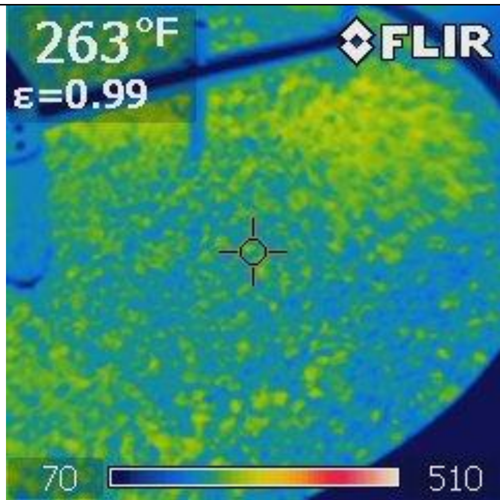
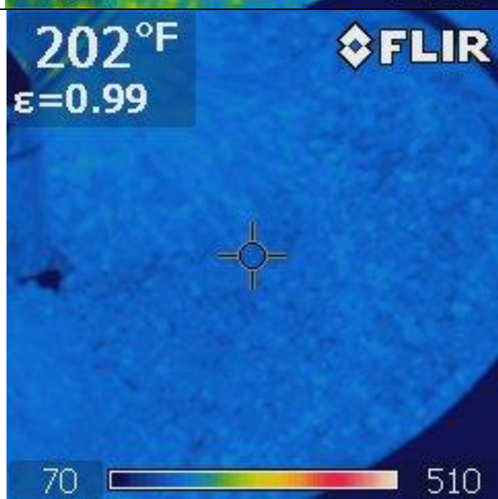
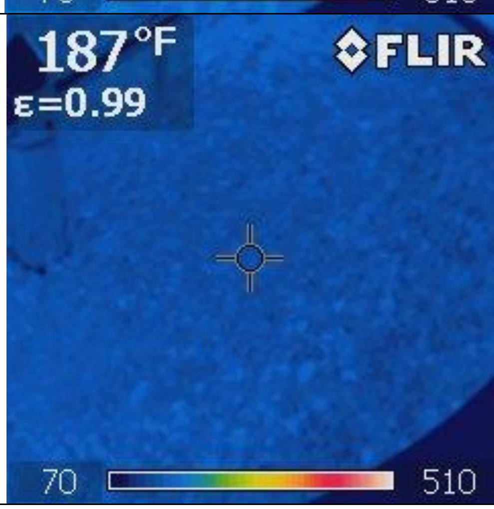
Mixing Test	Mixing Arm Type	Tracer Color	Average Mass % of Tracers (%)	Total Mass % of Tracers per batch (%)	Absolute Mass % Difference
1	Default	White	12.01	10	2.01
2	Default	White	13.18	10	3.18
3	Default	White	13.13	10	3.13
4	Default	Yellow	14.15	10	4.15
5	Default	Red	11.73	10	1.73
6	Default	Green	13.51	10	3.51
7	**Prototype**	**White**	**10.21**	**10**	**0.21**
8	**Prototype**	**Red**	**11.02**	**10**	**1.02**
9	**Prototype**	**Blue**	**9.90**	**10**	**0.10**
10	**Prototype**	**Yellow**	**9.77**	**10**	**0.23**

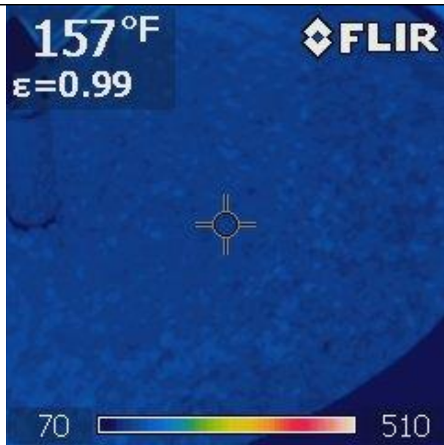
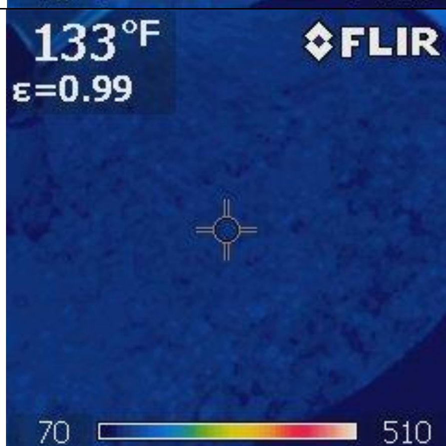
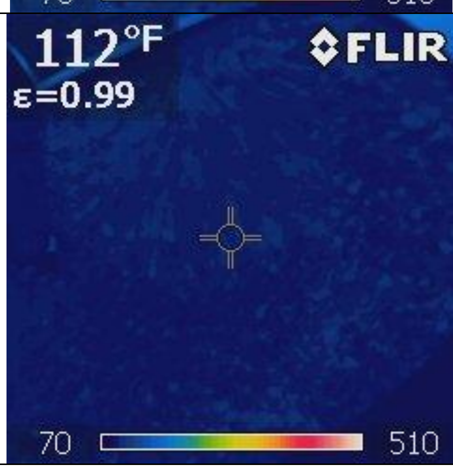
Mixing Tests	Mixing Arm Type	Average Mass % of Tracers (%)	Mass % of Tracers in Batch (%)	Absolute Mass % Difference	Lowest Standard Deviation (Best-Case)	Highest Standard Deviation (Worst-Case)	Average Standard Deviation
1-6	Default	12.95	10	2.952	1.213	4.713	2.760
7-10	**Prototype**	**10.23**	**10**	**0.225**	**1.240**	**2.863**	**1.926**

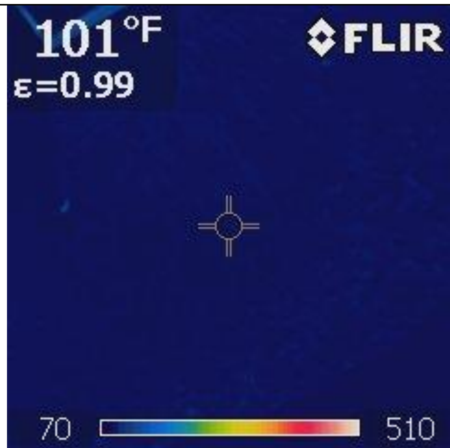
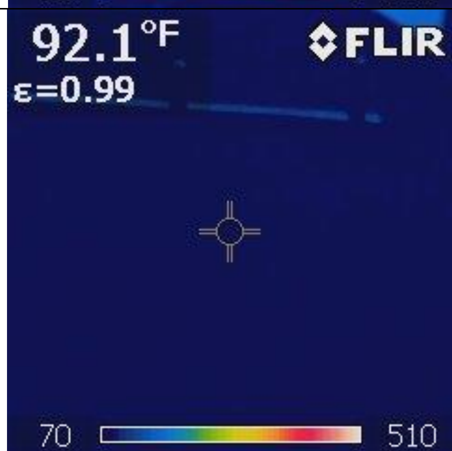
Appendix E: Detailed Results – Cooling Test

IR pictures – Default Rotary Arm (Picture taken every 30s):

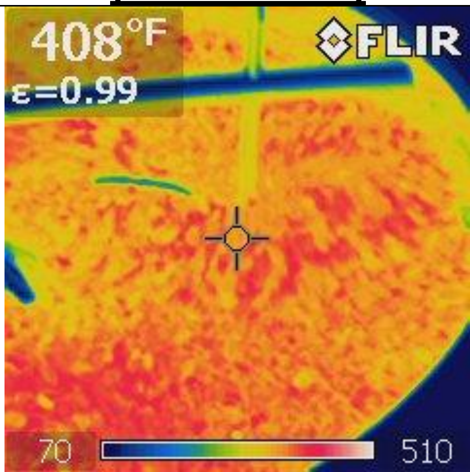
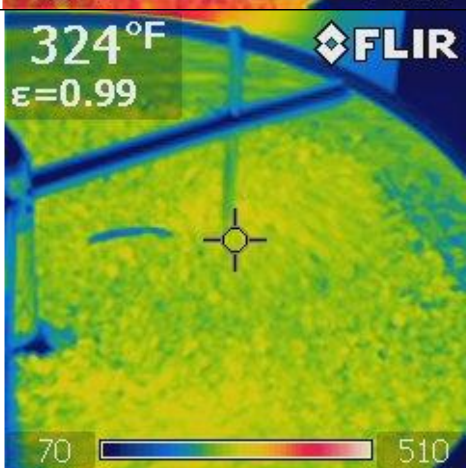
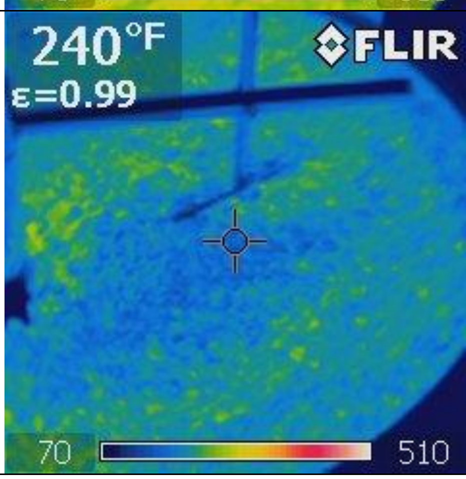
INFRARED IMAGE (DEFAULT)	TIME (MIN : SECONDS)
	**0:00**
	**0:30**
	**1:00**

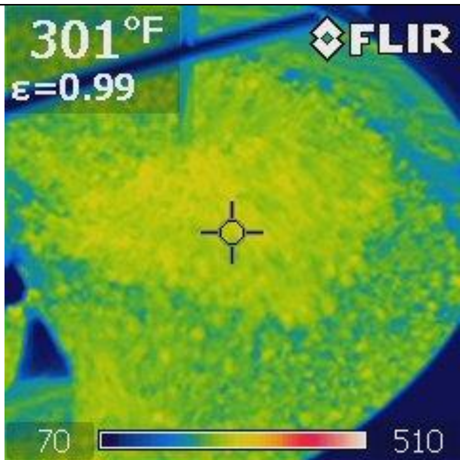
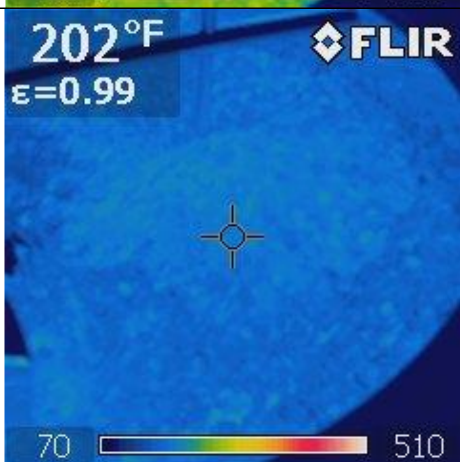
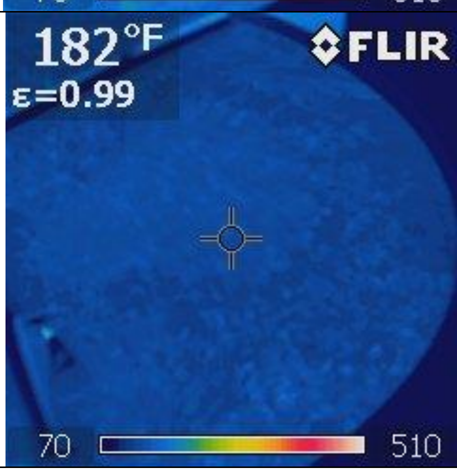
263°F ε=0.99 FLIR 70 510	**1:30**
202°F ε=0.99 FLIR 70 510	**2:00**
187°F ε=0.99 FLIR 70 510	**2:30**

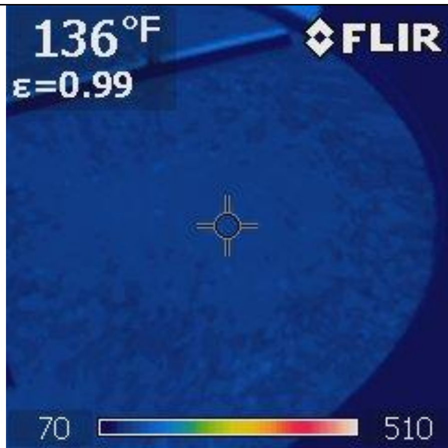
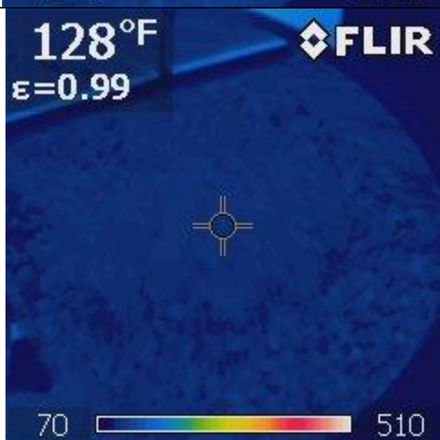
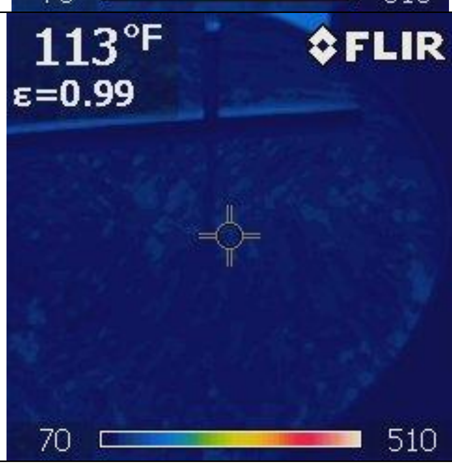
 157°F ε=0.99 FLIR 70 510	**3:00**
 133°F ε=0.99 FLIR 70 510	**3:30**
 112°F ε=0.99 FLIR 70 510	**4:00**

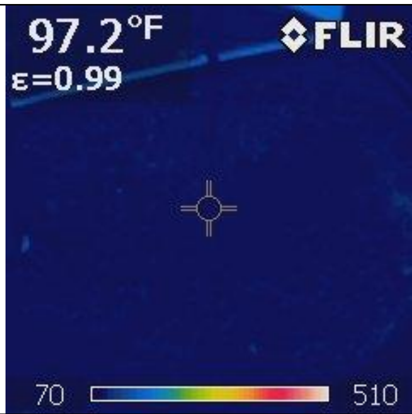
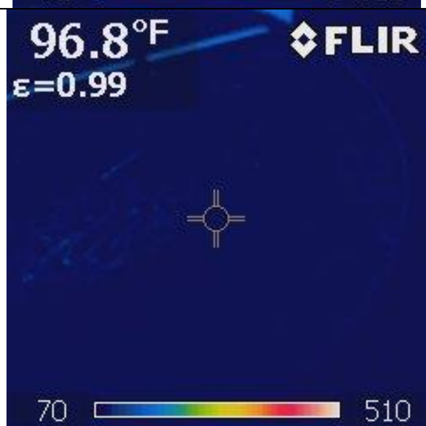
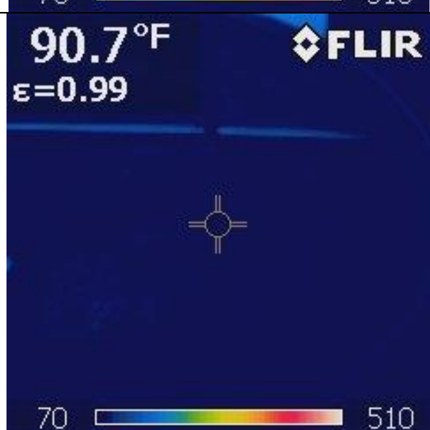
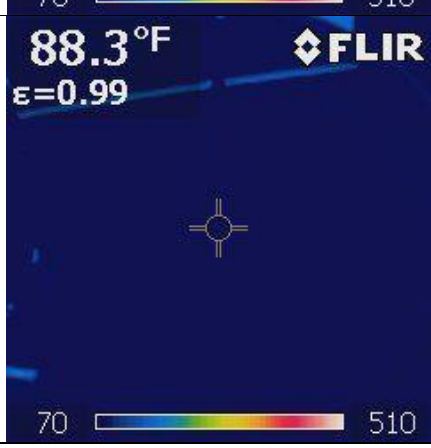
 101°F ε=0.99 FLIR 70 510	**4:30**
 92.1°F ε=0.99 FLIR 70 510	**5:00**
 85.6°F ε=0.99 FLIR 70 510	**5:30**

IR Pictures – Prototype Arm (Picture Taken every 30s):

INFRARED IMAGE (PROTOTYPE)	TIME (MIN : SECONDS)
	**0:00**
	**0:30**
	**1:00**

301°F ε=0.99 FLIR 70 510	**1:30**
202°F ε=0.99 FLIR 70 510	**2:00**
182°F ε=0.99 FLIR 70 510	**2:30**

 136°F ε=0.99 FLIR 70 510	**3:00**
 128°F ε=0.99 FLIR 70 510	**3:30**
 113°F ε=0.99 FLIR 70 510	**4:00**

	**4:30**
	**5:00**
	**5:30**
	**6:00**

COOLROAST & US Roaster Corp

Rotary Arm Redesign to Improve Mixing Capabilities of Coffee Roasters

CoolRoast Engineering Design Group:

Drew Sutterfield, Sibongile Hlatywayo,

Cameron Buswell, Jonathan Lim

US Roaster Corp

- Founded by Dan Jolliff over 33 years ago in Oklahoma City, US Roaster Corp excels in providing affordable coffee roasters of all sizes that suit their client’s individual needs.

Competitors

- Probat
  - Founded in Germany in 1868
  - Foremost competitor for U.S. Roaster Corp
  - Represented in over 60 countries worldwide.
- Diedrich Manufacturing
  - Founded in California in 1980
  - Operate 60 coffee houses across country

Project Outline

1. Improve mixing capability within cooling bin
2. Quantify mixing capability
3. Investigate cooling of beans
4. More visually appealing design

Analysis of Default Arm

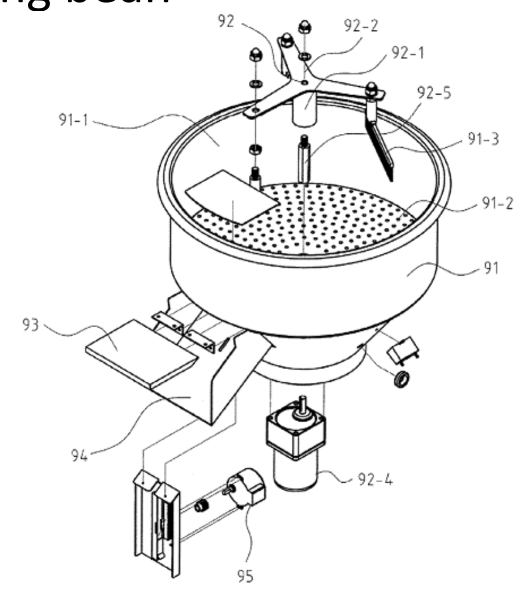
- Noticed ‘dead zone’ on the edges
- Didn’t move beans effectively around bin

Improvement Ideas

- Increase movement of beans from the top to the bottom of the bin and vice versa
- Increase surface area of implements
- Create recirculation of beans around the bin

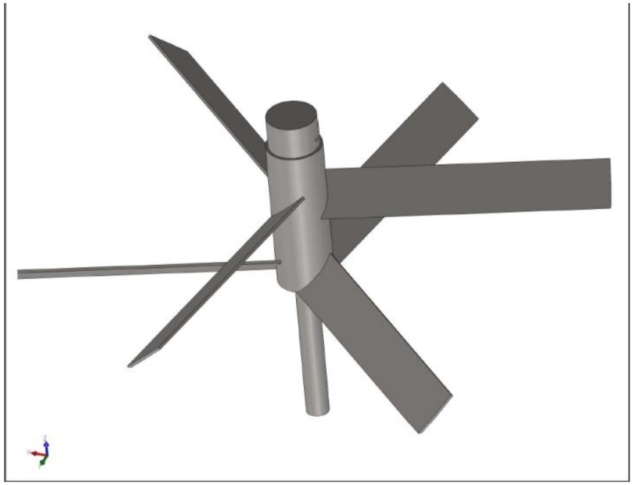
Patent Search

- Most of the patents dealt with commercial production of coffee, not small batch roaster machines
- Song, E. “Coffee roaster and controlling method of same”.
  - U.S. Patent #7875833B2. January 25, 2011.
- Kando, M., et all. “Method and device for roasting/cooling bean”
  - U.S. Patent #2011/0081467A1 . April 7, 2011.
- Smith JR., H.L. “Method for cooling roasted
  - U.S. Patent #3332780. July 25, 1967.

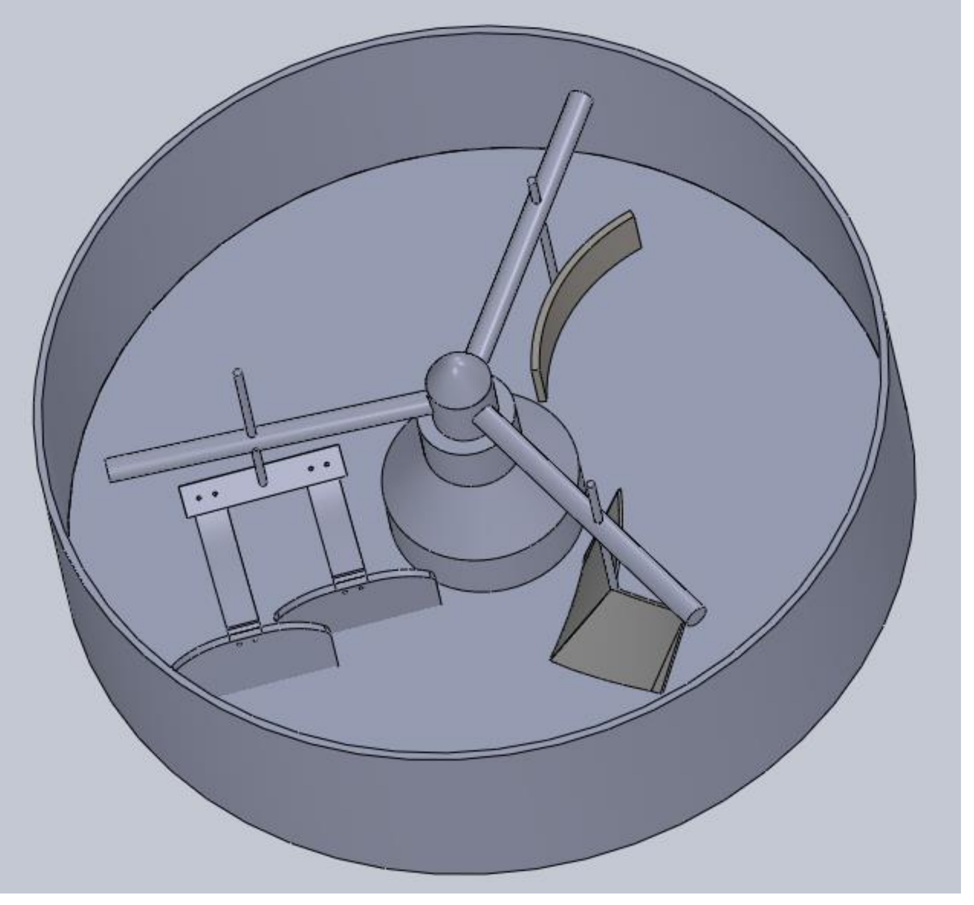


Initial Design Concepts

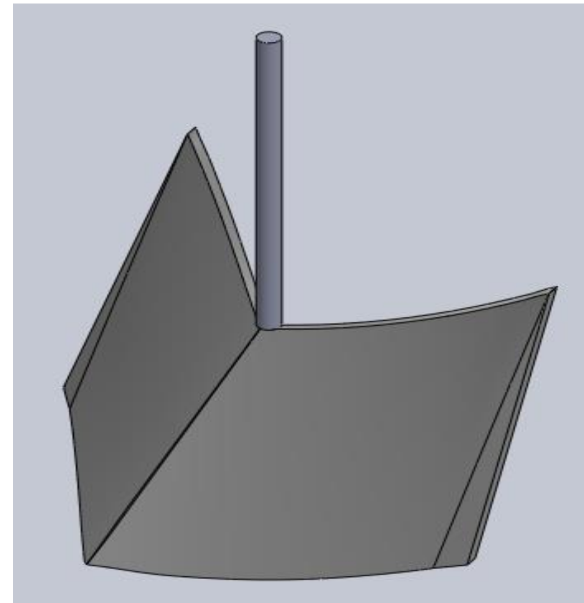
- Initial ideas for arm designs
- U.S. Roaster Corp. pointed out issues with both
- Met with US Roaster to discuss new ideas



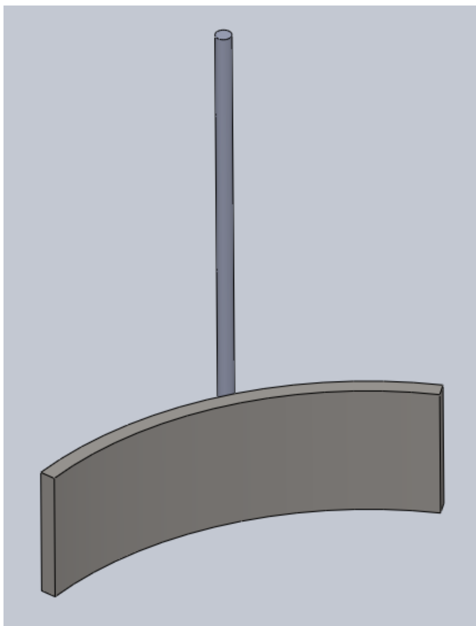
First Constructed Prototype

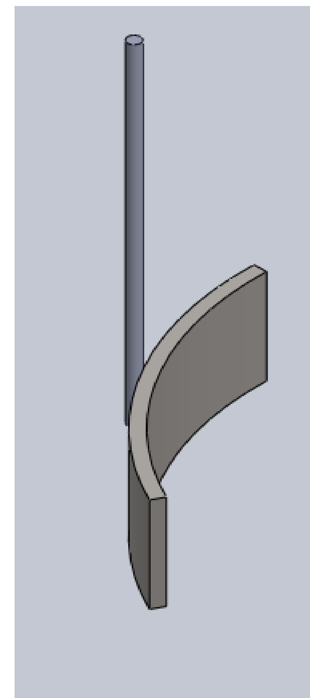


Design- Plow

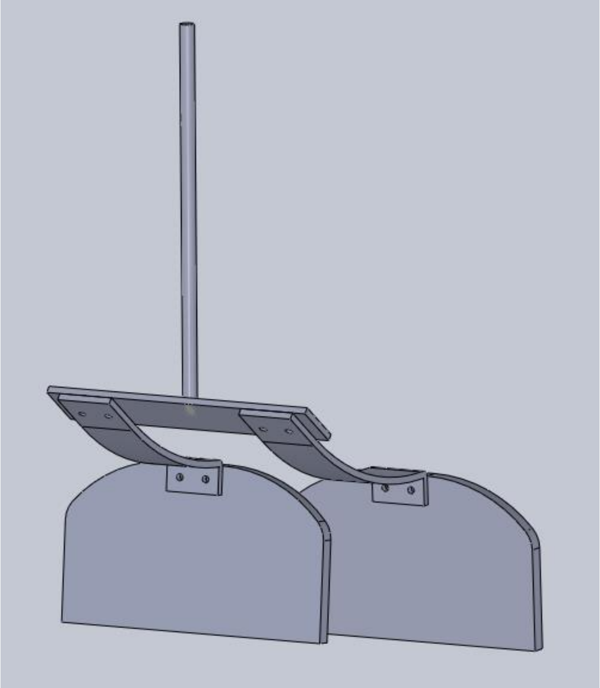


Design- Leveler

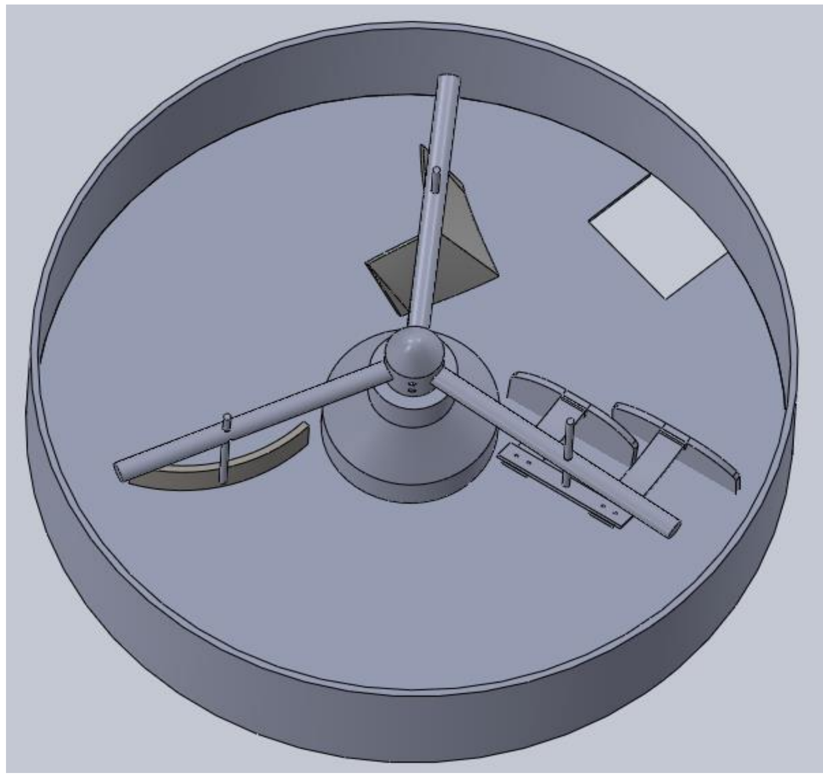




Design- Dragger Arms



First Prototype Constructed



Fabrication Process

1.) Sent CAD drawings to U.S. Roaster Corp.

2.) Met with U.S. Roaster Corp. to discuss modifications

   - Changed metal thickness of some pieces

3.) Conducted testing at the FAPC

Fabrication Process

4.) Traveled to U.S. Roaster

5.) Design complications-

- Dragger arms were creating a pile of beans
- Trouble emptying the bin

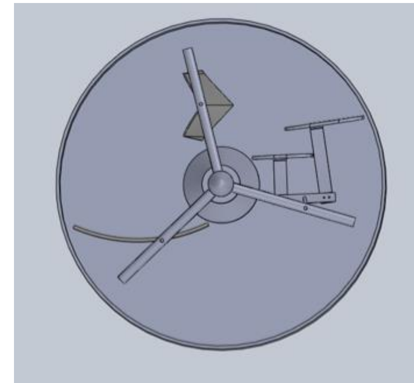
Fabrication Process

6.) Widening the outside dragger arm

7.) Increased the spacing in between the inside and outside dragger arm plates by 1.5 inches

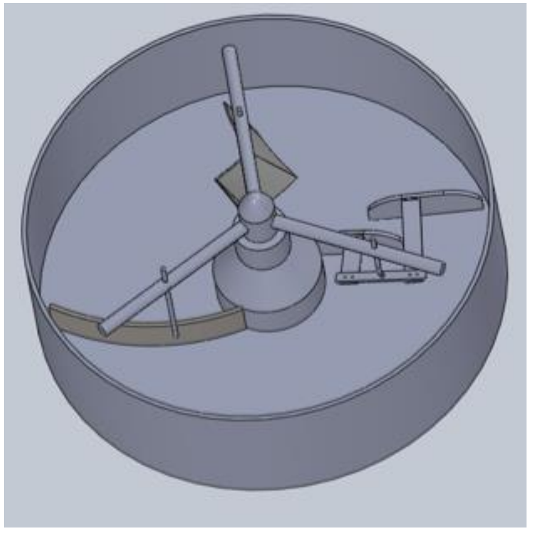
8.) Increased size of leveler

Final Design



Cost Analysis

- Design budget: $650
- Total prototype arm costs: $351
  - Material costs: $36
  - Labor costs: $315
- Mixing tests costs: $59



TESTING

Mixing Capability Tests & Cooling Tests

Mixing Capability Test - Background

- Derived from ASABE protocol (S380).
- Originally used for gauging the effectiveness of portable batch farm mixers for mixing ground corn.
- Modified for use in coffee roaster machines with the help of Dr. Timothy Bowser.

Mixing Capability Test – Protocol

- Total Weight = 12 kg
- Tracer Material: Spray-painted coffee beans.
  - 10% (1.2 kg) of total weight of each roasted coffee bean batch
- Stock Material: regular roasted coffee beans
  - Remaining 90% of weight (10.8 kg)
- For ideal mixing we would expect the tracer to make up 10% of samples collected

Mixing Capability Test – Protocol

- Stock beans deposited into cooling bin first
- Tracer materials layered on top.
- Cooling Bin set to 100% fan capacity and mixing speed.
- Duration of Mixing Capability Test: 3 minutes.

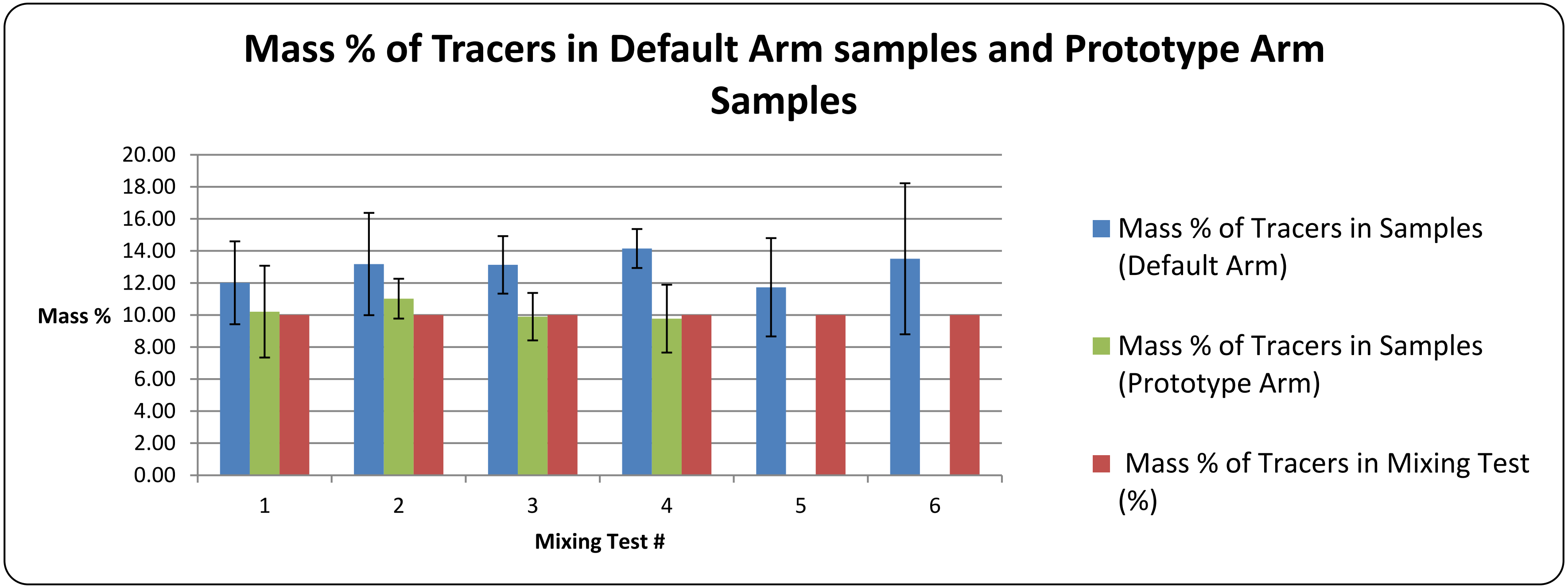
Mixing Capability Test – Protocol

- Six samples taken from mix.
- Samples labeled and arranged so that entire mixture is represented.
- Sample Measurements
  - weight of tracer beans
  - weight of stock beans

Mixing Capability Test – Compiling Data

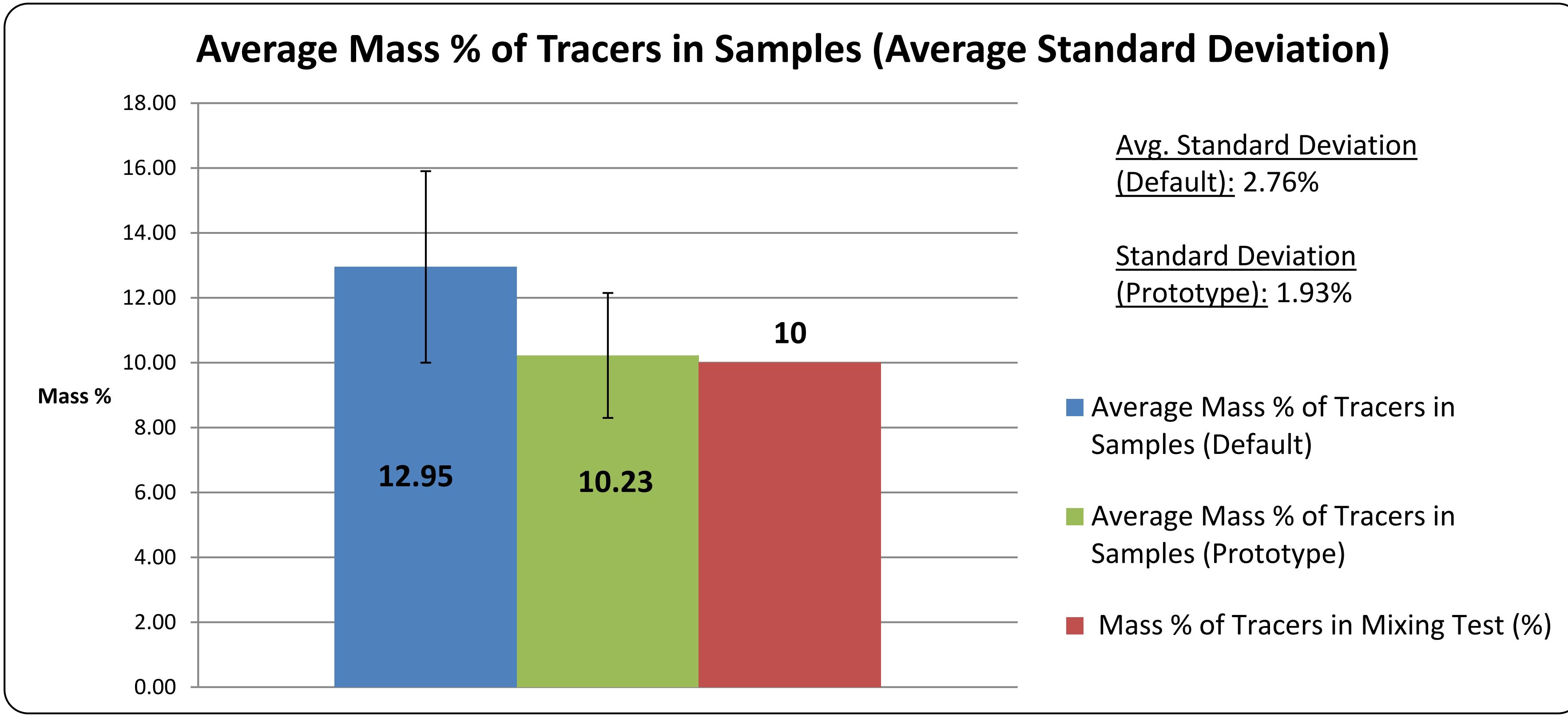
- Protocol repeated six times for Default Rotary Arm, and carried out four times for Prototype Rotary Arm.
- Differing color of tracer material for each test– saves time.
- Data compiled into notebook.
- Average values for mass percentage of tracer in each sample calculated along with standard deviation.

Mixing Capability Test - Results



Mixing Test	Mixing Arm Type	Tracer Color	Average Mass % of Tracers (%)	Standard Deviation (%)
1	Default	White	12.01	2.586
2	Default	White	13.18	3.191
3	Default	White	13.13	1.792
4	Default	Yellow	14.15	1.213
5	Default	Red	11.73	3.068
6	Default	Green	13.51	4.713
7	**Prototype**	**White**	**10.21**	**2.863**
8	**Prototype**	**Red**	**11.02**	**1.240**
9	**Prototype**	**Blue**	**9.90**	**1.482**
10	**Prototype**	**Yellow**	**9.77**	**2.118**

Mixing Capability Test - Results



Mixing Tests	Mixing Arm Type	Average Mass % of Tracers (%)	Mass % of Tracers in Mixing Test (%)	Average Standard Deviation (%)
1-6	Default	12.95	10	2.76
7-10	**Prototype**	**10.23**	**10**	**1.93**

Mixing Capability Test Results – Interpretation

- Mass of tracer beans in prototype arm samples closer to mass of tracers in mixing test than default arm samples.
  - Prototype Arm: 10.23% Tracer
  - Default Arm: 12.95% Tracer
  - Mixing Test Mass: 10% Tracer

- Prototype Arm has smaller standard deviation on average.
  - Prototype Arm: Average S.D. of 1.96% Tracer
  - Default Arm: Average S.D. of 2.76% Tracer

- Interpretation: Prototype Arm mixes beans more uniformly and consistently than default arm.

Cooling Test

- Designed to investigate the amount of time it takes for 12-kg roaster to cool a batch of beans to 90 degrees Fahrenheit.
- Utilizes FLIR i40 infrared thermal imaging camera.
- Coolroast design group instructed in its use by Dr. Frazier.
- Traveled to U.S. Roaster Corp. headquarters in Oklahoma City to test on 12-kg roaster.

Source: http://images3.cableorganizer.com/extech/flir-iseries-thermal-cameras/images/01_i50_thermal-camera.jpg

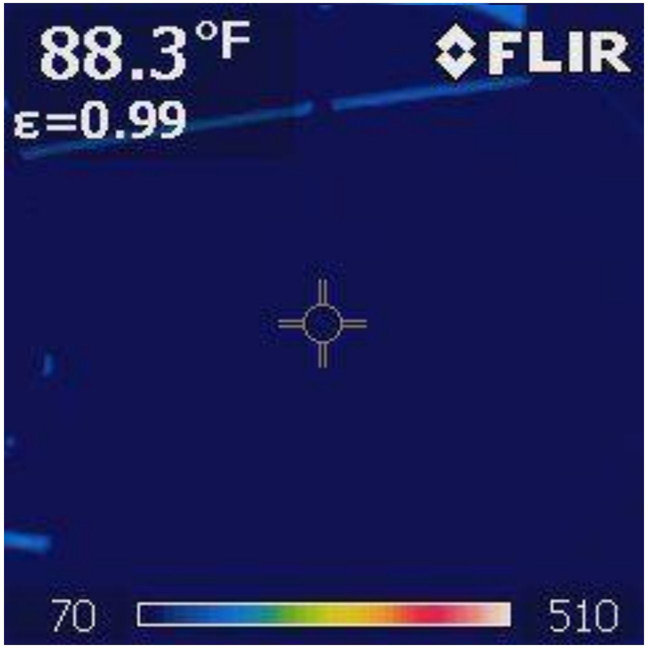
Cooling Test - Protocol

- Infrared camera set to measure temperature on a fixed scale of 70 – 510 degrees Fahrenheit.
- Full batch of unroasted coffee beans heated to 450 degrees Fahrenheit by 12-kg roaster machine.
- Camera held in stationary position, reticule aimed at a spot within coffee roaster cooling bin.
- Roasted coffee beans released into cooling bin, cooling commences with 100% fan capacity and 100% mixing speed.
- Thermal image taken of coffee beans as they empty into the bin and every 30 seconds until a temperature of 90 degrees Fahrenheit is reached.

Cooling Test - Results

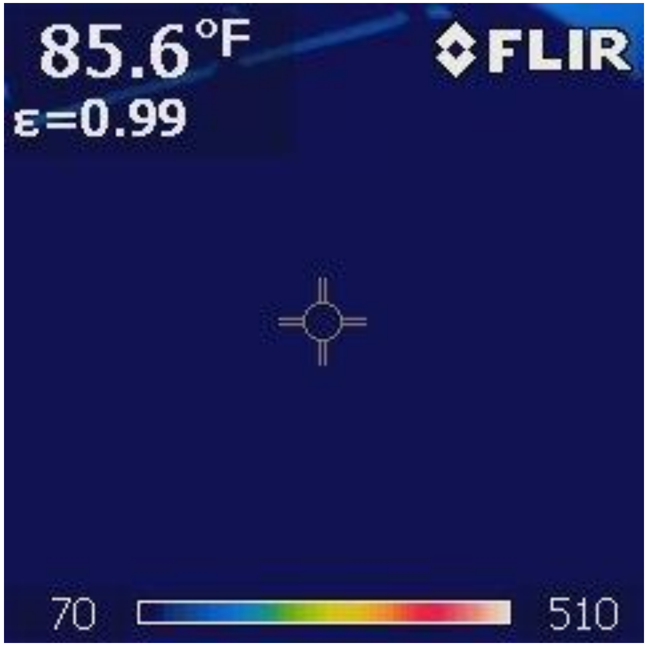
PROTOTYPE ROTARY ARM

Time = 6 min 00s



DEFAULT ROTARY ARM

Time = 5 min 30s



Cooling Test – Interpretation of Results

- Cooling time for Default Rotary Arm:
  - 5 minutes - 5 minutes and 30s.
- Cooling time for Prototype Rotary Arm:
  - 5minutes and 30s - 6 minutes.
- Cooling uniformity is similar.

Vacating Speed Tests

- Vacating speed test
  - Video recording of beans vacating cooling bins observed.
  - Three replications for Default Arm, three replications carried out for prototype arm.
- Results:
  - Default arm: 1m 15s.
  - Prototype arm: 1m 38s.

Recommendations

- Dragger attachment
  - Decreasing pile will decrease cooling time
  - Decrease width, increase gauge of flex steel pieces
  - Lower height of dragger plates
- Cooling bin
  - Consider increasing size of fan to increase air flow rate

Special Thanks To:

- Dan Jolliff at US Roaster Corp
  - Jeff and Dean
- Dr. Bowser
- Dr. Frazier
- Dr. Weckler
- Dr. Hardin
- Jake Nelson - Food and Agriculture Products Center

Design Report: Rotary Arm for Use in U.S. Roaster Corp. Coffee Roasting Machine Cooling Bins

CoolRoast Design group:
Drew Sutterfield
Jonathan Lim
Cameron Buswell
Sibongile Hlatywayo

Report Prepared for and Submitted to:
Dan Jolliff
U.S. Roaster Corp.

Dr. Paul Weckler, P.E.
Department of Biosystems and Agricultural Engineering, Oklahoma State University

Dr. Timothy Bowser, P.E.
Department of Biosystems and Agricultural Engineering, Oklahoma State University

Table of Contents

List of Figures

List of Tables

Executive Summary

A few years ago, the U.S. Roaster Corp conducted a customer survey about their current coffee roaster machines, in which they asked their customers about which aspect of their coffee machines could be improved. According to their clientele, their current coffee bean cooling system was the aspect that could use the most improvement. Thus, the CoolRoast design group was tasked to construct a new rotary arm design for the U.S. Roaster Corp's coffee bean roaster machines. This rotary arm mixes the beans as they empty into a cooling bin after being roasted. The necessary design specifications for the rotary arm were set forth in a meeting with the U.S. Roaster Corp on September 9, 2012, and are as follows: the rotary arm that the CoolRoast design group should perform better than the current rotary arm design in several key criteria in order to improve the cooling process. The new arm design should improve airflow within the coffee bean cooling bin, which can improve the rate of cooling. It should also mix the coffee beans in such a way so that the beans cool more uniformly. The arm should also mix the beans so that they cool from a temperature of 450 degrees Fahrenheit to about 90 degrees Fahrenheit within 5 minutes. It should also empty out the cooling bin in a timely fashion, and minimize the amount of coffee beans that are broken while the beans vacate the bin. The new rotary arm should also not deviate too far from the aesthetics of the rotary arms commonly used in other coffee roasters.

Statement of Problem

The need for this design was made apparent to the U.S. Roaster Corp after they assigned a previous engineering group from Oklahoma State University to discover which aspect of their coffee roaster machines needed the most improvement. According to a survey conducted by this group, the U.S. Roaster Corp's clientele described that they thought that the cooling mechanism in the coffee roaster machines could be improved. This presents a bit of a unique problem: in a meeting between the CoolRoast design group and the U.S. Roaster Corp that occurred on September 19, 2012, it was said that the consumers in the coffee roaster machine industry tend to shy away from purchasing roasters that stray too far from the traditional roaster look. Thus, the U.S. Roaster Corp cannot drastically change the design or aesthetics of the current cooling system, even if it does end up significantly improving the cooling aspect of their machines. It was decided that the rotary arm that mixes the coffee beans in the cooling bin attached to the roaster machine was the component that could be safely modified without breaking conventional roaster aesthetics. By improving the design of the rotary arm, it may become possible to improve the cooling rate of the coffee beans as they fill the cooling bin while cutting down on production costs of the coffee roaster machine. In addition, designing the arm to adhere to NSF standards could offer a unique distinction to the U.S. Roaster Corp's machine over its competitors.

Statement of Work

Scope of Work

The goal of our project is to improve the design of the U.S. Roaster Corp rotary arm that is currently used in their cooling bin designs. The type of work that we would need to do to accomplish this would involve:

- Drawing preliminary sketches/concept sketches of new rotary arm designs.
- Testing the current rotary arm design that the U.S. Roaster Corp uses in their cooling bin and gathering data from those tests. We will also need to do the same for our own rotary arm designs.
- Researching NSF International guidelines as well as consulting professors within OSU to determine how the rotary arm can be designed to adhere to NSF standards.
- Creating CAD models of preliminary sketches of prototype rotary arm designs.
- Determining if prototypes can be modeled in thermoplastic (via 3-D printing) or if the prototypes should be assembled from stainless steel.
- Testing these prototype rotary arms using heated coffee beans and analyzing the cooling bin using an infrared thermal imaging camera, and determining how well the beans are being mixed using white spray-painted beans as a visual aid.
- Testing and collecting data from our final design model using the thermal imaging camera, visual area evaluation method, and comparing it to the default rotary arm included with the cooling bin.
- Comparing data gathered from testing rotary arm designs and judging which design is best suited for the cooling bin according to cost, bean cooling uniformity, bean cooling speed, bean mixing capability, and bean vacating speed.
- Determining which rotary arm prototype is the most practical/efficient design.
- Creating a final prototype from the best design model in the appropriate final material; this will most likely be in stainless steel.
- Presenting our final design to U.S. Roaster Corp.

Location of Work

The entirety of the testing in this project will be carried out in the Robert M. Kerr Food and Agricultural Products (FAPC) Wet Processing labs, which is where the cooling bin model will be delivered to after it has been retrieved. The construction of the final prototype will be carried out in the BAE lab by the lab machinists. CAD work and other composition work will be done in the BAE computer labs in the Agriculture Hall buildings in room 208 and/or room 210; the Agricultural Hall building and the computer labs housed within are located within the bounds of the Oklahoma State University campus.

Period of Performance

11/19/2012 - 11/23/2012

- Model cooling bin retrieved from U.S. Roaster Corp and set up in FAPC lab.

11/28/2012 - 12/3/2012

- Infrared thermal imaging testing for default arm completed, at least one prototype arm designed in Solidworks.

11/30/2012 - 12/3/2012

- Finalize presentation to show U.S. Roaster how design project is progressing.

1/7/2013 - 1/13/2013

- All 2-3 prototype rotary arm designs modeled in Solidworks, cost analysis on prototype arms completed.

1/14/2013 - 1/18/2013

- Consultation with U.S. Roaster Corp about prototype selection.

1/21/2013 - 2/18/2013

- Construction of rotary arm prototype(s).

2/18/2013 - 2/21/2013

- Testing of prototypes and gathering data from prototype testing.

2/21/2013 - 2/25/2013

- Additional consultation with U.S. Roaster Corp about prototype performance, additional revision and refining of prototype design. Prototype testing report delivered to U.S. Roaster Corp.

2/26/2013 - 3/11/2013

- Revision of prototype according to U.S. Roaster Corp specifications; design and construction of final prototype commences.

3/11/2013 - 3/12/2013

- Testing of final prototype, consolidation of testing data. Performance of final prototype reported to U.S. Roaster Corp.

3/12/2013 - 3/14/2013

- Final rotary arm design selected by U.S. Roaster Corp.

3/15/2013 - 3/18/2013

- CAD drawings of selected prototype, performance summary of selected prototype, and other requested materials delivered to U.S. Roaster Corp. Preparations for final design presentation begins.

Acceptance Criteria

The stirring arm should ensure that the coffee beans in the cooling bin cool from a temperature of 450 degrees Fahrenheit to 90 degrees Fahrenheit within 3-5 minutes; this criterion assumes that the cooling bin fan is working properly. Our group was also given a cost of materials budget of approximately $650. The rotary arms should also be optimally designed to fit within the 12 kg coffee bean roaster cooling bin. The cooling bin itself has an inner diameter of 25.313 inches. According to the 12 kilogram coffee roaster AutoCAD drawings, the rotary arms need to be approximately 12.00” long. We do not currently know the rate at which the arms must rotate, and must wait until the U.S. Roaster Corp has completed and shipped the model cooling bin assembly before we can test the speed at which the rotary arm must rotate to achieve optimal cooling.

Special Requirements

A thermal imaging camera will also be needed to measure how uniformly the beans are cooling. The CAD software known as “Solidworks” will be utilized to draw up schematics for the rotary arm designs, and will be required by the machinery staff at the Oklahoma State University BAE lab in order to construct the rotary arm prototypes. Solidworks designs will also be needed to create the final prototype, which will be made of stainless steel. Various other materials may be needed to act as a contrast for the mixing tests, such as colored spray paint, non-coffee beans and/or wooden beads.

Required Resources

- U.S. Roaster Corp 12 kilogram cooling bin with current stirrer arm design installed
- Coffee beans
- Testing Materials for Mixing Tests (may include wooden beads, spray paint, non-coffee beans sorts of beans)
- Solidworks software
- Thermal imaging camera
- Thermometer able to withstand temperatures up to 500 degrees Fahrenheit
- Industrial Ovens capable of heating coffee beans up to 450 degrees Fahrenheit
- Metal material for prototype fabrication and final prototype fabrication from BAE lab
- Allocated time from BAE lab machinist
- Additional resources as testing protocols are developed

Task List

- Pick up model cooling bin from US Roasters.
- Deliver model cooling bin to the FAPC wet processing lab room.
- Measure dimensions of cooling bin.
- Test bean cooling rate and uniformity of bean cooling capability of the default rotary arm included with the model cooling bin using infrared camera.
- Evaluate mixing ability of default rotary arm included with model cooling bin using white spray-painted coffee beans (or other material) and visual area evaluation method.
- Organize test data into coherent document and select data for December presentation.
- Research information on how to make sure the design is NSF approved.
- Develop webpage for CoolRoast design team.
- Develop two prototype rotary arms and write justification for prototype designs.
- Develop testing protocol for determining mixing capability of rotary arms.
- Evaluate possible designs on basis of ease of fabrication and design aesthetic.
- Draw rotary arm schematics in Solidworks CAD program.
- Consult U.S. Roaster Corp on the aesthetics of prototype rotary arms.
- Adjust rotary arm aesthetics as needed according to U.S. Roaster Corp.
- Decide what type of metal(s) to use for constructing our prototype designs,
- Seek out parts supplier to provide materials for prototype rotary mixing arm parts.
- Collect information on shipping delay for needed parts.
- Acquire cost estimates for fabricating rotary arm prototypes from said metal; modify designs if design cost exceeds $650.
- Evaluate viability of using 3D printer to create rotary arm prototypes.
- Fabricate prototype rotary arm designs via BAE machine shop.
- Test bean cooling rate and uniformity of bean cooling capability of prototype rotary arms using infrared camera.
- Evaluate mixing ability of prototype rotary arms using white spray-painted coffee beans (or other material) along with visual area evaluation method.
- Compile prototype performance reports from testing data.
- Compare uniformity of cooling and mixing capability of prototype arms to that of the default rotary arm included with the cooling bin.
- Compare uniformity of cooling and mixing capability of final rotary arm design to that of the default rotary arm included with the cooling bin.
- Discard prototypes that perform worse than the default rotary arm design.
- Deliver prototype performance reports to U.S. Roaster Corp.
- Decide upon final design using gathered data from testing and input from U.S. Roaster Corp.
- Construct final rotary arm design.
- Deliver final rotary arm design by April 2013.
- Organize data into coherent document and select data for May product presentation.
- Create presentation for May product presentation.

Patent Search

A search on patents relating to coffee roaster machines and rotary arms was conducted using the "Google Patent" search engine. This was done to ensure that the rotary arm designs that the CoolRoast design group created would not infringe on any active patents. Four patents were found that pertain specifically to coffee roaster machine design. One design was patented by an Isaac M. Ginn in January 1894, and another design was patented by an H.L. Smith Jr. in July 1967. The third design was patented by three people in April 2011: Masanori Kando, Akira Kishimoto, and Tasutaka Katsuragi. The fourth design was patented in January 2011 by a Eugene Song.

Ginn's coffee roaster machine involved a hand-crank mechanism to turn a mounted pan that contains roasted coffee beans; the design does not appear to include any sort of rotary arm device for cooling the coffee beans. Similarly, H.L. Smith Jr.'s design involves dropping roasted coffee beans down a series of conical bins, and does not involve any sort of rotary arm to stir the beans with the intent of cooling said beans. The design patented by Kando et al. appears to use an air-exchange method for cooling the roasted coffee beans and shows no evidence of using a rotary arm to aid this process. The coffee roaster machine designed by Eugene Song, however, does include a rotary arm (referred to as a "stirring rotator" in the patent) that is intended to stir roasted coffee beans after the beans enter a cooling bin. A review of the claims section of this patent reveals that the heating system and the control system for said heating system are the items being patented, while the rotary arm is not. Nonetheless, it may be safer to create prototype rotary arms that are distinct from Song's design. The rotary arm in Song's design can be seen in Figure 1 (parts 92, 92-2 through 92-5):

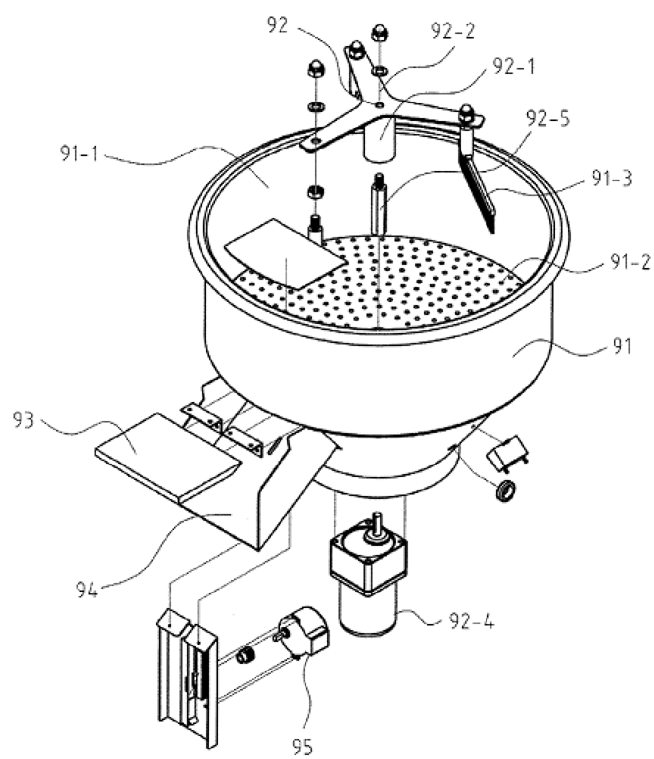


Figure 1: Rotary Arm in Eugene Song's Coffee Roaster.

Design Objectives

This document proposes several designs for a new rotary cooling arm design for use in the cooling bins of the U.S. Roaster Corp's coffee bean roasting machines. In order to create a satisfactory design for our client, the CoolRoast design team has several design objectives to fulfill:

1.) Improve the uniformity of cooling for the roasted coffee beans after they are deposited in the cooling bin of the coffee roasting machines.

2.) Improve the rate of cooling for the roasted coffee beans in the cooling bin.

3.) Improve the flow of air in the cooling bin when it is filled with the roasted coffee beans.

4.) Minimize the amount of coffee beans that are destroyed (i.e. crushed or ground) by the rotary arm in the cooling bin.

5.) The rotary arm design should also adhere to NSF standards, if at all possible.

The first objective is necessary due to it being a key demand of our client. If the uniformity of cooling for the roasted coffee beans is improved significantly, then it is believed that the taste of the coffee will be better. If the second objective is successfully fulfilled, then total length of time in which the coffee beans are cooled could be shortened significantly - it may become possible to run more coffee beans through the roaster in a single work day. As such, the fulfillment of this objective could positively affect company efficiency and profits. The achievement of the third objective may allow the U.S. Roaster Corp to build their coffee machines with less powerful fans to achieve the same cooling effect, which would reduce the cost of producing each coffee roasting machine. The realization of the fourth objective would improve the appeal of the machine; while a few broken coffee beans may not leave a lasting impact the taste of the coffee, it could negatively influence potential buyers' perception of the machine. If we minimize this risk, then there is less chance that the U.S. Roaster Corp's coffee roasters will be passed up by potential customers. If the rotary arm design fulfills NSF requirements, then that is another positive quality that can be assigned to the machine, which in turn could possibly boost sales.

In order to accomplish these objectives, we will need to analyze how the rotating arm attachments that we design will interact with the coffee beans. These interactions include: how well the arms stir the beans, whether the arms damage the beans or not, and how well the arm design improves the flow of air in the cooling bin. Our group will also need to analyze the uniformity of cooling in the bin by measuring how evenly the heat dissipates from the coffee beans. U.S. Roaster Corp. is willing to construct a cooling bin for us to utilize throughout the course of the project.

Technical Approach

Based on designs we observed while at U.S. Roaster we will be able to develop our own design concepts, as well as determine the ease of fabrication for these designs. Our team will then take these concepts and develop designs within the Solidworks program that can then be fabricated at the Bio-Systems lab. Once we have our rotating arm designs constructed, we will conduct experiments to see how well the beans are being mixed and screen the bean mixture for any damaged beans.

We are also interested in analyzing the forces (torsional/shear) that the coffee beans and rotating arms encounter under normal use. This will give us additional information that we can use to make additional modifications to our rotating arm design if need be. Depending on the price of bulk coffee beans, we may need to substitute a similar, less expensive bean for testing. Other calculations that were used here are discussed in further detail in the "Development of Engineering Specifications" section. Presently, we also have the following specifications: at 100% speed, the rotary arm turns 24 RPM when the cooling bin is filled with 19.94 lbs of beans. The motor of the rotary arm is rated at 3450 RPM at 0.5 HP, and the motor's torque is 0.76 lb*ft.

Another important aspect of our project to analyze is the flow of air that occurs through the layer of roasted coffee beans in the cooling bin. The fan removes heat from the beans by drawing air through the beans and the perforated plate below the beans. We will need to determine the specifications of the current fan assembly, which includes horse power and volumetric capacity. There are other variables that we will need to determine, such as the turning rate of the rotary arms at varying speed settings and at various bin capacities (how full the cooling bin is when the arm is turning), as well as the motor's specifications.

Identifying Customer Needs

Our customer and sponsor for this senior design project is U.S. Roaster Corp, which is based in Oklahoma City. We were tasked by them to create a new rotary arm design for use in their coffee bean roasters. Ideally, the new stirring arm will improve the uniformity of cooling within the roasted coffee beans after the beans have entered the cooling bin of the roaster. The new arm design should also improve the flow of air through the cooling bin. If the arm is designed and implemented properly, then it may be possible to use lower-power fans to cool the coffee beans, which could reduce the cost of building the coffee bean roasters. The stirrer arm design should not break or otherwise deform the coffee beans that it stirs, as broken or warped coffee beans can negatively impact sales and customer satisfaction. Our design solution should also ensure that coffee beans or other debris does not get stuck along the walls of the cooling bin during the coffee bean cooling process. The design should be able to fully vacate the cooling bin of cooled coffee beans in a reasonable amount of time.

U.S. Roaster Corp insisted that our final stirring arm design should be made from stainless steel. Their reasoning for this requirement is that stainless steel does not retain the flavor of previous coffee bean batches; this ensures that the distinct flavor and quality of each batch of coffee beans is preserved. U.S. Roaster Corp. also expressed interest in our design obtaining NSF certification, which could improve the reputation and marketability of the coffee roasters that use our design. U.S. Roaster Corp also stated that spending time and money on designing an aesthetically pleasing rotary arm design may be worthwhile, as it could potentially boost sales. A prototype rotary arm should be ready for construction by mid-November. Our group's final rotary arm design should be ready for consumer use before April 2013, as U.S. Roaster Corp would prefer to show off the new design at a coffee expo that takes place in April 2013.

Identifying Target Specifications

The stirring arm should ensure that the coffee beans in the cooling bin cool from a temperature of 450 degrees Fahrenheit to 90 degrees Fahrenheit within 3-5 minutes, assuming that the cooling bin fan is working properly. When the cooling process is complete and the cooling bin hatch is opened, the rotary arms should help the cooled coffee beans vacate the cooling bin in less than 5 minutes. Our group was also given a cost of materials budget of approximately $650. The rotary arms should also be optimally designed to fit within the 12 kg coffee bean roaster cooling bin. The cooling bin itself has an inner diameter of 25.313 inches. According to the 12 kilogram coffee roaster AutoCAD drawings, the rotary arms need to be approximately 12.00" long.

Generating Design Concepts

The various rotary arm designs that the CoolRoast group generated were done after observing how the U.S. Roaster Corp's initial rotary arm design performed in several criteria, as listed below:

- The first criterion was the overall time it took for the rotary arm design to dissipate heat in a certain amount of time; the coffee beans' temperature must drop from around 400 degrees Fahrenheit to about 70 degrees Fahrenheit within three minutes. As such, the CoolRoast group will measure the temperature of several spots within the coffee bean mass in the model cooling bin with a thermometer to get a better idea of the average cooling rate. This thermometer will also be used to measure the temperature of different layers within the coffee bean mass.
- The second criterion was the uniformity of the heat dissipation, which was a key customer requirement. By observing the pattern of the heat dissipation by using an infrared camera, it became possible to quantify the uniformity of the heat dissipation by assigning different numerical weights to the colors displayed by the camera.
- The third criterion was the speed at which the rotary arms could vacate the coffee beans from the cooling bin. After the shaft door is open, the vast majority of the coffee beans should vacate the cooling bin in less than 5 minutes.
- The last criterion was the amount of beans that were broken by the rotary arm; the presence of too many broken coffee beans in the cooling bin could dissuade customers from purchasing the coffee roaster.

Development of Engineering Specifications

An engineering analysis was conducted on the current rotary arm so that the CoolRoast design group could get a better idea of the parameters that we would need to analyze in the rotary arm. Firstly, the current rotary arm included with the model cooling bin was disassembled, and the individual pieces weighed on a scale located in the FAPC lab that the model cooling bin was contained in. A free-body diagram was drawn in order to quantify the forces and moments that were acting on the rotary arm assembly; from there, shear and moment diagrams were constructed to find the maximum shear and maximum moment acting on the rotary arm. These shear and moment calculations were then used to perform a weld analysis, which was used to calculate a factor of safety for the current rotary arm design. The factor of safety is a quantity that defines how “reliable” the device being analyzed is; in the context of welding, the factor of safety defines how reliable the welding is (the higher the safety factor on the weld, the less likely the weld is going to break/crack/warp). This analysis will be performed on the prototype rotary arms as well.

The mixing capability of the rotary arms needs to be quantified so that the mixing capabilities of the default rotary arm and that of the prototype rotary arms can be compared objectively. After consulting with several professors at Oklahoma State University, the CoolRoast design team discovered that this can be done by using a visual area determination (VAD) test. In this test, a material of similar density/weight to the coffee beans (but with a distinct coloration) will be added to the cooling bin as the roasted coffee beans mix. There have been a number of colored materials considered for this method: jelly beans, Red Hots candies, and spray-painted coffee beans. The CoolRoast design group has also considered using sets of materials that are entirely different from coffee beans (such as spray-painted kidney beans) as a proof-of-concept test for mixing. The materials that will most likely be used for the visual area determination test would be either white spray-painted roasted coffee beans vs. unpainted roasted coffee beans, or two sets of non-coffee beans that have been spray-painted two distinct colors.

The VAD test procedures must be carefully crafted so that the results of such a test can be easily reproduced and repeated with different variables. The analysis of the mixing will involve taking snapshots of the surface of the coffee bean mass every 10 seconds or so, and assessing the color composition of the surface of the coffee bean mix (% brown vs. % other color). With those calculations, it is possible to make an estimate of the distribution of the colored materials amongst the coffee beans. The snapshots can also be run through a series of computer programs to ascertain the statistical distribution of the colored material amongst the coffee beans. Using these methods can yield concrete numbers for either the default rotary arm and for the prototype arms, and can thus make comparing the performance of those objects much easier.

The CoolRoast design group has also conceived of a test in which the colored material is introduced to the top of the roasted coffee beans as the rotary arm turns, taking snapshots of the mixing process every 10 seconds, and determining how drastically the color composition of the bean mass changes over time. The reasoning behind this assessment is that if the beans are mixing well, the colored materials on the top of the bin will eventually be circulated throughout the mass of beans in the cooling bin. Thus, the color percentage of colored materials at the surface will be fairly variable throughout the test. If the color percentage is consistently uniform throughout the test, then it could be inferred that the rotary arms are merely moving the beans around and not mixing them. If the beans are being thoroughly mixed, then more beans will be exposed to the relatively cooler ambient air and will cool at a faster rate. The beans may also cool more uniformly as the beans will not stagnate in the same layer of beans as the rotary arm mixes.

Selecting Design Concepts

After careful consideration, the CoolRoast design group decided to select two rotary arm designs for initial prototyping. These prototypes are thought to address the design criteria set forth by the U.S. Roaster Corp and do not exceed the design budget. These arm designs will be fabricated, tested, and later redesigned in accordance to their performance and how U.S. Roaster Corp reacts to the prototype testing reports. If the U.S. Roaster Corp decides that an aspect of the prototype must be changed for whatever reason, then the CoolRoast design group will design a new prototype for fabrication and repeat the testing/feedback cycle.

The first prototype (depicted in figures 2 – 3) modifies the default rotary arm design by removing the attachments on the side bars. In their place is a bar assembly that features two horizontal plates that slant downward; these downward slanting plates are held in place by two slanted bars welded to the side bars. The reasoning behind this design is that the slanted horizontal bars will lift the coffee beans as it rotates, exposing more ambient air to the coffee beans and improving airflow. Thus, this design could improve the cooling rate and uniformity of the coffee beans. It is important to note that there will be a second bar assembly on the opposite side of the side bar.

Figure 2: Prototype 1, Front View

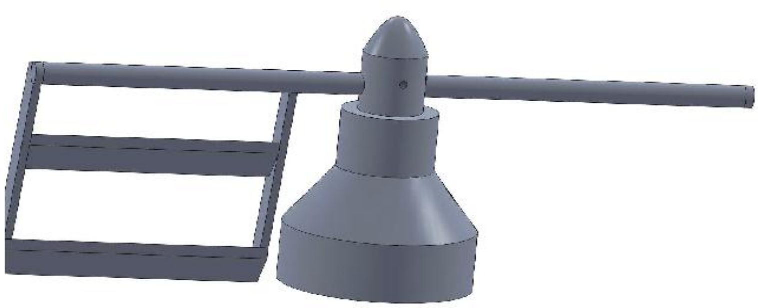


Figure 3: Prototype 1, Back View

The second prototype (seen in figures 4 – 5 below) does away with the conical sheath that covers the base of the rotary arm shaft, and instead replaces it with several angled blades. As the rotary arm stirs, the two sets of blades will mix the beans at the top and at the bottom of the cooling bin simultaneously. Ideally, the curvature of the blades will cause the ambient air to mix with the bean mass more thoroughly, which will improve the flow of air within the beans. In addition, the mixing action on two different layers of the beans may mix the beans more thoroughly than the default rotary arm design. This design also has fewer surfaces for the coffee beans to catch on and break. However, the design may be more expensive than Prototype 1, as it includes more metal for its construction. The bottom blades may also have to be elevated, as the bottom of the cooling bin may warp due to temperature changes and scrape against the blades as a result.

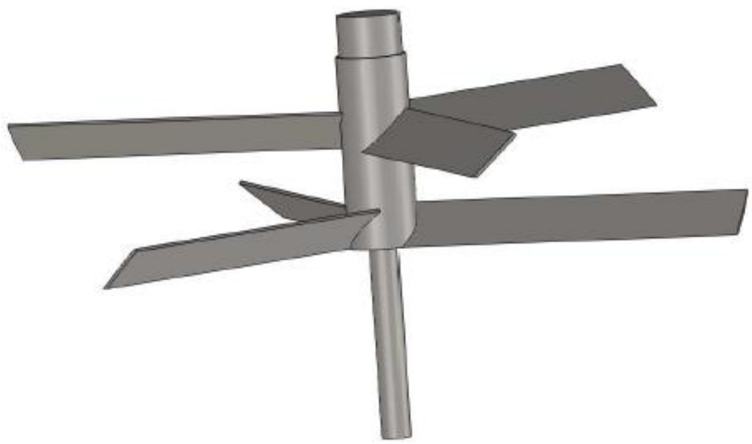


Figure 4: Prototype 2, Side View.

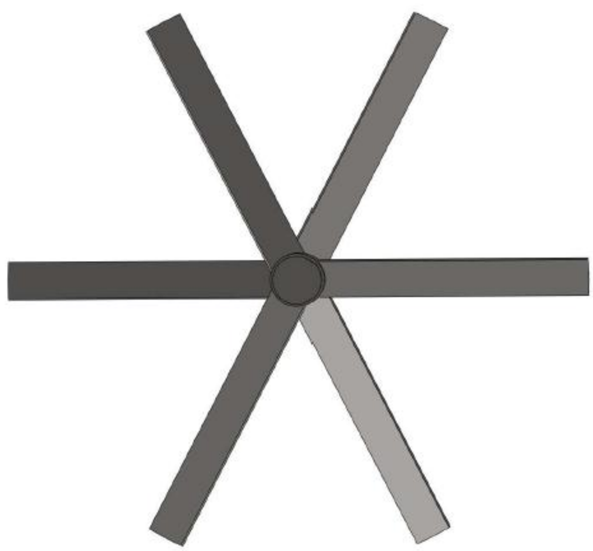


Figure 5: Prototype 2, Top View.

Environmental, Societal, and Global Impacts of Design Concept

The main environmental impact that the new rotary arm design could have on the environment is mainly tied with its construction. The metal that it will be constructed from will need to be mined from the Earth; that metal will need to be refined, shaped, and shipped. In addition, the rotary arm may boost sales of the U.S. Roaster Corp's coffee roasting machines, which will also incur an expenditure of electricity and fossil fuels. But aside from the fuel expenditure for its production, the rotary arm itself does not appear to directly influence the state of the environment. Similarly, the arm design may not have many sociological consequences if it enters full production. If the arm design boosts the U.S. Roaster Corp's coffee roaster machine sales significantly, however, it may be possible that overseas competitors may lose significant amounts of customers in the United States.

Project Management

The task that the U.S. Roaster Corp gave us required scheduling and planning for each individual aspect of the rotary arm's design. As the entire CoolRoast team consists of undergraduate students with full schedules, our group has had to balance working on this project with our own academic interests and obligations. Thus, the following Gantt chart was created to help facilitate our work on this design project:

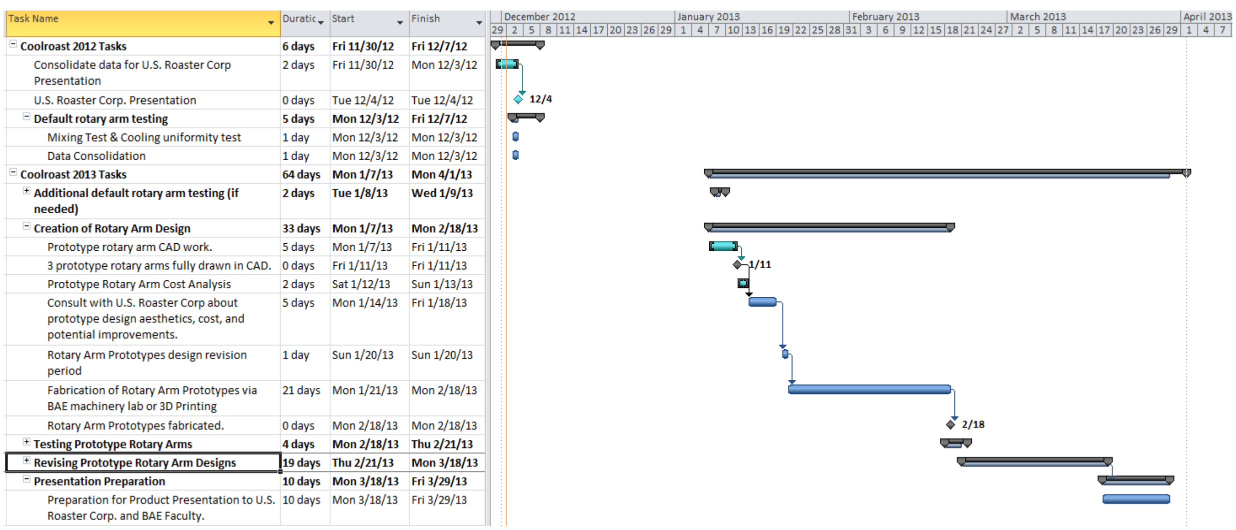


Figure 6: Gantt Chart for CoolRoast Design Group's Schedule (2012-2013).

As can be seen on the chart, there are several set dates that dictate the end of vital parts of our project. The CoolRoast group is hoping to submit the prototype designs for fabrication in 2012. The prototype testing process and feedback process with the U.S. Roaster Corp will occur in 2013; the CoolRoast design group hopes to have a finished product before April 2013. Many of these dates are summarized in the Scope of Work section in this document. This chart also indicates the deadlines for several deliverables to the U.S. Roaster Corp. Each of these deliverables is vital to the project's success, and represent what the CoolRoast design group has to show for our work. These deliverables are described in more detail in the following subsection.

Deliverables

The deliverables that will be given to the U.S. Roaster Corp will include several items delivered over the span of the design process. The first item is the technical analyses of the prototype rotary arms that were tested in the model cooling bin. These analyses will consist of the comparisons of prototype rotary arm design performance compared to the original rotary arm's design performance. The analyses will also contain information such as the timestamped infrared camera images of the coffee beans during mixing, the mixing capability assessment of each rotary arm measured via visual area evaluation, and a material cost analysis of the prototype in question. The CoolRoast team will also include a bill of materials needed to construct the final rotary arm design, as well as the estimated amount of labor required to fabricate the design and any possible quirks in the deisgn that may require special equipment to replicate. The last item will consist of the CAD drawings of the final rotary arm design. These drawings will either be created in Solidworks or in AutoCAD, depending on the U.S. Roaster Corp's preference.

Budget

The CoolRoast design team was allocated a design budget of $650 by the U.S. Roaster Corp. This means that the overall cost of producing the final product should not exceed $650. This budget does not include the cost of construction of prototypes or the acquisition of materials needed for the testing process; that cost is already covered by the Oklahoma State University funds set aside for the Senior Design course. Ideally, the cost that the U.S. Roaster Corp. should incur for producing this rotary arm design should be under $650. NSF standards dictate that metal items must be constructed from 304 Stainless Steel, which can impact the price of the prototypes. The following table shows the estimated costs of producing the prototypes from two different types of 304 stainless steel:

Table 1: Estimated Costs for Constructing Rotary Arm Prototypes.

Item	Metal Type	Price
Prototype 1	No. 4 Polished	**$100.00**
Prototype 1	2B Unpolished	**$80.00**
Prototype 2	No. 4 Polished	**$200.00**
Prototype 2	2B Unpolished	**$160.00**

Communication and Coordination with Sponsor

The CoolRoast design group first met with the U.S. Roaster Corp through a formal meeting between the team members and Dan Jolliff at the company headquarters, located in Oklahoma City, Oklahoma. During that time, the scope of the project was explained and the CoolRoast team was given a tour of the U.S. Roaster Corp facilities. The CoolRoast team was also shown functional rotary arms that were mounted on the cooling bins that the U.S. Roaster Corp had in storage. The team was also able to see the machining capabilities that the shop mechanics had at their disposal during the construction process.

After the initial meeting with Dan at the U.S. Roaster Corp headquarters, correspondence with the client was carried out via email through the team leader, Drew Sutterfield. By contacting Dan at U.S. Roaster Corp, Drew was able to communicate with Dan as the project progressed. The contact with Dan was consisted primarily of follow-up questions pertaining to the project in general, as the team worked to define the problem in greater detail. As the conversations continued, they shifted more on how construction of the cooling bin was progressing and about details that the business team required from Dan for completion of their analysis. It also included information about of the end of fall semester project presentation.

Team Qualifications

Drew Sutterfield is currently enrolled as a senior undergraduate at Oklahoma State University in Biosystems Engineering, with options in biomechanical and food process engineering. Having been involved with many projects throughout college has observed and developed the personal and technical skills that are required to coordinate a team of engineers effectively throughout a project. Having worked at the Food and Agriculture Products Center under Jake Nelson and Kyle Flynn for the past three years, he has a general knowledge of how the equipment needed for experiments at the Food and Agriculture Products Center operate. During high school welding and shop construction classes Drew developed a sensible view of how difficult or easy a part could be constructed in a shop setting.

Jonathan Lim is an undergraduate student who is currently enrolled at Oklahoma State University. He is currently a senior majoring in Biosystems Engineering (Food Processing option) and is also pursuing a degree in Human Nutrition (Pre-med option). He has worked on several research projects on finding renewable sources of ethanol fuel, and has written a scientific paper on the subject that is currently in the reviewing process. As a Biosystems Engineering students enrolled at OSU, he has a strong background in mechanical engineering subjects and has taken several courses that specifically deal with solving agricultural and environmental engineering problems. He also has learned how to present information to the public through his nutritional science education, and has strong technical writing skills due to the research projects and project reports he has created over the span of his education.

Sibongile Hlatywayo is a senior in Biosystems engineering at Oklahoma State University. She is pursuing a degree option in Bio-Mechanical engineering due to strong interest in mechanical engineering. She has worked under Dr. Marek a professor at Oklahoma state university on plant pathology research giving her a strong background research and project building. Having taken the majority of her core classes in Mechanical engineering she has a strong understanding of mechanical design and problem solving.

Cameron Buswell is a senior Biosystems Engineering (Biomechanical option) student at Oklahoma State University. Having been a part of several design projects throughout college that required CAD, programming, electronics, and fatigue analysis. He understands the steps necessary to complete a successful project and enjoys coming up with creative solutions to problems.

References

1.) Ginn, I. M. 1984. COFFEE-STIRRER. U.S. Patent No. 513,179.

2.) Kando, M., Kishimoto, A., Katsuragi, Y. 2011. METHOD AND DEVICE FOR ROASTING/COOLING BEAN. U.S. Patent No. 2011/0081467A1 .

3.) Smith JR., H.L. 1967. METHOD FOR COOLING ROASTED COFFEE. U.S. Patent No. 3332780.

4.) Song, E. 2011. Coffee Roaster and Controlling Method of Same. U.S. Patent No. 7875833B2.

Appendix A: Résumés of Team Members

Drew Sutterfield
drew.h.sutterfield@okstate.edu
(918) 348-4713

Permanent	Local
1609 Bluestem Rd.	209 1/2 South Duck Street
Fort Gibson, Oklahoma 74434	Stillwater, Oklahoma 74074

OBJECTIVE:

To secure a position within a reputable engineering company as an entry-level engineer that challenges me to incorporate the knowledge and work ethic that I have developed throughout my life, as well as allowing me to expand my field of experience and learn new material.

SUMMARY:

A Biosystems and Agricultural Engineering senior that has worked diligently to complete my degree within four years, with an above average grade point average. While developing relationships and friendships in college I have succeeded greatly and have had an enjoyable experience. I am extremely proud of my influential work during each of the past four summers to take time out of my schedule to be a counselor at Oklahoma Boys State; where high school seniors learn how our government and politics operate, as well as what patriotism truly is. I have had the privilege to work with approximately two hundred students through this program.

Skills and Accomplishments

- Acting as a Senior Counselor at Oklahoma Boys State in 2012
- Funding my college career by working on campus at the Food and Ag Products Center and through scholarships and other financial aid.
- Extensive knowledge of computers and intuitive ability to utilize them

Education:

Oklahoma State University	Stillwater, Oklahoma
Candidate for Bachelor of Science in Biosystems	August 2009-Present
and Agricultural Engineering	G.P.A. 3.43

Specific in Biomechanical Engineering and Food Engineering

Professional Experience:

Oklahoma State University Food and Agricultural Products Center, Stillwater, Oklahoma, Summer 2010-Present
-Harvesting meat from beef, swine, and lambs on the harvest floor
-Gaining experience in working with a supervisor and other students
-Incorporating Agricultural Engineering within a meat processing plant
-Working first-hand with a Suspentech/Cozzini Fat Injection System

Drew.Sutterfield’s Auto Detailing, Fort Gibson, Oklahoma, Summer 2009
- Learned how to financially manage a self-employed business

JONATHAN C. LIM

jclim@ostatemail.okstate.edu **4005 W 32nd Avenue**
(405) 269-2137 **Stillwater, OK 74074**

EDUCATION

Bachelor of Science in Biosystems Engineering, Food Processing Option (Expected: 2013)
Bachelor of Science in Human Nutritional Sciences (Expected: 2012)
Oklahoma State University, Stillwater, OK
GPA: 3.315/4.000

Oklahoma Regents Scholarship, 2005 – 2009

SELECTED SKILLS AND ACCOMPLISHMENTS

- Created an electronic control system that regulated humidity, moisture, and temperature for a model-scale greenhouse.
- Experienced with using Arduino Pro Mini microcontrollers and Arduino programming language.
- Completed NIH Web-based training course "Protecting Human Research Participants".

PROFESSIONAL EXPERIENCE

Undergraduate Researcher ***MAY 2012 – SEPTEMBER 2012***
Oklahoma State University **Stillwater, OK**

- Performed enzymatic assay experiments to ascertain the amount of starch in Sweet Sorghum samples.
- Studied technical literature to understand the workings of sugarbeet and sugarcane extraction facilities in the United States and overseas.
- Communicated with different companies to find and purchase a suitable assay kit for the research project.
- Created experimental samples as directed by the assay protocol.

Undergraduate Researcher ***MAY 2010 – AUGUST 2010***
Oklahoma State University **Stillwater, OK**

- Designed and performed experiments to discover the viability of using soft drinks as a source of ethanol fuel.
- Wrote a scientific paper detailing the methodology of the research project and results of the research project.
- Worked with a university professor to assess the importance of each experiment.
- Created Excel spreadsheets and graphs with appropriate functions and equations to consolidate the relevant experimental data.

Cameron Mancill Buswell

cameron.buswell@okstate.edu | (405)-416-0547
409 ½ South Duncan Apt. A, Stillwater, OK 74074

SKILLS AND ACCOMPLISHMENTS

Familiar with MS Word, Excel, Visual Basic, Pro-Engineer, and Solid Works.

Raced in the 2009 and 2010 Mountain Bike National Championships in Granby, CO.

Former Vice President and Mountain Bike Officer of the Oklahoma State University Cycling Club.

Have a Cat. 1 USA Cycling Mountain Bike License and race for Schlegel Bicycles and OSU Cycling.

Eagle Scout-Troop 117

EDUCATION

Oklahoma State University| Stillwater, OK Projected May 2013
Bachelor of Science: Biosystems Engineering - Biomechanical Engineering Option

EXPERIENCE

District Bicycles | Stillwater, OK Summer 2012
Mechanic

- Performed repairs, built new bikes, and helped customers with questions.

Oklahoma State University| Stillwater, OK Summer 2011
Carpentry Department

- Assisted with various projects throughout campus, primarily in the student housing complexes.

YMCA of the Rockies | Estes Park, CO
Building and Grounds/ Food Service Summer 2010

- Being a third-year staff member, I took on a more supervisory role for the AM kitchen crew and delegated instructions to newer employees.

Food Service Summer 2009

- As a returning staff member I was given additional responsibilities in the kitchen.

Food Service Summer 2008

- Learned how a large scale kitchen operates and basic cooking skills.

D-TABB & Associates | Oklahoma City, OK Summer 2006
Modular Furniture Mover and Installer

Sibongile Faith Hlatywayo

89 S University Place apt. 3 *405-880-5292*
Stillwater OK 74075 *sibongile.hlatwayo@okstate.edu*

Bachelor of Science in Bio-Mechanical Engineering
Oklahoma State University, Stillwater, Oklahoma

Professional Experience
Technician
Oklahoma State University, Stillwater OK, *May 2011-May 2012*

- Activate data control rooms
- Troubleshoot internet outages
- Install wireless internet coverage

Library Associate
Oklahoma State University, Stillwater, Oklahoma, August 2008-August 2009

- Serviced students by checking out items using computer system voyage
- Shelved books using numeric number system

Lab assistant
Plant Pathology Dept., Oklahoma State University, Stillwater, Oklahoma, *August 2005-May 2007*

- Assisted graduate students with research
- Autoclaved material, kept the research area sterile
- Watered and planted researched plants in the green house
- Prepared algae for the testing of Medicago truncatula mutants

TECHNICAL SKILLS

- Visual Basic
- Proficient with Microsoft Office programs, including MS Word, MS Excel, MS Power Point, MS Outlook
- Solid Works

LEADERSHIP
Internship
Heifer International Ranch, Perryville, Arkansas, May 2007- August 2007

- Proved experiential education to the visitors
- Taught a class about promoting sustainable solutions to global hunger and poverty

Student Organizations

Cultural Coordinator of African students Organization, Oklahoma state university, Stillwater Oklahoma, *May 2011-May 2012*

Rotary Arm Design for U.S. Roaster Corp.

Prepared by CoolRoast Engineering Design Group

Drew Sutterfield, Jonathan Lim,

Cameron Buswell, Sibongile Hlatywayo

MISSION STATEMENT

- We are committed to working with clients throughout the design process to understand their needs so that we can provide practical engineering solutions that exceed customer expectations.

Sponsor Information

- Based in Oklahoma City, OK.
- Fabricate and sell Coffee Roaster machines to clients.
  - Primarily U.S. cliental
- Repair of Coffee Roaster machines manufactured by other companies
- Sell fresh-roasted coffee beans

US Roaster Corp

- Cliental Survey results showed that cooling system of machines could be improved.
- Preferable to maintain some traditional aspects of past rotary arms, while modernizing them as well.
- The rotary arm in the cooling bin is the most

Background Information

- Rotary arm mixes freshly-roasted coffee beans after they empty into cooling bin.
- Rotary arm can affect several key factors.
  - Uniformity of bean cooling.
  - Bean cooling speed.
  - Bin emptying speed.
- NSF standards.

Problem Definition

Design Objectives & Goals

CoolRoast Design Goals

- Work closely with U.S. Roaster Corp to design a rotary arm that will enhance the quality of their coffee roaster machines.
- New rotary arm design should perform better than the current rotary arm currently used in the U.S. Roaster Corp's coffee roasters.
- Rotary arm design should help preserve the traditional design aesthetic of U.S. Roaster Corp's coffee roasters.

CoolRoast Design Objectives

- Improve the uniformity of cooling of coffee beans in the cooling bin.
- Improve the rate of cooling of the roasted coffee beans.
- Improve the flow of air in the cooling bin as it mixes.
- Minimize the amount of coffee beans that are destroyed (crushed or ground) by the rotary arm in the cooling bin.
- Adhere to NSF International standards if possible.

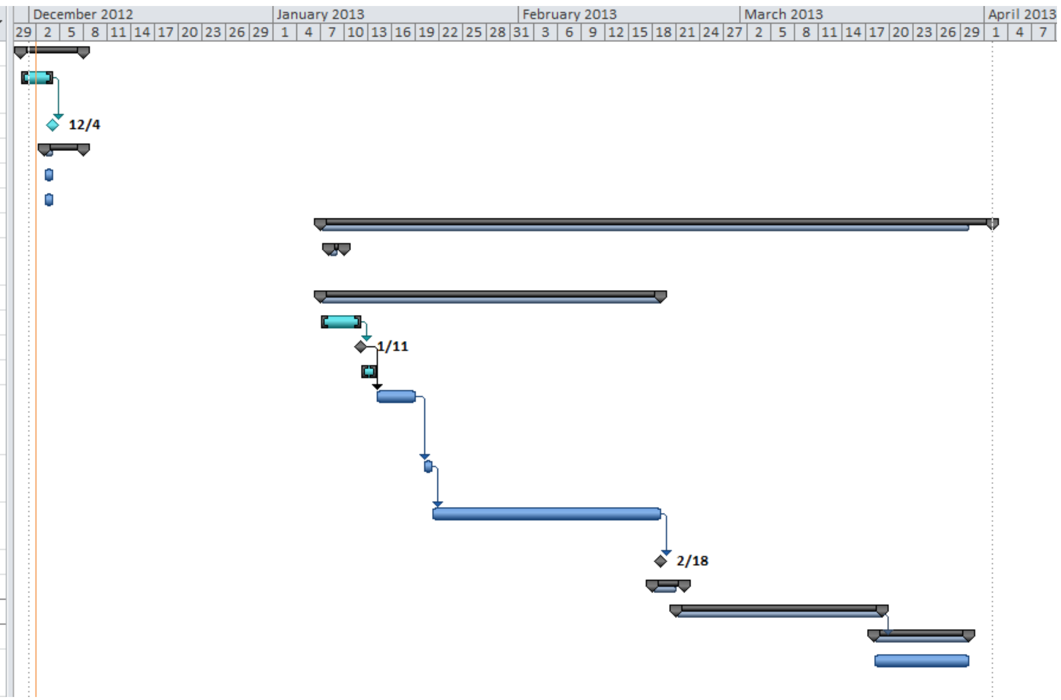
CoolRoast Design Constraints

- Cost of materials for each prototype design should not exceed $650.
- Prototype rotary arms will be designed to fit and rotate within the current 12 kg coffee bean roaster cooling bin
- Rotary arm design should not cause coffee roaster machines to stray too far from “traditional” look.
- Final product (not prototype) should be tested and approved before April 2013.

Scheduling of Project

Gantt Chart

Task Name	Duration	Start	Finish
Coolroast 2012 Tasks	**6 days**	**Fri 11/30/12**	**Fri 12/7/12**
Consolidate data for U.S. Roaster Corp Presentation	2 days	Fri 11/30/12	Mon 12/3/12
U.S. Roaster Corp. Presentation	0 days	Tue 12/4/12	Tue 12/4/12
Default rotary arm testing	**5 days**	**Mon 12/3/12**	**Fri 12/7/12**
Mixing Test & Cooling uniformity test	1 day	Mon 12/3/12	Mon 12/3/12
Data Consolidation	1 day	Mon 12/3/12	Mon 12/3/12
Coolroast 2013 Tasks	**64 days**	**Mon 1/7/13**	**Mon 4/1/13**
Additional default rotary arm testing (if needed)	**2 days**	**Tue 1/8/13**	**Wed 1/9/13**
Creation of Rotary Arm Design	**33 days**	**Mon 1/7/13**	**Mon 2/18/13**
Prototype rotary arm CAD work.	5 days	Mon 1/7/13	Fri 1/11/13
3 prototype rotary arms fully drawn in CAD.	0 days	Fri 1/11/13	Fri 1/11/13
Prototype Rotary Arm Cost Analysis	2 days	Sat 1/12/13	Sun 1/13/13
Consult with U.S. Roaster Corp about prototype design aesthetics, cost, and potential improvements.	5 days	Mon 1/14/13	Fri 1/18/13
Rotary Arm Prototypes design revision period	1 day	Sun 1/20/13	Sun 1/20/13
Fabrication of Rotary Arm Prototypes via BAE machinery lab or 3D Printing	21 days	Mon 1/21/13	Mon 2/18/13
Rotary Arm Prototypes fabricated.	0 days	Mon 2/18/13	Mon 2/18/13
Testing Prototype Rotary Arms	**4 days**	**Mon 2/18/13**	**Thu 2/21/13**
Revising Prototype Rotary Arm Designs	**19 days**	**Thu 2/21/13**	**Mon 3/18/13**
Presentation Preparation	**10 days**	**Mon 3/18/13**	**Fri 3/29/13**
Preparation for Product Presentation to U.S. Roaster Corp. and BAE Faculty.	10 days	Mon 3/18/13	Fri 3/29/13



- Main tasks in 2012: brainstorming about testing procedures and design concepts, testing of current rotary arm, development of prototypes
- 2013: Testing and evaluating prototypes, constructing final design, completing reports.

CoolRoast Investigations

Competitors , Patent Searches, Testing Process.

Main Competitor

- Probat

- Founded in 1868.

- Foremost competitor for U.S. Roaster Corp.

- Represented in over 60 countries worldwide.

- Roasters for coffee beans, cocoa beans, nuts, and cereal grains.

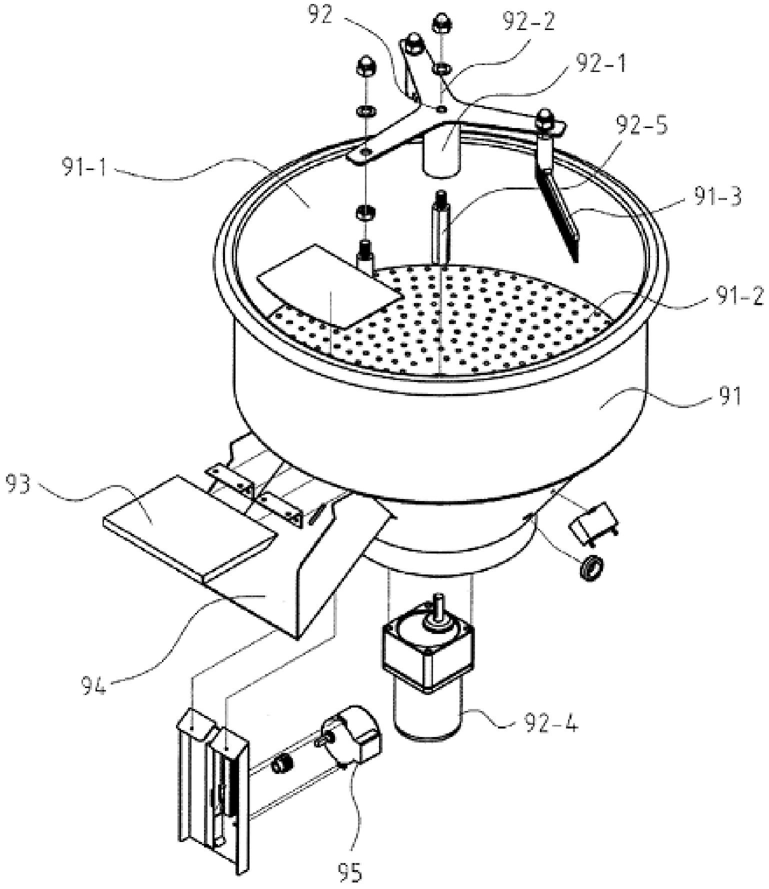
Patent Search

- Most of the patents filed for coffee deal with commercial production of coffee, not small batch roaster machines

- Kando, M., Kishimoto, A., Katsuragi, Y. “METHOD AND DEVICE FOR ROASTING/COOLING BEAN”
  - U.S. Patent #2011/0081467A1 . April 7, 2011.
- Smith JR., H.L. “METHOD FOR COOLING ROASTED COFFEE”.
  - U.S. Patent #3332780. July 25, 1967.
- Ginn, I. M. “COFFEE-STIRRER”.
  - U.S. Patent #513179. January 23, 1894

Patent Search

- Song, E. "Coffee Roaster and Controlling Method of Same".
  - U.S. Patent #7875833B2. January 25, 2011.



Location of Testing

- Carried out in the Robert M. Kerr Food and Agricultural Products Center (FAPC).
  - Wet processing lab

- FAPC resources made testing easier
  - Ovens to heat beans
  - Sanitary area to set up cooling bin

Testing Equipment

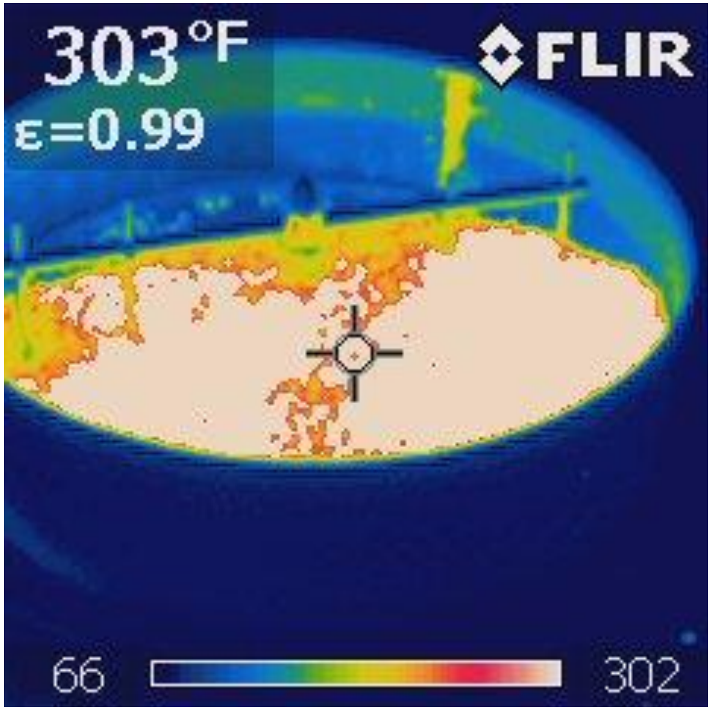
- Cooling Bin
  - Detachable Rotary Arm
  - Fabricated by U.S. Roaster Corp
- Coffee Beans for testing
  - Donated by U.S. Roaster Corp.
- Infrared Camera
  - Visual aid of heat distribution on surface
- Industrial Ovens

Testing: Thermal Imaging

- Infrared Camera

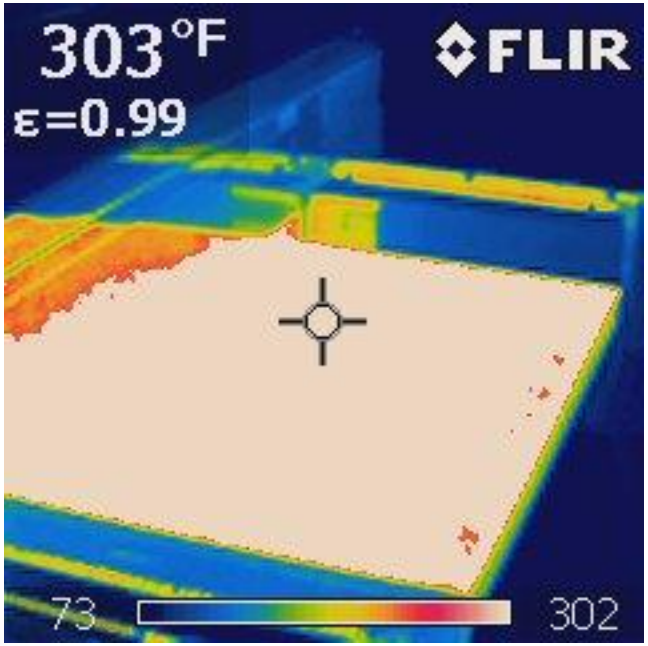
  Provided by Dr. Frazier

- Shows uniformity of cooling on the surface of the beans



Thermal Imaging

Beans exiting oven



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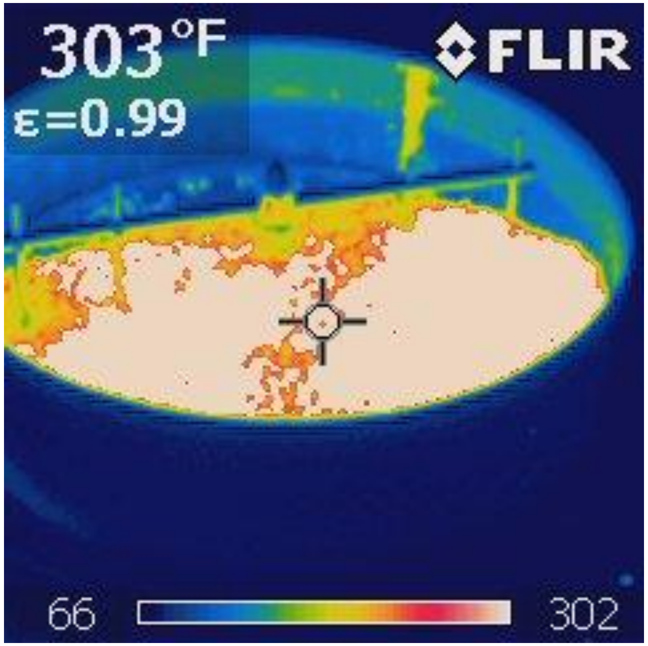
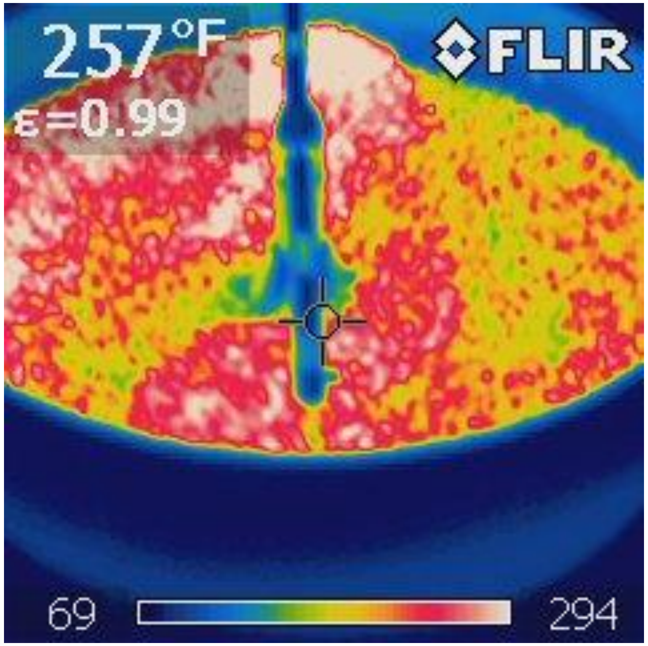


Thermal Imaging

60 seconds



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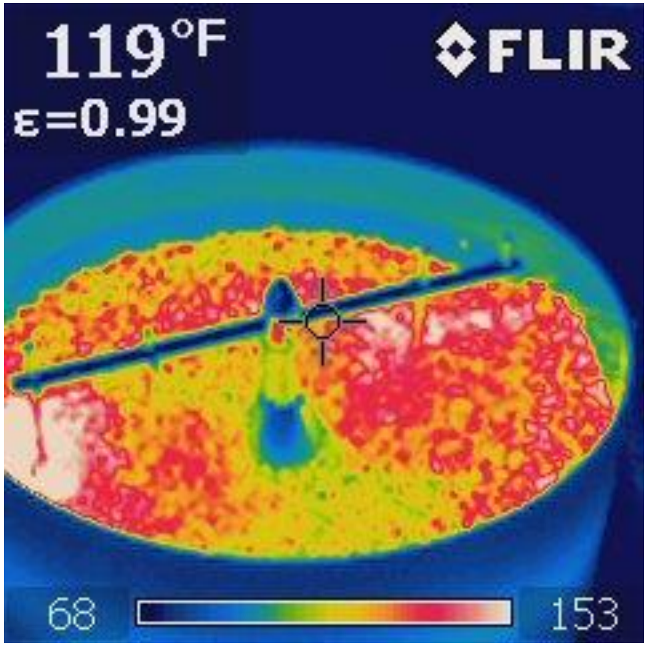

Thermal Imaging

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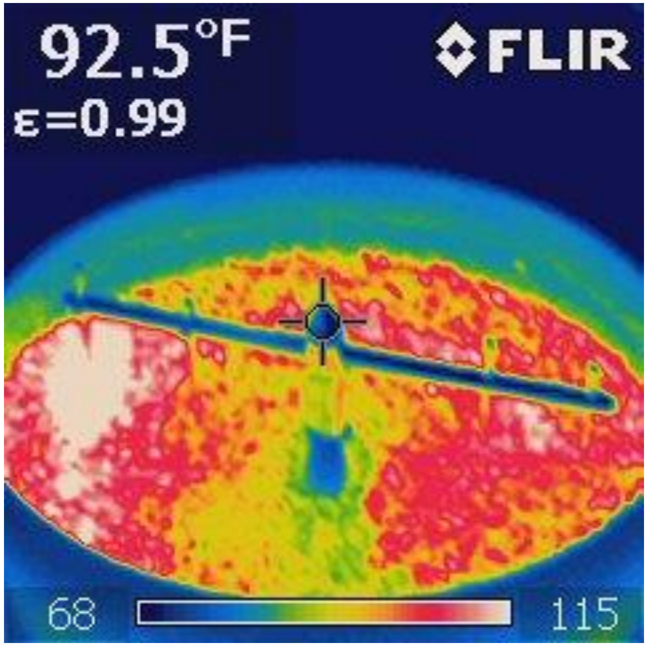

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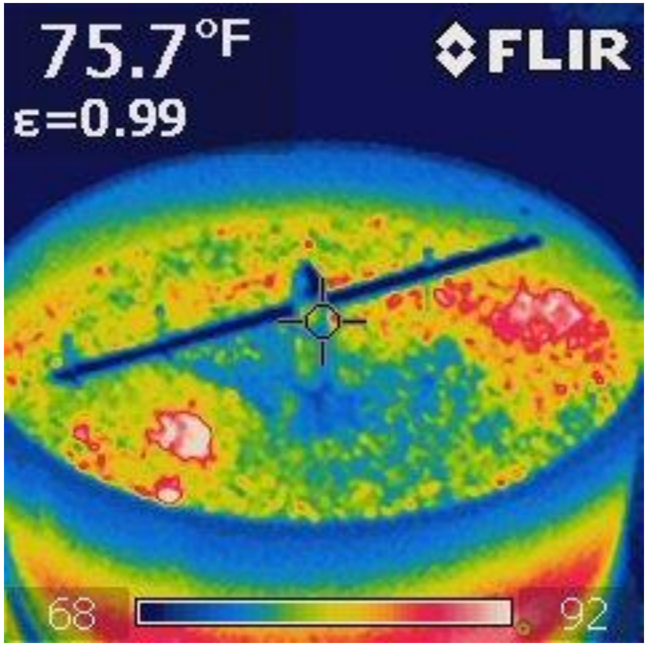


Mixing Test

- Visual aid test developed to look at the ability of rotary arm designs to effectively mix coffee beans
  - Compare and analyze original and prototype designs.

Mixing Test

- Originally thought that candy may imitate coffee beans
  - Testing disproved this theory
  - 3 tests
    - 2 with Jelly Beans
    - 1 with Red Hots

Mixing Test

Performed with Red Hots

Mixing Test

- Visual Area Determination method (VAD method)
  - Measuring mixing of colored material vs. roasted coffee beans.
  - Intermittent snapshots of coffee bean surface
  - Statistical distribution programs and algorithms.
  - % brown (roasted coffee beans) vs. % colored material (other material) over time.

VAD Method

- Colored Material mixed with coffee beans
- Snapshots of coffee bean surface
- Colored Material Provides contrast for snapshots
  - Material consideration list: jelly beans, Red Hots candies, white spray-painted coffee beans, different colored beans (non-coffee)

- Determine color fraction of surface beans
  - Observe distribution of colored material in coffee bean surface over time
  - Extrapolation: colored material distribution as coffee is mixed.
  - Quantify mixing ability of rotary arms

Engineering Specifications

Equations/Formulae, Calculations, etc.

Important Factors

- Initially considered performing force and weld analysis of the current design.
- Through inspection of design with Dr. Hardin we learned that a machinery analysis wasn't needed.
- Decided to focus on heat transfer aspect of project.
- Coffee beans encounter convective heat transfer by the air flow as well as conductive heat transfer between the beans and metal walls.

Heat Transfer Equations

- Convective: $q = h A (T_1 - T_2)$
  - Due to external argent (air)
- Conductive: $q = -k A (T_2 - T_1)$
  - due to the transfer of energy from rotation arm to the beans.

  where:

  q=heat transfer, W

  h= convective heat transfer coefficient, $W/m^2 K$

  k = conduction heat transfer coefficient, W/m K

  A= Normal area to the direction of heat flow

  T= Temperature, Kelvin

- $T_1 = 450°$
- $T_2 = 90°$

Future Testing Plans

- From the literature we found that coffee beans have similar physical properties to that of softwood.
- Use temperature probes or to provide temperature data at different depths in the cooling bin over time.

Design Considerations

- Believe that better coffee bean circulation vertically will improve cooling rate.
- Inclined pieces of metal to help move beans upward from the bottom of the bin.
- Prevent beans from collecting in piles as they are moved.

Generation of Design Concepts

Design Criteria

- Cool coffee beans from a temperature of 450°F to 90° F within 3-5 minutes.
  - Ambient air temperature not greater than 90° F
- Improve circulation of beans throughout cooling bin
- After cooling is completed, proposed designs should reduce the time taken to remove beans from bin
- Number of broken or warped coffee beans should be minimized.

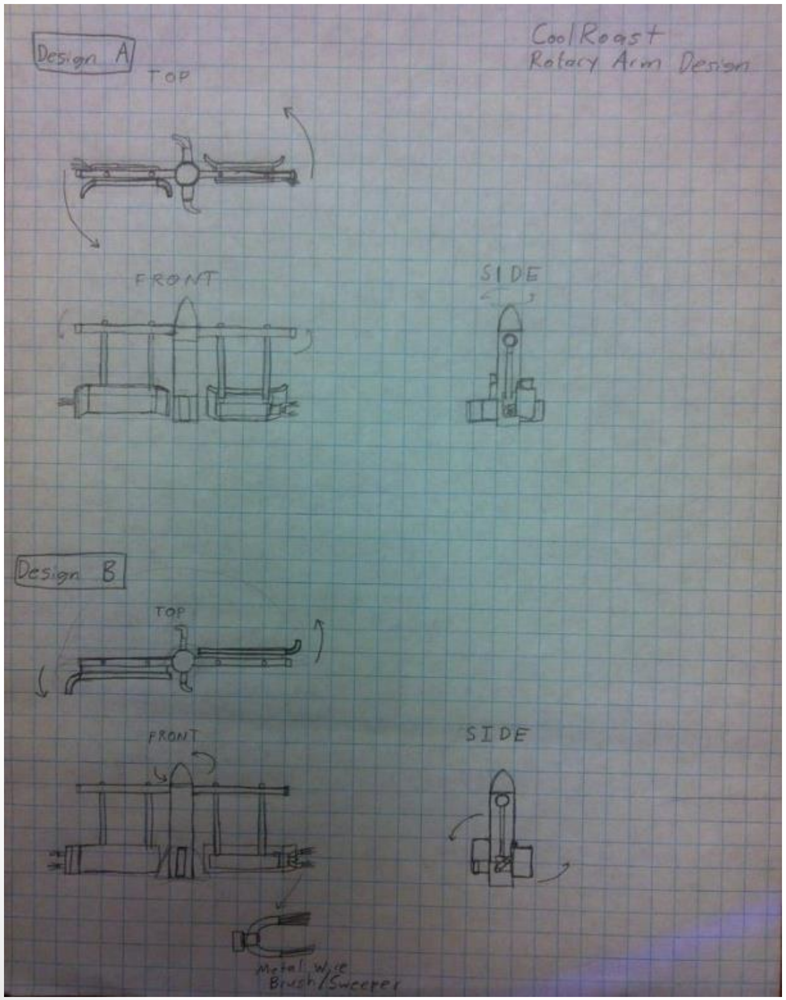
Future impacts of new design

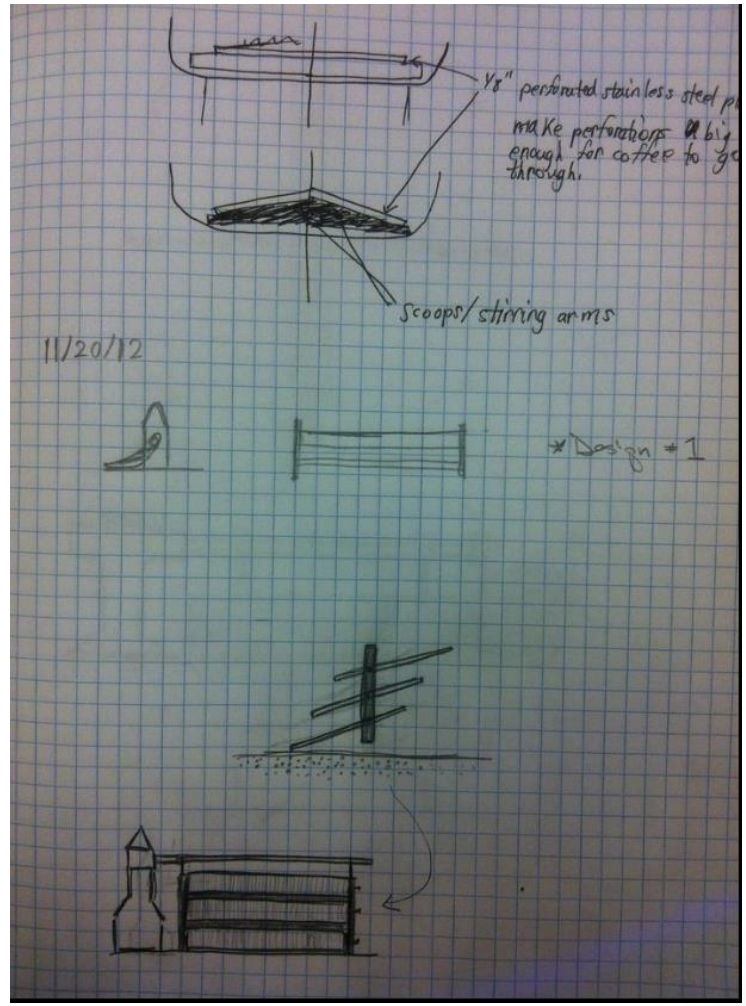
- Successfully designed rotary arm may:
  - Increase customer satisfaction by producing a more consistent product
  - Boost sales of U.S. Roaster Corp’s coffee roaster machines
  - Reduce fabrication costs of roaster machines.
  - Provide a competitive advantage for U.S. Roaster Corp’s against competitors

Plastic Modeling

- Consulted with Doug Enns about using 3D printer to construct plastic rotary arm models.
    - 3D printing is better suited for complex, small objects
- Concluded that 3D printing would be inefficient for our applications.

Brainstorming and Conceptual Design





Brainstorming and Conceptual Design





Default Rotary Arm Design

- Current design used by U.S. Roaster Corp

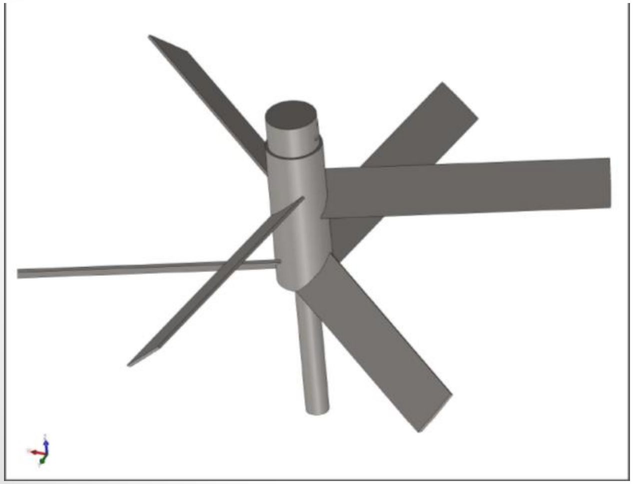
Prototype 1

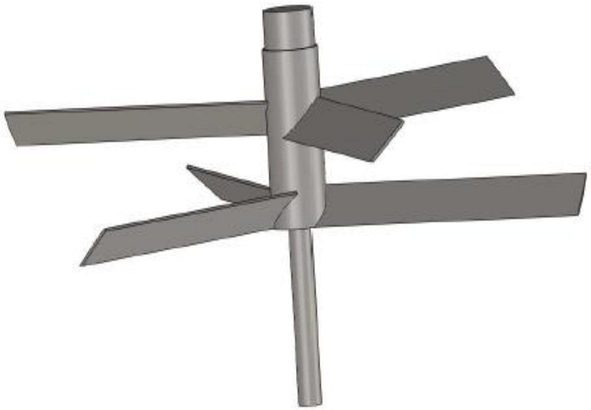
- Advantages
  - Easy to fabricate
  - Reduces bolts and other joint fasteners
  - Increases aeration of beans in cooling bin due to blade design

- Disadvantages
  - Does not clean sidewalls of bin
  - Currently the design is not flush between the inside plate and center piece of the bin.

Prototype 2

- Advantages
  - Increase lift caused by rotary arm, increase aeration
  - Reduction of crevices and bolts, easier to get NSF certified
  - Easier to clean than current design
- Disadvantages
  - Greater torque on motor, due to greater surface area pushing the beans
  - More metal in design, leads to higher cost of fabrication than current design





Design Project Budget

Predicted Budget, Other Constraints

Proposed Budget for Rotary Arm

- NSF standards require 304 stainless steel for food machinery.
- Surface Finish

No. 4 Polished

- First Prototype ($100.00)
- Second Prototype ($200.00)

2B Unpolished

- First Prototype ($ 80.00)
- Second Prototype ($160.00)

- Sr. Design Budget $650.00

Other Concerns

- Need more coffee beans for testing purposes
- Mixing tests & VAD Method
  - Use colored coffee beans, or use different non-coffee bean for proof-of-concept test?
  - No hard and fast way to quantify mixing capability
  - Consult with professors & research past mixing experiments.

Acknowledgements

- U.S. Roaster Corp
  - Dan Joliff, Dean Oldham, and staff involved in model cooling bin construction.
- Dr. Paul Weckler
- Dr. James Hardin
- Dr. Scott Frazier
- Dr. Timothy Bowser
- Dr. Yu “Jessie” Mao
- Oklahoma State University Food and Agricultural Products Center (FAPC)
- Jake Nelson
- Doug Enns

References

- Ginn, I. M. “COFFEE-STIRRER”. 513179. January 23, 1894
- Jolliff, Dan. "Re: OSU Senior Design CoolRoast team." Message to Drew Sutterfield. 24 Sept. 2012. E-mail.
- Kando, M., Kishimoto, A., Katsuragi, Y. “METHOD AND DEVICE FOR ROASTING/COOLING BEAN”. 2011/0081467A1 . April 7, 2011.
- Smith JR., H.L. “METHOD FOR COOLING ROASTED COFFEE”. 3332780. July 25, 1967.
- Song, E. “Coffee Roaster and Controlling Method of Same”. 7875833B2. January 25, 2011.
- http://www.probat.com/en/company.html