Computer Controlled Home Brewing System

A Baccalaureate thesis submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

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April 22, 2015

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ABSTRACT

Home brewing is a challenging task that I believe can be made much easier. The main problems most home brewers face are they have to do a lot of heavy lifting, handling very hot equipment, and maintaining consistency. There is a lot of equipment required when it comes to brewing at home. With all this equipment come many different steps to the process of brewing at your house. Current set ups have you transferring your mash into 4 or 5 different containers. Keeping all of these containers clean is also important in home brewing where even the smallest amount of bacteria can ruin the brew. With all of this transfer of liquid if you do not watch closely and work diligently you can easily ruin the batch. Another common way to ruin a batch of beer is to pour the beer from container to container to quickly causing an influx of oxygen greatly altering the flavor. It is also a dangerous process with the lifting of so much heavy equipment and working with an open flame. Getting burned is a very serious problem both from the hot equipment and the gas burner that most brewers use. Many problems home brewers run into are with all of the equipment and constantly having to move liquids from one container to another.

Maintaining constant temperatures is very important in brewing at home. Changing temperatures of your brew during some steps can change the chemical balance of the brew and if left unchecked will cause the brewers efficiency drop considerably. A lot of problems with brews come in with maintaining temperatures. Many home brewers can use the same ingredients and get different tasting and strength based on a temperature difference. Tracking temperature change is nearly impossible with most set ups. Without having a maintained temperature it is almost impossible to remain consistent.
Max Baker and I want to design and build a single container, computer controlled home brewing set up that one person can easily and safely handle. This will include lifting controls, controlled heating and rapid cooling, controlling the flow of various liquids, motor powered mixing, using an internal heating element, collecting data, and improving consistency across all processes. With all of the processes automated risk of injury would be as close to zero as possible. This project will also reduce the amount of ruined batches due to the reduced fluid transfer, lack of attention required, and reduces the amount of space needed. It will also reduce amount of containers to clean once the brew is complete.

OBJECTIVE

- Use computer controllers to automate the brewing process
- Combine our mash tun and boil kettle into one container
- Use motors to automate grain immersion and removal
- Have a stirring mechanism built in during mashing
- Include a chiller for quick cooling and moving into fermenter
THE BREWING PROCESS RESEARCH

People have been brewing beer for thousands of years. The process has not changed much over that time period but the equipment has. There are five main steps for brewing a good beer. The first one is malted barley or grain is soaked in hot water to convert the starches into sugars. Next the sugar solution is brought to a boil and hops are added to give it a bitter taste. The mixture is then cooled and yeast is added. This yeast eats the sugars and produces CO2 and ethyl alcohol. The last step is to add a little sugar to the now beer and bottle it. This will let the yeast produce the carbonation of your beer. (Palmer).

Making beer is not all that difficult if you make sure you keep a watchful eye. Cleanliness is a huge part of brewing. Any time that bacteria enters the beer after the boiling step can ruin your whole batch. Keeping these things in mind making a delicious brew is just a few steps and about a month away. The first step in making beer is called mashing. This is when you take the grains and soak them in hot water to convert the starches into sugars. The second is the boiling phase when you add the hops which give the beer its bitterness. When mashing it is important to maintain a constant temperature to make sure you are getting the most out of your grains. “There are several key enzyme groups that take part in the conversion of the grain starches to sugars. During malting, the debranching (chainsaw), beta-glucanase (weed whacker) and proteolytic (lawnmower) enzymes do their work, preparing the starches for easy access and conversion to sugars. During the mash, a limited amount of further modification can be accomplished, but the main event is the conversion of starch molecules into fermentable sugars and unfermentable dextrins by the diastatic enzymes (hedge trimmer and clippers). Each of these enzyme groups is favored by different temperature and pH conditions. A brewer can adjust the mash temperature to favor each successive enzyme's
function and thereby customize the wort to their taste and purpose” (Palmer). The chart below shows the different temperatures that these enzymes work at. Most brewers keep their mashing temperature right around 153° F for about 60-70 minutes. This can be achieved in a couple different ways. Some people just adjust the temperature of their stove or burner to stay at the temperature mark they are going for. I prefer to use a mash tun which is basically a cooler that you put your grains and hot water in and it will keep the temperature for the hour or so. To get the most sugars out of the grain and improve efficiency most homebrewers do a process called sparging. This is basically when you pour hot water (around 165 °F) through the grains to grab sugars that are attached to grain. By adding sparging to your brewing process you get a better beer with more sugars for the yeast to eat.

Next is the boiling processes. Once the mash/wort comes to a boil the brewer will add his hops. Each recipe calls for different types and amounts of hops but also for different times that they should be boiled for. After the wort has been boiled, usually for about an hour, it needs to be cooled down before you can add yeast. This is done with different kinds of chillers that use running water to cool down the wort quickly. Once the wort is cooled down to around 70° F it is moved to a fermentation vessel and yeast is added. The yeast will convert the sugars from the mashing process into alcohol and CO2. Most beers take a couple weeks while in the first fermentation phase. After primary fermentation is completed priming sugar is added and then the beer is bottled and capped. This sugar will be eaten by the yeast that is still in the beer and produce the carbonation. Bottles should be stored for another couple weeks before drinking. Making beer is a very enjoyable hobby but can be difficult and even dangerous through a couple of the steps.
Table 1 – This table shows the different enzymes during the mashing process and what temperatures they work at (Palmer).

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Optimum Temperature Range</th>
<th>Working pH Range</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytase</td>
<td>86-126°F</td>
<td>5.0-5.5</td>
<td>Lowers the mash pH. No longer used.</td>
</tr>
<tr>
<td>Debranching (var.)</td>
<td>95-113°F</td>
<td>5.0-5.8</td>
<td>Solubilization of starches.</td>
</tr>
<tr>
<td>Beta Glucanase</td>
<td>95-113°F</td>
<td>4.5-5.5</td>
<td>Best gum breaking rest.</td>
</tr>
<tr>
<td>Peptidase</td>
<td>113-131°F</td>
<td>4.6-5.3</td>
<td>Produces Free Amino Nitrogen (FAN).</td>
</tr>
<tr>
<td>Protease</td>
<td>113-131°F</td>
<td>4.6-5.3</td>
<td>Breaks up large proteins that form haze.</td>
</tr>
<tr>
<td>Beta Amylase</td>
<td>131-150°F</td>
<td>5.0-5.5</td>
<td>Produces maltose.</td>
</tr>
<tr>
<td>Alpha Amylase</td>
<td>154-162°F</td>
<td>5.3-5.7</td>
<td>Produces a variety of sugars, including maltose.</td>
</tr>
</tbody>
</table>
EQUIPMENT

**MASH TUN**

The mash tun is the container you use to start your brewing in. “A mash tun (pronounced as mash ton) is a vessel used in the mashing process to convert the starches in crushed grains into sugars for fermentation. Most mash tuns are insulated to maintain a constant temperature and most have a false bottom and spigot so that the sparging process can be done in the same vessel” (Brewwiki). Some brewers use a pot to do their mashing in. They usually use a large mesh bag to put the grain in. “If you have a controlled heat source, you can also make a mash tun from any pot large enough to hold the mash. In this case you just raise the heat on the pot, stirring as you go, until you reach your target temperature. Now you turn the heat down to maintain that temperature. The challenge is that it is difficult to maintain a steady temperature for a long time with a pot on a stove. However, commercial brewers who have temperature control systems do successfully use heated mash tuns” (Brewwiki). This way takes a lot of tweaking and is not very easy to maintain the correct temperature. I prefer to use an insulated cooler to maintain my temperature. “Arguably the most popular mash tun in use by homebrewers is a converted 5 gallon or 10 gallon Gott-style’ drink cooler. Gott is the Rubbermaid brand name, but there are many others who make the same style of drink cooler. This is a cylindrical, insulated drink cooler of the style you often see poured over the heads..."
of coaches at the end of US football games. The original cooler has a valve at the bottom for pouring the drinks out. This type of cooler is ideal for infusion mashing where hot water is
Following all of our research and experience we were able to determine the most effective way to brew beer. Our brewing system will need to include all equipment required to brew in one compact system. We will need to be able to maintain a temperature of 153°F for the mashing procedure and then reach boiling temps after grain removal. This will need to be done using a heating element. It then will cool the beer using an immersion chiller.
Controlling all of these processes and motors will be best served using an Arduino micro controller added to the grains, and the cooler is then sealed to maintain a constant temperature during the conversion process. A cooler will typically only lose a degree or two (F) during the hour long mashing process” (Brewwiki). These coolers usually have a false bottom to remove any grain particles so they don’t go into the boiling kettle.

**BOILING KETTLE**

The boiling kettle is the container that you boil your wort in and the container that you will add your hops into. There aren’t too many different kinds of boiling kettles. Most homebrewers use a large stainless steel pot or a keg that the top has been cut off and a valve added to the bottom. The size of the pot should be a couple gallons larger than the size of the batch you plan on making. When you mash and then sparge the grains you usually end up with a couple gallons more than what your final batch size is going to be. Also when boiling there is a lot of foam and bubbling and you don’t want to spill your precious beer. Almost all brewers use stainless steel for their boiling kettles, however copper is also a viable choice. Copper was used in the past in a lot of breweries. Stainless steel is easier to maintain and it is also stronger so it is the go to in today’s industry.
Cooling your wort is very important if you want to have a high quality beer. The main reason it needs to be cooled is so that the yeast can survive and work well. Yeast can only survive at certain temperatures, generally 68–72° F for ale yeast strains and 45–58° F for most lager yeast strains. However yeast health is not the only reason despite it being the most important one. If the wort is cooled rapidly it introduces much less opportunity for bacteria to get into your wort and grow. These bacteria can produce an off flavor in your beer and even ruin the batch. Rapidly cooling beer also will slow down the production of dimethyl sulfide, commonly referred to as DMS. DMS is an unwanted substance in beer that can give off a cooked corn smell. In order to produce good consistent beer you must have a consistent cooling method.

Cooling can be done in a plethora of ways, from the simplest submerging in an ice bath to counter flow chillers. An ice bath would not be a good option in our application and is not very efficient so we won’t be considering it. A very common cooling method for homebrewers is an immersion chiller. An immersion chiller generally is a long coil of copper tubing that is placed inside the hot wort. Cold water is run from a sink or hose through the copper coils and out the top through a hose. This cold water running through the coils absorbs the heat and carries it out of the wort. With a good sized immersion chiller, the wort can be chilled to the water temperature in around 30 minutes. Immersion chillers are popular due to their fast chilling time and being
inexpensive.

The most highly regarded way to chill wort amongst homebrewers is a counter flow chiller. There are two types of counter flow chillers, one using copper tubing and one using plates. A copper tubing counter flow chiller consists of a coiled copper tubing inside of coiled copper tubing. The hot wort is pumped through the inner tubing in one direction where the cold water is pumped through the outer tubing in the opposite direction. With a plate counter flow chiller the water is pumped in one direction through a series of plates and the hot wort is sent in the opposite direction through a different series of plates. Since there is more cold water working on the smaller amount of wort the counter flow chiller is very efficient and can cool the wort in under 10 minutes. The counter flow chiller is popular because it is the fastest way to chill wort, can be used for all batch sizes, and uses less water. Its biggest drawback is its price point and the difficulty to clean. Since wort is going through the coils you are unable to be sure that it is clean.
HEAT SOURCE

An induction burner allows for a much higher repeatability compared to an open flame. With a propane burner you constantly have to mess with gas level to control the boil. With an induction boiler you are able to set watt increments and maintain consistency. An open flame is able put out much more heat but with really no value added unless producing a very large batch. The initial set up costs are very similar in home brewing application. However the cost of use is much cheaper. Using a propane burner works out to a cost of about $5 per brew where using induction it works out to around $0.60 per brew.

MICROCONTROLLERS

There are all kinds of different microcontrollers. The two most popular ones are the Arduino and the Raspberry Pi. The purpose of a microcontroller is to be able to control multiple different systems. Both Arduinos and Raspberry Pi’s can take certain inputs and give a different output. Each of these boards have different strengths and weaknesses. Choosing the right one for your project is very important and will save a lot of time and effort down the road. Arduinos are good “When the main task is reading sensor data and changing values on motors or other devices. Given the Arduino’s low power requirements and upkeep, it’s also a good choice if your device will be constantly running and requires little to no interaction”. Raspberry Pi on the other hand should be chosen, “When you would otherwise complete your task with a personal computer. The Pi makes a slew of operations easier to manage, whether you intend to connect to the Internet to read and write data, view media of any kind, or connect to an external display” (Bourque).
**Research Conclusion**

Following all of our research and experience we were able to determine the most effective way to brew beer. Our brewing system will need to include all equipment required to brew in one compact system. We will need to be able to maintain a temperature of 153°F for the mashing procedure and then reach boiling temps after grain removal. This will need to be done using a heating element. It then will cool the beer using a counter flow plate chiller. Controlling all of these processes and motors will be best served using an Arduino microcontroller on our computer controlled home brewing system.
THE BREWCAT

FABRICATION
The BrewCat is made up entirely of 304 and 316 stainless steel and everything was tungsten inert gas (TIG) welded. All cuts were made with a pipe cutter and all holes were drilled with a drill press or hand drill.

Figure 7 – Zach Zanola Polishing BrewCat Kettle

The BrewCat grain basket was one of the more difficult things to fabricate. It is made up of a 400 micron 316 stainless steel mesh. In order to keep it together we ran rings around it vice gripped it and welded the rings together along with the stainless mesh. The seam of the stainless mesh was held together by soldering.
**Electric**

In order to control our hoist, heating element and pump we used six solid state relays, a 120 volt to 12 volt transformer and an Arduino micro controller. In addition to wiring we soldered our own circuitry.

Figure 9 – Soldering of Circuit Board

Figure 10 – BrewCat Electrical Box

Figure 11 – Wiring Schematic
**USER INSTRUCTIONS**

1. Plug in The Brew Cat.

2. Make sure that The BrewCat is filled with water to desired brew size.

3. Make sure BrewCat arm is swung out and turn on.

4. Heating element will begin heating, pump will start circulation, and hoist will drop grain basket to the ground. You will have 3 minutes to fill the grain basket.

5. After 3 minutes the grain basket will be lifted.

6. Swing arm over BrewCat kettle until aligned properly then lock into place.

7. Once the water reaches 153°F the grain basket will immediately drop into the water.
   
   The mash period has begun. This will go for an hour at 153°F and the basket will then pick-up.

8. The heating element is now heating to a boil. Once the BrewCat reaches boiling (there will be noticeable movement and bubbling of the wort) another hour timer will begin.

9. Once the BrewCat has reached boiling now is time for your first hop addition. The BrewCat is open to creativity. You have the freedom to do all the hop additions you want for those IPA’s.

10. After this hour is up it is time to cool your wort. Attach a hose to the plate chiller.

11. Make sure the wort outlet is over your bucket or carboy. Now turn on the hose and open up the BrewCat release valve. This should decrease the outlet temperature from 212°F to around 70°F.
**Testing**

To calculate your efficiency in brewing you take the amount of sugars you could get out of the grain and compare it to the amount of sugar you actually get in your wort. In our first five brews, while we were using our old equipment, we were averaging around 75%. With the BrewCat we had an efficiency of 84%. This is a huge improvement and will lead to better beer.

Table 2- BrewCat Efficiency

<table>
<thead>
<tr>
<th>BREW</th>
<th>Theoretical OG</th>
<th>Actual OG</th>
<th>Efficency</th>
<th>Batch Size (Gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown Ale</td>
<td>1.088</td>
<td>1.062</td>
<td>70%</td>
<td>5</td>
</tr>
<tr>
<td>OctoBROfest</td>
<td>1.097</td>
<td>1.073</td>
<td>75%</td>
<td>5</td>
</tr>
<tr>
<td>StolenKettle Ale</td>
<td>1.099</td>
<td>1.072</td>
<td>73%</td>
<td>5</td>
</tr>
<tr>
<td>IPA</td>
<td>1.098</td>
<td>1.07</td>
<td>71%</td>
<td>5</td>
</tr>
<tr>
<td>Christmas Ale</td>
<td>1.099</td>
<td>1.073</td>
<td>74%</td>
<td>5</td>
</tr>
<tr>
<td>Tech Expo CreamCat Ale</td>
<td>1.076</td>
<td>1.064</td>
<td>84%</td>
<td>5</td>
</tr>
</tbody>
</table>
CONCLUSION

The BrewCat did everything we set out to do and more. We were able to combine our mash tun and boil kettle into one container that allowed the freedom to brew anywhere from a 5-15 gallon batch. It maintains consistent temperatures using our heating element and temperature probe. We cut out the need of 2 people and eliminated all lifting with our computer controlled hoist. We removed the dangers of an open flame and saved money in the process. The Brewcat also increased our brewing efficiency over 10% on our first brew. This was a great project for the two of us. We learned a lot about fabrication, wiring, and the use of micro-controllers. Now we look forward to testing our project much more throughout our lives.

Figure 12 – The BrewCat
WORKS CITED


APPENDIX A

Support Arm Strength of Materials

We will be using 2” stainless steel 304 tubing for our support arm. The equations below are to prove that our support arm, that will be holding our hoist and grain basket, will be strong enough. The yield strength of stainless steel 304 is 31,200 psi. We used a simple force over area equation combined with the moment over moment of inertia. Our value came out to 3752 psi. This gives us a factor of safety of over 8. Below is the free body diagram.

\[ P = 105 \text{ lbs.} \]
\[ A = 0.736 \text{in}^2 \]
\[ \sigma = \frac{P}{A} + \frac{M}{I} \]
\[ I = \pi(D_o^4 - D_i^4)/64 \]
\[ I = \frac{\pi(2^4 - 1.75^4)}{64} = 0.32 \text{in}^4 \]
\[ M = 105bs \times 11 \text{ in} = 1155 \text{ in}lbs \]
\[ \sigma = \frac{P}{A} + \frac{M}{I} \]
\[ \sigma = \frac{105lbs}{0.736 \text{ in}^2} + \frac{1155 \text{ in}lbs}{0.32 \text{ in}^4} \]
\[ \sigma = 3752.04 \text{psi} \]
Support Legs Equations

We are using 4, 1” stainless steel tubes to provide support for stand. We expect the kettle (when full) and support arm to weigh about 250lbs. The yield strength is 31,200 psi. Using force over area we are able to calculate the strength needed to support the load. The factor of safety is over 150.

Leg Supports

\[ A = 4 \text{ legs} \times 0.34 \text{ in}^2 = 1.37 \text{ in}^2 \]

\[ P = 250 \text{ lbs.} \]

\[ \sigma = \frac{p}{A} = \frac{250\text{lbs}}{1.37\text{in}^2} = 181.89 \text{ psi} \]
Heat Transfer Equations

We first calculated how much energy we need to raise the water to the correct temperature. We then found how much energy is lost through the sides of the system. Our heat input is a 2000 Watt heating element. With the heat loss subtracted from the heat in we can figure out how long it will take to heat up the water.

From 70 °F to 153°F 8.5 Gallons

\[ Q = mc \Delta T \]
\[ Q = (32.1 kg)(4180)(46.11°C) = 6195861 \, W \]

\[ Q_{loss} = hA \Delta T \]
\[ Q_{loss \, max} = (5)(1.21m^2)(83.3°C) = 504.2 \]
\[ Q_{loss \, min} = (5)(1.21m^2)(0°C) = 0 \]
\[ Q_{loss \, avg} = \frac{Q_{loss \, min} + Q_{loss \, max}}{2} = 252.1 \, W \]

\[ Q_{in} = Q_{Element} - Q_{loss \, avg} \]
\[ Q_{in} = 2000 \, W - 252.1 \, W = 1747.9 \, W \]

Time to heat water

\[ Time = \frac{Q}{Q_{in}} \]
\[ Time = \frac{6195861 \, W}{1747.9 \, W} = 3546 \, seconds \, or \, 59 \, minutes \]
## Table 3– Heating Element Time Table

<table>
<thead>
<tr>
<th>Start Temp</th>
<th>Final Temp</th>
<th>Start °C</th>
<th>Final °C</th>
<th>ΔT</th>
<th>Gallons</th>
<th>Mass kg</th>
<th>Heating Element Watts</th>
<th>Heat Loss</th>
<th>Heat in</th>
<th>C of water</th>
<th>Q=mcΔT</th>
<th>Time Minutes</th>
<th>Total Brew Time (Minutes)</th>
<th>Total Brew Time (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>70</td>
<td>21.11</td>
<td>21.11</td>
<td>0.00</td>
<td>0.83</td>
<td>1.67</td>
<td>13.1</td>
<td>1.21</td>
<td>5</td>
<td>5</td>
<td>0.0</td>
<td>168.09</td>
<td>2.80</td>
<td>0.47</td>
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<tr>
<td>80</td>
<td>70</td>
<td>26.67</td>
<td>21.11</td>
<td>5.56</td>
<td>0.83</td>
<td>1.67</td>
<td>13.1</td>
<td>1.21</td>
<td>5</td>
<td>5</td>
<td>33.6</td>
<td>67.2</td>
<td>1.50</td>
<td>0.25</td>
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<tr>
<td>90</td>
<td>70</td>
<td>32.22</td>
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<td>0.83</td>
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<td>13.1</td>
<td>1.21</td>
<td>5</td>
<td>5</td>
<td>67.2</td>
<td>100.8</td>
<td>2.50</td>
<td>0.42</td>
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<td>100</td>
<td>70</td>
<td>37.78</td>
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<td>1.21</td>
<td>5</td>
<td>5</td>
<td>134.4</td>
<td>168.1</td>
<td>3.80</td>
<td>0.64</td>
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<tr>
<td>110</td>
<td>70</td>
<td>43.33</td>
<td>21.11</td>
<td>22.22</td>
<td>0.83</td>
<td>1.67</td>
<td>13.1</td>
<td>1.21</td>
<td>5</td>
<td>5</td>
<td>201.7</td>
<td>235.3</td>
<td>5.0</td>
<td>0.83</td>
</tr>
<tr>
<td>120</td>
<td>70</td>
<td>48.89</td>
<td>21.11</td>
<td>27.78</td>
<td>0.83</td>
<td>1.67</td>
<td>13.1</td>
<td>1.21</td>
<td>5</td>
<td>5</td>
<td>268.9</td>
<td>302.5</td>
<td>6.6</td>
<td>1.00</td>
</tr>
<tr>
<td>130</td>
<td>70</td>
<td>54.44</td>
<td>21.11</td>
<td>33.33</td>
<td>0.83</td>
<td>1.67</td>
<td>13.1</td>
<td>1.21</td>
<td>5</td>
<td>5</td>
<td>369.7</td>
<td>336.1</td>
<td>8.2</td>
<td>1.25</td>
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Home Brewing Survey

1. How experienced are you in home brewing?
   Moderately

2. How often do you brew?
   2-3 times/month

3. How many people do you usually brew with?
   Myself or 1 other

4. What is your average efficiency?
   Don’t normally calculate this

5. How long does it take you to clean your equipment?
   About an hour including initial sanitizing. About half an hour of cleaning prior.

6. Would you be interested in an automated all-in-one home brewing system? To kegging?
   Maybe, for right price

7. How much would you be willing to pay for an all-in-one home brewing system?
   $2,000

8. If you could make any part of the brewing process easier what would it be?
   Cleaning, washing, maybe sparge (easy with two people)

Comments:

Thank You for Filling Out Our Survey!

Sincerely,

Max Baker and Zach Zanol
Home Brewing Survey

1. How experienced are you in home brewing?
   - 3 matches so far

2. How often do you brew?
   - 1-2 times a month

3. How many people do you usually brew with?
   - 2 or 3

4. What is your average efficiency?
   - Don’t know

5. How long does it take you to clean your equipment?
   - 1 hr

6. Would you be interested in an automated all-in-one home brewing system?
   - Yes

7. How much would you be willing to pay for an all-in-one home brewing system?
   - $1600

8. If you could make any part of the brewing process easier what would it be?
   - Cleaning and Temp control

Comments:

Thank You for Filling Out Our Survey!

Sincerely,

Max Baker and Zach Zanola
Home Brewing Survey

1. How experienced are you in home brewing?
   3 batches

2. How often do you brew?
   Once a month but progressing

3. How many people do you usually brew with?
   Other

4. What is your average efficiency?
   Not calculated

5. How long does it take you to clean your equipment?
   60 minutes before 45 after

6. Would you be interested in an automated all-in-one home brewing system?
   Yes

7. How much would you be willing to pay for an all-in-one home brewing system?
   $1,000

8. If you could make any part of the brewing process easier what would it be?
   Temp control, cleaning, and sparging

Comments:

Thank You for Filling Out Our Survey!

Sincerely,

Max Baker and Zach Zanola

Cheers!
Home Brewing Survey

1. How experienced are you in home brewing?
   4 to 5 Gallon Brews

2. How often do you brew?
   2 / per month

3. How many people do you usually brew with?
   1 other person

4. What is your average efficiency?
   5 Gallon Brew For 5-6 hours

5. How long does it take you to clean your equipment?
   Super long - 25 min up front; 45 min after

6. Would you be interested in an automated all-in-one home brewing system?
   Yes, but still want to be integral part of process.

7. How much would you be willing to pay for an all-in-one home brewing system? If it's for just boil, All inclusive = $600

8. If you could make any part of the brewing process easier what would it be?
   Temp regulation, timer, pre-set instructions to follow.

Comments:

Thank You for Filling Out Our Survey!
Sincerely,
Max Baker and Zach Zanola
### APPENDIX C

#### QFD

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Figure 12- The BrewCat CAD
Support Arm

Figure 14- 2-D Support Arm
Figure 15- 2-D BrewCat Stand
Figure 16- 2-D BrewCat Kettle
# APPENDIX E

Coding

```c
#include <OneWire.h>

// OneWire DS18S20, DS18B20, DS1822 Temperature Example
//
// http://www.pjrc.com/teensy/td_libs_OneWire.html
//
// The DallasTemperature library can do all this work for you!
// http://milesburton.com/Dallas_Temperature_Control_Library
```

//User Inputs:
//MASH TEMP
const int MASHTEMP = 125; // Desired Mash Temp(deg F)
const int BOILTEMP = 145;
//MASH TIME
const int MASHTIME = 18000; // Desired Mash Time(milli sec.)
//BOIL TIME
const int BOILTIME = 18000; // Desired Boil Time(milli sec.)

boolean HeatUp = false;
boolean HoistDrop = false; // used for dropping basket at start of mash
boolean DoneMash = false;
boolean HoistLift = false; // used for lifting basket after mash is done
boolean MashTimer = false; // used for MASH TIME
long MashstartTime; // used for MASH TIME
boolean BoilTimer = false; // used for BOIL TIME
long BoilstartTime; // used for BOIL TIME

int MashTankTemp;
long startTime; // begins timer

int const PinDown = 6; // choose the pin for the relay 1&3 ssr
int const PinUp = 5; // choose the pin for the relay 2&4 ssr
int MashTime;
int test1;
int BoilTime;
OneWire ds(10); // on pin 10 (a 4.7K resistor is necessary)
const int heater = 12;
const int pump = 8;
void setup(void) {
    Serial.begin(9600);
    pinMode(heater, OUTPUT);
    pinMode(PinUp, OUTPUT); // declare relayPin as output
    pinMode(PinDown, OUTPUT); // declare relayPin as output
    pinMode(pump, OUTPUT);
    digitalWrite(PinUp, LOW); // turn relay OFF
digitalWrite(PinDown, HIGH); // turn relay OFF
delay(600); // drop basket to floor
digitalWrite(PinDown, LOW); // stops basket
delay(10000); // 10 minutes to load grain
digitalWrite(PinUp, HIGH); // lift grain
delay(700); // lifts grain up
digitalWrite(PinUp, LOW); // stop lifting
}
void loop(void) {
  startTime = millis();
  byte i;
  byte present = 0;
  byte type_s;
  byte data[12];
  byte addr[8];
  float celsius, fahrenheit, currentMashTemp;
  if (!ds.search(addr)) {
    Serial.println(" ");
    Serial.println();
    ds.reset_search();
    delay(250);
    return;
  }
  Serial.print("ROM =");
  for (i = 0; i < 8; i++) {
    Serial.write(' ');
    Serial.print(addr[i], HEX);
  }
  if (OneWire::crc8(addr, 7) != addr[7]) {
    Serial.println("CRC is not valid!");
    return;
  }
  Serial.println();
  // the first ROM byte indicates which chip
  switch (addr[0]) {
  case 0x10:
    Serial.println(" Chip = DS18S20"); // or old DS1820
    type_s = 1;
    break;
  case 0x28:
    Serial.println(" Chip = DS18B20");
    type_s = 0;
    break;
  case 0x22:
    Serial.println(" Chip = DS1822");
    type_s = 0;
  }
break;
default:
    Serial.println("Device is not a DS18x20 family device.");
    return;
}
ds.reset();
ds.select(addr);
ds.write(0x44, 1);  // start conversion, with parasite power on at the end
delay(1000); // maybe 750ms is enough, maybe not
// we might do a ds.depower() here, but the reset will take care of it.
present = ds.reset();
ds.select(addr);
ds.write(0xBE); // Read Scratchpad
Serial.print("  Data = ");
Serial.print(present, HEX);
Serial.print(" ");
for (i = 0; i < 9; i++) { // we need 9 bytes
data[i] = ds.read();
    Serial.print(data[i], HEX);
    Serial.print(" ");
}
Serial.print(" CRC=");
Serial.print(OneWire::crc8(data, 8), HEX);
Serial.println();
// Convert the data to actual temperature
// because the result is a 16 bit signed integer, it should
// be stored to an "int16_t" type, which is always 16 bits
// even when compiled on a 32 bit processor.
int16_t raw = (data[1] << 8) | data[0];
if (type_s) {
    raw = raw << 3; // 9 bit resolution default
    if (data[7] == 0x10) {
        // "count remain" gives full 12 bit resolution
        raw = (raw & 0xFFF0) + 12 - data[6];
    }
} else {
    byte cfg = (data[4] & 0x60);
    // at lower res, the low bits are undefined, so let's zero them
    if (cfg == 0x00) raw = raw & ~7; // 9 bit resolution, 93.75 ms
    else if (cfg == 0x20) raw = raw & ~3; // 10 bit res, 187.5 ms
    else if (cfg == 0x40) raw = raw & ~1; // 11 bit res, 375 ms
    // default is 12 bit resolution, 750 ms conversion time
}
celsius = (float)raw / 16.0;
fahrenheit = celsius * 1.8 + 32.0;
MashTankTemp = fahrenheit;
Serial.print("MashTankTemp ");
Serial.print(MashTankTemp);
MashTime = millis() - MashStartTime;
BoilTime = millis() - BoilStartTime;

if (MashTankTemp < MASHTEMP) { // Heat on before and during mash
digitalWrite (heater,HIGH);
Serial.print(" HEAT ON ");
}
if ((MashTankTemp > MASHTEMP) && MashTimer == true && HoistLift == false) { // Heat on before and during mash
digitalWrite (heater,LOW);
Serial.print(" HEAT OFF ");
}
if((MashTankTemp >= MASHTEMP) && MashTimer == false){ // starts timer for mash
MashTimer = true;
Serial.print(" MASHSTARTS!!!!!! ");
MashStartTime = millis(); // starts mash timer
}
if( HoistDrop == false && MashTimer == true){ // Drops basket during mash HoistDrop =
true;
Serial.print("Basket Drop");
HoistDrop = true;
digitalWrite(PinDown,HIGH);
delay(2000);
digitalWrite(PinDown,LOW);
}
if((MashTime >= MASHTIME) && BoilTimer == false && MashTimer == true &&
DoneMash == false){ //mash is complete and lifts basket before boil timer starts turns on heat
Serial.print("MashDone");
digitalWrite(PinUp,HIGH);
delay(2000);
digitalWrite(PinUp,LOW);
digitalWrite(heater,HIGH);
DoneMash = true;
Serial.print("HOISTLIFTTT");
}
if(MashTankTemp >= (BOILTEMP) && BoilTimer == false){ // starts timer for boil
BoilTimer = true;
Serial.print("Boil Started");
BoilStartTime = millis(); // starts mash timer
}
if((BoilTime) < BOILTIME && BoilTimer == true){
digitalWrite(heater,HIGH);
}
if((BoilTime) > BOILTIME && BoilTimer == true){
    Serial.print("BOIL DONE!!");
digitalWrite(heater,LOW);
}
if(BoilTimer == false){
    digitalWrite(pump,HIGH);
}
if(BoilTimer == true){
    digitalWrite(pump,LOW);
}