



A Preliminary Analysis of the Craft Beer Brewing Process

Kenneth Stephenson

North Dakota State University

Dr. Ganapathy Mahalingam

Architecture 771

Advanced Aarchitecural Design Studio

INTRODUCTION

As the third most consumed liquid and first most consumed in the realm of alcoholic drinks beer is considered one of the most important industries in the world. The oldest record of a recipe, which could in fact be the oldest recipe in the world, dates back to between 5 000 – 2 000 B.C. in what is now known as Egypt (Mauk, 2013). It is even thought to have been undocumented but still drunk nearly 5 000 years before even that (Mauk, 2013). Beer has been such a fundamental part of civilization that the country of Germany has even implemented a law that has stood for over 500 years called the Reinheitsgebot, or the German Beer Purity Law, stating only hops, barley, water, and later allowed for yeast can be considered beer (Nicholson, 2016). This journal celebrates the love of beer by identifying and explores the process of brewing beer through independent study, case study work, and digital analysis. To start, a detailed description of how the malts, hops, water, yeast, and additional flavors are added together in various pieces of equipment to make the end product of beer. Continuing, a brief analysis of the configuration of the different pieces of equipment and how they relate with each other. From there, a detailed look at the equipment used in the brewing process and how the different pieces of equipment connect.

B R E W I N G

Starting at the beginning all of the ingredients are collected. This includes, but is not limited to, malted barley, hops, yeast and fresh high-quality water. These ingredients are the base of brewing beer. Most of the flavor comes from the selection of different breeds of barley, hops and yeast. Water also plays a key role in the final flavor. Depending on the minerals that are found in the local water source it can affect the overall outcome of beer from its bitterness, salty-ness, to the pH balance that tends to be more basic than acidic (University Post, 2017). We start off with the malts. There are two types of malts; base malts and specialty malts. Base malts do not lend to the flavor that much but help by allowing more sugar to for the yeast to turn into alcohol. Specialty malts are where the flavor comes from. There are several kinds that can be mixed in any ratio to create a desired taste. These malts are placed into a malt miller to be ground to a specified size wanted by the brewers. After the malts have been milled they can head into a grist case to be stored for later consumption if the brewing process does not start right after being milled.

If brewing is started right after milling it will go right into the mash tun. Here an auger system will feed the grains directly into the tank. As the grain falls a pipe of water sprays the grains so that they do not clump up which helps make consistent beer. This process, named "mashing in" and takes between thirty and forty-five minutes long. The mash tun features blades that are attached to a motor that continuously mixes the malt with hot water (Specific Mechanical Systems, 2017). By doing so, the water steeps the malts for fifteen to thirty minutes pulling the starches from the grain to create the sugars that later turns into the alcohol. This process will typically take between Connected to the mash tun non-linearly is the hot liquor tank. The hot liquor tank is a vessel that holds and heats hot water. The temperatures range from 100 to 170 degrees Fahrenheit depending on the requirements for a certain style of beer (The Beer Connoisseur, 2017).

After the sugars have been extracted from the grains they are transferred through pipes and a centrifugal pump to the lauter tun that pulls what is now the sugary water which is named "wort" from the grain by a false bottom that is a screen system allowing only liquid call through. The bed of grains also acts as a filtration system keeping smaller solids from falling through the false bottom. As it drains it is pumped back into the tank creating clearer wort. This process is called vorlauf and takes forty-five to sixty minutes. The wort is then transferred to the brew kettle taking roughly two hours. After the wort has been removed from the lauter tun the grain that is left over is considered spent grain which takes thirty minutes to completely remove and rinse the tank. This spent grain can be collected and sold to farms for livestock feed for an additional profit and several breweries give away the grain for free.

P R O C E S S

In between the lauter tun and the brew kettle there is a smaller piece of equipment called the grant. This is primarily used during the vorlauf period of brewing and continues to be used as the wort is transferred into the brew kettle. The grant is used for three main reasons. One, to reduce the vacuum effect that happens when the recirculation period or the transferring period of brewing (Oliver). Secondly, it can be used for quality assurance purposes (Oliver). They can see whether or not the wort's clarity is improving or not and can adjust to the problem if needed. Lastly, for larger breweries that have a lauter tun with multiple outlets this can be an even greater tool for assurance as they can inspect the different ports and see if a portion of the lauter tun's grain bed is allowing for proper flow of wort (Oliver). Today's grants are of a simple cylindrical tank of various small sizes that has the wort flow through the bottom and then collected from a pipe that is connected to a pump on the side of the tank. This is done so that there is no splashing, in which can oxidize the wort creating several different issues to the final product (Oliver). It should be noted that many of the newer more efficient breweries do not have this style of grant anymore. Instead they have a system of valves and a complex computer system that makes sure that there is no vacuum being created in the transfer process. (Oliver).

The brew kettle is where the wort and hops added for flavor, aroma, and bitterness (Specific Mechanical Systems, 2017). Here the wort is brought back to a boil to stop the further breakdown of the sugars which will create off tasting beer in the end. It is in this tank that a large portion of flavor is decided; especially in the American craft beer portion of beer production as their beers tend to be heavily flavored with hops. Hops differ in several different ways. They can be added at any point in the boiling process to unlock the different aspects of the hops. If added earlier they tend to bring the bitter aspects out, in the middle of boil for flavoring, and at the end for the aroma (The Beer Connoisseur, 2017). The boil will typically last about an hour but can sometimes last up to two hours.

The flavor infused wort is then transferred into the whirlpool taking thirty minutes. This step circulates the wort to separate particulates unwanted for the enjoyment of drinking the beer. This process happens by when the wort is transferred from the brew kettle the inlet is angled so that it creates a circulating which forces the heavy particulates to settle to the bottom and in the middle of the tank. It will rest for thirty minutes. Hops can also be added during this stage for flavor and/or aroma. This is the last step in what is termed the "hot side" of the brewing process.

B R E W I N G

After the whirlpool, the wort is transferred through a heat exchanger to cool down as fast as possible (typically about an hour) as prolonged exposure to temperatures between 27-71 °C (80-160 °F) can infect the beer creating unwanted flavors. The heat exchanger transfers the unwanted heat from the hot wort to the water in the hot liquor tank to be efficiently used for the next batch. After the wort is cooled it is transferred into the fermentation tank.

The fermentation tank is where the wort is turned into alcohol. This is achieved by adding a selected yeast strain to the wort where the sugars will be eaten and transformed into Ethyl Alcohol, more commonly known as ethanol, and carbon dioxide. A valve near the top allows for the carbon dioxide to relieve pressure build up. This process lasts for typically 14 days for ales and 28 days for lagers. Hops may be added during this stage as well to create more intense flavors and aroma.

After what is called primary fermentation it can be moved to a secondary fermentation tank called the brite tank. This tank is used to clarify the alcohol creating smoother tasting alcohol. This step lasts from several days to several weeks depending on style of beer made with lagers and some ales being stored in cold conditions to further help the flavor profile. Another route to go that tends to take even longer but tends to produce higher quality beer is to go right to bottling where additional yeast is added to carbonate the beer while it conditions. Additional options may include barrel aging beer to create even more complex flavors (The Beer Connoisseur, 2017).

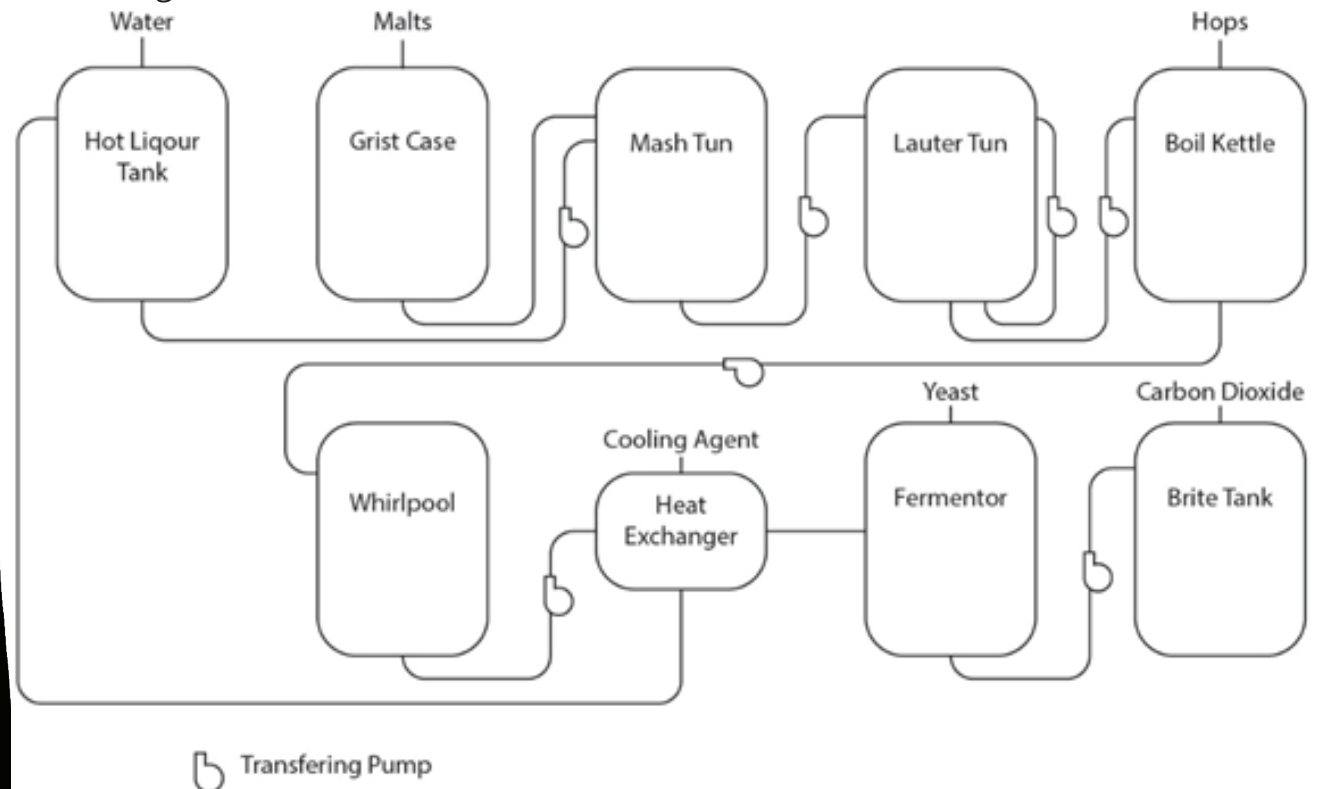
The brite tank can serve as several different functions. As previously stated a conditioning tank. But, also the carbonation and serving tank. Carbonation is achieved by what is called a carbonating stone (Specific Mechanical Systems, 2017). After carbonation is achieved the beer can be chilled and served directly from the tank to a tap system at the inhouse taproom. Secondly, it serves as a holding tank for additional equipment to bottle, can, or keg for external sales.

Lastly, the non-linear piece of equipment that is arguably the most important part of brewing is the sanitation equipment. This mixes water with sanitation solution to keep external microbes that can spoil the beer rendering beer undrinkable. This piece of equipment is connected to every piece of brewing equipment used in the crafting of beer. Finally, the whole process is a relatively closed process. The only openings in the tank outside of the brewing system are manholes to visually inspect the brewing process as well as manually cleaning.

Alterations

Described above are found in every brewery. There are different versions of these types though. Some breweries will attempt to save on the initial cost of start up as well as saves on floor space by combining tanks together. These systems are described as either 2, 3, or 4-vessel systems. A 2-vessel will have the mash tun and the lauter tun combined as well as the boil kettle and whirlpool as one tank. 3-vessel takes one of the 2-vessel systems and splits it up. Then 4-vessel separates them all as an individual tank for the 4 different processes.

This system is the most efficient for brewers who want to get as many brews as they want to complete in the day during shorter times. This is achieved by starting the next batches quicker. After the water and malts are transferred from the mash tun into the lauter tun they are able to start cleaning the mash tun (Ageuro, 2016). Then after the lautering process is complete and transferred to the boil kettle the next batch can be started (Ageuro, 2016). Whereas, if the brewery only had a 2-vessel system they would not be able to start cleaning the one vessel until the lautering process has been completed and transferred into the second, boil/whirlpool, tank (Ageuro, 2016). It is quoted by Rhinegesist, a 4-vessel brewery out of Cincinnati, that they are able to brew four times a day and can save up to three hours of their time (Ageuro, 2016).



Additional Equipment

In addition to the equipment above there are several pieces of equipment that play a background role in the production of beer. The two biggest background equipment that do not directly touch the product are the steam generator and glycol cooling system. The steam generator is connected to the hot liquor tank to produce hot water at the desired temperature. By connecting it to the hot liquor tank instead of the mash tun where the water and malts are mixed together it reduces the risk of scorching the malts creating undesired flavors. In addition, it is also connected to boil kettle to return the wort to boil. Steam can also be connected to the fermentation tanks if the tanks are outside and are subject to very cold weather. The steam connects to these different pieces of equipment by what is called a jacket. This jacket encases the side of the tank and heats it from all around. A huge part of the brewery is a small lab for quality control of yeast and the beer. Here they have a work area where they can test the count of the yeast to make sure that there are enough active to produce the proper quantity of beer. The lab will also have equipment to test the beer at various stages to make sure it holds to the standards that they are trying to achieve.

There is also optional equipment that are user's discretion on how they want to produce their style of beer. The largest breweries that produce mass quantities of beer tend to have a filtration system. After fermentation, they will run the beer through the filtration system removing yeast and other particulates that would make the beer look cloudy. A lot of craft breweries do not do this as it does typically affect the flavor of the beer. There are several ways to introduce the hops into the system. Majority will simply pour the hops in by hand via a man hole that is featured in all of the tanks. Alternatively, there are other systems. While in the boiling process the brewery can use what is called hop dosing. This features small vessels that the hops are poured into and then the wort will circulate through these vessels infusing the wort with the hops flavor, bitterness, and aroma. Additionally, there is a hop cannon. This is used for what is called dry-hopping the beer or introducing hops during the fermentation process giving a strong hop aroma. Lastly, there is what is called a hop back. This is a smaller sized tank that serves the exact same purpose as the lauter tun but with hops. When using whole cone hops they can serve as an additional filtration membrane further clarifying the wort.

EQUIPMENT

Continuing, I looked at the different pieces of equipment and studied how they function. This is all achieved by extensive analysis of several different breweries and brewing equipment manufacturers. It is to be noted that each piece of equipment can be manufactured in many shapes and sizes to accommodate majority of the different building shapes and sizes, the owners desired beer types they wish to brew, and the manufacturers machining capability. These specification drawings are to gage a general idea of the equipment and how they function in of itself as well as how they connect to each other. With steam being the most popular source of heating at the current time these specifications focus on this type over a direct fire system.

Many of the pieces of equipment have the same parts in them. Each piece will be described on their functions when they first come up. But, will be simply stated for the sake of redundancy.

There are two sides of the brewing process. The hot side and the cold side. Starting, the equipment on the hot side of the brewing process are the following: hot liquor tank, mash tun, lauter tun, and the whirlpool. From there it goes into the heat exchanger which converts the wort from the hot side to the cold side of the brewing process. The cold side consists of the fermenter, brite tank, canning, kegging, and bottling lines. As previously stated, there are two main sources of energy conversion. The steam generator for the hot side and the glycol system for the cold.

All images are at a $1/8'' = 1'$ scale and are for a 20-barrel brew system.

HOT LIQUOR TANK

First, the specifications for the hot side equipment.

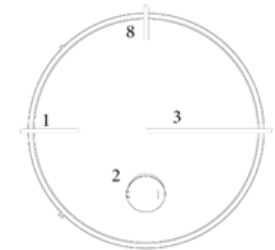
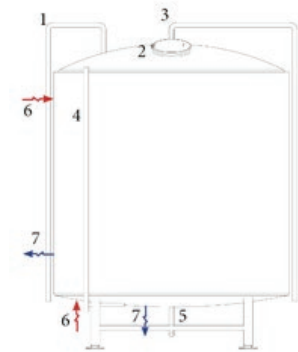
Starting with the hot liquor tank. The hot liquor tank also known for its shorthand HLT. This tank is typically double the quantity of a single batch output. Starting at number one in the image is the water inlet. The pipe size tends to stay around one and a half inches in diameter but can be found at bigger size if quicker input is needed. Continuing to number two is the manhole used for internal inspection and is typically around sixteen inches wide.

Number three is the pipe for the CIP system also known as clean-in place. This system saves the brewers large sums of time as it does not need to be disassembled.

All they have to do is connect the tanks pipe line to the sanitation equipment. This system will be found in all of the other pieces and will be simply referred to as the CIP system throughout. Moving onto number four is the liquidometer a simple system that has a ball that floats on top of the water to show how much water is in the tank. Connected to the liquidometer at the bottom is the thermostat. Giving the brewers the temperature of the water. In some breweries that are trying to modernize will not have these physical features but instead a digital thermostat and volume reader that relays its information to a computer.

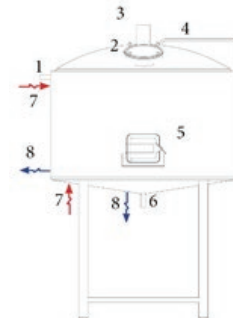
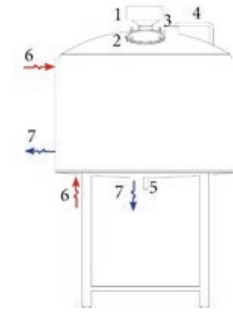
Number five is the tanks outlet that will feed the water via a pipe between one and a half inches to two inches in diameter. Number six is the steam inlet.

This goes into the jacket that wraps around the tank heating the water from all directions. This is featured on top of the tank and underneath at the highest point of the dome. Number seven is the outlet of the steam. This will be the condensation of water from the steam cooling down. Lastly, is number eight. This is a pipe that functions as a release valve to release pressure that may build up due to the heating of water.



Mash Tun

Once the water exits the HTL it enters the mash tun. Number one of the mash tun is the electric motor that turns the blades inside the mash tun. This also houses a chimney to release steam from the tank. Number two is another manhole. This features a glass window to see inside without having to open up the latch. It also is used after the mix has been removed to help manually clean the tank. Number three is where the grain and water is feed into the tank through. Water is poured into the tank but also is sprayed through another pipe at the grains so that once entered into the tank they do not clump up. This is done for a consistency reason. Number four is the CIP pipe system and number five is the tanks outlet. Six is the heat input; seven is the output of the cooled steam. Lastly, number eight is an encased light so that the brewers can see inside with the manhole closed.

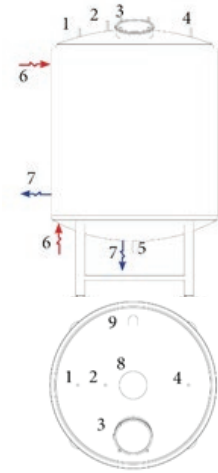


Lauter Tun

From the mash tun comes the lauter tun. Number one is the input pipe that is placed on the side instead of the top to reduce splashing inside of the tank. Number two is the upper manhole. Number three is the motor and chimney. Number four, again is the CIP sanitation system. Number five is the lower manhole. This is a more square hole at roughly eighteen by twelve inches. The bottom is right at the false bottom location and has a chute that helps push the spent grain away from the tank to be collected in another vessel. Lastly, numbers six is the tanks outlet. Seven and eight are the inputs and outputs of the heating source.

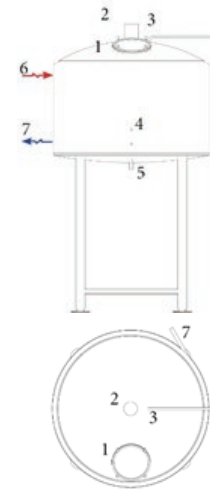
Boil Kettle

From the lauter tun the wort is transferred to the boil kettle. Number one is the tanks input pipe. Number two is pipe for the CIP system. Three is the manhole again with a glass window for viewing. Number four is a spare pipe in case the others have issues. Five is the kettle's outlet. Six and seven again are the heating source's inlet and output. Number eight is the kettle's chimney. Lastly, is the light for viewing.



Whirlpool

Next is the whirlpool. A simpler piece of equipment in the brewing process. Starting at number one is the manhole again for inspection. Number two is the chimney to relieve the steam and pressure and number three is the CIP system. Number four is the tanks wort output ports. They pull from the top port first as that is the most clear. Then pulls from the bottom once they can no longer from the top. Number five is the port for emptying out the rest of the tank this is stuff that will be discarded. Six and seven again are the heating source ports. Lastly, number eight is the input of the tank. It is put on the side, lower, and at a sharp on the tank to create the whirlpool effect reducing the need for additional systems.



Fermentation

After the wort leaves the whirlpool and is cooled by the heat exchanger. It is moved into the fermenter. The inlet comes back to the top of the tank at the port number one. Number two is a smaller manhole that is meant for the pitching of hops. This does not always have to be used but is there if what is called dry hopping is wanted. Number three is the CIP system. Four is the manhole for inspection when the tank is empty. Five is the output for the yeast that has settled down to the bottom of the tank.

Six is the thermostat port for temperature assurance.

Number seven is a access port for taking samples of the beer for quality assurance during the fermenting process. Continuing, is number eight this is the port for carbonation. Inside the port is connected to what is called the carbonation stone while the outside is a simple hose hookup of carbon dioxide. Number nine is the beers output port. This is put higher up in the tank to reduce the transferring of yeast. Number eleven and twelve are the temperature controlling ports. Now that the beer is on the cold side of the brewing process the temperature control system changes from steam to glycol. As glycol is pumped into the jacket system cold the pump in port is on the bottom instead of the top. As temperature rises so does the warmer glycol which is then collected at the top. This is a reverse of the hot side that uses steam. Lastly, is number twelve, this is the pressure release port. This pipe is put into a bacterium killing bath to assure that nothing get into the beer during the fermentation process thus spoiling the beer.



Brite Tank

Lastly, is the brite tank. This tank is another simple piece of equipment. If carbonation is not desired to be done in the fermenter. Number one is the CIP system. Two is the input port. Three is the manhole for personal inspection. Number four is for the carbonation. Five is thermostat. Six is the tank's output port. Lastly, six and seven are the temperature control ports.



Conclusion

The brewing process is a rather complex process that features a bunch of different parts to create beer. This article is intended to bring a wholistic study on how brewing is done and how all of the pieces of equipment that make the beer connect with each other. First, the journal touched on high level of detail how beer is made by breaking down what piece of equipment is used to do what part of the work. Then, lastly, using Revit and doing extensive analysis of the equipment used in the process models were made for the most important pieces of equipment in the brewing process. This features detail description of the different parts and their purposes that help with turning water, malts, hops and yeast into beer.



References

Aguero, T. (2016, March 23). Learning About Beer: The 4-Vessel Brewhouse. Retrieved November 22, 2017, from <http://www.brewminds.com/beer/learning-about-beer-the-4-vessel-brewhouse/>

Mauk, B. (2013, January 18). When Was Beer Invented? Retrieved November 20, 2017, from <https://www.livescience.com/32424-when-was-beer-invented.html>

Nicholson, E. (2016, April 29). Germany's Beer Purity Law Is 500 Years Old. Is It Past Its Sell-By Date? Retrieved November 20, 2017

Oliver, G. (n.d.). The Oxford Companion to Beer Definition: A grant. Retrieved December 14, 2017, from <https://beerandbrewing.com/dictionary/qASAhFhS4j/a-grant/>