RED AUTOMATION

2021

Flow Study for a Small Brewery

HOW EFFICIENCY CAN BE FOUND

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Glossary

- **Barrel** – A barrel is equal to 31 us gallons
- **Flow Meter** – a device that is used to track the flow a liquid or gas though a pipe
- **Kettle** – The container where the wort is cooked with hops and other flavoring ingredients.
- **Liquor** – Industry term for water that has had most chemicals and impurities removed.
- **Mashing** – the term given to the start of the brewing process, where crushed grains are mixed with water to form a porridge-like mixture called the “mash”. It is in the mash that malt and other cereal starches are transformed into sugars and proteins and other material are made soluble, creating the sweet fermentable liquid called wort.
- **Mash Tun (MT)** – A brewhouse vessel used to mix ground malt with temperature-controlled water.
- **Sparge** – Is the rinsing of the mash grain bed to extract as much of the sugars from the grain as possible without extracting puckering tannins from the process
- **Totalizer** – a device that keeps track of a running total of the volume of liquid that has ran though a given area of a pipe.
- **Wort** – The liquid extracted from the mashing process during the brewing of beer. Wort contains the sugars, that will be fermented by the brewing yeast.

Executive Summary

Study Goals

The first study goal was to determine how and where water losses occur in the brewing process. When beer is brewed, it is only heated for a short amount of time relative to the amount of time it takes to make a batch of beer. This heating is where most losses can occur in the beer making process. We set out to track a whole batch of beer as it cooked in the mash tun (MT), boiled in the kettle, moved to the fermenter, and was finally packaged into cans.

The second study goal was to see how much water is used by the attached tap room of the brewery. This was a secondary goal and was not the focus of our work. This work is less controllable than the more structured work of brewing beer, due to fluctuations in patron numbers or differences in human activities.

Study Parameters

We worked with a local brewery, Lo-Rez Brewing, which on average brews three to four batches of beer per week with an eight-barrel MT and kettle. We used an installed flow meter to measure how much water was brought into the MT. Where a permanent flow meter was not installed, we used a GE PT900 clamp-on flow meter to track fluid flow.

Study Outcomes

From the study, we found that while some water losses occur, overall, this brewery is very efficient in its water usage. Due to the current scale of this operation, the opportunities that exist to increase water efficiency may not be practical due to the extended payback period.

The brewery operations could gain efficiency as the brewery scaled up and was able to have install the tools that gain more product from the same number of resources. A mash press would be the largest tool that could be useful in the future by gaining wort from the mash with the same amount of energy and water used. A filter added on the discharge line of the kettle would also be beneficial in the short term by gaining wort and keeping the heat exchanger clear of solid matter.

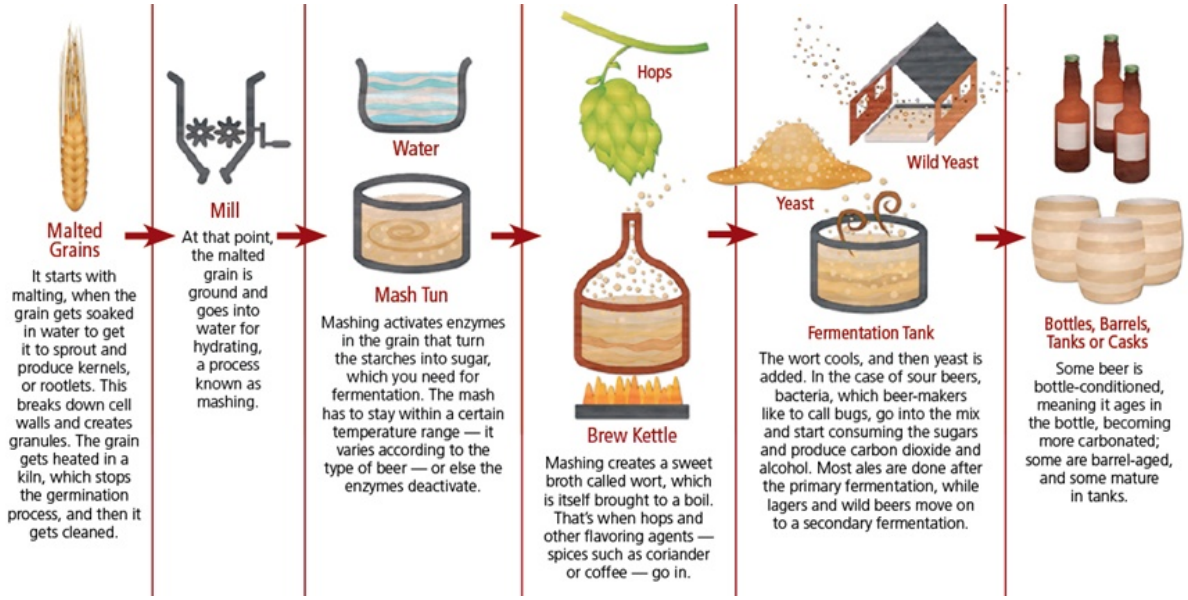
The tap room flow study showed that very little could be done to cut losses due to the factors outside the control of the brewery. The addition of dual-flush toilets and automatic faucet fixtures in the restrooms could theoretically cut water usage. However, the scale of this tap room may make the upfront costs hard to justify at this time.

Our conclusion is that the scale of the brewery has the most impact on how economically feasible it is to install water saving devices. All these devices could save water in our testing brewery, but at this time the payback period for those devices, in a brewery this size, would be much longer than for a larger one. As always it up to each individual brewery as to whether they wish to make the investment or not.

Introduction

RED Automation wants to help breweries find and eliminate water related inefficiencies. Inefficiencies due to water loss are bad for the environment as well as bad for the brewery's bottom line since resources are spent on water usage that does not result in sellable product. However, we understand that smaller craft breweries may not have the bandwidth to do all the leg work of finding these inefficiencies, finding a solution for fixing them, and ultimately implementing that solution. That is why we undertook this study, so we could learn from someone who faces these challenges every day. Also, so we could bring our water saving background to the brewing market and combine these two knowledge bases together for excellent outcomes. With the help of our brewery partner, Lo-Rez Brewing, we were able to track a batch of beer from brewing to canning. With that tracking we saw where inefficiencies creep in, where the brewery owner already does excellent work in efficiency, and what we think are ways to help save water usage and money.

Figure 1 Beer making process



Beer making requires cooking of grains and hops in different containers, as shown in Figure 1. Every time product is moved from one tank to another, solid matter is left behind that contains some of the product. This is valuable material that breweries are not always utilizing to its fullest potential. Sometimes this is unavoidable due to the prohibitive upfront costs of equipment, size of said equipment relative to space available, or lack of knowledge of said equipment. However, when utilized properly, this equipment can extract valuable product while minimizing waste streams.

We aim to show that small breweries can be extremely efficient, as was seen at Lo-Rez Brewing, while still having plans in place to gain efficiencies as they scale up the operation. This planning allows them to realize the full potential of such equipment.

Figure 2 Mash tun and kettle at Lo-Rez Brewing

Flow Study Design

We worked with Kevin Lilly of Lo-Rez Brewing to design this study approach. We identified the issues he wanted to address as:

- Lack of visibility of how much liquid he uses in his beer making.
    - As of now he only has one installed flow meter to see how much product he puts into his mash tun, as shown in Figure 2.
    - He does have some measuring sticks on his tanks to track product movement.
- Lack of visibility of how much liquid he uses in his tap room.
    - Currently his tap room is fed from the same feed line that feeds his liquor tanks.
- Lack of bandwidth to carry out this study alone.
    - Kevin is already doing great work of making beer and keeping his equipment well maintained. It has not been a priority to install flow meters, permanent or temporary, when he already has a system that works well enough for him at his current scale.

We designed the study to address the noted issues, with the aim to measure current data points and identify areas of improvement. For this study we used a GE PT900 clamp-on flow meter for all measurements unless otherwise noted.

Our study involved the following:

- Installing a meter on his fermentation tank, shown in Figure 3, from his kettle, to track how much waste material is left in said kettle.
- Installing a meter on his feed line for his hot water used in his tap room.
- Installing a meter on his feed line for his cold water used in his tap room.
- Installing a meter on his feed line for his hot water used in his brewing process.
- Installing a meter on his feed line for his cold water used in his brewing process.
- Installing a meter on a hose used in his mobile canning operations.

Figure 3 Beer fermentation tank

Flow Study Results

Flow Study Issues

As with most studies of this nature we ran into some issues with testing equipment. The largest issues we encountered were:

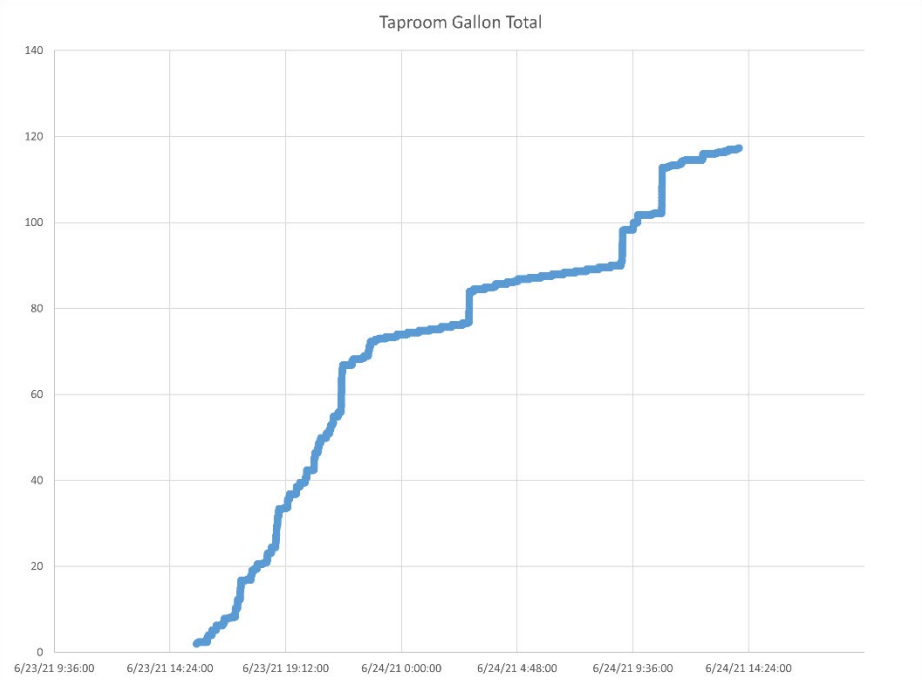
- When we installed the flow meter on the hot water lines of the brewery and tap room the electrode gel worked well for approximately 2 hours. After that time, the clamp-on meter started to get erratic readings and the totalizer couldn't show any real valuable data. We were unable to perform a second reading with different gel due to time constrains by RED Automation, and we therefore have a limited data set.
- We were unable to get accurate readings on the hose feeding the canning machine due to the noise of the canning operations and an air compressor. These both had bleed though noise that affected the accuracy of the flow readings.

Both issues were troubling, however, they were not the primary focus of this study. We were able to get accurate and repeatable data on all the cold-water lines and the transfer line from the kettle to the fermentation tank. With these issues identified, we will be able to anticipate the disruptions and plan accordingly for future studies. For example, bringing multiple electrode gels or planning extended reading time frames for hot water pipes.

Flow Study Successes

The first phase studied how much water was used by the tap room connected to this brewery. This involved attaching the flow meter to his cold-water feed line and letting it collect data for 24 hours. We saw a total of 118 gallons of water used. We didn't notice anything out of the ordinary other than a couple spikes presumably when a toilet was flushed, a sink ran, or his carbon filter did a backflush cycle, as shown in Figure 4.

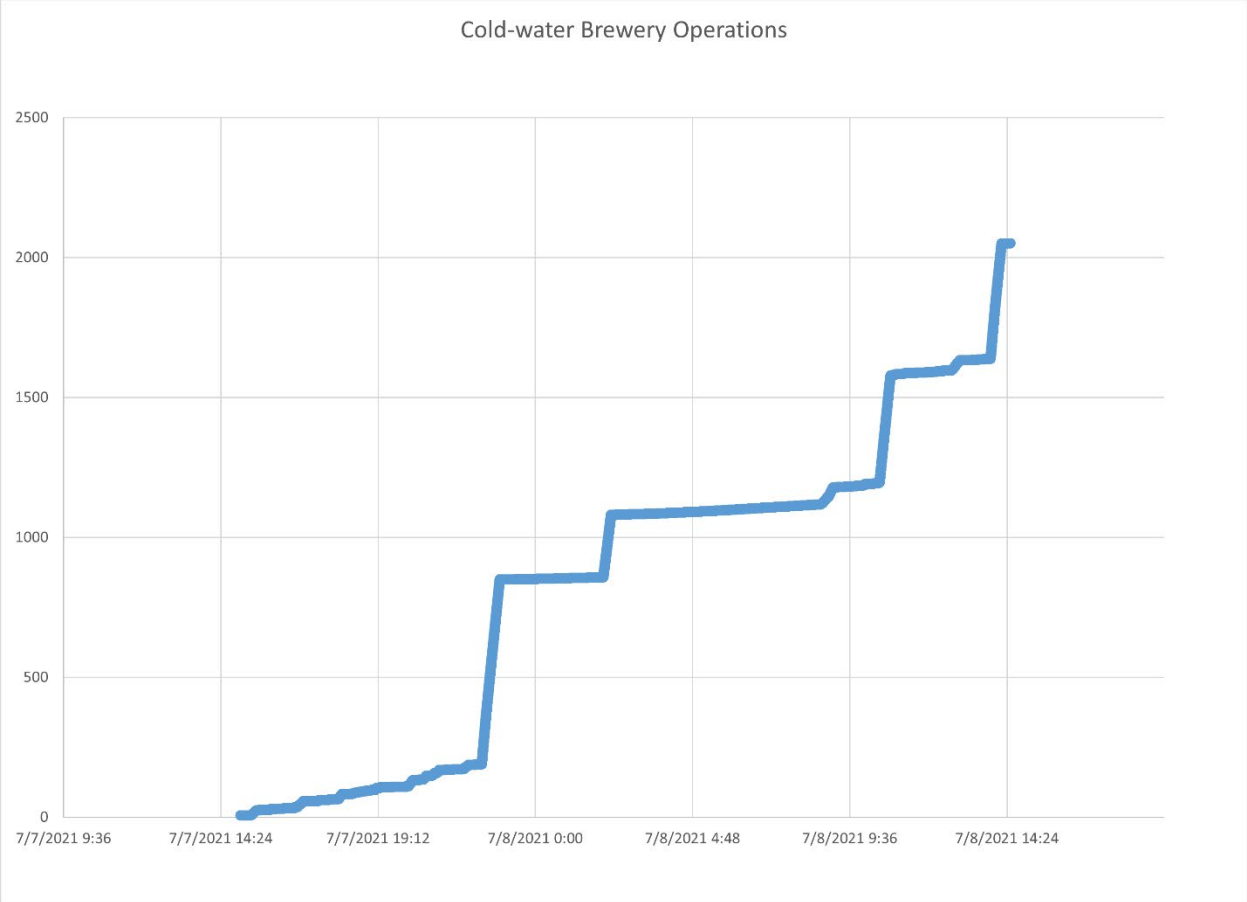
Figure 4 Total taproom gallon total



This data must be put into context that testing was done in June of 2021, when Chicago was coming out of the Covid-19 pandemic. This most likely is limiting the number of people who could use the tap room on a given day and could be skewing our testing lower.

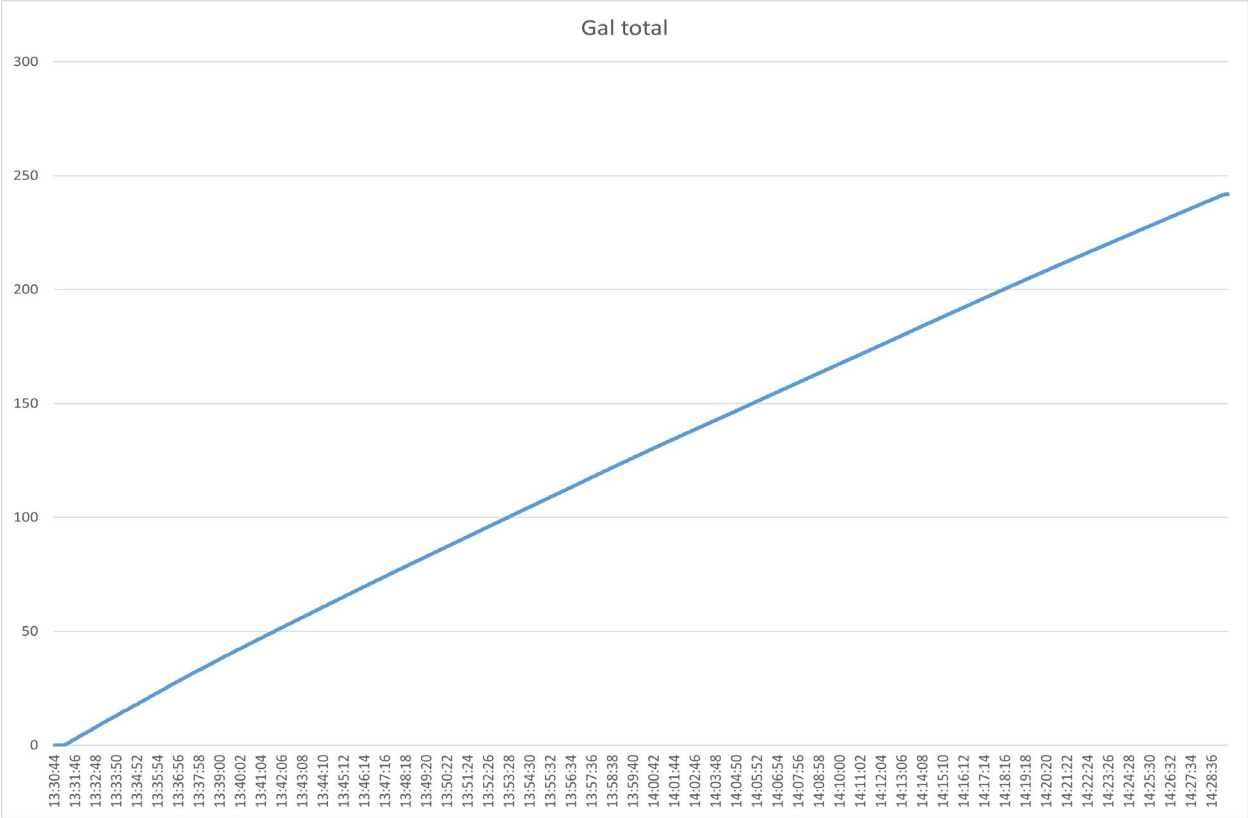
The second phase was to measure how much water he uses for brewing operations on his cold-water feed. For this phase Kevin used this water to fill his cold liquor tank, washing his MT and kettle, and two sinks that he uses for washing equipment and his hands. The day that we tracked this Kevin had to work late into the night to finish his brewing. That is shown by the large draws, in Figure 5, to fill his cold liquor tank that holds 20 barrels of water, or roughly 600 gallons. He filled the liquor tank several times. We again didn't see any data that did not match what we expected to see in these time frames.

Figure 5 Brewery operations cold-water gallon total



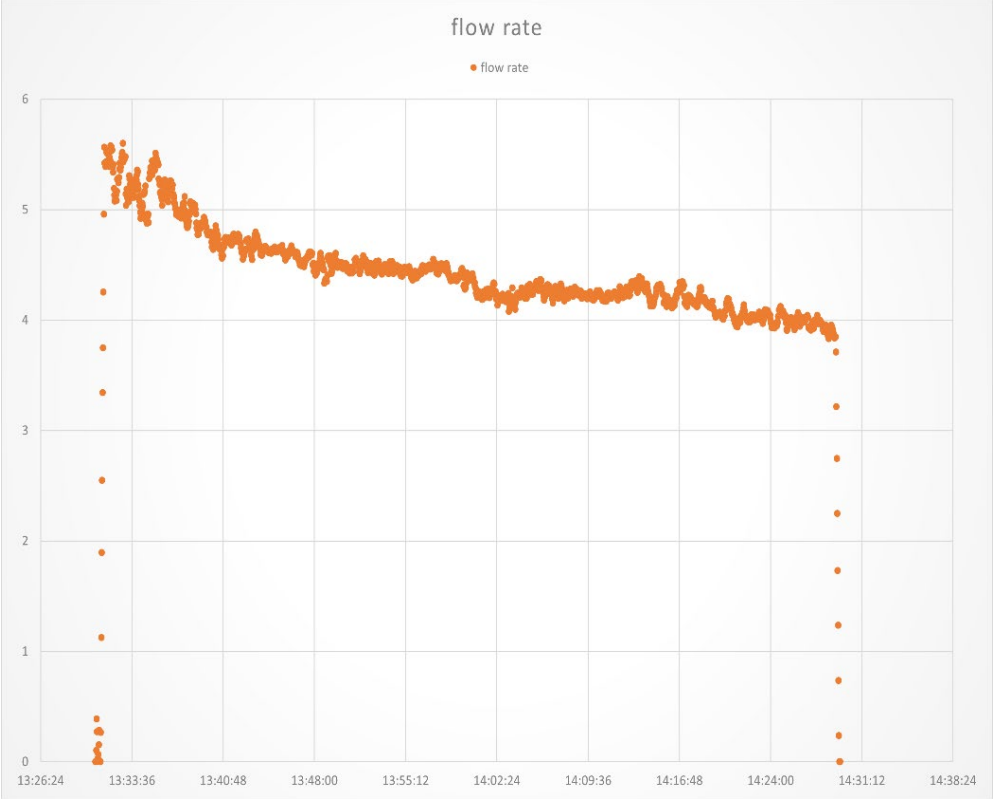
In the last phase of the study, Kevin moved 299.9 gallons of water from his hot liquor tank to the mash tun to mash and sparge his grains, as measured by his permanent flow meter. We were unable to track the flow between the MT and the kettle due to space constraints, but we were able to measure the movement of the wort from the kettle to the fermentation tank. The fermentation tank already had product inside it when we did this move. Kevin operates his pump to move the wort though a heat exchanger, cooling it enough to not kill the yeast inside the fermentation tank. The heat exchanger cycles water from the cold liquor tank into the hot liquor tank. This is an efficiency that he already had in place to reclaim the energy from the wort and use it for other parts of his process. The results of this move tracked 242 gallons of wort from the kettle into the beer fermentation tank. The time to move the product and the flow rate in moving it can be seen in Figure 6 and Figure 7, respectively. This data was very valuable for this study. It showed that between filling the MT and transferring to the fermentation tank, there was a loss of approximately 57.9 gallons.

Figure 6 Wort moved from kettle to fermentation tank gallon total



Currently, Kevin uses a measuring stick to determine how much product he is moving out of this tank. He calibrates it with known quantity and experience to give him a value of how much product is in his kettle. From our reading and his expectation, we both agreed this is a reasonable amount of product to have moved.

Figure 7 Flow rate from kettle to fermentation tank (gals/min)



Recommendations

Brewery Operations

From examining the brewery operations, we found three recommendations that would help a brewery have more visibility of the process, as well as tools and equipment that could help get more product out with every batch.

Mash Press

The recommendation with the largest impact would be a mash press, a press for getting more product out of spent grain, gaining back 10% or more wort at current gravity. Alternatively, such a press would allow for 10-20% less grain and 20-40% less water per batch, saving on raw material (Brewmation 2021). A mash press capable of handling the whole size of Lo-Rez's mash tun would cost approximately $51,000, just for the piece of equipment. This is no small cost, however, with an assumed brew rate of three times a week and an average keg sale price of $100, the payback time is something to consider, as estimated in Table 1.

Table 1 Mash press extra revenue calculation

Assumptions (based on three brews per week)	Extra Kegs per year	Extra Revenue per year (at $100 per keg)	Approximate Payback Time (years)
8% gained back by press	194	$19,400	2.6
9% gained back by press	219	$21,900	2.3
10% gained back by press	243	$24,300	2.1

The size of such a device would be roughly 20’ x 10’ for a floor footprint. Cost and size are obviously challenges for a small brewery to overcome. If you brewed 5 times a week you could further lower the payback period to between 1.6 and 1.3 years. If you brewed 6 times a week, the payback period could be as low as 1.04 years. Unfortunately, the issue of space is not so easily overcome. It would be our recommendation that even if a new brewery doesn’t have the capital funds for this item at start up, they find a space that would let them add this as they scale.

Kettle Strainer

Our second recommendation is a product commonly used in water treatment plants that could be effectively applied in a brewery setting. A water filter with a small screen size can catch hops material that comes out of the kettle prior to transferring the wort to the fermentation tank. While on site, Kevin had to leave a small amount of wort in the kettle to avoid solid matter entering the heat exchanger, perhaps three gallons or less. Even that small amount of wort, if moved through a filter, could result in an increase of sellable product and therefore revenue, as estimated in Table 2.

Table 2 Kettle strainer extra revenue calculation

Assumptions (based on three brews per week)	Extra Kegs per year	Extra Revenue per year (at $100 per keg)	Approximate Payback Time (years)
1 gallon wasted each batch to solid material	10	$1,000	4
2 gallons wasted each batch to solid material	20	$2,000	2
3 gallons wasted each batch to solid material	30	$3,000	1.3

These devices are compact, roughly 20”x 8”x 8”. They can cost anywhere between $1,500 and $5,000 dollars depending on material of construction and features. A basic stainless-steel model that requires the operator to clean the screen when liquid couldn’t be pushed though anymore runs approximately $4,000. This product could pay for itself in a maximum of four years and a minimum of 16 months. We would recommend this product as a great tool to help get more wort out of your process.

General Instrumentation

Our final brewery recommendation would be the addition of automation instrumentation in the process. This would include flow meters, temperature probes, pressure switches, pressure transmitters and countless other devices for system vision.

Right now, we have mentioned that Kevin has a feel for his process and knows how he likes to run his operation. We know that is how most operators like to work and is not uncommon in any field. Having the correct tools in place offers greater visibility and control over the process, highlighting areas for improvement that might not otherwise be apparent when the system appears to be “working” currently.

All the items we recommend would also need to be paired with a Supervisory Control and Data Acquisition (SCADA) system to gain the fullest benefit from the products. A SCADA would let all the field devices feed information into databases and could be used for decision making in other areas of the process. This would be a major investment for any brewery but conservatively we believe a small

brewery could get a powerful SCADA up and running for less than $25,000. The actual amount is dependent on the number of field devices implemented and how much automation is included. This item would have to be quantified in the amount of person hours saved in reporting or in some process control activity that someone must watch now but could be freed from if a SCADA was installed. To justify this investment, we would work with the brewer further to design an appropriately scaled system which would take tasks off the brewers' hands and put it in the hands of a computer.

Taproom Operations

The tap room is harder to quantify specific water savings due to the nature of humans and how they use water. The number of customers utilizing the facilities and even the season of the year will impact the amount of water used. For the restrooms, we recommend the installation of dual flush toilets and automatic faucet fixtures to reduce water usage. There are a wide variety of such fixtures available to fit budgetary and aesthetic considerations. As for the other tap room feeds – the sinks, dishwasher, and glass cleaner – those are already as efficient as current technology allows, when coupled with excellent bar staff training.

Conclusions

Over the course of this study with our wonderful partners at Lo-Rez Brewing, we learned a lot about the beer making process and the economics of beer making. We cannot stress enough that Lo-Rez Brewing is already doing a wonderful job of getting as much product as possible out of the raw materials, given the tools they have. The tools and equipment that could help them get even more products out would have payback periods that could be very long and could be difficult for a brewery to justify at a small scale. However, we think that some of our recommendations could be implemented now with reasonable payback periods compared to upfront investment. Hopefully technological advancements will result in more tools that help small breweries have greater options in the future, allowing them to gain more efficiencies even at small scales.

If you would like us to do an assessment of your brewery's process, please reach out to us at:

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