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INSTALLATION AND MAINTENANCE OF UNIVERSAL TANKS IN SMALL-SCALE BREWERIES

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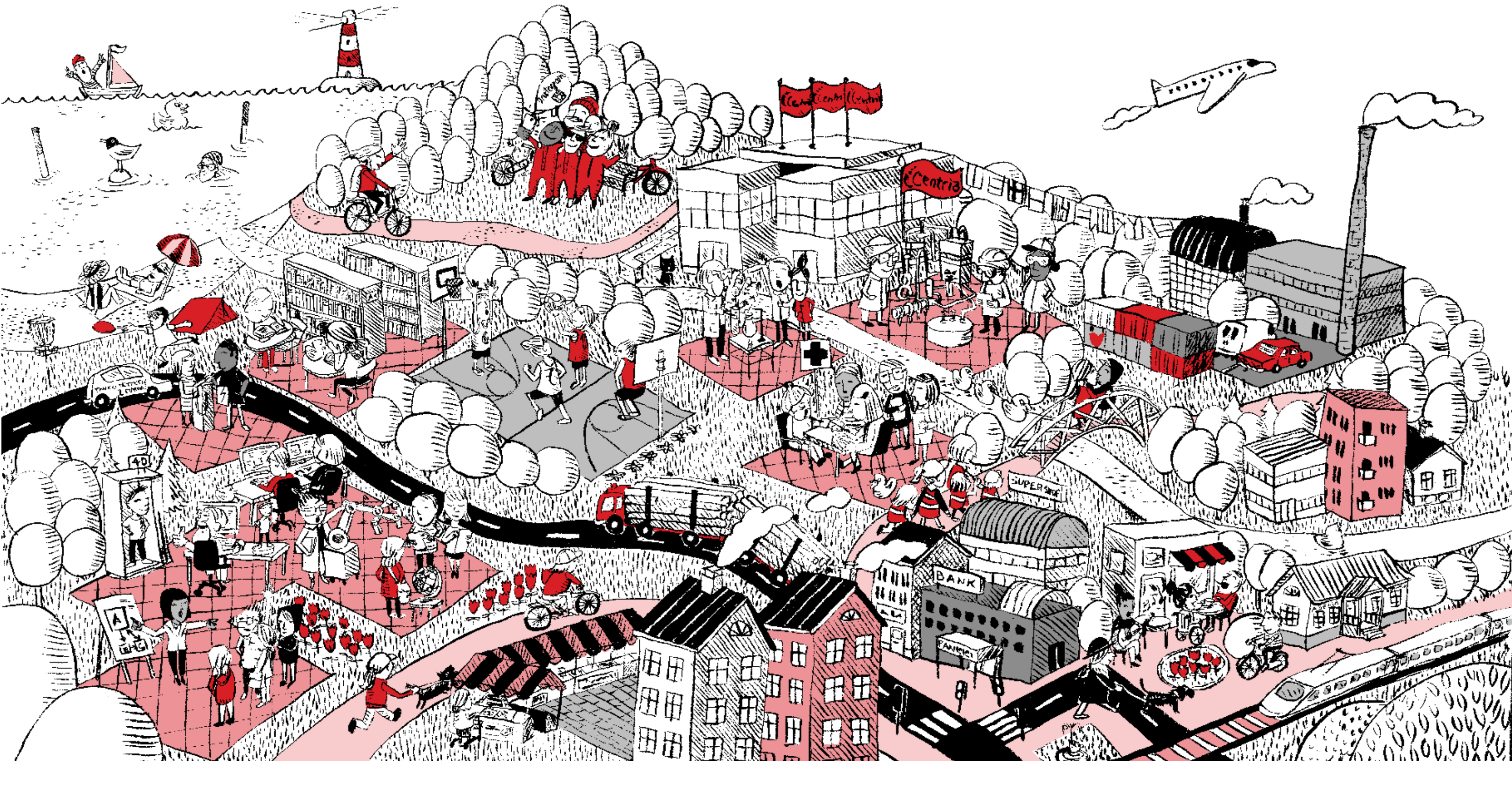

ABSTRACT

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The most famous yeast is beer yeast. In the fermentation stage of producing beer, yeast converts sugars into alcohol. A significant factor is the amount of oxygen present during beer fermentation. In the absence of oxygen, conditions are more favourable, and more alcohol can be formed at the end. In contrast, increasing the amount of oxygen leads to bacterial growth and an overall deterioration in fermentation. That is why fermentation is done in impenetrable reservoirs (fermentation tanks). The proper installation and maintenance of fermentation-storage tanks is an essential step to provide efficient and healthy fermentation of the beer and its further storage before being bottled and delivered to the customer.

The main purpose of this thesis was to summarize and evaluate all the installation and designing work done of the universal tanks in the Kahakka Brewery, located in Kokkola. From the beginning of the year 2021, Kahakka brewery started to expand its production capacities. The amount of the produced beer wanted to be increased three times greater than before. To achieve that, five new universal tanks were ordered with 3000L volume each.

The complete process of the brewery expansion involved earlier planning and design of the facility space for the new tanks' locations, installation of the tanks in place, and making brand new glycol cooling line for each of them. As the last stages, testing of the system was done with the necessary troubleshooting processes and further sanitization and preparation of the tanks for their first fill.

The project was finished in the middle of March 2021. Since the installation, all tanks operate normally. However, a couple of issues could not be fully resolved, including the cooling line welds and incomplete proper insulation, which creates heat loses during cooling processes. In addition, because of common connections and the same glycol chiller, existing and new cooling lines had inconsistencies in the proper circulation of glycol and, therefore, in the accurate cooling of a particular tank at given temperatures. This problem was partially solved using a one-way check valve.

Key words
Universal tanks, fermentation/storage tanks, beer, brewing, cooling line

CONCEPT DEFINITIONS

WORT

A sugary liquid that is extracted from grains in the mashing stage of brewing. Added yeasts in wort produce beer in the fermentation stage.

OG

Original gravity. The general measure of fermentable sugars in the wort before fermentation stages.

HOPS

Dried flowers (seed cones) of the hop plant. By adding to the wort or beer, hops are adding aroma and flavour.

PRIMARY-FERMENTATION

It is the primary phase, where most of the wort sugars will be converted to alcohol and carbon dioxide.

GREEN BEER

It is a beer that just has done its primary fermentation and is not yet conditioned and maturated before packaging.

SECONDARY-FERMENTATION

Period of aging that occurs after the primary fermentation. Almost no yeast activity at this stage.

MATURATION

Stage of beer production, including secondary fermentation and any additional time needed for beer final formation before packaging.

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1 INTRODUCTION

Nowadays, beer is considered one of the world's most popular alcoholic drinks. The history of beer and its production goes back hundreds of years. Due to such popularity of this alcoholic beverage, the amounts of it produced worldwide are close to 1.9 billion hectoliters. (Statista, 2021) The diversity of the breweries and their products is huge, starting from home brewing systems and ending up with giants' facilities for beer production. With the great demand coming constant improvements, technology, and beer facility growth. One of the important aspects of beer production is its primary fermentation right after its brewing. Fermentation of the beer includes yeasts that interact with the sugary liquid (wort) and through time convert all the sugars in the wort into alcohol compounds. Here come fermentation tanks. Fermenters are used for alcoholic fermentation at various temperatures and pressures, depending on what beer type one wants to brew. One of the side products of this process is heat, which is why a fermenter must be able to maintain and regulate the desired alcoholic fermentation temperature. Efficient temperature, pressure, yeast concentration, and tank oxygen level control allow the brewer to carry out the processes as planned, without unnecessary and unwanted complications. The second important step after fermentation is transferring beer to the storage tank for keeping the beer in the tank at certain temperatures to save its composition and flavorings before it will be distributed to the customer.

In addition to these two types of vessels, some vessels can take beer for fermentation and further storage in the same place. Such a tank is a single tank for the fermentation and maturation of beer. The use of such tanks has a limited but increasingly widespread application in the brewing industry. Like many significant modern advances, this technology has a history dating back some 112 years from its original conception. Nathan L. proposed the closed fermenter in 1908, and it has now been more than 90 years since its first practical installation as a dual-purpose tank (universal tank). (Harris, 1980.)

The main aim of this thesis work is to make a well-structured and reliable source for everyone interested or planning to install and implement dual-purpose vessels in their beer production facility. The project of designing the production space and further installation of five fermentation-storage tanks with each volume of 3000L was already completed at the Kahakka Brewery, located in Kokkola, Finland. Installation of the tanks and the cooling line to them was completed by this thesis author with Kahakka Brewery CEO, Nicke Kavilo.

2 THEORY

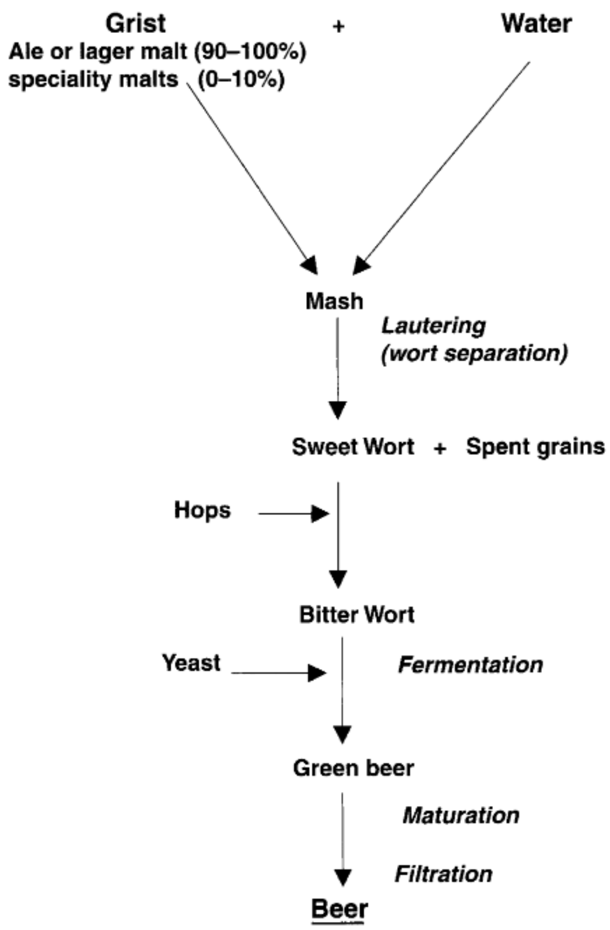
Before considering the process of installation and maintenance of the tanks it is essential to know the basic principles and steps of beer production. This chapter provides general theoretical background, including parts of beer composition and its main production steps, classification, combination, and usage of different fermentation-storage tanks, and finally, cooling methods for the tanks to manipulate the temperatures.

2.1 Beer structure and production stages

The art of brewing has more recently evolved into the science it is today as a result of the increased knowledge of both the ingredients and the process. To summarize, beer is made from an aqueous extract of barley grains that have been allowed to germinate. Enzymes produced during germination digest the cereal starch to form sugars and these are then converted into alcohol by yeast. Hops are added to provide characteristic flavours and aromas. Therefore, the base ingredients for the beer are barley, water, yeasts, and hops. Each component has a great impact on the final beer product and should not be neglected. (Thimmappa, 2020.)

2.1.1 Brewhouse system processes

Although in process terms brewing is complex, the underlying principles are relatively simple. Three main stages may be distinguished: pre-fermentation steps, fermentation, and post-fermentation processing, in which the green beer is matured, clarified, and packaged. (Boulton, 1991, 131-133) Figure 1 below shows the schematic representation of the brewing process.



.FIGURE 1. Simplified diagram of the brewing process (Hughes & Baxter, 2001, 5)

Before the barley malt is entered the brewhouse to proceed the steps shown in Figure 1, a malting process takes place. The role of this process is to generate enzymes, which will later convert starch into soluble sugars, at the same time getting rid of the в-glucan cell walls and some complex insoluble proteins. (Goldammer, 2008, 23.) The malting process can be separated into three primary phases, which are presented in Table 1.

TABLE 1. Malting process stages (Goldammer, 2008, 23-26)

Process name	**Description**
Steeping	Main goal of this phase is to hydrate the endosperm mass and provide equitable growth during germination
Germination	Germination of the wet barley by manipulating it at proper temperature and humidity. During this process necessary for conversion enzymes are formed
Kilning	Drying step of malts at various temperatures done in kiln

After malting is finished, the barley malt is ready to be delivered to the brewhouse for further processing. The brewing process starts by milling the barley or wheat grains into smaller particles. Such a process can be also named grinding. The main purpose is to reduce the grains to smaller, finer sizes. Such mechanical decay of the grains increases later in the extract production process. Picture 1 shows the process of milling the barley grains by the usage of the two-roll mill. After the malts have been grinded to the right particle size, they are involved in a series of stages, including mashing, wort separation, and boiling. (Goldammer, 2008, 143-149.)

PICTURE 1. Grain milling unit (Shandong Tonsen Equipment Co, 2021)

Mashing is the first stage done after milling. Here, the crushed malts are mixed with the water at specific temperatures in the mash tank (MT) to boost and benefit the chemical changes started in the malting process: amylolytic enzymes impart starch into fermentable sugars. Usually, temperatures for mashing differ from 45 up to 70 degrees Celsius. This temperature range allows the malt to gelatinize (make it sensitive to enzyme attack). The result of the mashing stage is a liquid extract called wort, which is having the specific original gravity (OG), proteins, and a proportion of sugars (both fermentable and non-fermentable). All listed properties will influence the fermentation stage of the beer. (Eblinger, 2009, 165-173.)

When the mashing process is complete, the formed wort needed to be filtered and separated from all the non-dissolved solids that remained in the mash. This step is called wort separation and its main objective is to yield clear wort. It is quite an essential stage because the solids present in the mash can contain oily material, tannins, great loads of proteins which may further affect the fermentability of sugars and general beer taste. The most common method nowadays in America and Europe for wort separation is lauter tun (PICTURE 2). Such a system has a drill base plate which makes it possible for the wort to pass through it into the next tank (boiling kettle). After wort transferring, all insoluble mash will be left behind the lauter tun. An additional stage called sparging to the wort separation can be done. During sparging, the hot water (around 70-78 degrees Celsius) is flashed on top of the grain bed. The main function is to extract wort from the mash and abolish soluble components. (Eblinger, 2009, 182-184.)


PICTURE 2. Lauter tun for mashing and wort separation (Broadhurst, 2018)

The last part done in the brewhouse system before transferring product to fermenters is wort boiling. In the tank called boiling kettle (BK) the wort is boiled quite intensively, and other additives can be added at this stage. An example can be hops, which are added to the wort to bring spicy, decorative aromas in beer, or calcium chloride to bring down the total pH of the wort. In the case of hops, the boiling process helps to extract the needed segments from the hops (isomerization), which would be quite impossible during any other stage of brewing. Besides that, the boiling stage has some more outcomes: sterilization of wort, colour development, and cumulation of proteins (trub). (Boulton, 1991.) The most widely used method among the breweries for trub and cumulated protein removal after boiling is the whirlpool. It is most effective if hops used during production are in form of extracts or pellets. One of the latest advancements in the brewhouse is the combination of the BK and whirlpool. In this case, a pump is utilized to create a vortex effect, which draws water from the bottom of the tank and feeds it into a tangentially positioned inlet. Such solutions have some advantages among other technologies:

simplified brew process, saving space of the brewhouse as well as costs (one brewing tank instead of two). (Goldammer, 2008, 206-216.)

After boiling and whirlpooling are done, the wort is almost ready to be transferred to the fermentation vessel for its further fermentation into actual beer and maturation. Only the cooling stage is needed to be implemented. Practically, the desired temperature for fermentation is between 5 and 18 degrees Celsius. (Stika, 2009.) This variation depends on the beer type (bottom-fermented or top-fermented beers). The wort cooling process is commonly done with the plate or frame heat exchangers. There are two major techniques to compete wort cooling used in the breweries: single- and two-stage cooling. In the first method, only a city water line is used to cool the wort coming from the BK. While passing the heat exchanger the cold water flow absorbs all heat from the wort. Control of the outcome wort temperature from the heat exchanger can be done by changing the wort transferring speed. Second method is implemented in the brewhouse systems in case if the water temperature is not cold enough for the right heat exchange between the liquids. In this case, the wort is going to pass the heat exchanger, where the greater part of the heat will be transferred to the water. The wort flow will be then directed to the second stage, where a colder glycol solution is going to absorb the remaining heat from the wort. (G&D Chillers, 2020.)

After leaving the heat exchanger, the cooled wort is then transferred to the fermentation vessels and from that moment it is ready to receive yeasts and start fermentation processes. The transfer of the wort is typically done via a special food hose connected with one end to the outlet of the heat exchanger and the other end straight to the fermenter. It is very important to do sanitization processes of the food hose before pushing wort to it to prevent any sort of contamination and bacteria presence (any parameter can dramatically change the fermentation process). The most common techniques of hose sanitizing are pasteurization (treatment with closer to 100 degrees Celsius water) and CIP. (Parker, 2021.) The last process will be described more in detail in the process part of this work.

2.1.2 Fermentation, maturation, and packaging

In simple terms, fermentation is the process during which the carbohydrates (sugar or starch) presented in the obtained wort are converted into ethyl alcohol and carbon dioxide under anaerobic conditions. The general formula of the fermentation stage is drawn in Figure 2. Besides main product formation, a diverse number of other by-products are produced, which later results in the beer flavour properties and profile. Such factors make yeast provide the beer with unique characteristics and differentiate one beer from another. The fermentation process counted as started when the chilled wort was successfully transferred to the fermenter and the yeast was added. (Hughes & Baxter, 2001, 9-11) The procedure of adding yeast to the wort to activate fermentation is called pitching (Beer & Brewing, 2021).

$$\underset{\text{Glucose}}{C_6H_{12}O_6\,(aq)} \xrightarrow[\textit{Enzymes (yeast)}]{15\ ^{\circ}C} \underset{\text{Ethanol}}{2CH_3CH_2OH\,(aq)} + 2\,CO_2\,(g)$$

FIGURE 2. Enzyme-catalysed fermentation formula of carbohydrates (Thimmappa, 2020)

The yeast cell growth during the fermentation stage is provided by amino acids. This means that by the end of fermentation the yeast will commonly gain its mass. When the yeast has converted all sugars, the process is going to slow down and by flocculation of the yeast cell, they might be dropped to the bottom of the tank or accumulated on the top (depending on the method used). However, nowadays beer is mostly fermented in closed and insulated cylindrical tanks (fermentation vessels). The bulk of the yeast can be removed and be can now proceed to the maturation stage. (Goldammer, 2008, 233-245.)

After primary fermentation, the so-called ‘green beer’ still has some unwelcome compounds which will be essentially removed by conditioning. The maturation stage involves a stage called secondary fermentation to perform beer finishing. Secondary fermentation typically occurs after transferring the beer to another vessel right after primary fermentation is done. The yeast activity at this stage is quite low, so the main purpose of secondary fermentation is carrying the beer to a post-fermentation step will soften its flavours and aromas, as well as allow the yeast to fall out of solution, resulting in a cleaner finished result. The duration can range between a week and six months. (Northern Brewer, 2018.)

Now the products have achieved their final quality and ready for packaging. Generally, beer is stored in glass bottles, cans, or kegs. The components of the bottling line (PICTURE 3) can vary from one to another, depending on the factors of the brewery, but still, there are series of processes that can be outlined: sterilization of beer, rinsing of bottles, filling bottles with beer, labelling, packaging. (Hughes & Baxter, 2001, 11-13.)

PICTURE 3. Meheen Manufacturing bottling/labelling line (Packaging Strategies, 2015)

2.2 Fermentation-storage vessels

There are currently a relatively large number of different systems(tanks), and their combinations are available for beer fermentation and conditioning. In this section, the brief historical background, and the development of the fermenters through the time will be discussed, as well as the classification and application of the tanks based on the fermentation process stage.

2.2.1 History and development

Fermentation tanks (FVs) are vessels for conducting fermentation reactions for the wort into beer with the help of yeasts. Nearly all that may store liquid can be a possible fermenter. (Tim, 2018.) They have changed almost continuously throughout time. Over the past 70 years, the engineering used to make fermentation tanks has advanced significantly. The advancement of fermenters has gone along with the development of brewing techniques and approaches. The first written documents date back to the Egyptian civilization, where ceramic jars were utilized as vessels. The fermentation and storage of the beverages (mostly beer and wine) were handled in such jars for thousands of years. (Eblinger, 2009, 3-6.)

The very first historical illustration of the brewing technologies in the European part (approximately 1000 ad) showed that the most used material for fermenters was wood, specifically oak. And such materials were in great demand and use up to the 1800s. Through time the resin or tar was added to the wooden tank, creating the so-called lining of the tank. The purpose of the lining was to operate as an inner surface of the vessel to protect the beer from the direct contact of the wood. These modifications allowed for the breweries to sanitize and operate fermentation tanks much more efficiently, decreasing the presence of the microbes and off-flavours. (Kissmeyer & Garret, 2021.)

Already at that period, wooden tanks could be manufactured with different parameters and had colossal sizes. Most know fermenting tank, because of its accident, was in “Horse Shoe” brewery, London. This vessel was more than 6 meters tall. On one day of October in 1814 year, one of the iron arms that held the tank in place snapped. The tank exploded, triggering a chain reaction with neighbouring tanks, destroying the wall of the facility, and flooding the street. At least eight people died because of this case. This incident prompted brewers to look for different kinds of materials, other than wood, for oversized fermentation tanks. Later in the 19th century, most new and expanding large breweries incorporated square concrete fermentation tanks tiled with tar or slate. (Johnson, 2021.)

During the primary fermentation process, extensive heat is produced which results in increasing the general fermentation temperatures. Such changes will have a negative impact on the yeasts' well-being and, therefore, cooling is important. (Kucharczyk & Tuszynski, 2018.) The temperature factor during the whole brewing process as well as cooling technologies will be described in-depth in the following section. In the beginning, cooling of tanks was achieved either by circulating chilled air in the fermentation rooms or by circulating chilled water through metal coils inside the vessels. Generally, coils were manufactured from copper or brass, mainly because of their conducting properties. on tanks tiled with tar or slate. (Kissmeyer & Garret, 2021.)

With the active industrialization soon the desired materials for the manufacturing of the tanks were mild steel. However, this material has its drawbacks: direct contact with the beer would cause the tank to rust, affecting the taste properties of the beer at the same time. To resolve this issue, lining with glass or epoxy polymers was implemented. (A&G Engineering, 2019.) At the same time, great improvements were constantly being made to beer fermentation vessels. While open fermentation types of vessels were still applied, the practice was gradually shifted to fully closed fermentation. Closed fermentation supported the cleaning processes and allowed to reuse carbon dioxide formed during fermentation. (Kissmeyer & Garret, 2021.)

During the first half of the 20th century, aluminium as a building material became relatively cheap and economical. Many breweries were using this metal as their choice for fermenters. The main superiority of this material was its lightweight and resistance to corrosion by wort and beer, so no more additional lining was needed in the tank. The only serious downside of the aluminium was its corrosion to sodium hydroxide (lye) because this compound was used as the predominant detergent for cleaning purposes in the breweries. (Kissmeyer & Garret, 2021.)

After a short period of time, stainless steel started to be utilized as a building material on an industrial scale. Numerous benefits are coming along with the material and to the present day, stainless steel is used as the basic material for the construction of fermentation and storage tanks, as well as other brewing production equipment (piping, valves). (Kane, 2015.)

2.2.2 Universal tanks

Until the middle of the 20th century, regardless of the building material used, all fermentation tanks had a cylindrical body. It was common practice to stack them horizontally on top of each other in production halls. Individual insulation of each tank was also rare because it was not economically viable. Because of this, all fermentation tanks were used only for fermentation, from where the beer was transferred for maturation to another tank by means of connected hoses. (Kissmeyer & Garret, 2021.)

In the 1960s innovation was introduced, which was that fermentation and maturation could take place in one tank. This improvement was a cylindroconical tank (a cylindrical base placed vertically with a cone-shaped bottom). Such vessels were called "universal tanks" or uni tanks for short. These vessels have slanted, cone-shape bottoms which, among other advantages (FIGURE 3), allow brewers to easily remove yeast for disposal or repitching (PICTURE 4). Unitanks began to spread rapidly around breweries and over the past half-century, this type of tank quickly replaced all existing fermentation tanks. (Bryggeriudstyr, 2021.)

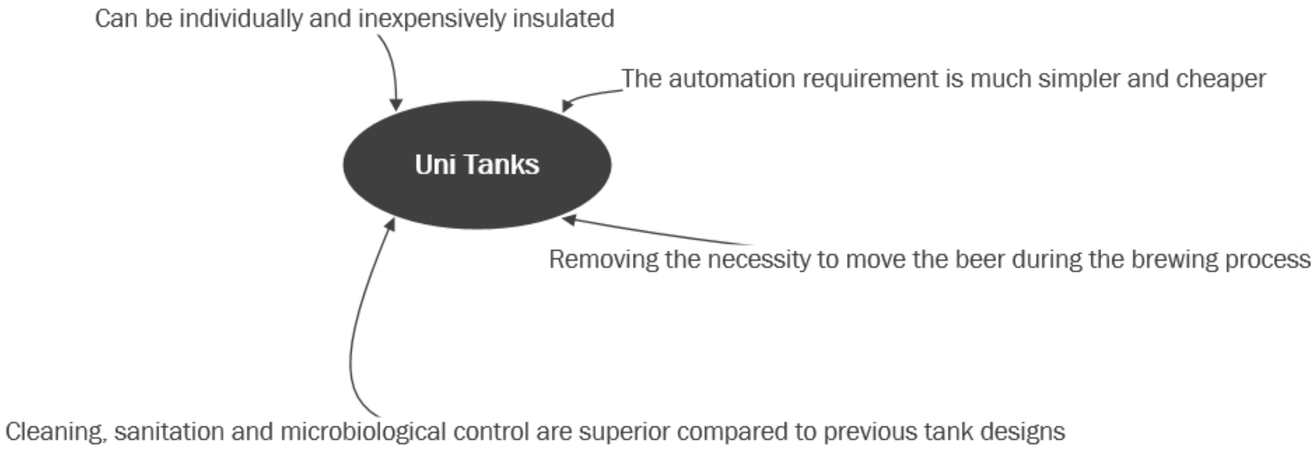


FIGURE 3. Benefits of using universal tanks (adapted from Kissmeyer & Garret, 2021)

At about the same time, the general geometry of the cisterns was studied, which led to their thinning and elevation to save space. However, it was soon discovered that if the universal tanks exceeded the proportion of 5:1 in height to diameter respectively, it was almost impossible to achieve good mixing, and difficult for the yeast due to excessive hydrostatic pressure. Therefore, it is now recommended that such tanks be embedded proportions between 1:1 and 5:1. (Kunze, 2004, 416-419.)

Modern universal tanks have one or more cooling jackets for more optimal movement of beer during fermentation and allow breweries to operate the tank at less than full production capacity. Additionally, since the advent of these tanks, they have been very well suited to be located outdoors, greatly reducing space and construction costs for large production facilities. The vast majority of breweries nowadays use cylindroconical tanks. (Kunze, 2004, 419-420.)

PICTURE 4. Universal tanks for fermentation and maturation (Premier Stainless Systems, 2021)

2.2.3 Classification of fermentation/maturation tanks

Even though many breweries use similar technologies and components in their production (for example a general-purpose tank) there is quite a great variation in the design of tanks for fermentation, maturation, and storage of beer. This section provides the general classification of all types of fermenters, their illustration, and their usability in the brewery. To make it easier to distribute information about each kind, the table format will be used (TABLE 2, TABLE 3, TABLE 4).

Currently, there are three main categories of beer processing tanks. Primary beer fermentation tanks are designed for the primary fermentation of wort to green beer. These types of tanks have no pressure units. The second type is for beer maturation. In these tanks, pressure units exist. Tanks for the beer conditioning are constructed to store the beer and promote its final conditioning. (Beer tanks, 2021.)

TABLE 2. Primary beer fermentation tanks (Beer tanks, 2021)

Tank name	**Design**	**Description**
Opened fermentation vats (OFV)		Uncovered brew fermentation vessels within the form of the bathtub square measure among the standard brew production technology. The advantage is that the risk of assembling “blanket” of dead yeast on the surface of brew.
Cylindrical fermentation tanks (CFT)		Stainless steel non-pressure cylindrical containers for the primary fermentation of beverage. They are equipped with checkup door, sanitizing shower. Sometimes sight glass can be also part of the set-up for controlling the fermentation process.
Cylindrically-conical simplified non-pressure fermentation tanks (CCT-SNP)		Stainless steel non-pressurized containers for main beer fermentation. Such vessels have cylindroconical shape for easier yeast separation from beer. Usually fitted with an inspection door, sanitizing shower and valves for discharging yeast or beer.

TABLE 3. Tanks for both primary and secondary fermentation processes (Beer tanks, 2021)

Tank name	Design	Description
Cylindrically-conical pressure tanks (CCT-C/SLP/SHP)		Have conical bottom and cylindrical base. Made from stainless steel. Besides checkup door, sanitizing shower and valves for yeast discharging, this type of tanks also fitted with adaptable pressure valve. Pressure hold of the tank can be varied between 0 and 3 bars.
Modular cylindrically-conical pressure tanks (CCT-M)		Extremely universal vessels that allows an optional layout of the tank for beer production. Suitable for all applications such as fermentation, maturation, carbonation, flotation, filtration, and bottling processes in the needed configuration. Maximum pressure range is also between 0 and 3 bar.

TABLE 4. Tanks for beer maturation and storage (Beer tanks, 2021)

Tank name	**Design**	**Descript**
Maturation tanks (MLT)		Tanks with the cylindrical shape for the secondary fermentation of the beer. Generally, those tanks have sanitary shower, inspection door, as well as pressure and draining valves.
Cylindrical beer tanks (BBT)	 	Stainless steel vessels that are suited only for the temporary beverage storage and its preparation for kegging or bottling. These BBT tanks have accessories for controlling tank pressure, sanitizing shower, check-up door and additional valves for beer transportation in and out. Pressure limit is usually 3 bars.
Serving tanks (DBT)		Vessels for storing final product directly in the restaurants. Design for easy beer serving directly into glasses with the help of air compressor. Can be also equipped with the portable plastic bags to prevent the contact of beer with air.

There is an additional equipment kind that exists for yeast processing. Such equipment can be split into two main categories: simple yeast storage containers and controlled yeast storage. In the first case, general glass or stainless steel vessels can be utilized for passive yeast storage and collection. These vessels are created for placing inside the fridge. The second arrangement type is stainless steel vessels for the guarded collection and storage of the brewer’s yeasts. These tanks are well-insulated and have cooling jackets, which allows locating these tanks in any place at the production facility(PICTURE 5). (Czech Brewery Systems, 2021.)

PICTURE 5. Tanks for yeast storage and collection (Czech Brewery Systems, 2021)

2.3 Cooling line

Temperature control systems or simply chillers are part of the many production processes that take place in a brewery. It is difficult to overestimate their importance, which is why they are considered one of the most important components. (Grainfather, 2020.) In the production process, during the mashing and boiling phases, a great deal of heat is generated, which is then removed by the cooling systems. There are three main cases in production where chillers are most used. The first case has already been described earlier in the section with two-stage cooling of the wort with a heat exchanger. The cooling system can also be present in a beer bottling line, where the basic principle is to place a heat exchanger between the bottling line itself and the dispensing tank. In this case, the beer will not receive any additional heat while it is moving through the hose. The third and most important process is fermentation, where the chiller is used in the fermenter after the yeast has been added and the conversion has started. (VanderGiessen, 2019.)

Among other factors, the temperature is the most critical and significant value in the fermentation process because any extreme temperature changes can ruin the final flavors and aroma in the product, which will affect very low quality. Each type of yeast has temperature ranges in which it works most effectively. Temperature differences can greatly affect the performance of the yeast. Generally, the lower the temperature, the slower the yeast will work, and vice versa, the higher the temperature, the faster. (Grainfather, 2020.)

The most effective way to monitor and control temperatures inside the brewhouse is with glycol-based chillers. These cooling systems use propylene glycol or a mixture of glycol and water to extract excess heat and then dissipate it either in a heat exchanger or freezer system. These glycol-based chillers allow you to set the right temperatures, re-cool heated coolant coming from the vessel in preparation for recirculation and produce high-quality beer. Figure 4 gives a schematic representation of how the chiller system is connected and interacts with the fermenters. (Cold Shot Chillers, 2021.)

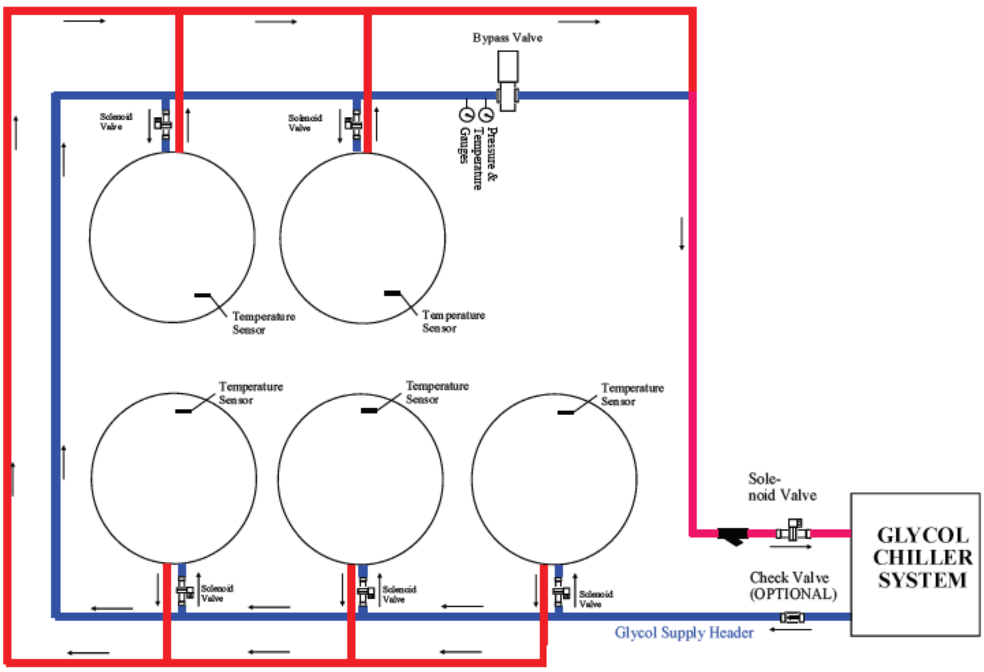


FIGURE 4. Glycol chiller system working principle (American chillers, 2019)

Propylene glycol is an organic anti-freeze agent. The freezing point of glycol is about -59 degrees Celsius, but a combination of glycol and water has a more moderate freezing point. Because of this, a mixture of glycol and water can cool the same wort much faster than water alone and avoid the formation of harmful ice inside the brewing unit. (Hieronymus, 2014.)

For the interaction of the coolant with the wort or beer, special cooling jackets are used in the tanks. Such jackets are a technology of temperature regulation, achieved by cooling the beer from the outside. In modern tanks, cooling jackets are a cavity between the inner and outer walls of the tank through which coolant flows to regulate the temperature inside the tank. Also, jackets can be made of flexible material with the same cavities. This type of jacket is wrapped around the unit and thus thermoregulation occurs through a simple process of heat exchange. Cooling jackets offer some advantages in use, such as the relatively easy adjustment of temperature levels, which allow for more uniform cooling and thus fermentation. Other advantages include the prevention of accidental contamination of the beer, since the integrity of the unit is not compromised, and the installation and maintenance of such a cooling system are quite simple. (Cold Shot Chillers, 2021.)

3 PROCESS DESCRIPTON

As it was already mentioned in the introduction section, Kahakka brewery launched a new, large project in January 2021. The main goal was to increase the volume of produced beer per week, which will enable the most stable distribution of products and thereby gain a significant foothold in the Finnish market. To achieve that, five new universal tanks were ordered to the facility. The choice in favour of such vessel type was made for several reasons. First, Kahakka brewery is considered as a small-scale brewery, and therefore, there is space limitation in its production facility. Universal tanks allow making all fermentation and maturation processes all in one place, without a need for beer transfer, as well as installations of additional maturation/storage tanks. Another reason is that the brewery already has universal tanks but smaller in size (500L and 1000L volumes). Thus, the production team had already a general understanding of how to operate such tanks (filling, yeast management, sanitizing).

In this section, the complete project of installing new universal tanks from the moment they were delivered until their ready for the very first fill with wort will be described. To systematize and better understand all the steps, this work was divided into separate sections, which will be presented below.

3.1 Universal tank and its parts

All ordered uni tanks are identical to each other with a 3000L filling capacity. Appendix 1 gives detailed information about tank sizes and other technical parameters. Schema for the tanks was provided by the manufacturer. It will be used a lot for planning the brewery space for new equipment. Although uni tanks have similar look and parts, there are different models and configurations of uni tanks exist. Below will be described parts specifically for tanks received in Kahakka brewery. Table 5 represents the main tank parts and their accessories.

TABLE 5. Universal tank parts (Beer tanks, 2021)

Accessory name	Illustration	Description
Tank body		Tank itself which is produced from the stainless steel. Pressure limit is 3bar. Cylindrical top part and conical bottom part are developed for efficient beer production. Equipped an inspectional door in the front and different outlets to place and fix accessories for it.
Ladder		This is optional part that was ordered by the brewery to have easier access to the top part of the tank, where yeast and hops manipulations are done with the beer, for instance.
Bottom throats		These are two draining pipes welded to the disc which is connected to the bottom of the tank. One pipe can be used for draining and gathering biomass, other pipe has greater length inside the tank, which allows to collect only clear beer during bottling without taking any yeasts or other solids.

(continues)

TABLE 5 (continues)

CIP arm		Such CIP pipe connected on the side of the tank is designed for sanitizing the tank with the cleaning solutions. On top, the CIP arm is joined with a spray ball, which allows to spread the cleaning solution more efficient inside the vessel.
Pressure unit		On the opposite side of the tank there is another arm connected to control the pressure of the tank. The pressure unit is connected to the bottom end of the tank and allows to monitor and adjust the pressure of the vessel (equipped with manometer and air-lock).
Sample valve		This valve is connected to one of the side outlets of the tank and it is used for taking beer samples for tasting and making necessary analysis.
Carbonation stone		Carbonation stone with the control valve is connected to the tank just above the sample valve. The purpose of the stone is to carbonize the beer. Carbonization is achieving by injecting CO_2 into the beer throw the small pores in the stone to reach desired CO_2 level of the beer before filling it into the bottles.

(continues)

TABLE 5 (continues)

Filling level		The level is designed to visually track the amount of beverage inside the tank. It is used when the beer is filled to the bottles or kegs directly form the tank.

All tanks were delivered to the brewery in the special metal casing (PICTURE 6) to protect them from any damages that could happen during transportation. All other accessories for the tans were also well-packed and delivered in separate containers. After receiving the tanks and their corresponding parts, the whole inventory was made before the beginning of the installation work. This procedure is quite critical for projects of this size and should not be skipped, because a lot of parts and components will be involved later in the installation process, and it is fairly easy to lose the count and significantly prolong the launching time.

PICTURE 6. Tank delivery in metal case (Khandobin, 2021)

Therefore, I and the rest of the production team made the complete inventory for each tank, as well as cooling line pieces, including pipes and pumps. All categorized accessories were stored then in the brewery warehouse, but not tanks themselves. Due to the rather large size of them and the limited space in the brewery, it was decided to place the tanks temporarily in a rented building next to the brewery and to install the tanks gradually, with two series, so that during their installation there would be enough working space inside the production area.

3.2 Planning and blueprinting

The very first step in every project is proper planning. Having a clear visualization and all necessary information allows completing almost any project in the best high-quality and the most accurate. Moreover, the proper outlining automatically saves working time by having a clear image of what should be done and how everything should look at the final state. For the current project in the brewery, there were two main constituents, which needed a proper blueprint: free productional space distribution between new tanks and their proper position for easier access to complete daily operations. In Figure 5, the schematic representation of the brewery is drawn before the start of installations. As it can be seen, the right side of the production area consists of a brewhouse (HT + MT + BK), as well as fermentation/storage vessels (FVs and BBTs). The left side remained empty all the time and was used primarily for packing the beer and deliveries.

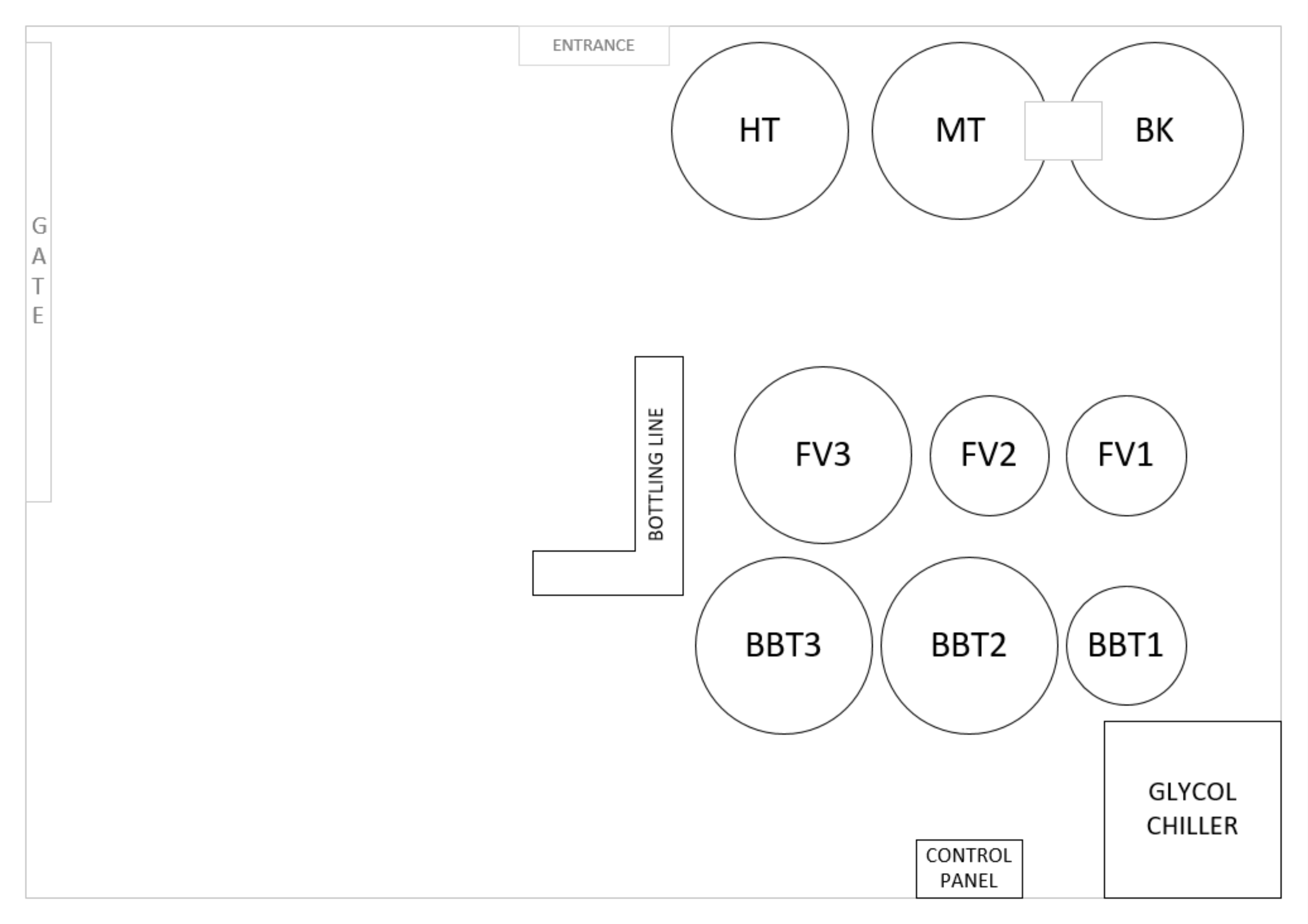


FIGURE 5. Production area of Kahakka brewery before the installation of uni tanks (Khandobin, 2021)

This left part of the building was intended for the five new vessels, and it must be laid out and measured in detail for the project. I started by taking measurements of the whole right perimeter of the building: from the gate until the bottling line. The height of the tanks was considered before making an order and it was confirmed that there is no conflict with the building ceiling and all operations on the top of the tank can be easily performed. Since that moment, the only important parameter for tanks lining in the production area was their diameter (width). The diameter of the single tank is 1660mm (APPENDIX 1) The total length of wall 1 (closer to the gate) is 4170mm and the length of wall 2 (opposite to wall 1) was measured to be 6820mm. It is important to mention that obtained measurements for wall 1 and wall 2 are not their full-lengths, because only the free space for installing was determined. Taking into account both wall lengths, it was decided to place three uni tanks next to wall 2 and the remaining two to wall 1, respectively. All prior measurements for the tank placement can be seen in the Figure 6 below.

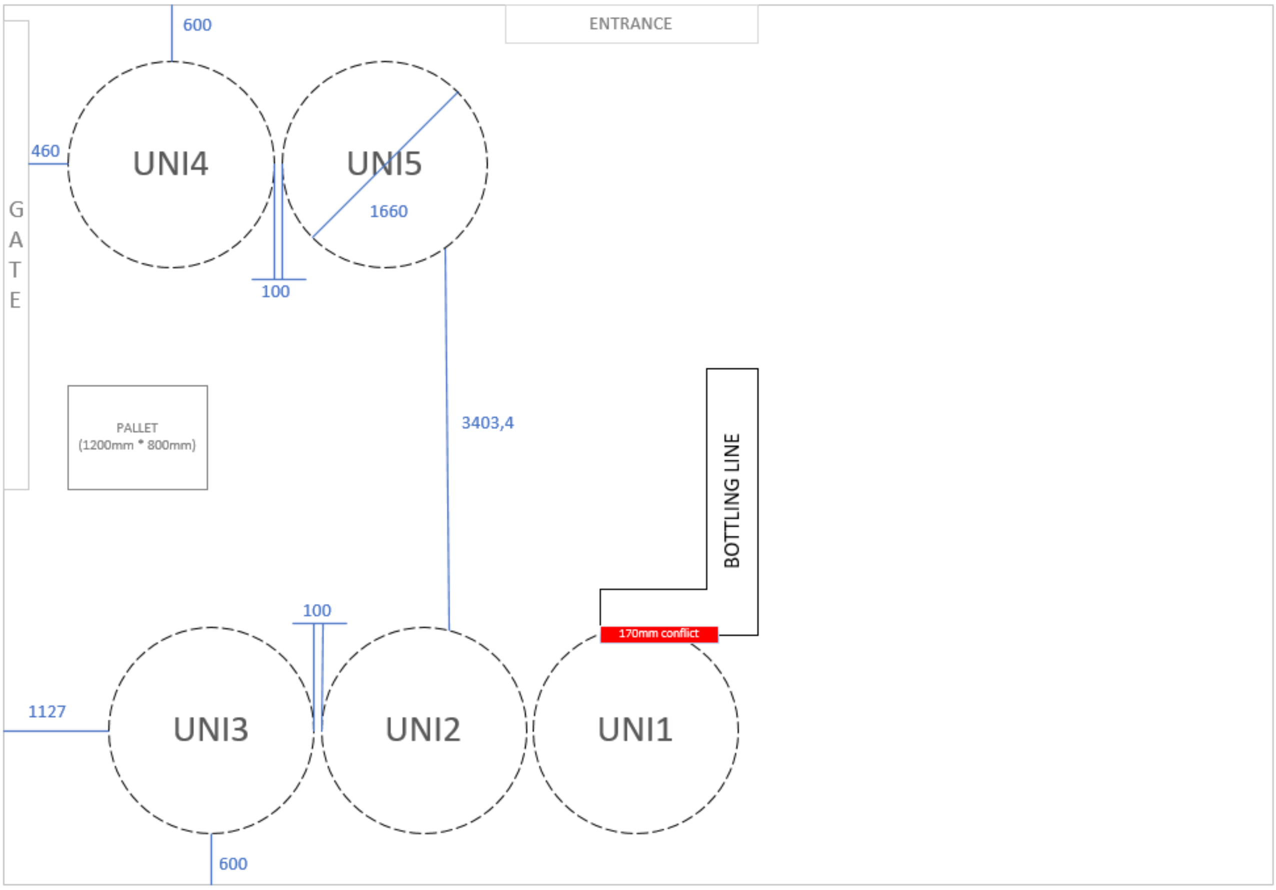


FIGURE 6. Blueprint for the uni tanks position with given measurements (Khandobin, 2021)

As is seen from this figure, I have chosen the minimum distance of 100mm between the tanks to save space and have more accessibility to different sides of the production area, as there is constant urgency to move different equipment and small pallets. Angled position of both CIP and pressure arms of the tank (appendix 1, top view) allows to consider only the diameter of the tank as the total width, and thus, there is no need to account for additional space for it between each tank. Also, there is still easy access for one person to go in between tanks, because of the conical shape and height (1700mm) of the tank bottom part. The next important measurement is the total distance from the wall to the tanks. Tanks cannot be pushed fully to the wall because there should be space for the cooling pipeline going from the tank, for all necessary maintenance, and to access all sockets, which are placed on both walls. By a practical test, it was found that this length should be about 600mm. And with this length from the walls, the total production area is calculated to be around 3500mm length, which is optimal for all production operations. The only conflict was the Uni 1 tank and the bottling line (FIGURE 6). But it was quite easily resolved by moving the bottling line 1000mm away from the tank to the opposite direction. All the rest measurements were found and adjusted practically depending on the production needs, so only the length between tanks and distance from the wall to the tanks is the same for each to have them lined and make a good visual representation of the place. The challenge in the alignment of uni tanks was that wall 1 and wall 2 are not exactly parallel to each other. Because of that, I was making a correlation line of one of the walls to have precise measurements for both sides and have great alignment. After completing all needed measurements, I marked the exact area for each tank in the production facility with tape, making the unloading and installing tanks in place much easier (PICTURE 7).

PICTURE 7. Tanks location markings (Khandobin, 2021)

3.3 Tanks installation

To have space for cooling line manufacturing and because of the production schedule, it was decided to deliver and install tanks on the place in two goings: first two tanks (Uni 4 and Uni 5) and after one week rest three tanks (Uni 1, 2 and 3). Because all five tanks are identical to each other, all measurements for the cooling line were done by me during this week based only on one tank to save time and make further installations easier. The next section has a detailed description of the cooling line design and corresponding manufacturing procedures. The first two tanks were delivered to the brewery on the 21st of January 2021. They were placed inside the production area on the right-marked places with the help of a crane and forklift (PICTURE 8). At this step, the tank is not yet stable on the surface, because all the floor in the facility is tilted to the direction of the drain for water and any liquid removal. Uni tanks are designed in a way that it is possible to adjust the height of every individual leg of the tank. Therefore, after placing the tank on the right spot, the height of every leg was adjusted with the help of the bubble level that the central axis of the tank is perpendicular to the surface. The same procedure was done with Uni 1,2 and 3 tanks after one week during their transportation and fitting (PICTURE 8).

PICTURE 8. Setting all five universal tanks in the correct position (Khandobin, 2021)

The very last procedure to complete before the beginning of the cooling line assemble is to rinse both cooling jackets of all tanks. This process is not essential, but it was still decided to perform it. The main reason was that after welding the tanks at the original factory, manufacturing particles could remain inside the jackets, which could contaminate the coolant in the future. And the coolant line uses the same fluid (circulates in a closed-loop). Therefore, it was decided not to skip the flushing stage of the jackets. The rinsing of each jacket was completed in a quite simple way: the water hose is connected to the inlet of the jacket and the dump hose to the outlet. Then the water flushes through the whole jacket, it takes all the dirt and dust and leaves then through the dump hose. This operation was made for every universal tank. After finishing this step, tanks were ready to be connected to the new cooling line.

3.4 Cooling line design and manufacturing

This part of the project was the most challenging and took most of the processing time. The importance of the cooling line and temperature control was already mentioned in the theoretical part of the thesis. The whole complexity of the cooling line build was due to several reasons: manufacturing each tank connections, pipeline and supports must be produced from scratch; the new line should be then completely insulated to avoid any heat exchange and condensation on the pipeline; the cooling line should be connected to the existing line in the brewery without interfering with the functionality of the latter.

Figure 7 represents the general cooing line design for the universal tanks. There are two main lines, where is the first line (blue) going from the chiller system to the inlets of the uni tanks, and the second line, on the contrary, facing back towards the glycol tank after heat exchange with the tanks. As it can be also seen, each tank has two inlets and two outlets for the glycol to go. This is because every individual uni tank has two separate cooling jackets welded inside due to its huge size. A separate jacket has one inlet and outlet and one temperature sensor, making it possible to monitor and adjust the temperature of the top and bottom parts of the tank independently.

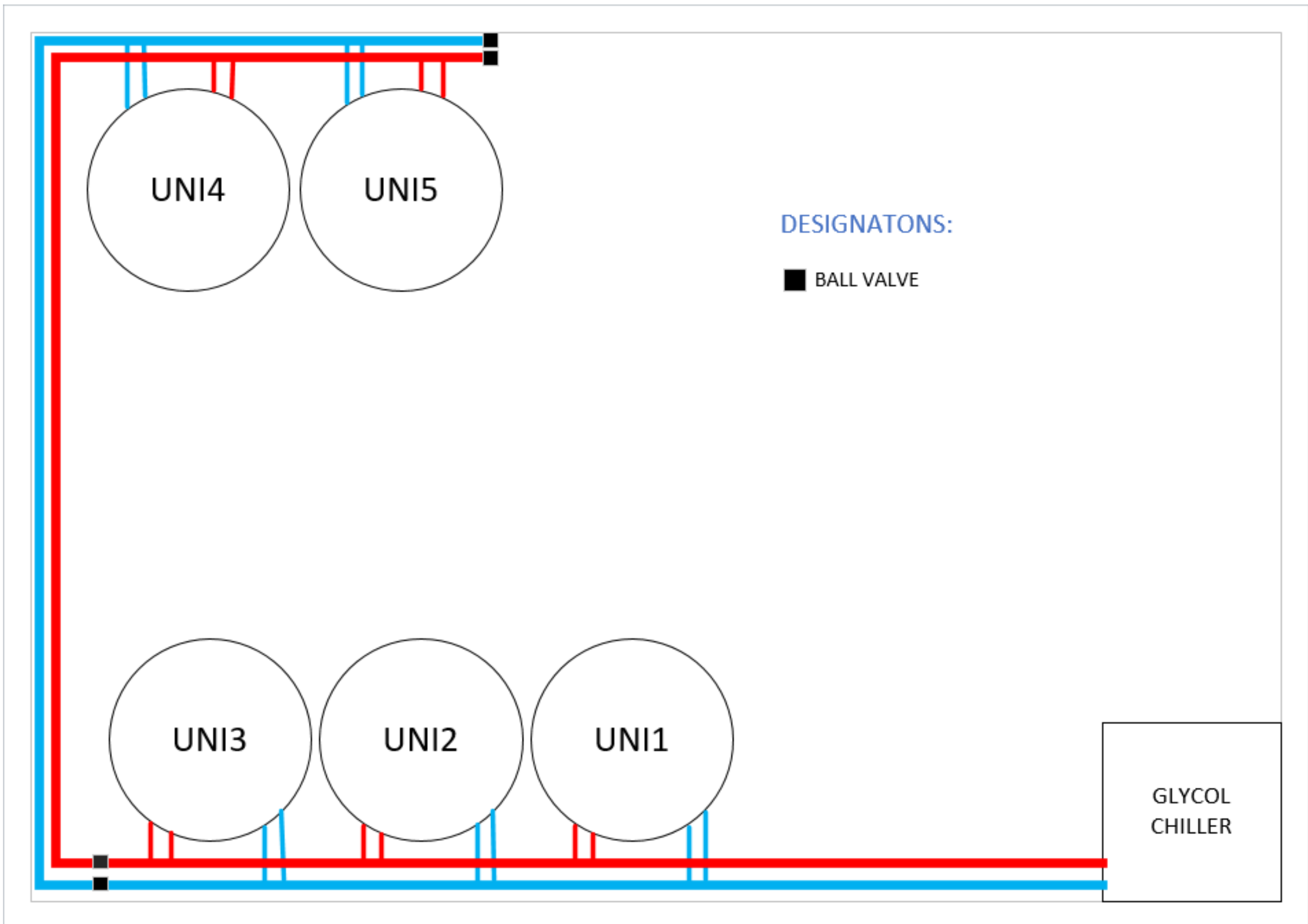


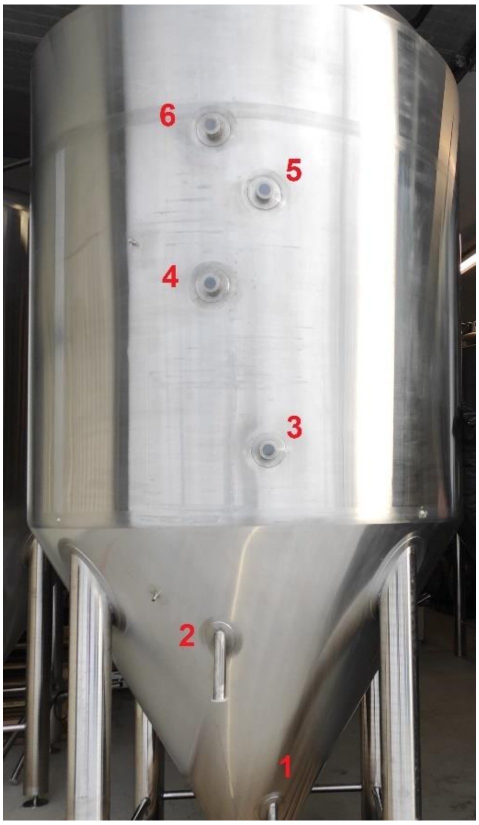
FIGURE 7. Cooling line architecture for universal tanks (Khandobin, 2021

The whole cooling line was made from PVC pipes. This widely spread synthetic plastic polymer has some advantages among other materials: great flexibility; availability of different nozzles, angles, and connections that allow building lines for almost any shape of building; pressure holds up to 25bars, the pipe can be effortlessly cut ton reach the required length. Picture 9 illustrates the PVC pipes used for the line manufacturing at Kahakka brewery as well as an example of fittings to construct the right direction. To join a pipe with the corresponding connector, a standard PVC pipe welding machine was used. The entire work process consists of rapidly melting (about 250 degrees Celsius) the side of the pipe and adapter and then quickly joining them together. After melting, the connection must be made fairly quickly and accurately, because the material cools and hardens very quickly.

PICTURE 9. Pipes and connectors before welding (Khandobin, 2021)

3.4.1 Building colling pipeline

For easier cooling liquid flow understanding inside the jackets, I added numbers to inlets and outlets on the backside of the tank (PICTURE 10). Numbers 1,3 and 5 are aligned on the right side of the tank and are inlets for the jackets. And numbers 2,4 and 6 are accordingly outlets. The first bottom jacket has an inlet at number 1 and an outlet at number 2. The second top jacket has an inlet at number 3 and the final outlet at number 6. Inlet 4 and outlet 6 are connected between each other and help to transfer liquid to the very top part of the jacket (PICTURE 10).



PICTURE 10. Cooling jackets inlets and outlets (Khandobin, 2021)

It was decided to start the construction of the cooling line by making all the connections going directly into the tank jackets. From illustration 16 it can be seen that for each tank it is necessary to fabricate 5 separate connections (two inlets and outlets and 4 with 5 to connect each other). Additional complexity was given by the fact that all the pipes had to go up and not be fixed at floor level. The location of the line at the floor level creates a lot of difficulties during the production processes of the brewery. Firstly, with this location, it is very difficult to clean the floor because the pipeline will limit the flow of water into the drain. Second, there can be a lot of weekly operations in the brewery that involve transferring beer from one tank to another using removable hoses routed typically across the floor surface. Such moves can easily do mechanical damage to the glycol line.

When the load of the first two tanks was completed in the brewery, I started to manufacture all these five connections to the tanks based only on one tank (all universal tanks have identical parameters). It was quite a good strategy because by measuring and learning how to weld the first connection piece, I could easily repeat the same procedure for four other tanks. With that, by the end of the week, I manufactured all five pieces for every tank (PICTURE 11).

PICTURE 11. Example of same pre-welded parts for each uni tank (Khandobin, 2021)

When the second load of the three other tanks was done, I began to connect all pieces on place for every vessel. It was soon detected that some pre-manufactured pipes and connections made from measuring only one example tank could not be fitted properly on place for other tanks. The whole problem turned out to be not a quite correct original welding of the tank inlets and outlets at the factory where they were sent from. According to Figure 16, all openings must be positioned in the same direction, but due to the cylindrical shape of the base, some openings have a slight difference in their direction. And these differences were unique from tank to tank. Long pieces did not need build, as in picture 11, because such length allows to bend and adjust pieces properly for each tank. However, shorter welded pieces do not have the same flexibility due to their length, so I was redesigning them. Picture 12 shows the short piece that could not be properly fitted to the tank inlet. And with that manufacturing of all pieces and their installation on each tank were done.

PICTURE 12. Invalid welded pipe connection (Khandobin, 2021)

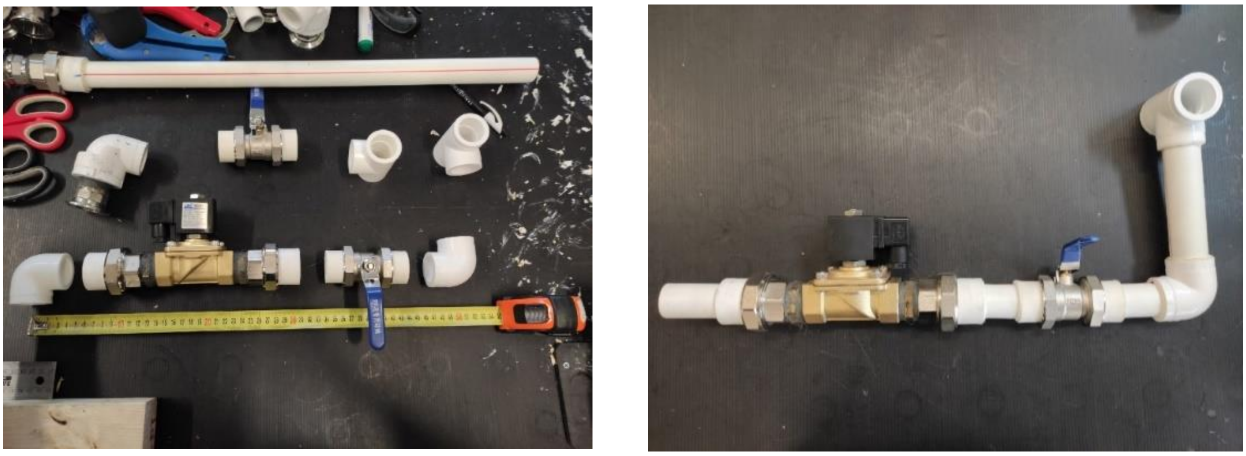
The next stage of the building was welding the complete line starting from the glycol tank, going along with all tanks on both sides of the production area, and coming back to the glycol reservoir. Before welding and installing the line in place, several supports were positioned all around the perimeter just below the height of the tank. these supports are designed to hold the entire mainline and distribute the weight evenly. Welding the entire line of pipes to connect the tanks and glycol tank was not a very difficult process for me, because it is straight lines welded with 90-degree angles to turn the lines in the right direction. The only difficulty was to put the pipeline in place on top of the gate because there was also located the gate opening mechanism (PICTURE 13). Also, on the left side of the illustration near sealing two welded airlocks can be observed. Their role is to release all the air from the pipe system. Because air has less density than water, it will eventually rise to any high points. That is why these airlocks for both line directions were installed right on the highest level of the line.

PICTURE 13. Installing the line on top of the gate (Khandobin, 2021)

Up to this point, all parts for the pipeline were manufactured and welded on the constructional table and fixed on place afterward. These are the main cooling pipeline and all four sets of pipes leading to each tank inlets and outlets. From now, the main goal was to connect these two components (tank opening with the mainline). As it was written before, each tank has two inlets and outlets for glycol solution to travel into the jackets. Thus, four connections must be made and welded for one tank to connect it later with the mainline. Construction of two outlet connections did not have any additional complexity, rather than a ball valve welded in between the joining pipe to be able to stop glycol flow if needed.

Making inlet connections between tank and line had additional manufacturing stages. Brewer should be able to control the amount of glycol going inside the jacket to maintain the temperature inside the tank. And this can be achieved by solenoid valves and temperature sensors. A solenoid is generally an electromagnet, which is capable to convert the electrical current into mechanical energy. More specifically it receives this electrical energy and uses it to form a magnetic field to further create a linear motion. In our case, the linear motion is the motion of the plunger inside the solenoid. Depending on the original state of the plunger, such motion allows to open or close the valve. So, as soon as temperature status needed to be maintained, the control box will send the electrical signal to the solenoid, and it will perform the motion of the plunger inside. (Tameson, 2021.)

Coming back to the inlet connections between the tank and the line, the following part consists of the ball and solenoids valves. After measuring the distance between the tank and the line and taking into account the length of both valves, I cut and prepare the welding of the pieces (PICTURE 14, left side). It was very important to turn and weld each solenoid in the right direction because these solenoids can be classified as direct-operated solenoids. That means they can only allow media to flow in one direction. And in the case of universal tanks, this direction should be conducted to the tank jacket. The final result of welded inlet connection can also be seen in picture 14 on the right side.



PICTURE 14. Solenoid welding (Khandobin, 2021)\

After all the inlet and outlet connections had been premanufactured, I started to join the mainline and tanks with them. Welding this time cannot be done on the constructional table and must be performed in place because both parts that needed to be joined were already fixed. Welding at height cannot be done by one person, thus all connections were done by me with Nicke Kavilo. Results can be seen below in picture 15. From the top view (PICTURE 15, left side), a pair of two inlets (solenoids) and two outlets (ball valves) connected to each tank can be viewed. From right side of picture 15 we can see the design of the pipeline in action: all the connections are aligned and going straight up to the main cooling line without touching the flooring.

PICTURE 15. The mainline connected with tanks (Khandobin, 2021)

Because of the ball valves after the first three tanks (FIGURE 7), we were focusing primarily on connecting and completing Uni 1, 2, and 3 tanks. The remaining two tanks were completed when the first was already operating and filled with the beverage. This was done to continue the production function of the brewery as soon as possible (growing demand for beer in the market). For better understanding, Figure 8 illustrates the cooling system behavior when ball valves are closed. In such configuration the glycol is not traveling further than Uni 3 tank from the glycol station. It will stop at the valve and return to the chiller system.

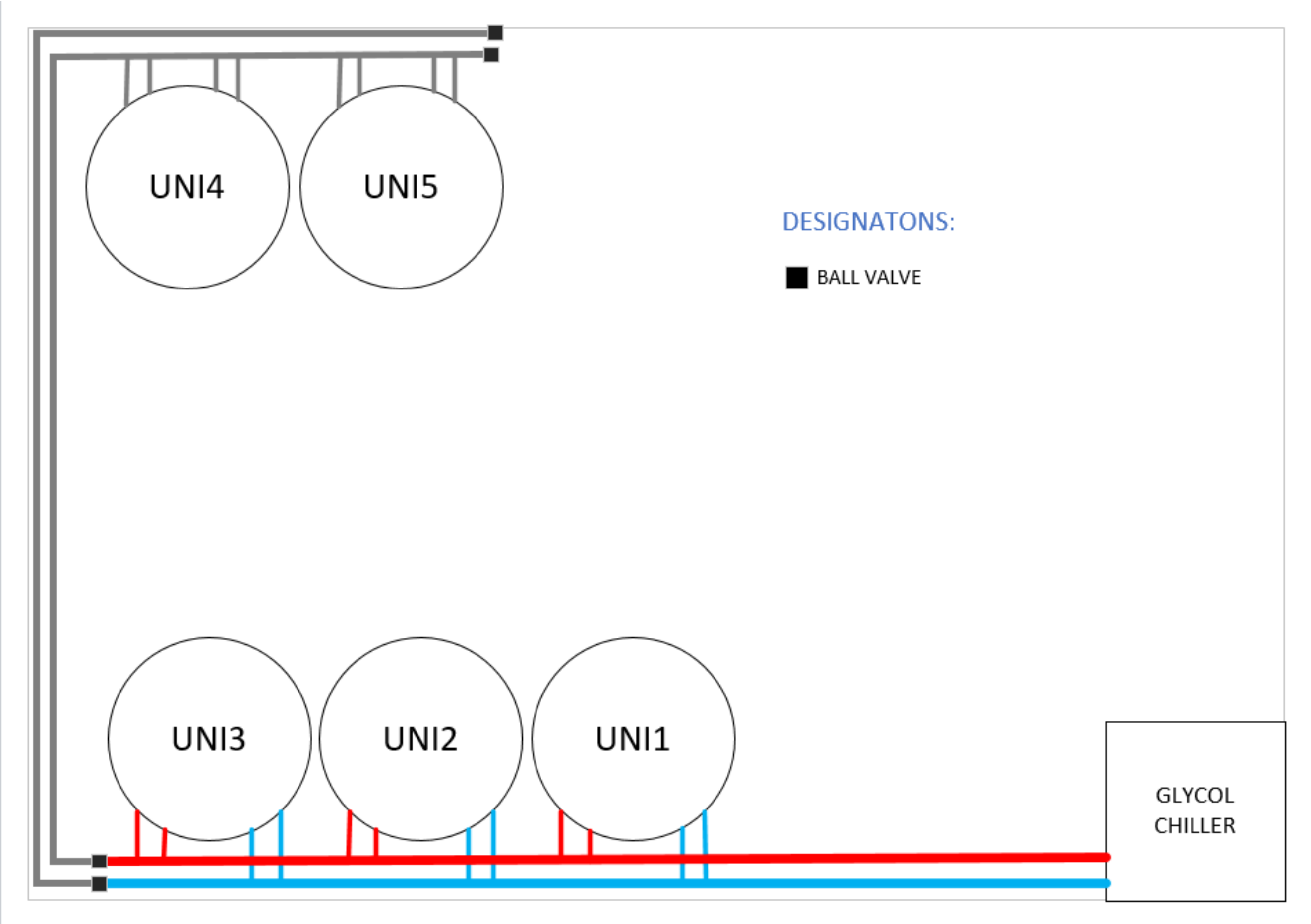


FIGURE 8 Glycol line performance with closed ball valves (Khandobin, 2021)

3.4.2 Line pressure test

Before insulating the line and running the cooling solution, the mainline must be pressure tested. Although the movement of the glycol inside the pipeline is almost not creating any pressure, it is still a good practice to run a pressure test to test the line and check for possible leaks, especially in the places, which were manually welded. According to the information written on the PVC pipes, they can deal with the pressure up to 25 bars, which was quite an impressive number for me. Our productional team decides to create the pressure inside the pipeline with city water supply. The average pressure of the water line is 8 bars, which is enough for our test purposes. The examination was not done at once for the whole line, but instead was divided into two parts, according to Figure 8. The line going from the glycol tank and line coming back to the tank were tested also separately. To one end of the pipeline was connected the water supply, another end has pressure meter and dump hose (PICTURE 16).

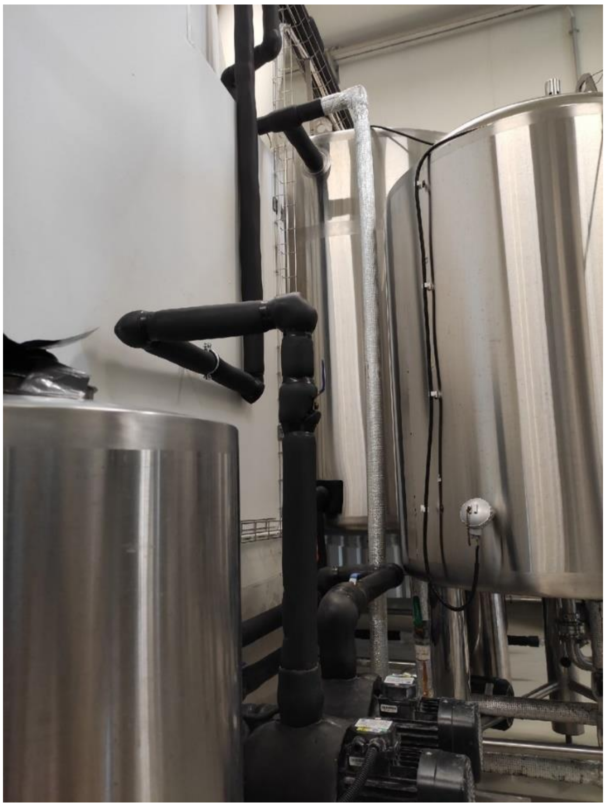
It is important to mention that all the inlet and outlet valves to the tanks were closed, so the water will not enter tank jackets.

PICTURE 16. Line pressure test (Khandobin, 2021)

As soon as the water had started to run through and filled the tested part of the pipeline, I have closed the valve on the opposite side, thereby creating pressure. With the help of the pressure meter, also shown in figure 24, I could easily see the current tension on the line and adjust if needed. Another team member was walling and examine the line at the same time to detect any damages or leaks. After the test was completed, the pressure was released, and the water was drained from the cooling line. The same procedure was completed for all line sections. The pressure test showed no obvious leaks, and our cooling line was well-constructed and ready to be connected to the existing cooling line and further insulated.

3.4.3 Connecting new line to the existing

The movement of glycol through the pipeline is realized with the help of a pump. In Kahakka brewery, we are utilizing centrifugal horizontal pumps for all productional processes. Originally, there was only one pump that circulated glycol through all FVs and BBTs tanks. With the construction of a new cooling system for the universal tanks, the brewery ordered two new pumps to redo the line and to be able to disperse glycol to the existing line and the new one from the same glycol tank (PICTURE 17). Rebuild the line to the glycol tank was a relatively simple procedure. All we did was connect the two lines with a t-shaped tee, and then a line coming from the glycol tank to the inlet of each pump, and a line leading to the tanks to the outlet. And of course, the return cooling line coming from the tank goes back to the glycol tank and the cycle is closed.



PICTURE 17. New pumps for glycol circulation (Khandobin, 2021)

3.4.4 Insulation of the line

With the completely build and tested cooling line, it was finally time to cover the whole pipeline with the insulation material. It was decided to use nitrile rubber pipe insulation material (PICTURE 18). It is just as widespread as PE foam insulation for pipes. The reason for covering our new cooling system with nitrile rubber is its high resistance to water vapor diffusion and slow conducting capacity. These properties prevent condensation, minimize energy loss, and additionally prevent airborne dust. (Armacell, 2021)

PICTURE 18. Nitrile rubber insulation (Jinan Reteck Industries Inc, 2021)

The insulation that was originally ordered was closed, with no cuts made beforehand, so to cover it, it was necessary to cut it along its entire length, then put it on a section of pipe and cover it by gluing both ends together. Such a process is very time-consuming and was complicated by doing most of the work at height. Because of this, even during the construction phase of the line, the insulation material was tried to put on the pipe before it was welded to other parts, thereby reducing the number of material cuts, which made the system more airtight, as well as significantly reduce the amount of overall work. In the picture 15 (left side) the joining of the line has just been completed, but some parts of the line (especially the long ones) have already been pushed into the insulating material beforehand. When very long pieces of insulation material were glued, I did not always have time to join all the ends before the glue dried completely, so I put electrical tape on top to make it as tight as possible. Also, for comparison, we ordered the same material but with already made pre-cut for quick coverage of the pipes (PICTURE 18, right side). With this material, it was easy and quick to cover pipelines at height because both cut sides already had the adhesive layer applied for quick bonding, and it was not necessary to use glue. But later, the disadvantage was that the pre-applied adhesive held the two pieces in place very loosely and constantly diverged, even when using the correct diameter. Self-gluing with special adhesive turned out to be much more effective.

PICTURE 19. Complete insulation of universal tanks (Khandobin, 2021)

The insulation stage took a considerable amount of time (three months) compared to the total duration of the project. The final appearance of the cooling line can be observed in picture 19. At the same time with insulation works, there was a team of professional electricians who worked in the brewery. They were connecting all the temperature sensors of the tanks and solenoids to the new sensor control panel. For providing all the electrical cables to the control box, additional support was installed right on top of the main cooling line. After the connection was done, we were able to see each tank on the screen and maintain temperatures for each tank and its jacket (PICTURE 20). And with the completion of these last two phases, the entire construction of the cooling line was complete.

PICTURE 20. Touch-screen control panel (Khandobin, 2021)

3.4.5 Troubleshooting the line

With the beginning of the filling of the uni tanks with a beverage, the new cooling line was officially opened, and the glycol solution was piped in. But after a while, we noticed some undesirable changes: each universal tank was cooled constantly to the lowest temperatures, which was very destructive for the fermentation process taking place inside (favourable temperatures are about 16 degrees Celsius). Any temperature settings on the new control panel were systematically ignored.

It was soon discovered that the existing cooling line was pushing the glycol back to the universal tanks, causing a rapid decrease in the temperatures. This was happening because of the t-piece part that is connecting the outlets of both lines before entering the glycol tank. (PICTURE 21, 2). At the beginning of filling and operating uni tanks, there was not much need for a cooling agent. Thus, the amount of glycol circulating in the new system was much less than in the existing line for FVs and BBTs vessels. While returning to the glycol tank, the glycol solution of the existing line did not experience any counter flow from the new line and, therefore, instead of turning from the t-piece part to the right (direction of the glycol tank), glycol solution was going to the outlet of the new line, forming the reverse movement of the whole circulation. Solenoids could not control the flow, as it was more powerful than their holding capacity. Such incorrect movement of the glycol solution was also affecting the old cooling line: glycol solution was not returning to the chiller system and, therefore, could not be cooled down before been used again. After going through the new line circuit in the reverse direction, glycol returned to the inlet connection, which both lines are also sharing (PICTURE 21, 1) From this inlet connection, “warm” glycol was re-entering the existing line and could not decrease the temperature of the tanks.

PICTURE 21. Connection of the two cooling lines to the chiller system (Khandobin, 2021)

To limit the flow of glycol from the old line toward the universal tanks, it was decided to install a spring non-return one-way valve (PICTURE 22) near where the lines joined that allowed glycol to flow back from the universal tanks and prohibited reverse flow (PICTURE 21, 3). After installing there was a slight concern that being stopped with the one-way valve from pushing the glycol in the opposite direction, the glycol of the old line would still prohibit the movement of the new glycol line, because of the force differences. But after restarting the system, both lines started to operate in normal mode and the tanks cooled only to their exposed temperatures without any conflicts between each other.

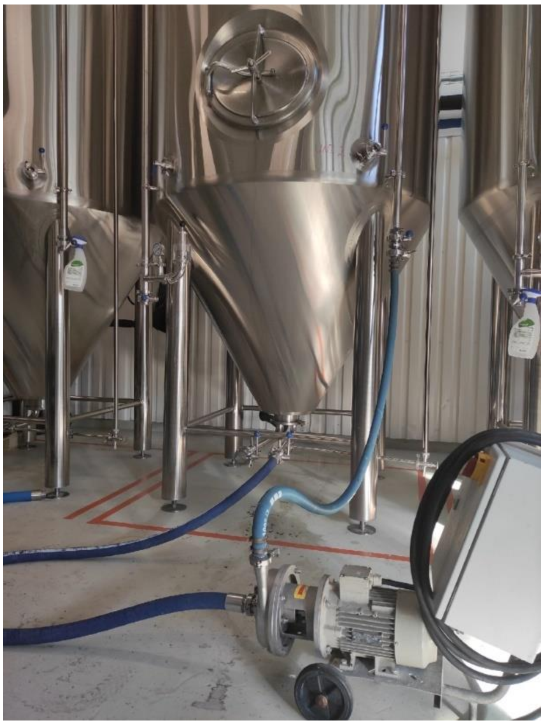

PICTURE 22. One-way non-return spring valve (Snitelea, 2021)

3.5 Tanks sanitization/preparation for the first fill

The final stage of the project was to prepare the tanks for their future filling with a beverage and perform the corresponding cleaning procedures beforehand. The sanitizing process started with placing all the accessories (TABLE 5) of the individual tank into the containers with a solution of lye. The only ladder was not sanitized because it has no direct contact with the product. Lye has high alkaline content which allows dissolving all the dirt from the surfaces. I left all pieces in lye solution over a night. The next day each piece was brushed with cleaning liquid and then rinsed. Because of its height, the level meter could not be placed in any container, thus the sanitization of it was done with the small pump by running two cycles. The first cycle is lye solution, second is a peracetic acid solution. It is a common strong acid used for industrial equipment disinfection. In between these two cycles, the level was rinsed with water.

The next step was to connect all the accessories directly to the tank. Most of the pieces have a small connection area, which makes it incredibly simple to put them in place. The only struggle was the bottom part of the tank, specifically the bottom throats. They are welded to the same rounded piece, which is attached to the bottom of the cone with a gasket and clamp. This element is quite big, and it was tough to fix it flat and as tightly as possible. With all accessories in place, cleaning procedures of the inside of the tank can be initiated.

Breweries use such a term as the CIP (Cleaning in place), which is a method of cleaning the inner surfaces of the tanks and their corresponding valves and pipes. Continuous cleaning allows the necessary quality to be maintained on microbiological and chemical levels. The universal tanks already have pre-installed components for cleaning the inside of the tank, such as the CIP arm and shower head (TABLE 5) on top of it to disperse cleaning solution all over the interior surface. To run the cleaning solution, a moving centrifugal pump is used in the brewery. The outlet is connected to the CIP arm and the inlet to the very bottom dump throat, creating a closed cycle to run chemicals (PICTURE 23). In Kahakka brewery, we perform three main cleaning cycles with different chemical solutions. The duration of each cycle is approximately 20-25 minutes. The solution can be added to the tank through the inspectional door and removed with a dump hose connected to the bottom throat. Between each chemical, the cycled tank must be rinsed for around 5 minutes with pure water to avoid the interaction of different chemicals.



PICTURE 23. Connecting the pump to the uni tank to perform CIP (Khandobin, 2021)

First is the solution of lye with water. It is preferable to have water heated up to 80 degrees Celsius or more to make lye work more efficiently. If there is no possibility to used hot water, lye enhance can be added to the solution. The next chemical to be run is water and nitric-based descaler (pascal) compound. Pascal is extremely effective at removing inorganic limescale deposits. This time there no need to heat the water to high temperatures, as a standard city water channel can be used. The last cycle is done with the combination of water and peracetic acid at the right proportions to perform the final tank disinfection. At the same time with running peracetic acid solution, all openings of the tank should be closed and well-sealed to form the completely closed environment for future beer formation.

But because the tanks had only just been installed, our team decided to run all three cleaning cycles not only through the CIP arm but also through the other openings, such as a longer bottom throat and pressure arm on the other side. Each cycle was completed twice to ensure all stain removal. The inlet of the pump in each case was connected to the same dump throat, but the outlet was changing its position: the first position for sanitizing is the CIP arm, the second is the long bottom throat and the third is the pressure arm. To have a clear illustration of both bottom throats' designs, I have attached picture 24 below. It shows the throats from the inside of the tank. The long bottom throat has a pipe going up to 490mm (appendix 1) and can be used for pure-product draining. The second throat is used all the time only for draining. Therefore, during each of the cleaning procedures, the solution is entering the long throat of the tank and leaving from the dump throat, ensuring the entire cleansing of the bottom part.

PICTURE 24. Bottom throats of the tank; inside view (Khandobin, 2021)

3.6 Tank pressure test

The ability of tanks to keep and maintain a constant pressure inside is the essence of good beer formation and maturation. Therefore, before filling the tank with the beverage, a pressure holding test must be performed. Before all else, I connected the dump and water hoses to both bottom throats (PICTURE 25, 1 and 2). Then I filled the tank with about 60-80 litters of water from the bottom. This was done to make it easier to detect leaks: after pressurizing the tank, if there is any leaky connection at the bottom, I will be able to see water droplets coming out of the corresponding connection. After closing the entire vessel, the air was pushed in through the CIP arm with help of an air compressor (PICTURE 25, 3). Following the manometer readings, I pressurized the tank up to 1.5bars. Immediately after pressurizing, I have noticed a water leakage at the bottom. It became obvious that the bottom throat round piece was not in place and properly connected. To make it airtight I released all the pressure and drained the water. After that, the piece was fixed, and the pressurizing procedure was repeated. On the second attempt, everything was successful. Other universal tanks had the same pressure test before their first fill. Three out of five tanks had the same issues with not sealed bottom part. After completing pressure hold, tanks were completely ready to fully operate in the Kahakka brewery and the project was considered as finished.

PICTURE 25. Tank pressure test (Khandobin, 2021)

4 DISCUSSIONS AND CONCLUSIONS

The total duration of the Universal Tank Project was two and a half months (January 2021 to mid-March 2021). This time includes a month of planning and preliminary preparation, as well as two and a half months of installing the tanks themselves and manufacturing the new cooling line. For a project of this size, I think that is a fairly short turnaround time. The underlying factors in my opinion for such a fast, high quality and efficient job are the good planning and organization of the work room, as well as the excellent cooperation of the whole team and the clear allocation of responsibilities during the execution of the work. All five tanks were already filled with beer and operating normally by the end of March, so by that time the project was considered complete, and the expansion of Kahakka Brewery's overall production was considered as a successful one.

Although there were no critical errors and miscalculations, there were and still are some gaps and shortcomings that need to be corrected during the project and after its completion. The first, and probably the biggest challenge was the installation of the pipes for the cooling line under the ceiling at a great height. Because of the lift gate and the very small space for operations, the installation of the line needed better planning and more technical equipment from the beginning. Some connections and insulation could have been prepared in advance before going upstairs and installation, which would have resulted in better quality and shorter installation time, but because of inexperience, an optional part of the installation was performed at height and for safety reasons, the work was very slow. The second significant difficulty is the conflict of the new and old cooling lines, which has already been described in detail earlier in the section 3.4.5 Troubleshooting the line in the practical part. Although the problem has been partially solved, the not quite elaborate and correct connection of the two lines still has a negative effect on the operation and cooling of the tanks. In our solution, we blocked the glycol path from the old line directly to the new line but did not do the reverse. So far, this has not created any difficulties or disruptions, because the FVs and BBTs are constantly filled with beer and need to be cooled. This creates the need for glycol and the right resistance to the new line, preventing it from pushing the excess glycol solution and creating uncontrolled cooling. But it cannot be ruled out that the old line will stop working if there is no need to maintain temperatures. And such a shutdown would automatically break the balance of the lines and the proper cooling of absolutely all tanks. Therefore, to further improve the operation of the lines, it is necessary to remove and rebuild all the connection points of the two lines and make them isolated and operating independently of each other.

The other shortcomings are not as significant, but also needed qualitative fixes. These include a tighter and better connection of all parts of the cooling pipes: after a month of operating the new tanks, a couple of places in the line with small leaks were found. The problem was fixed fairly quickly but had to wait until most of the tanks were emptied and the glycol circulation could be temporarily put on hold to repair it. In addition, our team had not calculated in advance the required volume of glycol solution for the new system to be added to the glycol tank. At the point when all the tanks were filled and permanently cooled, there was not enough glycol for the two systems and it simply did not have time to cool between different cycles, which had a negative effect on the efficiency of lowering temperatures in the tanks. To resolve this issue, an additional 1000L of glycol solution was added to the chiller system.

All of the above repairs, modifications and improvements require additional materials. At some points, we had no material left to use, including insulation material and some joints. Some of the necessary items could not be delivered directly from Finland and Europe, which increased the time to complete the work and created unnecessary downtime. Therefore, for future projects and works, any possible loss of material had to be considered and orders should be completed in advance to ensure the best working environment.

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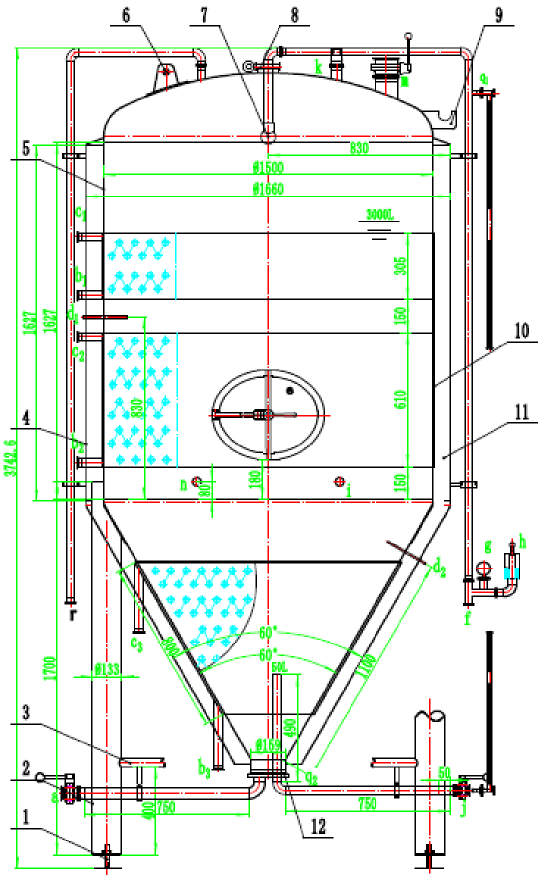
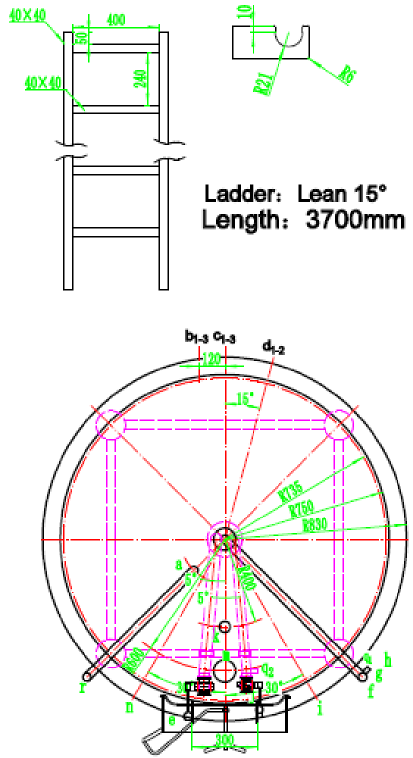
APPENDIX 1

Technical parameters of universal tank





Technical Standards

1.罐体焊缝应保证平齐，不得有凹凸棱角及划痕。
The welding line should be smooth and tidy, concave & convex edges and scratches are not allowed.

2. 焊缝抛光到Ra小于0. 8微米
The polishing accuracy of welding line should be <0.8μm

3. 制造完毕后，设备内及夹套打压检漏，压力3. 0Bar 保持24小时
After finished, the whole tank and jackets should be tested by filling air, keeping 24hours with 3Bar pressure.

Technical Parameters (技术参数)

	Interior (内胆)	Jacket (夹套)
Material (材质)	SUS304	SUS304
Working pressure (工作压力) Mpa	0.2	0.3
Design pressure (设计压力) Mpa	0.4	0.5
Tank Size (罐尺寸) mm	Ø1660×3750	
Quantity (数量)	5	
Cooling meth (制冷方式)	Glycol water cooling (乙二醇水制冷)	
Insulation material (保温材料)	Polyurethane (聚氨酯)	
Insulation thickness (保温层厚度) mm	80	
Outer tank thickness (外胆厚度) mm	2.0	
Inter tank thickness (内胆厚度) mm	3.0	
Cover tank thickness (封头厚度) mm	3.0	
Cone angle (锥角)	60°	
Cone volume (锥部容积) L	765	
Cylinder volume (筒体容积) L	2875	
Effective volume (有效容积) L	3000	
Total volume (总容积) L	3640	

Table of pipe connection (管口表)

NO (序号)	Size (尺寸)	Purpose (用途)	Connecting style (连接方式)
a	Ø51*1.5	Drainage port (排污口)	Clamp (卡箍)
b_{1-3}	Ø38	Glycol water inlet (乙二醇水进口)	Clamp (卡箍)
c_{1-3}	Ø38	Glycol water outlet (乙二醇水出口)	Clamp (卡箍)
d_{1-2}	Ø10	Temperature probe (温度探头)	
e	530×430	Side manhole (侧人孔)	
f	Ø38*1.5	CIP port (CIP接口)	Clamp (卡箍)
g	Ø38*1.5	Pressure gauge (压力表)	Clamp (卡箍)
h	Ø38*1.5	Spunding valve (水封阀)	Clamp (卡箍)
i	Ø38*1.5	Sampling port (取样口)	Clamp (卡箍)
j	Ø38*1.5	Beer outlet (出酒口)	Clamp (卡箍)
K	Ø51*1.5	Safety valve (安全阀)	Clamp (卡箍)
m	Ø102	Dry hops port (干投口)	Clamp (卡箍)
n	Ø38*1.5	Carbonation port (充碳口)	Clamp (卡箍)
q_{1-2}	Ø19*1.5	Liquid level with hose (PU液位计)	Clamp (卡箍)
r	Ø38*1.5	Vent port (排气口)	Clamp (卡箍)

Specification (规格)

NO.	Name (名称)	Connecting style (连接方式)	Size (尺寸)	Qty (数量)	Material (材料)
12	Clamp (卡箍)	/	Ø159	1	SUS304
11	Thermal insulation layer (保温层)	/	80mm	/	PU
10	Jacket (夹套)	Welding (焊接)	/	/	SUS304
9	Ladder hanging ear (挂梯挂耳)	Welding (焊接)	/	2	SUS304
8	Washing pipe casing	Clamp (卡箍)	Ø102mm	1	SUS304
7	Cleaning ball (清洗球)	Thread (螺纹)	Ø38mm	1	SUS304
6	Holding ring (吊耳)	Welding (焊接)	/	2	SUS304
5	Inner jacket (内胆)	/	t3	1	SUS304
4	Outer jacket (外包)	/	t2	1	SUS304
3	Leg braced (支腿拉撑)	Welding (焊接)	Ø38mm	4	SUS304
2	Supporting leg (支腿)	Welding (焊接)	Ø133mm	4	SUS304
1	Adjusting bolt (调节螺栓)	Thread (螺纹)	M27	4	SUS304

Shandong Innovative & Craft Brewing Equipment Co., Ltd
山东奥拓啤酒设备有限公司

Scale	1 : 23	Assembly Diagram	3000L 发酵罐 3000L FV
Weight		Date	NO.2020-08-11