UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

Colegio de Ciencias e Ingenierías

Design of a Beer Bottle Washer Machine

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RESUMEN

En este documento, el diseño de una lavadora de botellas de cerveza se lleva a cabo considerando los requerimientos del cliente. Los criterios de ingeniería se aplican para una selección final del prototipo y selección de material de los componentes. Se consideran las restricciones de diseño, especialmente a partir del presupuesto y ciertos componentes. Una vez que se elige un diseño final, se elabora un proceso de fabricación completo. Durante su proceso de diseño, se considera que las normas de ingeniería y operativas mantengan la seguridad del operador durante el proceso de lavado. Los cálculos y simulación de software: Sistema de tuberías, transferencia de calor y diseño estructural del rack se realizan para validar el diseño seleccionado. Los resultados de la simulación validan los datos del sistema de calefacción y los cálculos estructurales del rack, pero el sistema de tuberías debe rediseñarse dado que la bomba está sobredimensionada. Se elabora un manual de fabricación y operación considerando los resultados de la simulación. Se elabora un plan de prueba y validación de experimento para ejecutar en la máquina cuando su ensamble final esté listo. Los diseñadores han propuesto un indicador de éxito que la máquina debe seguir para garantizar parámetros de operación adecuados. Los diseñadores sugieren los parámetros de operación de seguridad; estas instrucciones deben seguirse durante el diseño y la operación. Una vez finalizado el diseño, el trabajo futuro propone la elaboración completa del prototipo siguiendo los planos de taller y todos los estándares. La propuesta de presupuesto incluye considerar la mejor opción de materiales y fabricantes. Al final, el diseño cumple con todos los requisitos del cliente y todos los estándares de ingeniería considerados por los diseñadores, las mejoras podrían llevarse a cabo en el diseño mediante la optimización de algunos diseños y materiales.

Palabras Clave: Sistema de tuberías, simulación, subsistemas, estándares de ingeniería, plan de prueba de prototipo, sistema de calentamiento, automatización, cotización, diseño asistido por computadora

ABSTRACT

At this document, the design of a beer bottle washing machine is carried out by considering the requirements of the client. Engineering criteria is applied for a final prototype selection and component material selection. Design constraints are considered, specially from budget and certain components. Once a final design is chosen, a complete manufacturing process is elaborated. During its design process, engineering and operative standards are considered to keep operator security during the washing process. Calculations and software simulation of: Piping system, heat transfer and structural design of the rack are done to validate the selected design. Simulation Results validates the data of heating system and structural calculations of rack, but the piping system must be redesigned given that the pump is oversized. A Manufacture and operation manual is elaborated considering the simulation results. An experiment validation and test plan are elaborated to execute on the machine when its final assembly is ready. Designers have proposed a success indicator that the machine has to follow to guarantee adequate operation parameters. Safety operation parameters are suggested by the designers, these instructions must be followed during design and operation. Once the design finished, future work proposes the complete elaboration of the prototype by following the executed workshop planes and all the standards. Budget proposal is including, considering the best option of materials and manufacturers. At the end, the design accomplishes with all the client requirements and all the engineering standards considered by the designers, improves could be carried out into the design by optimizing some designs and materials.

Keywords: Piping System, simulation, subsystems, engineering standards, prototype test plan, heating system, automation, manufacturing, quotation, computer aided design

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INTRODUCTION

A Beer Bottle Washer Machine was designed for the Food Engineering Plant at Universidad San Francisco de Quito, where students produce and bottle sodas, seer and other beverages. Moreover, to reduce their footprint, they reuse their beer bottles, and wash them by hand. However, they needed a device to help them to do it in a fastest, easiest and more efficient way.

The main requirements of the Beer Bottle Washer Machine were specifically made by the client, who asked for the device to have a production rate of **290 Beer Bottles and 2 Beer Barrel Containers per hour (80 Beer Bottles & 2 Beer Barrel Containers a day)**. The device had to perform *3 Washing Cycles* (**Bottle Pre-Washing, Washing & Residues Removal and Rinse)** that last **3 minutes each.** Moreover, the Beer Bottle Washer Machine had to be manufactured using **Stainless Steel,** use **Sodium Hydroxide (NaOH)** during the Washing Cycle and Recirculate Heated Water (**80 Celsius Degrees)** during the Rising Cycle.

The Design of the Beer Bottle Washer Machine had to be approached around **three constrains**. The *First one* supposed the use of some equipment -i.e. a Squared Shape (62 x 82 x 50 cm) *Stainless Steel Tank* and 2 *Centrifugal Pumps* (1 HP and 0.5 HP). The *Second Constrain* referred to the fact that all the parts of the device had to be easily *dismountable* for being washed without much effort. *The Third Constrain* required that the Beer Bottle Washer Machine costs at most 300 USD because that was the *Budget* assigned for the Project.

Considering all the requirements described before, a Prototype of the Beer Bottle Washer Machine was Designed and it is shown in *Figure # 23*. It uses the *Stainless-Steel Tank* provided and it is divided into two compartments. In this way, the Beer Bottle Washer Machine is able to use two fluids -i.e. Sodium Hydroxide (NaOH) and Heated Water- during its operation. Both fluids are moved by the 2 *Centrifugal Pumps* provided and go through a dismountable stainless-steel piping system to get into the Beer Bottles. The Distributing System feeds 24 Beer Bottles per cycle in order to reach a production rate required. This is possible by placing the Beer Bottles into a Bottle holder rack which ease the transportation of the bottles around the device.

However, the **Third Constrain was not met** because the Bottle Washer Machine was quoted in 1942.68 USD. But it is almost impossible to get the device built for 300 USD because it is made of Stainless Steel, which is a really expensive material to work with. The future steps are the manufacturing and testing of the device, since Food Engineering Plant Managers already approved the design shown in *Figure # 23*. For this reason, it can be said that the scope of the project was reached.

Problem Statement and Project Specification

The present project represents the Design of a Small-Scale Bottle Washer Machine for the Universidad San Francisco de Quito (USFQ) Food Engineering Plant. The plant is dedicated, among other activities, to the production of Craft Beer reusing their Beer Bottles. In this way, they have to wash 80 Beer Bottles by hand every day. This procedure takes a big inversion of time. Also, by doing a manual washing the norms and regulations given for this process can't be met since it involves very high temperatures and dangerous chemical compounds.

Within the alimentary industry there are a lot of bottle washer machines but most of them are dedicated to the large and medium scale industries. It is not common to find machines for the small industry they usually are design for capacity of thousands to millions of bottles per hour. The USFQ uses its food Plant mostly for academic purposes this is the why a small machine that meet their requirements is very necessary where a production don't exceed the 100 bottles per day and this activity is done just a couple days a week. A small washer machine with a washer capacity of tens to a couple of hundreds, top, is very necessary for this kind of industries where the production scale is very low compared to the other industries.

The process involves two different treatment zones simplified from the big washer machines designs. The caustic zone is the first part of the process where the chemical compound NaOH (sodium hydroxide) also known as caustic soda, is pumped inside each bottle at 30-35 ºC resulting in the elimination of microbes and dirt residues. In the hydra zone, water is pumped to the bottles at 75-85ºC, this temperature ensures that the water can reach the smallest cracks in the glass removing all the caustic soda remaining from the previous process. (Gajjar, Patel & Singh, 2015) These temperatures are very important to the process to ensure the cleaning is doing correctly. Another parameter which must be considered for a well performed process cycle time (time the bottles spend in each zone), "Certain amount of time is required to heat up the bottles and cool down for the beverage filling operations. Time considered is the time required for the caustic soda to penetrate the bottle, spray inside the bottle to remove the dirt and mud, bottles and bottle carriers drain off the washing compound before the next treatment zone and completely drain the rinse water before discharging from the bottle washer machine." (Gajjar, Patel & Singh, 2015)
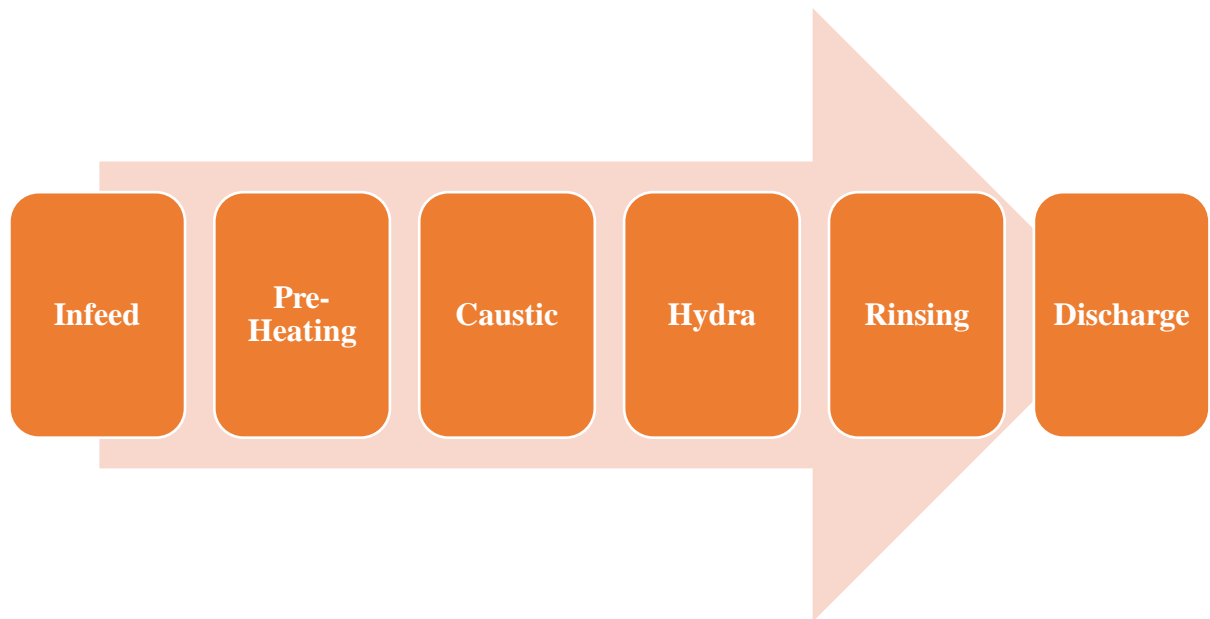
Figure # 1: *Diagram of bottle washing process*

The group general objective for the project is to build an automatic small-scaled bottle washer that fulfill the requirements for machines used in the Ecuadorian food industries which will be discussed further ahead in the report. The requirements made for this project will be listed below:

The Universidad San Francisco de Quito Food's Engineering Plant provided a stainless-steel tub which should be used for the entire process, so it was divided into 2 Compartments. They also provided 2 Centrifugal Pumps to move the Washing Fluids that will take part in the process.

1. The process will take two treatment zones: the caustic zone and the hydra zona.

2. The whole process must be automatic; this includes the pump and the heating system.

3. The prototype should be capable of being completely disarmed for an easier cleaning.

4. The system should be capable to wash at least 80 beer bottles of two different sizes: 12 oz. And 22 oz. And 2 beer barrels.

5. The heating system must be capable of heating water at 75-85 ºC (hydra zone) and caustic soda at 30-35 ºC (caustic zone)

6. For a better assembly of the system, a bottle holder basket should be design along the pipe and automatization needed in the project.

7. All the machine should be built with the appropriate norms and requirements of the Ecuadorian alimentary industry.

The machine should have a piping system to pump different liquid compounds into each zone. The piping system should begin extracting the compound from its reservoir located in each half of the tub.

The project considers five different parameters for the development of the weighted objectives which are: cost, size, precision, weight and operating safety. Being a budget-limited project, the cost of the system is the most critical parameter overall.

Followed by size and precision, these parameters are almost as important as the first one since the prototype to develop must be the smallest and as accurate as possible due to the small dimension tolerance of the system itself. The weight and operation systems are both equal important for the project design. The weighted objective table shown below has been made with these parameters.

Table # 1: *Weighted Objectives*

CRITERIA	Cost	Size	Precision	Weight	Operating Safety	E+1	Weighted
Cost	-	1	1	1	1	4	0,4
Size	0	-	1	1	1	3	0,3
Precision	0	0	-	1	1	2	0,2
Weight	0	0	0	-	0,5	0,5	0,05
Operating Safety	0	0	0	0,5	-	0,5	0,05
					Total	*10*	*1*

Design Concepts and Selections

To get into the machine's final design, it is important to consider a constraint of design given by the client. The stainless-steel tub illustrated at **Figure # 2** must be used as reservoir tank for both fluids.

Figure # 2: *Stainless Steel Tank*

First, milestones must be solved before the development of a final design. For this reason, a subsystem division has been done. Each subsystem must complete a specific task, once each of them have been accomplished, the machine will complete with its production properly. The Milestones considered are listed below:

Water Heating

One of the most important things in the develop of the current project is the heating mechanism for the water so it reaches, at least, 75-85 ºC. For this purpose, three different options are suggested for the design. The first one is using an electric resistance to reach a temperature above de 85 ºC so it doesn't lose too much heat during the water's recirculation process, this prosses will require a control system to be installed. The second one, is a conventional gas water heating, by heating the pipeline, the water will reach the needed temperature for the process. The last one is a hybrid system between a resistance water heater and a conventional one. This way, the water inside the tank will stay at a certain temperature and it will gain some more during the pipeline circulation process.

Bottle-holder Rack

Considering the Rack design, two possible ways could be taken. The first one, considering project costs, a plastic rack could be used. This plastic rack could be easily found at any beer distribution center for a price of $3.50 USD. The problem with this alternative is the subjection system between the rack and the reservoir, which is complicated to manufacture given the weight and the material of the rack. Additionally, this kind of rack is just for a specific size of bottles, a subjection system between the rack and the bottle must be designed to avoid accidents and failure in the system. If a plastic rack is used, structural failures could be occasioned. Another restriction with a plastic rack is that their dimensions are fixed, and it occupies a significant space in the system which have very limited room to work in.

In the other side, a personalized beer bottle rack can be design. This structure can be adjustable for different major diameters and it allows to optimize space, quantity of bottles used, and most important, the subjection systems will be designed especially for the tank where the washing process will be performed in.

Piping System

The problem found with this design criterion is the Thermal Conductivity, Energy and pressure losses which can appear in the fluid movement inside the pipes. Thermal conductivity is one of the most important criteria to be considered during the design of the project because, as said before, to meet standards, the machine should wash and rinse bottles with water heated at 75-85 ºC. To reach this temperature, a water heating system has to be designed. However, after this system heats the water, it must be able to maintain the liquid temperature constant in order to meet the standards. For this reason, it is important to appropriate choose the pipe's material in order to maintain temperature and reduce energy losses.

Also, it is important to consider the sanitary regulations that must be followed for machine to operate in a food plant. Corrosion must be avoided as much as it is possible to keep the security of the rest of the plant and to avoid contamination over the food and the bottle's surfaces. Two viable solutions are proposed: Design a piping system with cupper pipes or stainless-steel pipes.

Considered all these factors, selection criteria were applied obtaining the results showed in the following section.

Evaluation and Selection Concepts

To solve milestones found during the Beer Bottle Washer Machine design, the following criteria are going to be considered to solve de different problems discussed in previous sections.

Water heating

For this Milestone, the criteria taken in consideration are:

- Operating Safety Cost, Precision, Operation safety, Weight.

For this, we've considered four different parameters to choose the best option por the project:

Cost and precision are the most important parameters since this project has a limited budget, and it must reach the stipulated temperature, and rack-pipe bottle alignment so the cleaning process is effective.

Operation safety is the next most important parameter because high temperatures, electric connections and chemicals will be managed during the machine operation.

System weight is the least important parameter since it has to me able to move around without too much problems, but it is not as critical as the previous ones.

Considering all this information, a selection matrix has been built to help the group choose from the different options presented to solve the water heating milestone.

Table # 26 allows to understand that the better option for the project, considering all the parameters is a resistance heater. This is, by far, the best option among the three others presented. In the other hand, the gain heater and the hybrid heater are very similar options, after the analysis, the conventional water heater (gain heater) is considered a slightly better option than a hybrid mechanism.

Beer Bottle Rack

For this Milestone, the criteria taken into consideration are:

- Cost, Size, Precision, Weight, Operating Safety.

It is important to mention that Cost and Size are the most important parameters for this case because the budget of the Beer Bottle Washer Machine should not exceed the 300 USD, and the size of the rack should let it fit inside the tank without any problem of blocking the piping system.

As shown, the best options to be applied is the design of the rack. One of the non-analyzed parameters is the facility for the operator to manipulate the structure and the design complexity. Concluding, it is better to adapt a new system to our specific design than picking up an existent one.

Pipe Selection

For this milestone, four different parameters have been considered to help the selection of the best option for the project:

- Cost, Weight, Thermal Conductivity.

It is essential to mention that, as in the previous selection, cost is an important parameter. However, in this case, there must be a balance between the loss of energy during the process and the material cost. The project has two options for the material for the pipe: Stainless steel and copper.

Table # 30 shows the best option for the pipe's material is stainless steel because its thermal conductivity will help the system conserve more thermal energy during the water distribution. In the long run, a copper pipe would cause a big loss of thermal energy generated in the heating process, only by heat transfer. Recall that copper has a thermal conductivity of **401 W / (m · K)**, while stainless steel has a conductivity of **16.3 W / (m · K).**
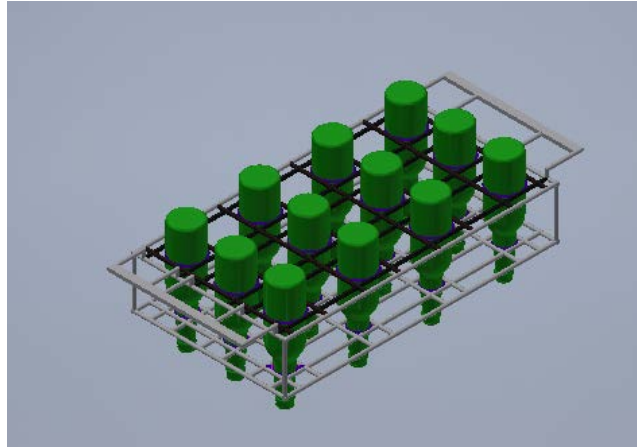
Figure # 3: *Final design of the Rack*

Figure # 5: *Final design of water heating system. Reprinted from*

Alibaba 2020. https://www.alibaba.com/product-detail/High-

Resistance-Electrical-Coil-Stainless-
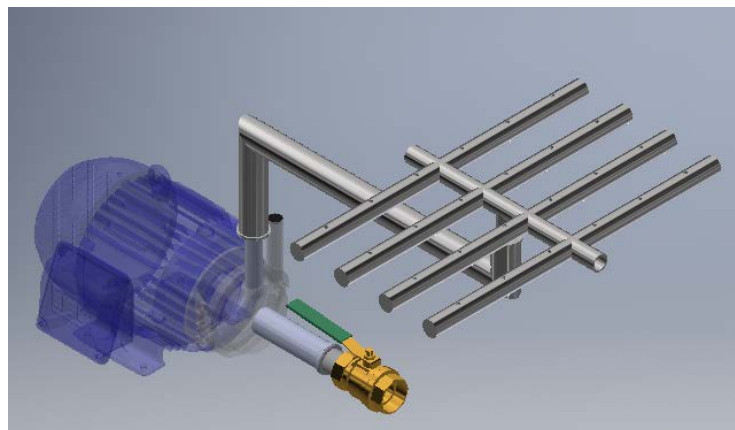
Figure # 4: Final design of piping and tubing system

Project Management

Activities Management

Due to the worldwide problem during the production of this project (coronavirus) a plan B has been made an adapted to meet as much of the initial requirements as possible. Considering that physical development of the project won't be carried out, all simulations, reports, calculations, reporting and meetings have been changed to an online modality. The **Table # 2** shows the calendar with the changes which took place throughout this period, considering all development stopped on March 15, 2020.

Table # 2: *Schedule of activities*

	Task Name	Duration	Start	Finish	Status
1	Problem definition	4d	01/13/20	01/16/20	Complete
2	Costumer's parameters definition	4d	01/16/20	01/19/20	Complete
3	Necessary calculation for the pipeline	8d	01/19/20	01/26/20	Complete
4	Previous prototype's experimentation	2d	01/27/20	01/28/20	Complete
5	Data collection for design	4d	01/27/20	01/30/20	Complete
6	1st CAD design proposal	10d	01/29/20	02/07/20	Complete
7	Discussion of proposals/food plant	5d	02/06/20	02/10/20	Complete
8	Welding tank separation plate	15d	02/06/20	02/20/20	Complete
9	Calculation 1 & 2 report	15d	02/11/20	02/25/20	Complete
10	Calculation 3 & 4 report	16d	02/22/20	03/08/20	Complete
11	2nd CAD Final design	19d	02/24/20	03/13/20	Complete
12	Discussion of Final Design/food plant	5d	03/09/20	03/13/20	Complete
13	Project quote and proposal analysis	6d	03/09/20	03/14/20	Complete

	Task Name	Duration	Start	Finish	Status	Mar 8	Mar 15	Mar 22	Mar 29	Apr 5	Apr 12	Apr 19	Apr 26	May 3
10	Calculation 3 & 4 report	16d	02/22/20	03/08/20	Complete									
11	2nd CAD Final design	19d	02/24/20	03/13/20	Complete									
12	Discussion of Final Design/food plant	5d	03/09/20	03/13/20	Complete									
13	Project quote and proposal analysis	6d	03/09/20	03/14/20	Complete									
14	Progress report	2d	03/14/20	03/15/20	Complete									
15	Design for manufacturing	15d	03/16/20	03/30/20	Complete									
16	Mechanical Drawings	15d	03/22/20	04/05/20	In Progress									
17	Maintenance and technical manual	15d	04/16/20	04/30/20	Not Started									
18	Final presentation	1d	05/05/20	05/05/20	Not Started									
19	Project portfolio	44d	03/26/20	05/08/20	In Progress									

Source: Smartsheet Inc. (2013)

Budget Management

This project, being a design that will be performed following the Ecuadorian food industries standards, must be modeled of stainless steel. For this reason, costs increase significantly and must have specialized treatment with first-class professional equipment.

Universidad San Francisco de Quito provides to the group 300 USD budget the development of the project. However, an additional budget provided by the client is under consideration. Also, each student who are part of the project is allowed to contribute with a small budget to achieve the client's requirement.

Due to the aforementioned, a quote has been made for the entire project, which will be found in the Appendix B – Project Management. This quote can be discussed to achieve lower costs and be adjusted to the group budget.

Engineering Standards

Considering the assemble, operational and design standards for the Beer Bottle Machine Washer development have been considered. To select these standards, it is important to consider safety, life-time operation of the system and internal regulations given since the system counts with food grade components.

Stainless Steel managing

As mentioned into criteria selection method, stainless-steel pipes are going to be used. According to *The European Stainless-Steel Association,* one of the most attractive features of this material is its corrosion resistance. There is no chemical reaction between the mentioned material with any kind of food. According to the *Europe Framework Regulation 1935/2004*, stainless steel is one of the most reliable materials which does not transfer constituents to foods in quantities that could endanger human health or could bring an important change into the food composition. This same normative, recommends

the usage of AISI 304 material because of its versatility and tolerance to powerful detergents (Partington, 2006).

The corrosion resistance property of this material comes from a protective film with a chromium-rich oxide that avoid penetration of components into the base material. The mentioned film is able to regenerate in case that the surface is penetrate or damaged by a tool. Considering a hydrodynamic analysis, the roughness of this material has a very low value which decreases the major losses into the fluid and avoids the pressure drops that is important into the functionality of the Bottle Washer Machine. It is important to mention it that this kind of materials has a wide range of temperatures frequently encountered in the production of food, in the case of the bottle washer, the temperature of the water or even the production of steam, will not affect to the life time of the pipes and does not affect the drastic change of temperatures (Partington, 2006).

The construction of the Beer Bottle washer machine, will follow the design principles of:

> *"The EC Machinery Directive 98/37/EC: 1998 [15]* states that machinery 'must be so designed and constructed as to avoid any risk of infection, sickness or contagion". *EN 1672- 2: 2005 [16]* demands that a machine must be 'capable of being properly operated, cleaned and maintained'" (Partington, 2006).

For the welding process, the same European standards are going to be followed, this mentions the process has to be taken down into the welding of stainless-steel food grade materials. Cleaning processes should be performed before and after the process, this will avoid the presence of contaminants such as oil, grease, oil and different solvents. Also, normative suggests, is recommendable, while working with stainless steel, not to work in the same place with carbon steel materials because it could affect the carbon

particles of the base material and that's a non-desired result for this process. Also, an appropriate cleaning of the base material is necessary by using noncorrosive acids and different brushes which will clean particles that may affect to the welding process. Additionally, to avoid imperfections and the insertion of powders inside the material during the cutting process, a laser cut process will be performed (Partington, 2006).

According to the normative, there are some recommendations to follow during the process (Partington, 2006):

- Molten metal must be shielded from atmospheric oxidation by means of a gas or a slag or a vacuum to preserve optimum corrosion resistance.
- Work by following the G211 normative to determine the state of the Heat Affected Zone (HAZ).
- During welding, execute sensitization process should be carried out by allowing the formation of chromium carbide particles. This will avoid the combination of chromium with oxygen to not affect the stainless-steel corrosion resistance.
- Avoid great amounts of temperature gradients at the HAZ, this will prevent the production of micro fissuring and cracks on the material.

For this machine construction, European standards will be used for managing the stainless-steel. European community stablishes regulations for an adequate manipulation and operation of this material, which after analysis, contributes more safety parameters than the Americans regulations. The additional standards are:

Table # 3: *European Standards*

Food processing machinery	EN 1672-2; Food processing machinery — Basic concepts — Part 2: Hygiene requirements.
Tubes and pipes	EN 12502-4; Protection of metallic materials against corrosion — Guidance on the assessment of corrosion likelihood in water distribution and storage systems — Part 4: Influencing factors for stainless steels.

NaOH safety data sheet: Handling and hazards

NaOH or commercially know as caustic soda, is chemical substance used in the industry field. For this specific project, caustic soda is used to clean the glass bottles prior its use to bottle up alcoholic beverages. Caustic soda is a very important component in the bottle washing process. However, it also is a very dangerous chemical which should be properly managed. According to LabChem's safety data sheet, the following instructions should be followed at all time to avoid any accident the chemical can cause due to bad management.

Table # 4: *Handling and storage precautions for NaOH*
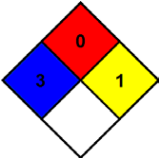
Handling precautions	- Avoid Raising dust - No contact with surfaces with water - Keep substance free from contamination - Use corrosion-proof equipment - Do not discharge the waste into the drain
Incompatible products	- Strong acids - Strong oxidizers - Combustible materials - Metals
Storage temperature	20 [°C]
Heat and ignition sources	Keep away from heat sources
Prohibition on mixed storage	Keep away from: - Strong acids - Metals - Organic materials - Combustible materials
Storage area	Requirements: - Hermetic - Dry

	- Corrosion proof - Well ventilated - Watertight
Packaging materials	- Stainless steel - Nickel - Polyethylene - Paper Avoid: - Lead - Aluminum - Copper - Bronze - Tin - Zinc - Textile

Source: LabChem's NaOH safety data sheet

Also, it is important to understand the hazards the caustic soda means. The following table shows the GHS-US labeling for the product:

Table # 5: *Hazard information for NaOH*

Hazard Pictogram	
Hazard Statements	H314 – Material can cause severe skin and eyes injuries H318 – Material can cause eye damage H402 – Material is dangerous to aquatic life.
NFPA Pictogram	
NFPA Statements	3 – Material cause serious damage and permanent injuries 0 – Material will not burn under normal conditions 1 – Material is stable but can react under high temperature and pressure
Personal protection	F: Safety glasses Synthetic apron Dust respirator gloves

Source: LabChem's NaOH safety data sheet

If the complete information is needed see the ¡Error! No se encuentra el origen de la referencia. **-** ¡Error! No se encuentra el origen de la referencia. for the entire NaOH data sheet.

Stainless Steel Welding

"The welding process affects the mechanical and corrosion resistance properties of both the joint and adjacent areas" (Euro Inox, 2006). The high temperatures of the weld have consequences on the material, so the following recommendations given by the author must be followed to reduce the effects on the material and obtain better results.

- During the welding process itself, the molten metal must be shielded from atmospheric oxidation by means of a gas or a slag or a vacuum in order to achieve and preserve the optimum corrosion resistance and mechanical properties in the joint.

- During welding, chromium and carbon in the stainless steel can form chromium carbide particles, a process known as sensitization. This reduces the chromium available to combine with oxygen and so form the chromium oxide passive layer which gives stainless steel its corrosion resistance. (Euro Inox, 2006)

On each side of the material, the HAZ (Heat Affected Zones) will form because it will be brought to melting temperatures. These areas will be affected with respect to the technique used in welding, carbon composition of the steel, filler materials and subsequent chemical treatments

It is important to remember that high temperatures can distort the material and generate high stresses during cooling, a feature of the welding process. In addition, it should be mentioned that the weld can generate microcracks in the material.

"Welding is followed by cleaning. A 'thermal tint' will form around the weld causing the thermal resistance to decrease" (Euro Inox, 2006). To solve this, the pickling is carried out, which allows the controlled erosion of the weld and thus prevents oxidation.

MATERIALS AND METHODS

Material and Component Selection

The Bottle Washer Machine is going to operate with sodium hydroxide (NaOH) - better known as caustic soda- and heated water during its operation. Sodium hydroxide (NaOH) is a corrosive substance used for the manufacture of cleaning products such as soaps, detergents and bleach (Chemical Safety Facts, s/f). However, in this case the Washer Machine is going to help with the dissolution and cleaning of the beer and any oil or grease remaining in the surface of the bottles. It is very possible that the use of caustic soda and heated water is going to cause corrosion in the device's material. Corrosion is a destructive attack suffered by a material, usually metallic, by chemical or electrochemical reaction with its environment (Gomez, 2004).

Moreover, the permanent exposure of the device against corrosive elements suggest the use of materials that will not be affected by corrosion by its characteristics. Stainless-steel contains chromium and nickel that give it these characteristics. "On the surface there is a thin film of very dense chromium oxide that constitutes a shell against corrosion attacks. If this chromium oxide film covering the stainless steels is removed, it is re-formed immediately when chromium is combined with oxygen from the ambient atmosphere" (Upcommons.upc.edu, s / f).

According to BRC standard, all the equipment using in food industry has to be made of stainless-steel (Gomez, 2004). Furthermore, the use of corrosive fluids during

the operation of the machine imposes the use of Stainless Steel for the manufacturing of the device.

Table # 6: *Criteria selection for Stainless Steel*

Stainless Steel < Copper				

Cost analysis				
CRITERIA	**Stainless Steel**	**Copper**	**E+1**	**Weighted**
Stainless Steel		0	0	0
Copper	1		1	1
		Total	1	1

DESIGN FOR MANUFACTURING

To apply the manufacturing design technique properly in the bottle washer machine, the project was classified into 4 subsystems:

- Piping system
- Basket and transportation of the bottles
- Water Heat subsystem
- Reservoir tank

Piping System

This system has been optimized by different tests and the analysis of the prototype **(Figure # 2)** developed before the final design of the system.

Figure # 6: *PVC Prototype designed by the Client*

The decision has been taken based on the following reasons:

- The piping system has to be detachable for cleaning purposes.

- Hot water has to going to be transported by the piping system.

- No leaks should be present during operation.

The first one of the client's requirements is that the system must be completely detachable because the reservoir tank has to be used for other different applications. Also, the client wants to be able to clean the tank and the entire pipe system following hygiene standards over the industrial food plants machines.

Leaking problems can be avoided by using stainless steel as manufacturing material. Also, this problem could be avoided by welding or flanged joints since. Threaded joints are not an option because this joining method does not warrant an effective joint between materials and serious bacterial outbrake in a long-term.

The weldability of the stainless steel makes it very viable option as base material. Considering the high cost of this material other materials like PVC or allows the

manufacturer to distribute more money in other critical parts. However, as analyzed in previous sections, stainless-steel properties like thermal conductivity, corrosion resistance, weldability and taking into consideration industrial standards, make this material the most eligible for the manufacturing process.
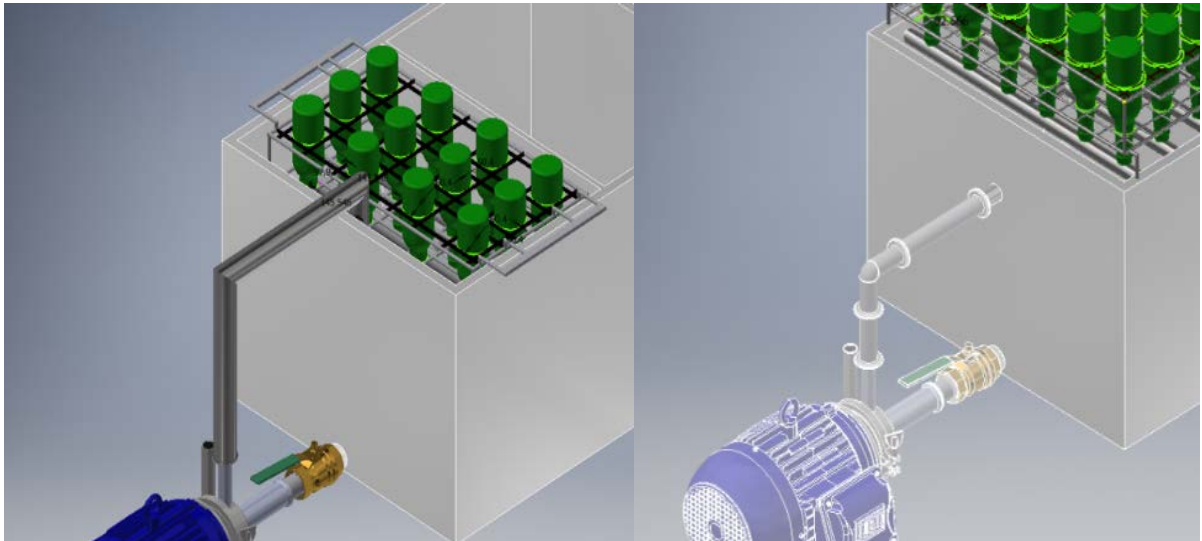
Figure # 7: *Piping System Optimization*

Water Heating Subsystem

The water heating subsystem was optimized by the analysis of the heat input that the system needs and by the cost and effectiveness of the heat exchanger needed on the water reservoir tank. For the heat input to the water two options have to be considered: Electric water boiler and 4-Kilowatts stainless-steel resistances. The stainless-steel resistances were selected even if more time will be needed to get to the desired temperature of 85 °C.

For the system, at least 2 resistances will be needed, each of them costs almost 100.00 USD which, compared to the boiler cost of 500.00 USD, represents a lower impact to the project budget. Also, if the boiler is considered, the water will have to be reinjected

into the boiler pipe which will represent, beside the extra cost, an important pressure lost during the machine operation.

Stainless steel resistances are well known for its effects against corrosion, and it allows to occupy less energy than the boiler. The system operation temperatures can be controlled by PLC's using thermocouples and stablishing operation temperatures constrains. A switch could be able to jump in case of an overheating. Also, it has to control the power input to the electric resistances.
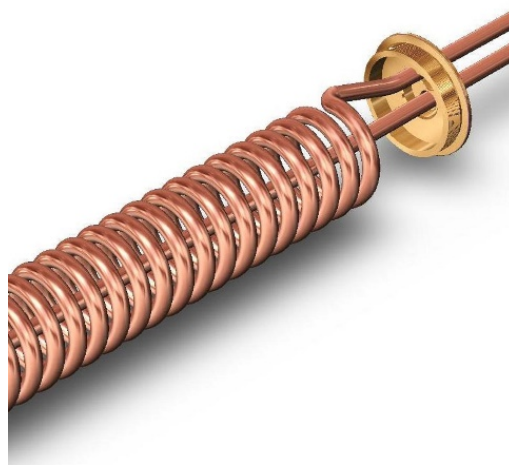
Figure # 8: *Electric Resistances illustration*. Reprinted from *Alibaba, 2020,*

https://www.alibaba.com/product-detail/Solar-Water-Heater-Immersion-

Coil_62007207589.html

Bottle-Holder Rack

The original rack model was a traditional commercial bottle basket which had a PVC pipe water distribution system. This model with doesn't count with good ergonomics design and a correct bottle fasten method. A viable option has been considered to assure the correct positioning of the bottles, precision, easy mobilization, and stress resistance to the weight of the set of bottles.
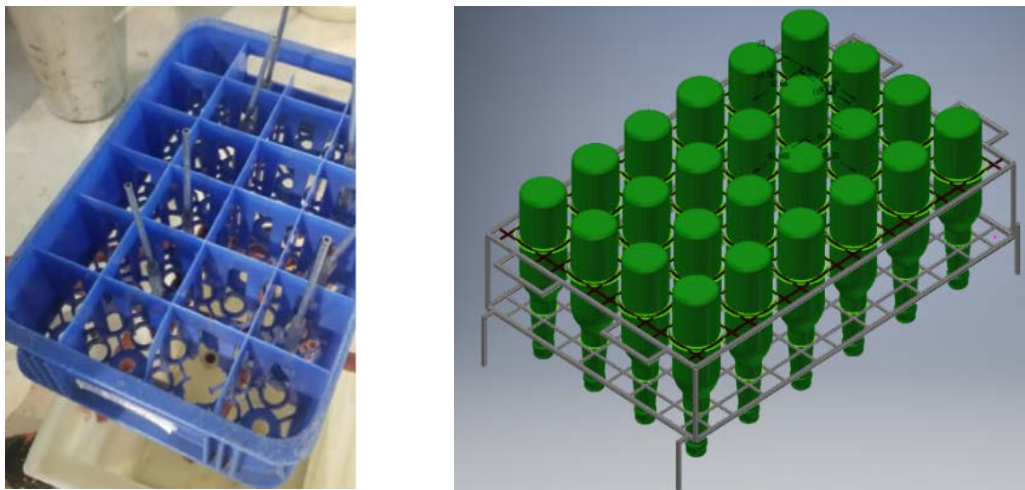
Figure # 9: *Basket optimization*

The new model can hold twenty-four bottles per cycle during the washing process. This new option is made of rods which form a rack to hold the bottles by their neck and its base by means of elastic cables at the top as it is shown in **Figure # 9.** On the sides, the rack has two handles so that it can be moved from the washing section to the rinsing section. This model manufacturing requires cutting, bending and welding of rods with a certain precision. The base rods are 7 [mm] while the internal rods will be 4 [mm]

Water Compartments

In the plant the washing process was done in a small plastic tank of around thirty centimeters supported by a moving structure at the bottom. (*Figure # 10a*) The ergonomics was uncomfortable for the operator and it didn't follow any fabrication standards so it can operate in an industrial food plant.

The U.S.F.Q industrial food plant provided the project a stainless steel tank shown in the *Figure # 10b.* The tank has the correct dimensions so it can be divided into two different compartments which will be transformed into the two washing stations mentioned in previous sections.

Additionally, it is necessary to include pipe inlets with incoming ferrules for easy assembly of the main pipe. Two liquid outlets have to be included in the base of each

compartment to drain the water and the caustic soda after when the washing process has

finished (*Figure # 10c*)**.**

Figure #10a: Old bottle washer machine
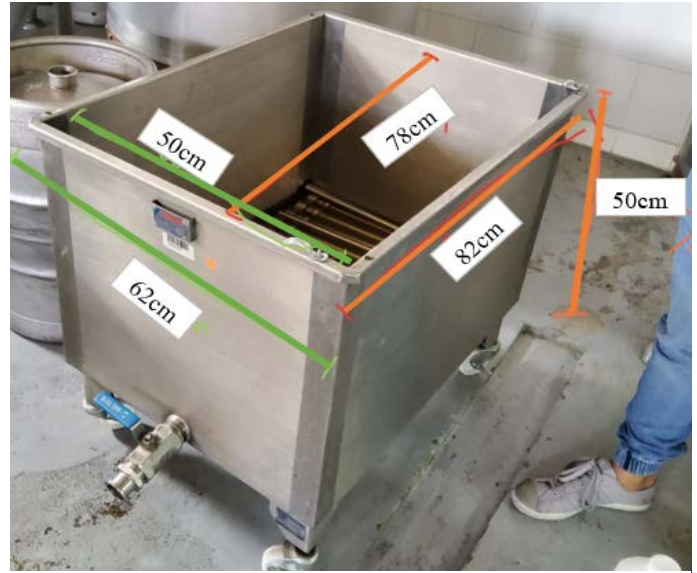
Figure #10b: Stainless-steel Tank
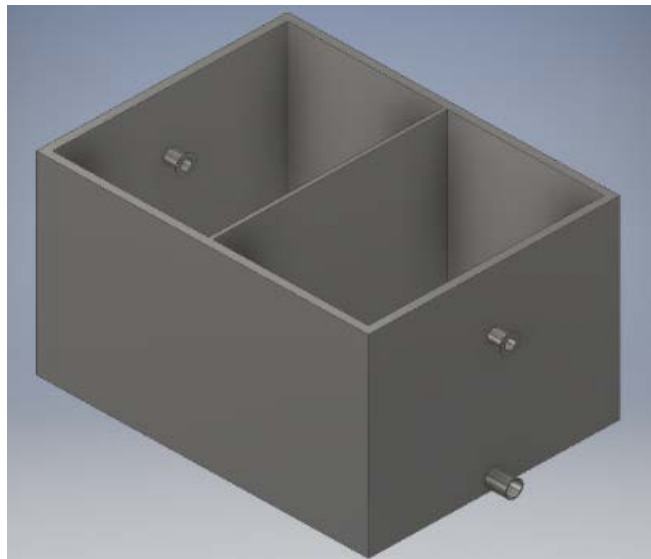
Figure #10c: Final Tank Optimization

Figure # 10: *Tank Optimization*

A detailed diagram was elaborated to show the sequence to follow to complete the assemble of the bottle washing machine. The **Table # 28** added into the **Appendix B – Project Management, Gaant Chart:** shows each step to follow in order to complete the correct assemble of each subsystem and how they connect to the final manufacture of the entire system.

Each subsystem must be connected to the reservoir system with the purpose to recirculate both fluids during the machine operation. There are two parts of the diagram, the first one is the design, it is about the parts selection and the acquiring processes. The second part is the production. It shows which steps must be followed to assemble each subsystem and where and how they have to be connected into the final assemble.   The operator has to review the diagram after the assemble process. The machine must be validated and tested before it is delivered to the client.

Planification for execution

It is necessary to analyze the dates each step of the diagram is going to take place in. Also, all the activities need a responsible of each part of the assemble, that's why this process is detailed with a Gaant Chart which shows the date and the responsible of each activity. Gaant Chart is illustrated at **Table # 28***Table # 7.*

Table # 7: Detailed dates

Week	Dates
1	**Start Date:** 02/03/2020 **End Date:** 08/03/2020
2	**Start Date:** 09/03/2020 **End Date:** 15/03/2020

3	**Start Date:** 16/03/2020 **End Date:** 22/03/2020
4	**Start Date:** 23/03/2020 **End Date:** 29/03/2020
5	**Start Date:** 30/03/2020 **End Date:** 05/04/2020
6	**Start Date:** 06/04/2020 **End Date:** 12/03/2020

Table # 7 illustrates the activities to be done and each responsible to complete them. The black label corresponding to Fernandez/Moreno CIA LTDA, is the company in charge to develop the stainless-steel welding because certified professionals are needed for this task. This company has been chosen because its warranty offered, and the low cost compared to other options analyzed

Table # 18 and *Table # 19* contains details of all the parts which make up all the piping and reservoir systems. The length and diameter tolerances are defined, and their respective measurement instruments are mentioned. Finally, in the last column the measurement responsible has been designated.

Table # 20 contains the pump specifications which will be used in both reservoirs. The pumping system is designed to work with a flowrate of 99.6 [L/min]. A tolerance of $\pm$ 1 [L/min] has been defined given that the simulation verifies that this difference does not affect considerably to the normal function of the bottle washing machine.

Table # 21 is composed by two sections which contains the different measurable parameters and their corresponding measurement. Each of these components need to control different parameters to warrant that the system is working correctly.

Finally, *Table # 22* shows the part list for the pump controller, here, there are no parameters to be measured given that this is just a control subsystem.

Quotation

As mentioned in previous sections, the budget is one of the most important and limiting parameters for the development of the project. For this reason, is necessary to mention the costs of each subsystem. Many quotations have been received; however, this section will consider the most convenient ones considering costs, materials and warranty.

Piping System Costs

Table # 8: Piping system detail cost

Ctd.	Descripción	PVP	Subtotal	IVA	Total
2	Distribuidor Ø1" 24 boquillas SS304	278.11	556.22	66.75	622.97
2	Conexión Ø1" Ø1.5" bombas SS304	147.16	294.32	35.32	329.64
1	Pulido Tanque Agua Grit 120	0	0	0.00	0.00
1	Transporte equipo USFQ Instalación del equipo	0	0	0.00	0.00
					952.60

Controller, **Water Heating System and Basket costs**

Table # 9: Detail Costs of basket, water heater and pump controller

Ctd.	Descripción	PVP	Subtotal	IVA	Total
1	Tablero de control SS304	275	275	33.00	308.00
1	Sistema de control temperatura SS304	415	415	49.80	464.80
2	Soporte 24 botellas SS304	97	194	23.28	217.28
1	Transporte equipo Instalación USFQ	0	0	0.00	0.00
					990.08

Both costs lists come from the same company, Fernandez/Moreno CIA. LTDA. This supplier was chosen because their offer of a 1-year warranty for welding failures, installation mistakes, corroded materials, electrical factory failures and transportation. Considering this supplier, the final cost of the bottle washing machine will be of **1942.68 USD including taxes.**

Finally, once the entire system has been assembled, it is necessary to measure and define if each process has been correctly done by applying success parameters. Each success parameter will be analyzed according to each subsystem. A color scale has to be defined to show the success level of the system.

Subsystem	Description	Success Indicator			Indicators
Piping System	This system must control: Size of pipes (Tolerances) Welding of joints (AWS G211 Normative) Installation of fittings Permeability (No fluid leaks)	Sizes, joints, permeability fittings are correct	Sizes, joints, permeability fittings are barely correct	Sizes, joints, permeability fittings are not correct	Green: No corrections Yellow: At least one of the parameters is incorrect, needs corrections. Red: The entire system is failing, it needs to be totally repaired.
Water Heating System	This system must control: Temperature (85°C $\pm$ 3 °C) Relay system to stop the system if it is overheating. Increase or decrease temperature if the system needs (automatic control)	Temperature, relay and automatic control are correct	Temperature, relay and automatic control are barely correct	Temperature, relay and automatic control are not correct	Green: No corrections Yellow: At least one of the parameters is incorrect, needs corrections. Red: The entire system is failing, the system does not reach to temperature, relay system is not working and temperature is not controlled, system must be redesigned and reassembled.

Pump	This system must control: Flow rate of $99.6 \left[\frac{L}{min}\right] \pm 1 \left[\frac{L}{min}\right]$ Low vibrations No leaks when joined to the piping system (Sealed)	Flow rate, vibrations and sealing are correct	Flow rate, vibrations and sealing are barely correct	Flow rate, vibrations and sealing are not correct	Green: No corrections Yellow: At least one of the parameters is incorrect, needs corrections. Red: The entire system is failing, excess of vibrations on the system, fluids are leaking in the joints and flow rate is not the desired. Pump is not well installed, and probably, the pump must be changed for a different that accomplish with the desired parameters.
Basket	This system must control: Stable bottles when they are on the basket. No bending Fit correctly on the reservoir tank holders	Stability, bending and fitting are correct	Stability, bending and fitting are correct	Stability, bending and fitting are barely correct	Green: No corrections Yellow: At least one of the parameters is incorrect, needs corrections. Red: The basket is bending, the bottles have no stability (Risky) and the basket does not fit on the reservoir tank holders.

| Pump controller | This system must control: Emergency stop button Timer Signal lights (green: when the system is on; red: when the system is off) | Stop button, timer and signals are correct | Stop button, timer and signals are barely correct | Stop button, timer and signals are not correct | Green: No corrections Yellow: At least one of the parameters is incorrect, needs corrections. Red: E-Stop is not working, signal lights are incorrect and the timer cannot be programmed, the system must be redesigned and reprogrammed. |

Table # 10: *Success Indicator*

Finally, the success of the entire assembly has been measured and classified as the following color-scaled success indicator shows:

Table # 11: *System success indicator*

■ (Green)	All the subsystems are correct (Green state), 24 bottles will be washed with water at 85℃, Both fluids have a flow rate of 99.6 [L/min], there is no water leaks, temperature is always controlled and maintained according to the desired, automatic control of the pump works correct and the basket holds the bottles properly
■ (Red)	At least one subsystem is not correct (yellow or red), so, if one of the subsystems does not works correct, the entire system must be stopped until the problem is fixed.

Process Detail

The detailed process considers the activities developed during the semester and the costs came from invoices by service and material providers.

Table # 12: *Detailed Process for Manufacturing*

Piece	Process	Detail Process	Observations	Cost	Time
Piping System	Welding	▪ Design the piping system ▪ Verify the design with simulations and calculations ▪ Obtain the stainless-steel tubes and pipes ▪ Obtain the elbows, tees, joints and the rest of accessories ▪ By following de AWS D18 Normative, weld the joints and verify that there is no leaking and also inspect visually that the HAZ	The process detailed and the cost are considered for each piping system, for the bottle washer machine that we have designed, we need two piping systems	$477.00	3 Weeks
Water Heating System	Tube Bending and electrical connections	▪ Select the material of the coils ▪ By calculations, verify how much power is needed by the system ▪ Search in the national market which coil is similar to the material needed and analyze how many coils are needed for this application ▪ Assemble the connection with thermocouples, relay system and set all the electrical connections that are involved to the coil	For our application, we will need stainless steel coils. This base material will allow us to counteract the effects of corrosion and the	$923.00	2 Weeks

		▪ Install the heaters on the tank ▪ Verify that the system works properly and test if the temperature is the desired	system will last much time than others like cupper or bronze.		
Bottle-holder rack	Rods bending, cutting and welding	▪ Select rack material ▪ Design the basket with respect to the weight it will support ▪ Obtain the rods according to the calculations obtained. ▪ Cut the rod according to the plane measurements. ▪ Bend rods to simplify weld joints ▪ Weld the rods according to the plan and hooks that will hold the elastic cord ▪ Install the elastic cord in the basket with a proper fit	It is important to keep in mind the precision of the measures of the mesh of rods so that the neck of the bottle is aligned with the nozzles of the distributor tank. The basket must be light so that it can be transported to different places	$217.00	1week
Reservoir Tank	Cutting Welding	▪ Cut and weld the plate dividing the tank ▪ Cut and weld the pipe with the ferrules ▪ Weld these pipes into the tank ▪ Drill tank, the basket rods will enter these holes ▪ Drill into the bottom of the tank for the water outlet. Put a cap	The welded pipe in the tank is made of stainless steel and is used for the entry and exit of fluids	$170.00	3 days

RESULTS AND DISCUSSION

Design Report

One of the requirements of the bottle washer is that it be removable due to cleaning as it will indirectly be related to food. Due to this, sections and parts have been designed for a better explanation.

Because the food engineering production plant has provided the project with pipes, pumps and the tank, the design with its calculations has been developed based on the dimensions of these elements and their capacities. The optimal conditions that the pumps should work were obtained, this helped not to have shortage of water or soda due to its circulation in the pipeline. In addition, it has been verified that the power and the number of nozzles do not cause the bottles to come out of the basket

Pipelines

It is essential to section the piping system that will recirculate the water and soda since this will allow to thoroughly clean each of the parts. The material used for the elaboration has been stainless steel for its resistance to corrosion and thermal insulation compared to other options such as PVC pipes or hoses. This pipe will be made with an outer diameter of 1in and a thickness of 2mm. The ends will have ferrules that will help the coupling between them through clamps
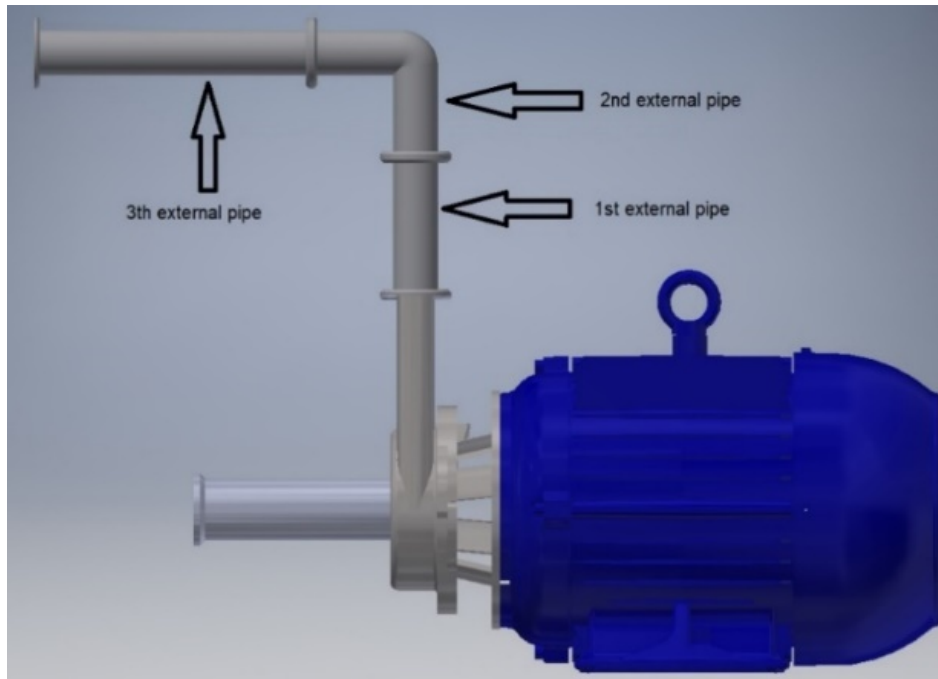
Figure # 11: *External pipes*

➢ **External Pipes**

The internal pipe is made up of two pipes. Internal pipe # 2 is similar as external pipe # 2. These pipes are also called elbows and are the same dimensions for easy handling at the time of assembly and disassembly.
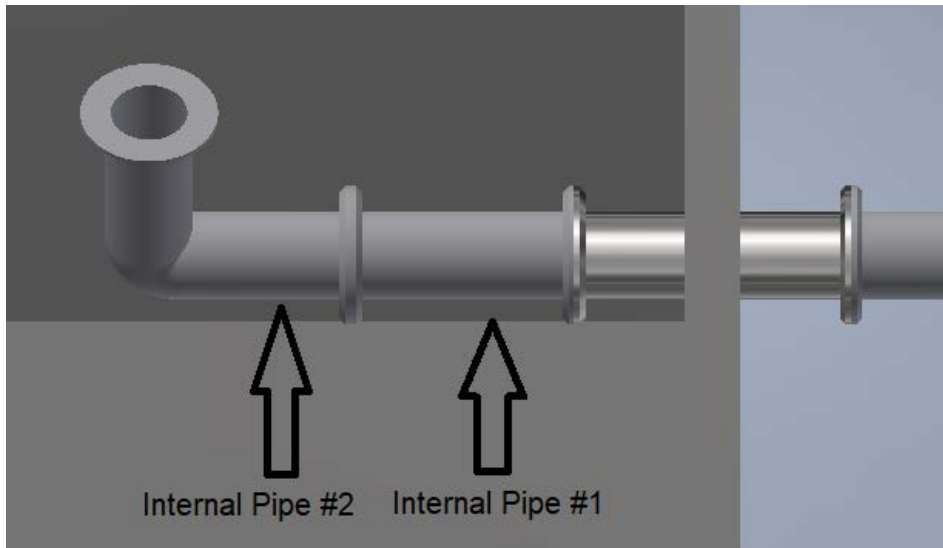
Figure # 12: Internal pipes

The ferrules have a standardized form since they must be adjusted by clamps that are equally standardized, so measures already established by the manufacturers will be used. Ferrules will be welded to the ends of the pipes. Gaskets are used that prevent fluid from escaping from the pipes**.** The design of the ferrule is as follows:
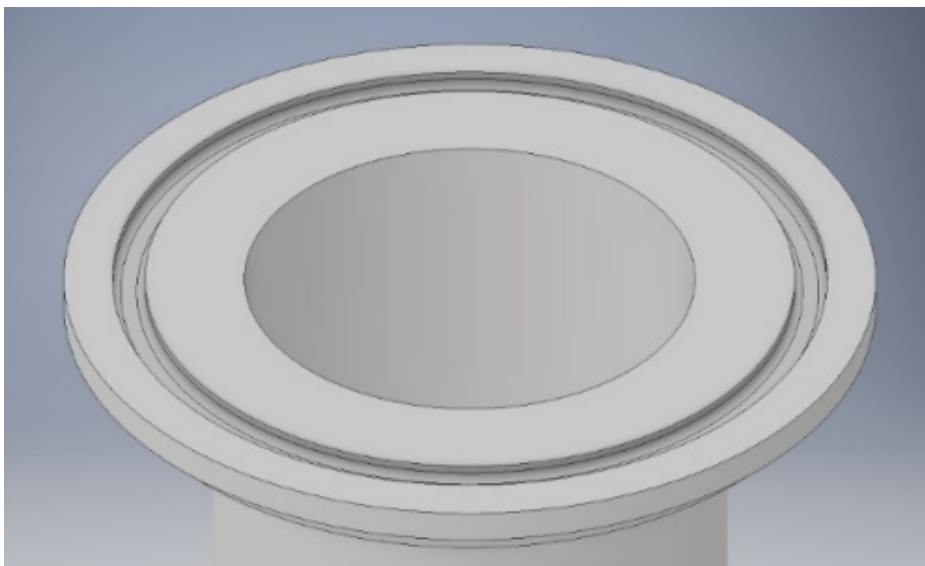
Figure # 13: Ferrule model standard
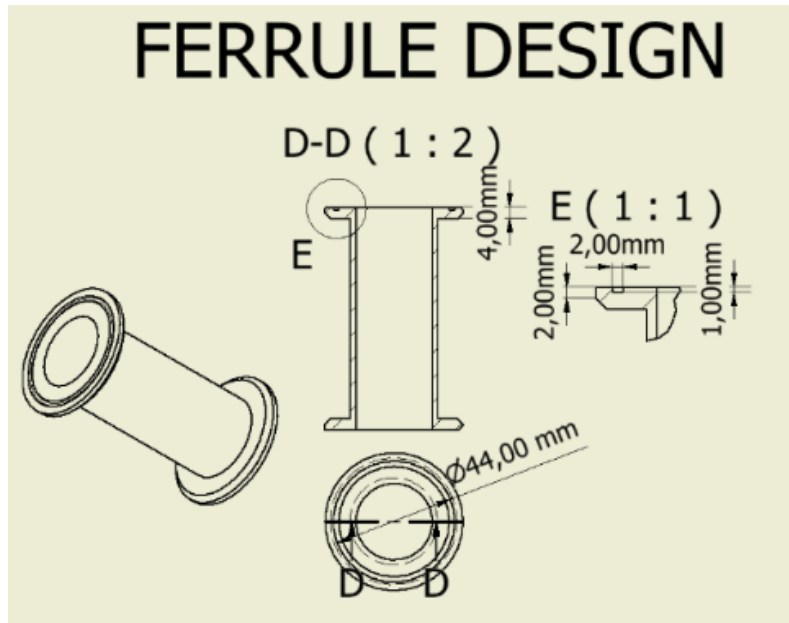
Figure # 14: Ferrule design standard

The water distribution piping has been designed with stainless-steel tube provided by the customer. The pipe dimension is 1-inch external diameter and 2mm thick. The design was made to clean twenty-four bottles at the same time. The position of the holes is important because they must be correctly aligned to the necks of the bottles (**Figure # 15**). Nuts will be welded to the water outlet holes so that the nozzles can be screwed .
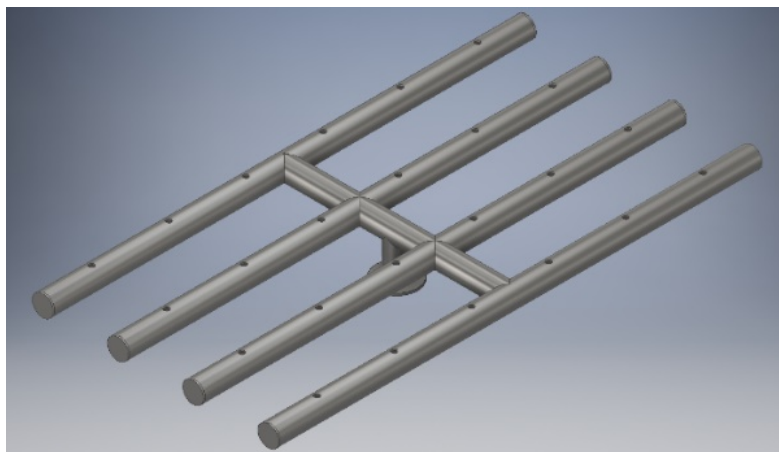
Figure # 15: Water distributor model

The customer has provided with the tank to modify it. The **Figure # 16b** shows the tank before its modifications and in the **Figure # 16a** and a 3D model of this design

can be viewed. A stainless-steel plate will be welded in half to separate the soda and water processes. On the sides, the pipes for the exit and entrance of fluids will be cut and welded, this also allows the pipes to be demonstrable and cleaning can be carried out without any obstacle. It is important to make a hole and place a plug at the bottom to expel the used water. These dimensions are important because we need to calculate the volume of water the machine is going to use, even it helps us to model the frame of the basket. (*Figure # 16a*)
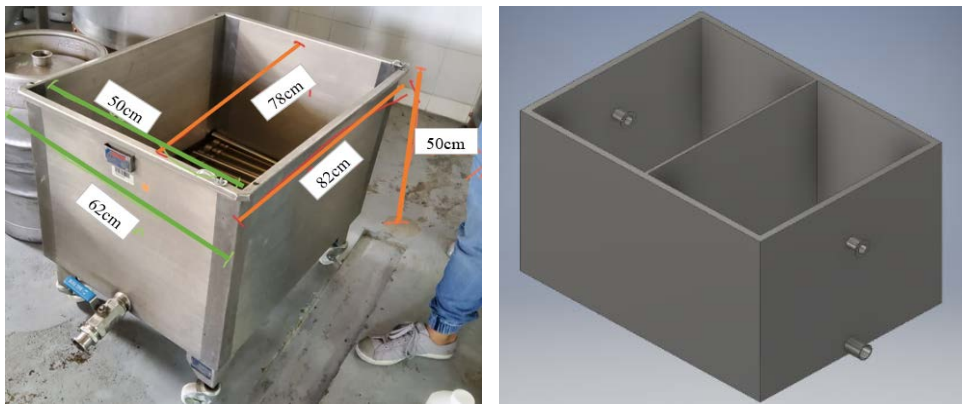
Figure # 16: *Changes made to the Tank. Left, before changes. Right, after changes.*

The basket was designed for cleaning 24 bottles. This contains a mesh made by rods to insert the bottle neck at the base of the basket and at the top there is a mesh of elastic cables that allow the holding of different sizes of bottle bases. On the sides there are handles that allow you to lift the basket and remove it. At the lower corners there are 4 rods that allow the basket to be inserted into 4 holes that contain the tank and thus prevent it from moving. It is important to know the dimensions of the bottle because the dimensions of the basket depend of what kind of bottle are being used (*Figure # 18*). The dimensions are the following:
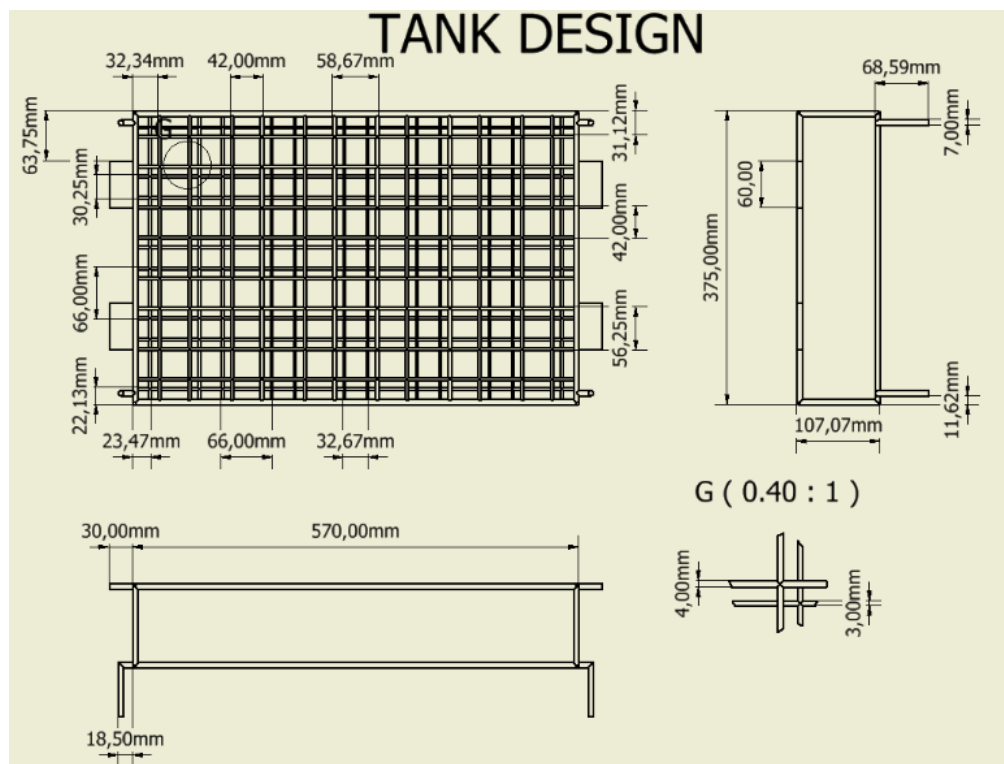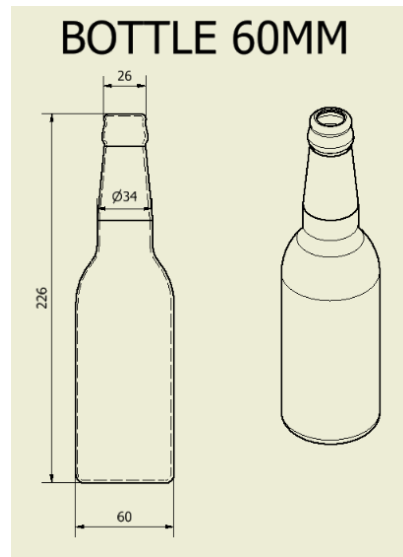
Figure # 18: Dimensions of the bottle
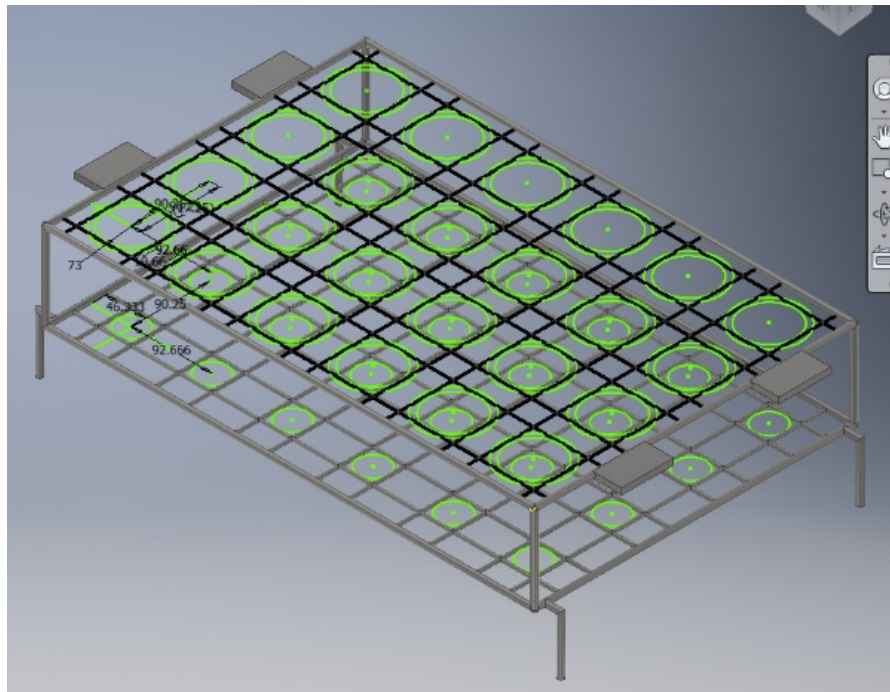
Figure # 19: Basket model

The inclusion of the nozzles was important since it allows the direction of the water jet and to have a better cleaning. The valves included in the tank are for a 1 1/2 in

diameter pipe (*Figure # 22*). Pumps have also been supplied by the customer and are 1HP

and 1 / 2HP each (*Figure # 20* and *Figure # 21*)

Figure # 20: Pump ½ HP

Figure # 21: Pump 1 HP
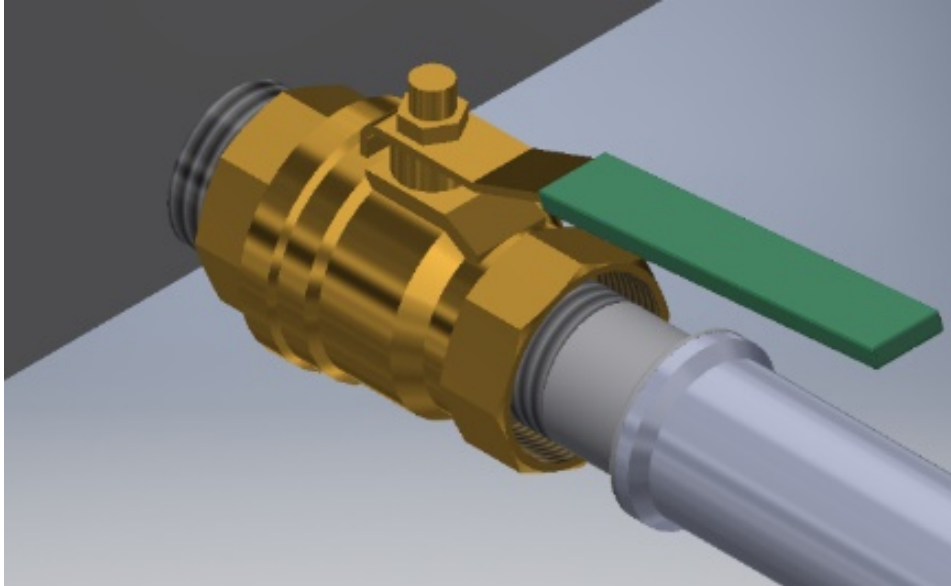
Figure # 22: Valve model

The *Figure # 23* shows the final model CAD in Inventor Software. A stainless-steel plate is welded in the middle of the tank to divide it in two and carry out the process with water and caustic soda in different sections. Different models and options have been analyzed in order to reduce expenses due to the high cost of stainless steel and its machining.
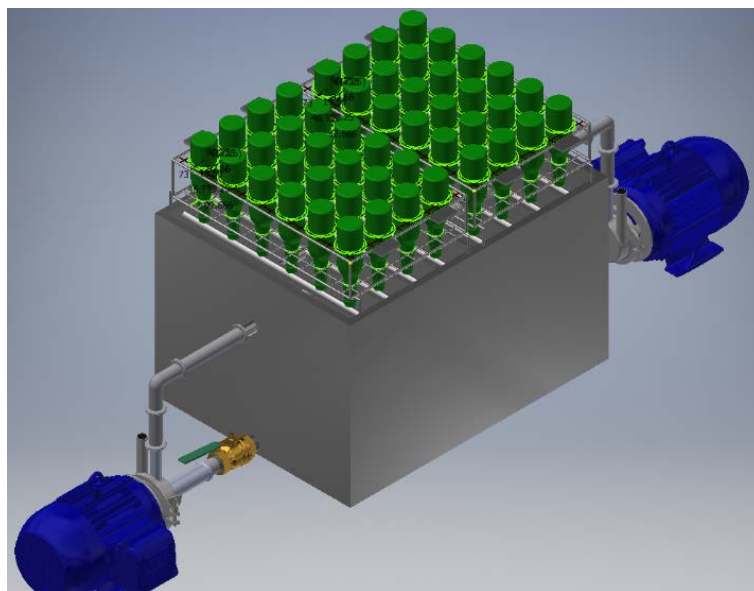
Figure # 23: Washer Bottle Final Model

Engineering Experiment for Verification

Leak Testing

Leak testing is performed to check the sealing integrity over a pipeline system by applying internal pressure to a predetermined limit and then checking the joints and components seals for leaks (Huitt, 2008).

Considering the normative **ASME B31.3,** the test will be carried out considering the data provided at *Table # 23* at the **Appendix B – Project Management.**

Pressure Testing

The pressure test is a procedure that consists of verifying that the final pressure in a system is that required for the correct operation of the machine. A practical way to achieve verification is to check the height of the water leaving the system as seen at *Figure # 24*:
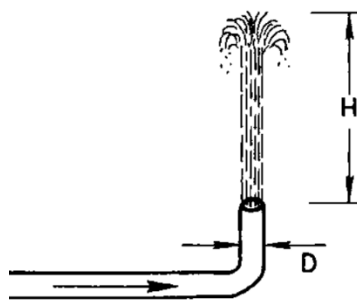
Figure # 24: *Height to measure*

For the height check a camera is used. The maximum height and time will be checked by using each frame and a meter in the background of the video. It is always important to keep control of the process and track the activity to locate the problem if there is a variable pressure and that the search for the solution is carried out in the shortest possible time. It is essential that the experimentation be carried out at the same time so that the variables are the same. The form contains the following key points at *Table # 24* at the **Appendix B – Project Management.**

This method is very effective and practical since high technology is not required for the measurement. A cell phone camera, a meter and analyzing each frame is enough to verify if there are pressure drops and therefore height differences.

In this system, it is necessary to take man tests to ensure that the pressure has not varied. The height at which the jet must reach is 2 meters above the nozzles.

Prototype Test Plan

The test plan will be performed for each design constrains purposed in the project. There will be 6 different engineering criteria to be analyzed in the test plan, these are: pipe and bottle-holder rack dimensions, bottle holder rack stress test, flowrate test, pressure test at the nozzles, fluid temperature at the reservoir and the nozzles, time of operation test. Each test will be performed in the same order as it was mentioned. To advance to the following test, the previous one has to be approved following the criteria detailed in the sections bellow. The ***Table # 13*** shows the acceptable values each criterion should have to be approved

Table # 13: Engineering criteria and test plan requirements

Engineering Criteria	Acceptable values	
Pipe and bottle-holder rack dimensions test	The tolerance for pipe length is $\pm$ 5 [mm] and for its diameter $\pm$ 1 [mm]	The tolerance for the rack and the distributor dimensions is $\pm$ 1 [mm]
Bottle-rack stress test	The rack should resist a load of 20 [kgf] symmetrically distributed independently at the top and at the bottom of the structure. If possible, to perform, the structure should resist a stress 20 [MPa] in compression in the universal test machine.	
Flow rate test	Main Pipe Minimum: 170,23 [l/min] Maximum:170,23 [l/min]	Distributor pipe Minimum:15,59 [l/min] Maximum:26,48 [l/min]

Pressure test	Main Pipe Minimum:0,221 [KPa.g] Maximum:50,904 [KPa.g]	Distributor pipe Minimum: 0,006 [KPa.g] Maximum: 0,065 [KPa.g]
Fluids temperature test	At the nozzles the fluid temperature should be within 60-80 [ºC]	At the top of the reservoir the fluid temperature should be within 70-90 [ºC]
Time of operation test	The machine should operate during 5 complete cycles each one of 10 minutes. The operation time should be 60 [min] non-stop working.	

Pipe and bottle-holder rack dimensions test

The piping system includes two subsystems, the first one is the main pipe (***Figure # 12***) which connects the everything from the pump to the distributor pipe (***Figure # 15***). The main pipe length dimensions are not as critical as the distributor pipe, this is why the tolerance for the main pipe's accessories length is **± 5 [mm].** The inner pipe diameter has to be 1 [in] or **25,4 [mm]** since there are an important number of accessories to be attached to each other along the mine pipe, it is important that they fit as exactly as possible therefore the diameter tolerance for the entire pipe system is **± 1 [mm].**

The rack ant he distributor pipe should be as precise as possible because the each bottle top, hold upside down by the rack, has to fit in with each nozzle in the pipe, if any dimension differs by a more than a couple millimeters, part of the nozzles would be pointing outside the bottle and this could produce the hot water is sprayed everywhere causing serious problems and even injuries to the operator. For this reason, **a ±1 [mm]** tolerance is applied to the system.

The dimension test consists in perform **10 different length and diametral** measurements with a caliper and a measuring tape to each accessory for the entire piping system. This amount of measurements will prevent or decrease to a minimum the human

mistakes during the process. If any of the accessories doesn´t meet the stablished tolerance it should be reported to the manufacturing manager, so it is appropriately rectified or re-manufactured. If all the items are correctly measured and approved within the tolerance measurement, the test can be considered as successful.

Bottle-holder rack stress test

The bottle-holder (*Figure # 19*) has to holds a maximum of **9,36 [kg]** under normal operation conditions. This includes the weight of **24 12onz**. - beer bottles. For the test a minimum safety factor of 2 will be applied. The test consists in apply 20 [kg] of total weigh first symmetrically distributed in top side of the rack and then applied the weigh hanging in the bottom side of the structure. The system should hold both distributions type without suffering any permanent deformation or any indicator of cracks in the material or the welding joints.

If an indicator of failure is detected, the rack should be analyzed for manufacturing mistakes and rectified if possible. Otherwise, the structure has to be remanufactured and re-tested until the visual results are satisfactory enough to be consider a successful test. The rack can be tested also in the universal test machine in the mechanical department of the U.S.F.Q applying a total stress of **20 [MPa]** in compression in the middle of the structure, under the same conditions of approval mentioned before. The test will be performed only if the rack can be fitted inside the machine and can be placed in the correct position for the test.

Flow rate and pressure test

The flow rate and pressure test will both consist in analyze the data given by the corresponding measurement mechanism installed in different sections of the washing machine. The pipe system will have two zones of flow and pressure measurement. Within

the main pipe and the distributor pipe a pressure gauge and a flow meter will be installed. Then, the system will have a total of two of each of these mechanisms. The first pair (pressure gauge and flow meter) will be installed along the main pipe. The second pair will be installed at the farthest points of the distributor pipe, taking its center as the origin point. Since the distributor has two equal distance points, each one of those will have one measurement mechanism either a flow meter or a pressure gage.

For the main pipe, the pressure gage will constantly give a value which should be within the **0,2** and **51 [KPa]** or **0,3** and **7,4 [psi]** (common units used in pressure gauges). For this test, a simple gauge check during operation will be enough to assure the mechanism is operating correctly. The pressure value will oscillate according to the gauge's location, if it is located near the pump, the value should be closest to the **7,4 [psi].** However, if the gauge is near the distributor, the value measured should be close to the 0,3 [psi]. This same methodology is applied to the distributor gauge. However, since the location of it is specified to be at the farthest point from the center the value it should give should be close to **0,0008 [psi] (0,006 [KPa])** this value can't be higher than **0,01 [psi].** If the measurements are within the given values, the test is successful otherwise maintenance may be necessity to fix the possible problems

The flow rate in the main pipe should remain constant at approx. 170 [l/min] so the flow meter should always mark this value with a tolerance of **± 5 [l/min].** In the distributor, considering the flow meter will be located at other of the farthest points in the mechanism, the value should be close to 16 [l/min] and in cannot get higher than **27 [l/min].** If the flow meter gives values too low or too high than the minimum and maximum values, the machine should be analyzed during maintenance to find and fix the possible problem.

Fluids temperature test

There are two liquid temperatures to test: the fluid temperature at the top of the reservoir tank and the temperature at the distributor pipe which will, approximately, the temperature at the outlet if the nozzles. The temperature in the first scenario should be within **70-85 [ºC]** this temperature will allow the liquid, water or caustic soda, to be at an acceptable temperature at the outlet of the pipe distributor which should be around **60-85 [ºC]** depending of the fluid.

For the first case, the test will consist in measure the temperature with an industrial thermometer, if the temperature is the acceptable the test will be successful. Otherwise the preheating procedure and the heating components will be analyzed to find where the problem is so it can be fixed.

For the second scenario the test will involve a more complex method, since a thermocouple should be installed a one on the farthest points from the center of the distributor point. This is with the intention to measure the temperature at, what is supposed to be, the coldest point in the system. The thermocouple should be installed during the manufacturing process and must be adapted in the control system. The validity of the test will be proven with the same criteria mentioned before. This test, as the flow rate and pressure test, has to be done every time the machine will be operating since these are very important parameters for each cycle

Time of operation test

The machine has to operate during a minimum of **5 cycles** when used. Each washing cycle occurs during two phases caustic face and the rising face, both faces are the same procedure using different liquids, caustic soda and water respectively. The cycles in each phase will last **5 minutes** of operation. The operation test will consist in stress the machine to it maximum operation capacity during **10 to 15 minutes,** during the

operation the system shouldn't present any irregularity. After the operation each system will be analyzed to find overheating, leaks, or any component damage. If the system is without any damage, the test will conclude as successful. Otherwise, the damage component will be analyzed, the causes of failure studied, and the part will be changed if needed. Once the problem has been solved, the test will be performed again with the same failure parameters.

Table # 14: *Specific parameters vs test plan to validate them*

Requirement	Test to apply
All elements length dimensions should be within a 10 [mm] tolerance according to the drawing's dimensions.	Pipe and bottle holder rack dimensions test.
All pipes diameters should be within a 1 [mm] tolerance according to the drawing's dimensions.	Pipe and bottle holder rack dimensions test.
The bottle holder rack should resist a 20 [kgf] load without presenting important or permanent deformation	Bottle-rack stress test
The flow meter in the main pipe should mark a value of 170 [L/min] while operating at its maximum capacity.	Flow rate test
The flow meter in the distribution pipe should mark a value between 15-27 [L/min] while operating at its maximum capacity.	Flow rate test

The manometer in the main pipe should mark a value between 0,2-51 [KPa.g] while operating at its maximum capacity.	Pressure test
The manometer in the distribution pipe should mark a value between 0,006-0,07 [KPa.g] while operating at its maximum capacity.	Pressure test
The industrial thermometer at the tank should mark a value between 85-90 [ºC]	Temperature test
The thermocouple in the distribution pipe should mark a value between 75-85 [ºC]	Temperature test
The machine should operate for one hour or an equivalent of 5 cycles time non-stop and should not present any signal of misfunction.	Operation time test

Safety Through Design

Safety during the process is very important, it doesn't matter if it is in the beginning of the design of the mechanism or at the operating process safety should be always present in every engineering procedure. Therefore, this project took into consideration a list of type of risks with their own specific one that may affect one way, or another the system developed.

There are many types of risks to be consider in every project, but for this one in in particular the list is reduced into six types that could affect different procedures involved in the project. These types are listed below:

- Economic resources

- Security

- Legal

- Technical

- Environmental

- Operative

For each one of these two to three specific risks are applicable to be analyzed and mitigated so they can be prevented to happen. For every risk the analysis classifies depending on two parameters, the probability and the gravity or impact that the risk may have. For each parameter are five sub parameters for better understanding (very low – low – medium - high – very high) each one of these rated from one to five respectively. Multiplying both parameters previously described, with the number given to each one of their sub parameters is possible to quantify the value of the risk being 1 the lowest and 25 the highest. The next figures help shows, in a better way, the previously explained with a color scale for each sub parameter:

Table # 15: Value of risk quantified by the relation probability - impact of risks

			GRAVEDAD (IMPACTO)				
			MUY BAJO	BAJO	MEDIO	ALTO	MUY ALTO
			1	2	3	4	5
PROBABILIDAD	MUY ALTA	5	5	10	15	20	25
	ALTA	4	4	8	12	16	20
	MEDIA	3	3	6	9	12	15
	BAJA	2	2	4	6	8	12
	MUY BAJA	1	1	2	3	4	5

■	Riesgo muy grave. Requiere medidas preventivas urgentes. No se debe iniciar el proyecto sin la aplicación de medidas preventivas urgentes y sin acotar sólidamente el riesgo.
■	Riesgo importante. Medidas preventivas obligatorias. Se deben controlar fuertemente llas variables de riesgo durante el proyecto.
■	Riesgo apreciable. Estudiar económicamente ai es posible introducir medidas preventivas para reducir el nivel de riesgo. Si no fuera posible, mantener las variables controladas.
□	Riesgo marginal.Se vigilará aunque no requiere medidas preventivas de partida.

Figure # 25: Color scale of value of risks

After the analysis of the **12** specific analysis listed in the figure below there was found that most of the risk have values of 20 to 25 which represent very serious risks. However, there are types of risks that should be consider priority over the other ones. For instance, security and environmental types of risks are, for this project, more critical than legal or technical problems. This is because these can affect directly to people or environment's health. For this kind of risks the solution is to follow the respective procedures that rules this kind of operations. Also, a good management of dangerous compounds, also ruled by certain international regulations can help mitigate these risks. For security and technical risks related to the procedure itself something so simple like using the respective safety equipment and implementing safety devices to the prototype like an emergency stop button can help eliminate very serious risks like injuries, electric or chemical risks. The *Table # 16* shows the risk analysis in detail.

Security risks have been the principal consideration during the machine design. The system should operate with the maximum precisions as possible since it will operate with hot fluids and electrical components. For these reasons, the design has been made do the bottles will be well secured during operation and the nozzles can be fixed inside each bottle, so the fluids jet won't be splashed dangerously outside the machine. Also, both compartments in the tank are design to have a maximum of **84 liters** (**40 cm** height inside de tank) so the liquids won´t spill.

Economic resources were another of the risks for the machine development. The machine will operate according to alimentary operational standards, so it has to be built with stainless-steel, an expensive material. Also, al the manufacturing processes involving this material are just as expensive. The budget fixed for this project wasn't enough even with a

very economical design. For this reason, in case of the development of the machine, a minimum of **2000 USD** are necessary for good results.

Table # 16: Color scale of value of risks

TIPO	RIESGO	DESCRIPCION	Probabilidad (Ocurrencia)	Gravedad (Impacto)	Valor del Riesgo	Nivel de Riesgo	MITIGACION	ESTATUS
Recursos Económicos	Manejo de Recursos	Dificultad de conseguir los recursos necesarios para la elaboración de los prototipos	5	5	25	Muy grave	Cotizar con varios proveedores para minimizar en lo posible gastos y utilizar la menor cantidad de recursos posible	Vigente
	Riesgo Económico	Falta de presupuesto para completar el prototipo final	5	5	25	Muy grave	Realizar la menor cantidad de pruebas físicas posibles utilizando simulaciones y cálculos para así disminuir los costos de prototipos y pruebas	Vigente
Seguridad	Riesgo Eléctrico	Contacto Eléctrico del Operador con la Bomba. Contacto Eléctrico con el Fluido y transmisión sobre el equipo	4	5	20	Muy grave	Diseño de una estructura para poder sugetar y aislar electricamente la Bomba. Diseño correcto de Puesta a Tierra. Utilizar Cables Idoneos para las conexiones Electricas.	Vigente
	Riesgo Químico	Contacto de la Sosa Caustica con la Piel u Ojos del Operador	4	5	20	Muy grave	Utilización de Equipo de Portección Personal (Gafas, Mandil, Guantes) para la manipulación del Equipo	Vigente
	Riesgo de Lesiones	Manipulación de las Botellas por parte del Operador puede causar lesiones debido a su peso y a la Geometria del Equipo	5	5	25	Muy grave	Diseño del Sistema de Sujeción de Botellas basado en Peso Maximo de manipulación recomenadado para una Persona. Diseñar el Equipo tratando de evitar filos cortantes y esquinas punteagudas	Vigente
Legal	Riesgo de Demanda por Patentes	El diseño del Equipo va a ser realizado basandose en Patentes existentes, por lo que puedes ecistir demandas de Propiedad Intelectual	5	5	25	Muy grave	Evitar copiar los Diseños Preexistentes	Vigente
Técnicos	Riesgo de falla en manufactura	Riesgo de tener un proceso deficiente de soldadura y se produzca una mezcla de fluidos entre ellos	4	5	20	Muy grave	Aplicar normas especiales de soldadura en placas de acero inoxidable y normas de soldadura en pantas de alimentos	Vigente
	Riesgos de cálculo	De efectuar mal el cálculo de transfrencia de calor no vamos a alcanzar la temperatura deseada en el tanque	5	2	10	Importante	Sobredimensionar el sistema moderadamente y rezliar simulaciones que verifiquen la validez de nuestros cálculos	Vigente
Ambientales	Sustancias Peligrosas	Mal manejo de sustancias de lavado de botellas	5	5	25	Muy grave	El cliente, debe informar al operador encargado sobre el manejo adecuado de sustancias y así evitar que las sustancias ocupadas afecten al ecosistema que lo rodea	Vigente
	Mal manejo de desechos	No manejar bien las sutancias de desecho después del proceso de lavado	5	5	25	Muy grave	Considerar las normas ambientales de manejo de desechos y así evitar sanciones por parte de las entidades competentes	Vigente
Operativos	Salpicadura de sustancias peligrosas	Salpicadura al operador de sosa o agua muy caliente	5	5	25	Muy grave	Instalar una pantalla de seguridad que evite el contacto del operador con la sustancia	Vigente
	Falla eléctrica	Falla del sistema de calentamiento de agua, produciendo un cortocircuito	5	5	25	Muy grave	Instalar sistemas de parado de emergencia en caso de presentarse anomlías en el sistema eléctrico o sistema de calentamiento.	Vigente

Results, Discussion and Conclusions

Pipe simulation results analysis:

The pipe system simulation is very necessary to fully understand the behave of the system and to validate the design made before so this way the suppositions made are verified or corrected if needed. For the simulations of both piping systems, the water distribution system and the caustic soda (NaOH) distribution system, the software Pipeflow was used. This program allows the user to make the piping circuit which, in this case, each one has all the components which are incorporated in a real.

➢ **Overall System Analysis:**

As mentioned before, the piping system will be exactly the same for both of the washing machine parts. The only difference between the systems will be the liquid they will operate with (water and caustic soda). The system has all the components specified before in the design section such as the tank, pump, valves, elbows, tee's, nozzles, joints, and the pipe itself. The mentioned circuit is shown below:
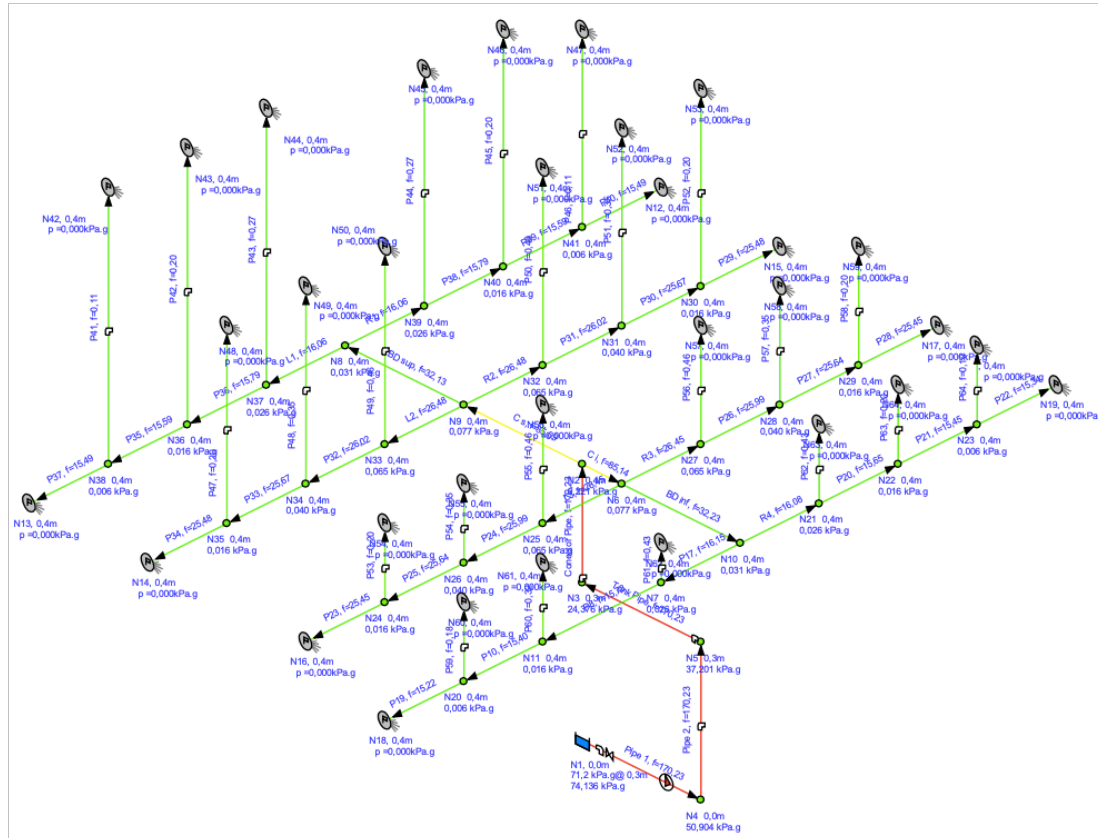
Figure # 26: Piping circuit for simulation in Pipeflow.

The first simulation was made for the water system taking into account the parameters detailed in Table # 31. This simulation ends up in a big

change for the pumping system. The pump available and used for the design and calculations (provided for the U.S.F.Q) is overqualified for

operation purposes. In other words, the dimensions and the volume needed by the system to operate is too small for the pump. The Figure # 26

shows the operation point of the system using the properties of this pump.
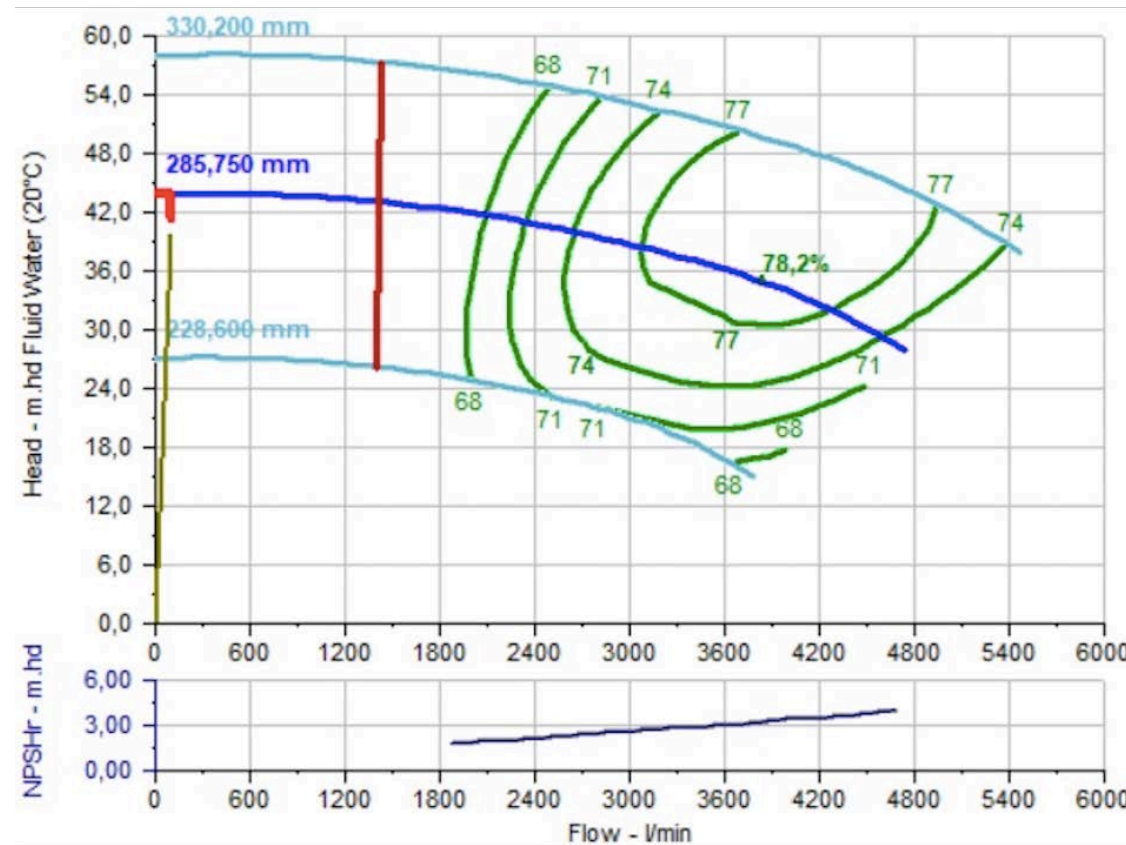
Figure # 27: *System curve overload with the 1HP pump performance curve and operation point of the system.*

The **Figure # 27** shows the operation point marked in red. For a flow rate of 99,6 l/min needed for the operation of the system is clear to see that the point before ideal operation point of the pump marked by the vertical red line which overlays the pump curves. Also, the system curve represented by the brown line doesn't reaches the pump performance curve, represented by the blue line. This shows the previous statement made, the pump is overqualified for this system.

```
>>> Warning:
Pipe 1, Liquid Flow Velocity is high (8,057m/sec)

>>> Warning:
Pipe 1,Pump => Flow rate is Outside Preferred Operating Region for this pump.

>>> Warning:
Pipe 1,Pump => NPSHa is not sufficient
NPSHr=0,391  m.hd Fluid, NPSHa=-18,291  m.hd Fluid (Too Low - Cavitation may occur at the
pump)

>>> PROBLEM:
Pipe 1,Pump => NPSHa = -18,291 - NPSHa cannot be negative
```

Figure # 28: *System results with the 1HP pump.*

The results show a very important cavitation problem. The system will have a net positive suction head available (**NPSHA**) lower than net positive suction head required (**NPSHR**). Since the value of the **NPSHA** is negative, which shouldn't happen, this shows that the system should be approximately 18 meters below the pump so the cavitation can be prevented. By using the pump, the system will suffer significant damage in the pipes joints and in the pump itself due to the cavitation in the system. The software counts with a big catalog of commercial pumps, using this a better pump for the system was selected with the following specifications:

Speed rpm	Pref. Op From l/min	Pref. Op To l/min	Flow In/Out l/min	Velocity m/sec	Suction Pressure kPa.g
1750	122,99	228,41	170,23	4,688	-19,945

Suction Pressure kPa.g	Discharge Pressure kPa.g	Pump Head (+) m.hd Fluid	Pump NPSHr m.hd (absolute)	Pump NPSHa m.hd (absolute)	Pump Efficiency Percentage	Pump Power Kilowatts
-19,945	53,722	7,527	0,629	8,070	51,84	0,4024

Pump Data

Name:	Pump
Catalog:	General
Manufacturer:	Generic
Type:	End suction
Size:	1-1/2x1-6 AA
Stages:	0
Speed:	1750 Rpm
Impeller Diam:	5,000 inch
Min Speed:	900 Rpm
Max Speed:	1750 Rpm
Min Diam:	4,000 inch
Max Diam:	6,060 inch

Figure # 29: *Re-selected pump specifications.*

➤ **Water piping system simulation results:**

With the new pump selection, a good simulation with very acceptable results was obtained. The needed flow is still the same of 99,6 l/min.

With the same dimensions and specifications of the pipe system except for the pump the result is show in the figure below.
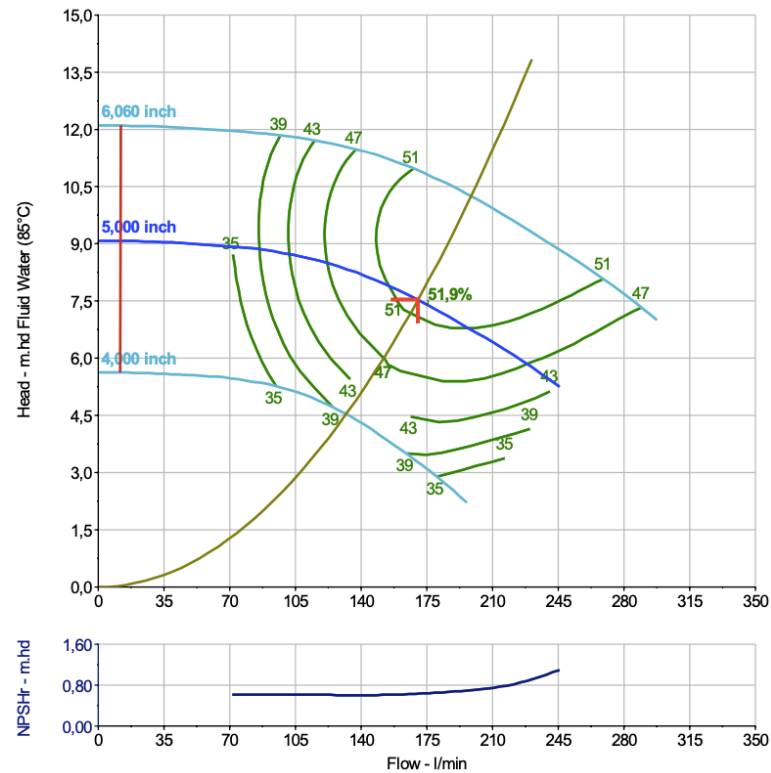
Figure # 30: System curve overload with the re-selected pump performance curve and operation point of the system for the water piping.

This show a better system performance, the selected pump curve in blue overlays with the system curve in brow in a very acceptable point. For this point the system work with 51,84% of efficiency. Since the pump is working with a flow of 170,23 [l/min.], a higher flow than the minimum required (approx. 15 [l/min.]) and a higher flow than the flow rate needed, the pump selected is very adequate for the system. Having a higher flow that the required is not a problem for this system because of the regulation valve the system has and because a higher flow rate at the beginning represent a higher flow at the exit of the nozzles and this causes no problem in the system. The head of 7,5 [m] obtained in the simulation is far more acceptable for the system than the almost 45 [m] obtained using the overqualified pump.

The other results of the simulation show that the cavitation problem present before has been completely corrected since the system will have a net positive suction head available (NPSHA) of 8,07 [m] this is higher than net positive suction head required (NPSHR) obtained of 0,629 [m]. This proves once more that the re-selected pump works in a very acceptable rage of performance for the system. Also, the results of flow rate, pressure, and velocity in the farthest nozzle therefore more critical ones are: 0,43 [l/min], 0,026 [kPa], and 0,195 [m/s] respectively. These values represent acceptable results than the ones obtained with the 1 HP pump for the nozzle requirements because these were too high for the small dimensions of the system.

Caustic soda piping system simulation results:

For the caustic soda de need flow rate is the same of 99,6 l/min. The piping system and dimensions and criteria of indicial temperature and pressure are still same as the ones specified for the water.
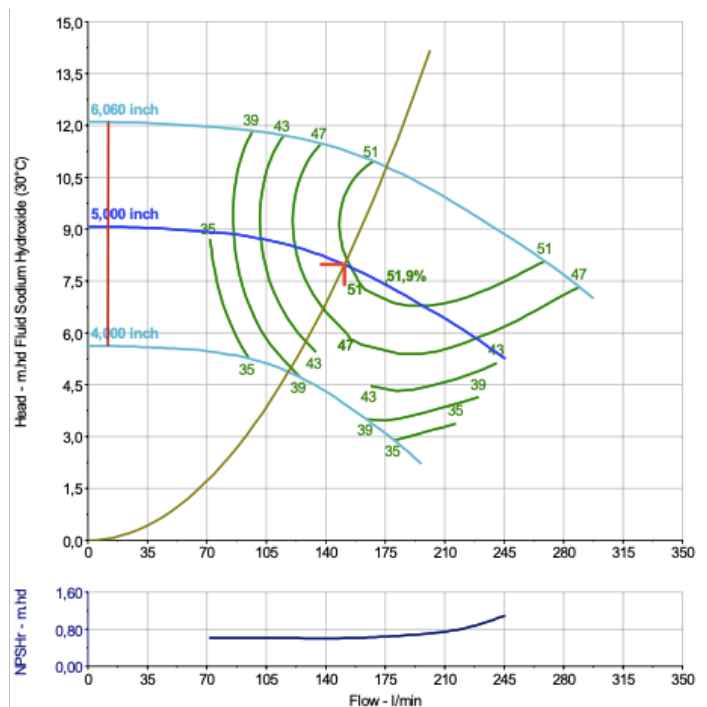
Figure # 31: System curve overload with the re-selected pump performance curve and operation point of the system for the caustic soda piping.

The figure shows that the re-selected pump works, for the caustic soda piping system as acceptable as for the water system. The pump curve in blue overlays with the system curve in an operation point of a flow rate of 151 [l/min.] and a head of 7,97 [m]. Very similar results than the obtained for the water system. This shows that the same pump can be used in both systems in the washing process. At the point of operation, the procedure has an efficiency of 50,72 %, a very acceptable value for the operation.

The other results of the simulation show that the cavitation won't be a problem in this system either. The system will have a net positive suction head available (NPSHA) of 7,977 [m] this is higher than net positive suction head required (NPSHR) obtained of 0,607 [m]. This also proves that the pump selected is adequate for the whole piping system in the washing machine since it operates good with both fluids water and caustic soda providing a flow rate higher that the required and having no problems of cavitation.

The detailed report of this simulations is presented in ¡Error! No se encuentra el origen de la referencia.

Bottle-holder rack structural simulation results analysis:

The bottle-holder rack, as mentioned in previous sections, was designed using the Autodesk Inventor software. This program allows to apply the required loads into a structural system previous designed, obtaining the different stresses and deformations the system is exposed to. The rack shown in ***Figure # 32***, during operation, holds 24 beer bottles. Depending of the bottle characteristic, the rack will adjust for different sizes of bottles. For the analysis, a 390-gr bottle was chosen for the simulation. The rack holds itself over the tank adapting its four legs to both sides of the tank breadthwise as shown in the ***Figure # 33***,
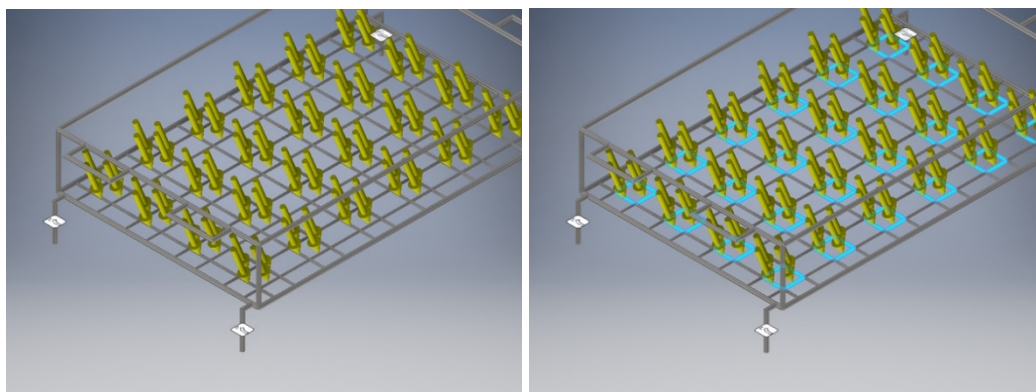
Figure # 32: load distribution at the bottle-holder rack during operation.

As shown in the ***Figure # 32*** the force produce by a bottle weight is distributed in four points in the rack. The bottles are hold by their neck upside down for the washing process. Since the bottle weight is symmetrically distributed, the magnitude is divided by 4 and applied as vectors shown in ***Figure # 33***. Also, a fixed constrain, non-movement point, is applied to the four supporting legs of the structure since these are the fasteners of the rack to the tank.

Load Type	Force
Magnitude	0.958 N
Vector X	0.000 N
Vector Y	0.885 N
Vector Z	-0.366 N

Figure # 33: Load magnitude applied to the bottle-holder rack during operation.

The calculation made in previous sections show a 2D structural analysis for one of the many beams the rack has, submitted to the most critical scenario which is that the entire weight of the bottle is hold in just one point of one beam and not in the 4 points mentioned before. The calculation gave a stress due to the momentums and the different forces applied to the beam. However, comparing a stress applied on a certain axis with the yield strength of the material may not be precise enough for determining if the structure will resist or not the given operating conditions. This is why the Von Mises stress (σ') is very important since it analyses the stresses considering volume and angular distortions this makes this magnitude a very good indicator to be comparted with the material yield strength (σ_y) knowing that if $\sigma' > \sigma_y$ the design is good and it will resist the operation condition. Otherwise, the system will experience failure and it is not a good design for the needed conditions. This allows to give a bigger and more specified result based on micromechanical principles and energy models to determine if the experimented forces will produce stresses which will or will not cause failure.

Once the parameters have been specified the simulation can be performed and analyzed. First, the Von Mises stress, which is an indicator of good or bad structural design in the failure theories is shown by a magnitude and a color scale on the structure as a visual interpretation of the stress along the structure in *Figure # 33*. The simulation gives a maximum Von Mises stress of **18,11 [MPa]** which compared to the yield strength of the material of **205 [MPa]** gives safety factor of approximately **11 ul.**
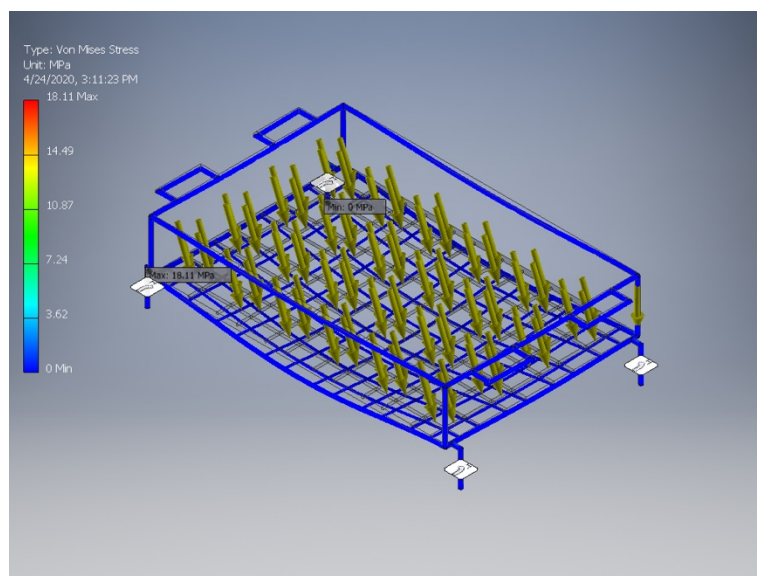
Figure # 34: Von Mises stress at bottle-holder rack during operation

The calculation and the simulation both give the same conclusion, the structural system of the project won´t represent a critical criterion for the design. The calculation showed a stress of approximately 33 [MPa], in the more critical operation scenario, which compared with the same yield strength as before gives a safety factor of 6 [ul]. As mentioned before this may be not a good enough failure indicator for the system. That is why the simulation and the Von Mises factor showed before are important, this allows to validate or discard previous assumptions made in the process. However, both safety factor obtained are acceptable for the project and leads to the same conclusion mentioned before. The difference between the magnitudes are because of the type of analysis, in the calculations the system taken was just a small part taken as critical. The simulation took into consideration the entire system into normal operations conditions and assuming the design will be manufactured as precise as possible. Even though both analyses are different considering precision and criticality, those results still represent a very good design for the structure.

Another good parameter to validate the structure design is the deformation suffered during normal operation conditions. The ***Figure # 34*** shows the displacement of the structure under the conditions previously exposed. The maximum deformation is located at the center of the structure with a magnitude of approximately 0,17 [mm] a very small deformation and an acceptable one since it won't be critical enough to deform the location of the bottles in the nozzles for the washing process. Since the structure will be operating within acceptable failure indicators and the stress don't exceed the yield strength of the material, any deformation in the structure caused by the operation conditions previously exposed won't exceed the plastic deformation regions.
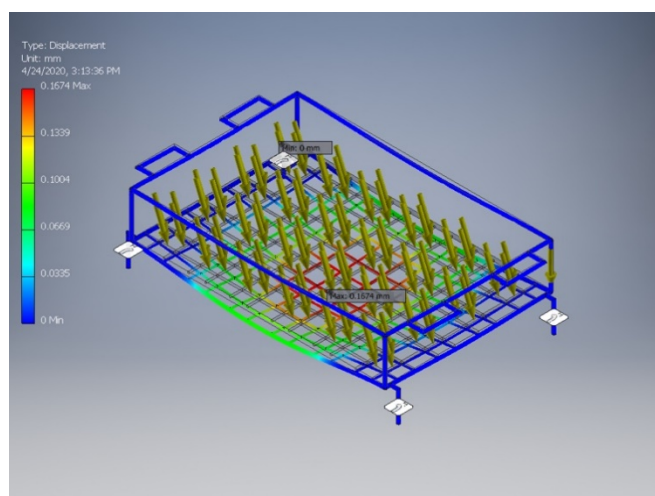
Figure # 35: Deformation at bottle-holder rack during operation.

Future Work

Once the system has been virtual animated, the drawing has been approved by professionals, and the results of the simulation indicate that a physical system can be reproduced successfully with acceptable safety factor for each subsystem: liquid heating, structural, and piping system; the construction of the actual bottle washer machine is one of the two steps missing in the project. With the supplier's price for the respective

manufacturing processes and with the international standards for these procedures, once the first prototype is assembled, the system can be tested to verify it meets the Ecuadorian alimentation industries standard and the international mechanical standards for the machine to operate.

The second procedure to perform and according to the previous one, the machine has to be tested to meet the client needs and criteria. The prototype's test plan has to be performed entirely to certify that all the parameters analyzed are within the tolerance proposed in the project: pipe measurements, fluids temperature, flow rate, pressure, weight tests and time of operation. Depending of the results given by this test plan, the project could be either approved for delivery and installation to the costumer or revised in case one or more of the parameters don't meet the specified condition of operation. If a failure is detected, the test plan for the corresponding system correction has to be followed

Once the machine is installed, the customer has to be trained for a correct usage of the machine, taking into consideration all the procedures and security equipment detailed in the manual. The machine has to be in operation during three months before the first maintenance is done, this one is for verification purposes analyzing how the machine will behave in a long-term operation. The client will be provided with every tool and procedure explanation for the correct maintenance of the machine. As a group responsible of the development of the machine in every aspect, all the members are in obligation of provide the respective solution for any problem presented with the machine within one year after its installation.

For future projects like this one, is important to take into consideration the delicate the system must be in terms of following manufacturing and operational standard since it will operate within the alimentary industry. Also, is important to notice, for the same

reason, the materials a machine like this has to use are very expensive and it is very hard to find some ways to decrease costs for materials or manufacturing process without prejudice the long-term operation of the system. This is why a medium to big budget is needed for this kind of projects, depending on how important and precise the process has to be different ways to approach some subsystems, like the liquid heating system for example

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APPENDIXES

Appendix A

Engineering Drawings:

Parts List			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Tank	
2	2	Pipe Pump-Elbow	
3	4	Piping Elbow	
4	2	Pump	
5	2	Pipe Elbow-Tank	
6	2	Pipe Tank-Elbow	
7	2	Pipe Pump-Elbow	
8	2	Water Distributor Pipe	
9	2	Parker Brass Ball Valve XV520P XV520P-20	
10	2	Basket	
11	24	Bottle	
12	34	Ferrule	

Tolerance	Weight		
N/A	N/A		

	Date	Name	Bottle Washer Machine	Scale
Drawn on	04/04/20	Martín Dávila		1/20
Reviewed by				
Approved by				

USFQ	Code	Surface Treatment/Coating	Sheet #
	N/A	N/A	1/12

Pipe
Tank-Elbow

C

C (1:5)

500

320

1.64

12.7

50

A (1:5)

156.14

2.78

Ø 44.45

Ø 31.75

10.08

20

10

20

B

A

B

620

580

310

385   385

820

Ø38.1

Ø44.45

Ø50

Ø46

B-B (1:15)

Tolerance	Weight	Material		
± 0.1		Stainless Steel 310		

	Date	Name	Title		Scale
Drawn on:	13/05/20	Andi Villacis	Beer Bottle Washing Machine Tank		1:10
Reviewed by:					
Approved by:					

USFQ	Code	Surface Treatment - Coating	Sheet #
	BBW-T-01	Polished	2

Ø50

27,75

31,75

194

Tolerance		Weight	Material:		
±0.1			**Stanless-Steel 304 Tube 40S**		
	Date	Name	Title:		Scale
Drawn	4/4/20	Gabriel Gallo	**Pipe Elbow-Tank**		1:2
Reviewed					
Approved					
USFQ			Code	Surface Treatment/Coating	Sheet #
				Ferrul Welded to pipe, see sheet #12 for ferrul details	4

73.85

62.85

R25.88

R10

42.98

R15.88

R13.88

73.85

Tolerance	Weight	Stainless Steel 304 tube 40S		
± 0.1	N/A			
	Date	Name	Piping Elbow	Scale
Drawn on	03/04/2020	Ivan Nolivos		1:2
Reviewed by				
Approved by				
USFQ		Code	Surface Treatment/Coating	Sheet #
		N/A	Ferrul Welded, see sheet 12 for details	#4

B   B-B (1:1)

B

72.65

45°

2   2

7.13

Ø 46

31.75

Ø27.75   Ø50

A

R20

R22

A (2:1)

Tolerance	Weight	Material	
± 0.1		Stainless Steel 310	

	Date	Name	Title	Scale
Drawn on:	13/05/20	Andi Villacis	Beer Bottle Washing Machine Pipe Tank Elbow	1:1
Reviewed by:				
Approved by:				

USFQ	Code	Surface Treatment - Coating	Sheet #
	BBW-T-01	Polished	5

Ø50

27,75

31,75

97,15

Tolerance		Weight	Material:		
±0.1			**Stanless-Steel 304 Tube 40S**		
	Date	**Name**	Title:		**Scale**
Drawn	4/4/20	**Gabriel Gallo**	**Pipe Pump-Elbow**		**1:1**
Reviewed					
Approved					
USFQ			**Code**	**Surface Treatment/Coating** Ferrul Welded to pipe, see sheet #12 for ferrul details	**Sheet #** **6**

24 holes of R3.23

92.67

R11.18

576

90.25

Ø25.4

25.4

Ø25.4

Ø22.35

296.15
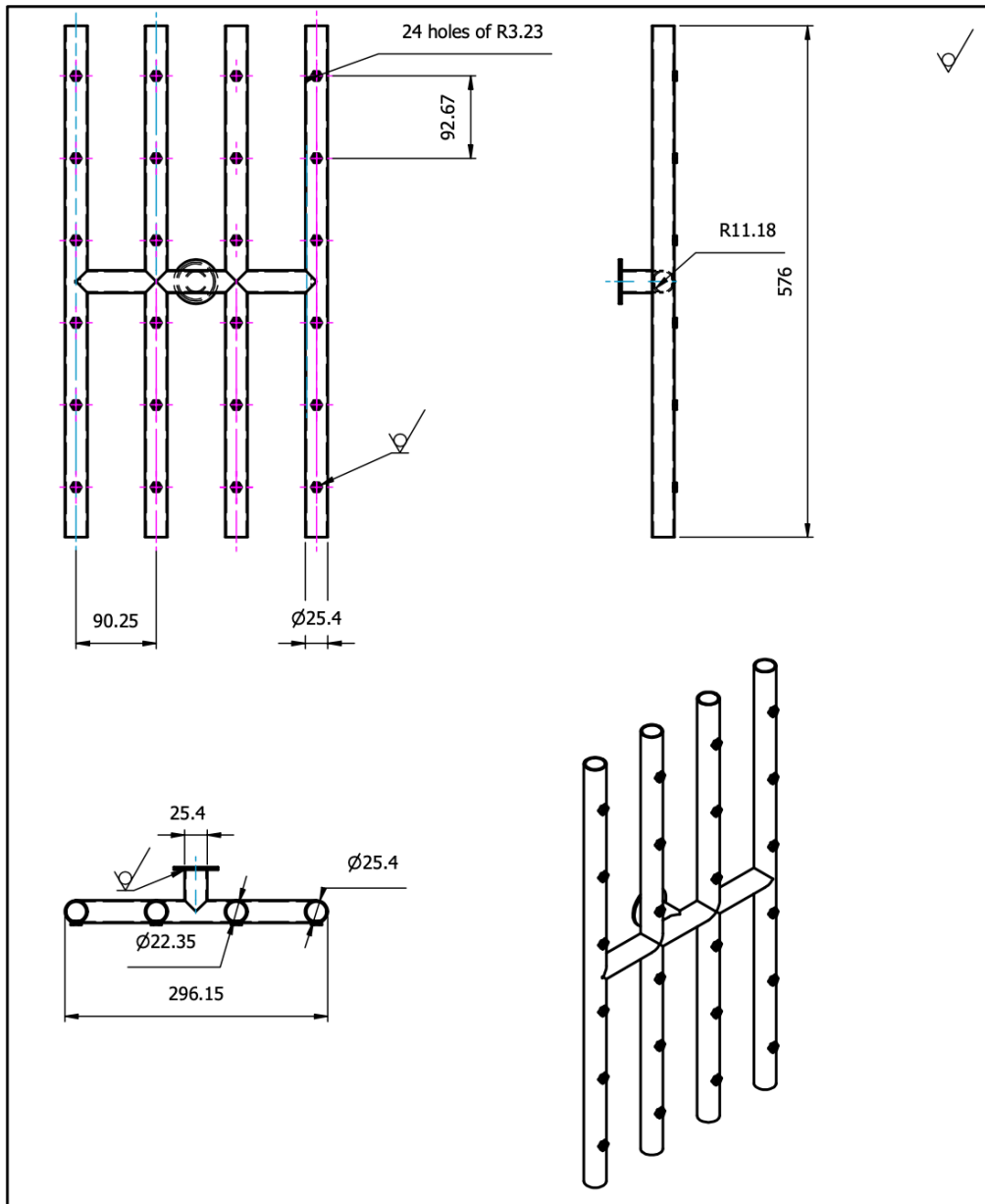
Tolerance	Weight	Stainless Steel 304 tube 40S	
± 0.1	N/A		

	Date	Name	Water Distribuitor Pipe	Scale
Drawn on	03/04/2020	Ivan Nolivos		1:6
Reviewed by				
Approved by				

USFQ	Code	Surface Treatment/Coating	Sheet #
	N/A	24 nuts welded. Ferrul welded, see sheet 12 for details	#8

35 570

107

69

26

34

25 51 60 27 13 12

24 34 48 24 60 12 50 87 100 7

B

B (0.40 : 1)

3

4

Tolerance ±0.1	Weight	Material: Stanless-Steel 404		
	Date	Name	Title: Basket for bottles	Scale 1:2
Drawed	4/4/20	Gabriel Gallo		
Reviewed				
Aproved				
USFQ		Code	Surface Treatment/Coating	Sheet # 8
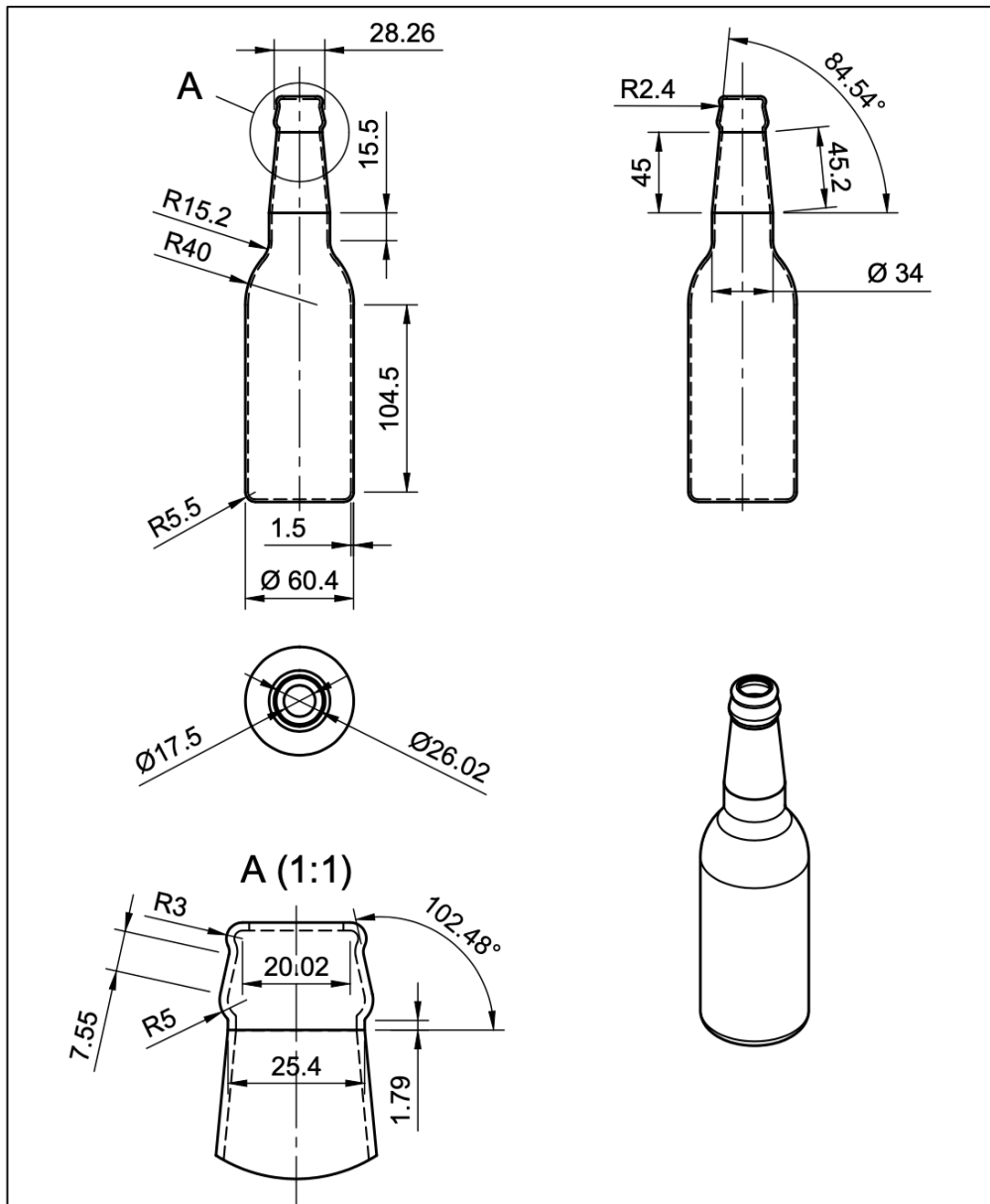
28.26

A

15.5

R15.2
R40

104.5

R5.5

1.5

Ø 60.4

R2.4

84.54°

45

45.2

Ø 34

Ø17.5

Ø26.02

A (1:1)

R3

102.48°

20.02

7.55

R5

25.4

1.79

Tolerance	Weight	Material	
± 0.1		Stainless Steel 310	

	Date	Name	Title	Scale
Drawn on:	13/05/20	Andi Villacis	Beer Washing Machine Bottle	1:3
Reviewed by:				
Approved by:				

USFQ	Code	Surface Treatment - Coating	Sheet #
	BBW-T-01	Polished	10

N8

3,23

1

7,12

25

4.88

M6.5

Tolerance ±0.1	Weight	Material: Stanless-Steel 304		
	Date	**Name**	Title: Nozzle		Scale 5:1
Drawn	4/4/20	Gabriel Gallo		
Reviewed				
Approved				
USFQ		Code	Surface Treatment/Coating	Sheet # 10

Ø21,4

25,4

29,29

154,29

Ø50

Tolerance	Weight	Material:		
±0.1		**Stanless-Steel 304 tube 40S**		

	Date	Name	Title:		Scale
Drawed	4/4/20	Gabriel Gallo	**Pipe Accesory for Tank**		**1:1.5**
Reviewed					
Aproved					

USFQ	Code	Surface Treatment/Coating	Sheet #
		Ferrul Welded to pipe, see sheet #12 for ferrul details	**11**

N6

| 31.75 H7 | 31.768 |
| | 31.75 |

Ø50

D | | D

Ø31,75 H7

Ø44

D-D (1 : 1)

45,99

2

4

R1

Tolerance	Weight	Material:		
±0.1		Stanless-Steel 304		
	Date	Name	Title:		Scale
Drawed	4/4/20	Gabriel Gallo	Ferrul		1:1
Reviewed					
Aproved					
USFQ		Code	Surface Treatment/Coating	Sheet #
				12

Appendix B – Project Management

Quotation Report:

FERNANDEZ MORENO	PROFORMA	Revisión No.. 02
		Fecha: 16 Mar 2020

Quito, 16 de Marzo de 2020

Proforma No 20200316-USFQ-001

Señores:
Universidad San Francisco de Quito
Attn.: Ing. Norbert Muller
Presente.-

De mis consideraciones:

Adjunto sírvase encontrar detalle de la cotización solicitada para **CONTROL AUTOMÁTICO LAVADORA BOTELLAS**, con las siguientes características:

Características : Control automático PID de temperatura mediante termocupla tipo J. Calentamiento mediante resistencias eléctricas 1.5kW a 80°C y permanencia a esa temperatura. Volúmen aproximado 50L. Control automático mediante display que permite regular la temperatura del proceso. Incluye pantalla programable, luces de funcionamiento, botón de encendido.

Resistencia	: 1.5kW, : A-240 TP 304
Tablero control	: 250x200 : A-240 TP 304
PID	: Control de temperatura automático. Opcional, control de encendido de bomba mediante señal térmica.
Termopares	: Tipo J.

Filosofía de funcionamiento: Calentamiento constante de agua (nivel de 400mm, temperatura programable).
Material
Couplings y bocas : A-240 TP 304
Soporte botellas :Ø3/8" A-240 TP 304, corte láser 2mm espesor.

OFERTA ECONÓMICA:

Ctd.	Descripción	PVP	Subtotal	IVA	Total
1	Tablero de control SS304	275	275	33.00	308.00
1	Sistema de control temperatura SS304	415	415	49.80	464.80
1	Sistema de control variador con control de temperatura	135	135	16.20	151.20
1	Plancha separación tanques SS304	76.5	76.5	9.18	85.68
2	Soporte 24 botellas SS304	97	194	23.28	217.28
1	Transporte equipo Instalación USFQ	0	0	0.00	0.00
					1226.96

NOTA.- Se garantizan pruebas de calentamiento P&I.
Todas las juntas serán sanitarias.
No incluye cálculos ingenieriles de dimensionamiento, estos planos serán otorgados por la USFQ.

DATOS DE GARANTÍA: 1 año contra defectos de fabricación.

CONDICIONES GENERALES:

Precio total	: $ 1095,50 + IVA
Forma de pago	: 50% anticipo – 50% entrega
Lugar de entrega	: Instalaciones USFQ – Montaje incluido
Plazo de entrega	: 3 semanas de recibido el anticipo
Garantía	: Un año contra defectos de fabricación

Sin otro particular nos despedimos de usted, y quedamos en espera de sus gratas órdenes

Atentamente,

Esteban Fernández
Ingeniero de Proyectos

Diego Vásquez de Cepeda y Av. Galo Plaza Lasso, Intercambiador de Carcelén
Telf.: 0987529549
esteban.fernandez.davalos@gmail.com
Quito - Ecuador

Appendix B.1: Quote one temperature control, tank separation and one basket

	PROFORMA	Código: USFQ-DLB-01
		Revisión No.: 01
		Fecha: 10 Mar 2020

Quito, 10 de Marzo de 2020

Proforma No 20200310-USFQ-001

Señores:
Universidad San Francisco de Quito
Attn.: Ing. Norbert Muller
Presente.-

De mis consideraciones:

Adjunto sirvase encontrar detalle de la cotización solicitada para **DISTRIBUIDORES LAVADORA BOTELLAS Ø1"**, con las siguientes características:

Geometría   : Alimentación Distribuidores, esquema adjunto referencial
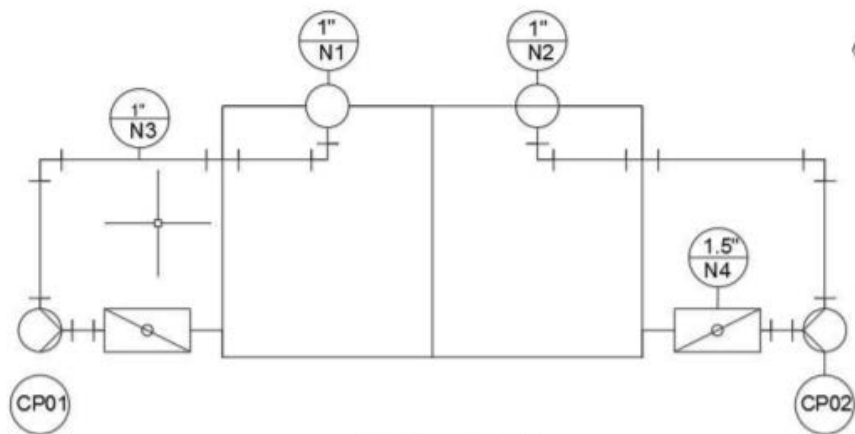
VISTA PRINCIPAL

Geometría   : Distribuidor 24 boquillas, esquema adjunto referencial.
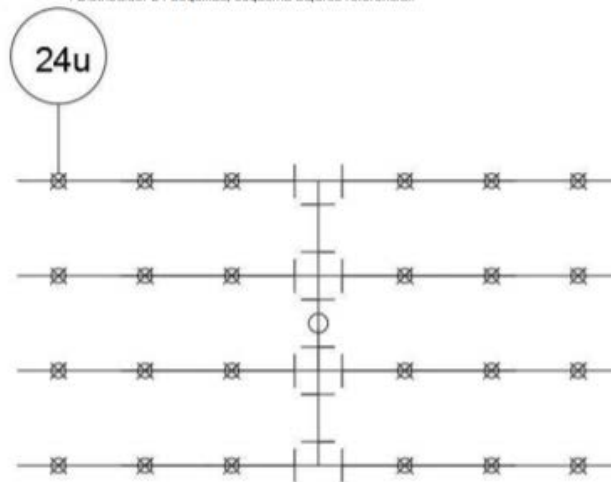
Appendix B.2: Quotation pipes, ferrules and clamps Part 1

		Código: USFQ-DLB-01
FERNANDEZ MORENO	**PROFORMA**	Revisión No.: 01
		Fecha: 10 Mar 2020

Tubería   : Ø25.4mm
Espesor   : 1.5mm
Largo   : Manifold de acuerdo al interior del tanque.
Altura   : Boquilla de acuerdo a botella.
Capacidad : Nominal de bombas provistas por la USFQ
Conexiones: Soldadas y mediante sistema FERRULE – CLAMP. Todos los accesorios son sanitarios.
Material
    Alimentación distribuidores   : A-240 TP 304, espesor 1.5mm
    Distribuidores   : Ídem
    Boquillas y accesorios   : Ídem

OFERTA ECONÓMICA:

Ctd.	Descripción	PVP	Subtotal	IVA	Total
2	Distribuidor Ø1" 24 boquillas SS304	278.11	556.22	66.75	622.97
2	Conexión Ø1" Ø1.5" bombas SS304	147.16	294.32	35.32	329.64
1	Pulido Tanque Agua Grit 120	0	0	0.00	0.00
1	Transporte equipo USFQ Instalación del equipo	0	0	0.00	0.00
					952.60

NOTA.- Se garantizan pruebas hidrostáticas, no incluye pruebas hidrodinámicas.
Se incluye gratuitamente pulido No.4 (Grit 120) del exterior del tanque de agua.

DATOS DE GARANTÍA: 1 año contra defectos de fabricación.

CONDICIONES GENERALES:

    Precio total   : $ 850.54 + IVA
    Forma de pago   : 50% anticipo – 50% entrega
    Lugar de entrega   : Instalaciones USFQ – Montaje incluido
    Plazo de entrega   : 3 semanas de recibido el anticipo
    Garantía   : Un año contra defectos de fabricación

Sin otro particular nos despedimos de usted, y quedamos en espera de sus gratas órdenes

Atentamente,

Esteban Fernández
Ingeniero de Proyectos

Appendix B.3: Quotation pipes, ferrules and clamps Part 2

Gaant Chart:

Table # 17: Gaant Chart for manufacturing process

	Semana 1	Semana 2	Semana 3	Semana 4	Semana 5	Semana 6
Quotation of material and parts	🟧					
Approval process	🟥					
Shop and transportation	🟦					
Contact with the welding company	🟩					
Separation of the tank by welding a stainlees steel sheet	🟧🟩🟥🟦					
Slice of pipes		⬛	⬛			
Welding of joints		⬛	⬛			
Instalation of ferrules and Accesories		⬛	⬛			
Elaboration of water heating system		⬛	⬛			
Eliaboration of the temprature control system		🟩🟧	🟩🟧			
Ellaboration of the pump control system		🟥🟦	🟥🟦			
Verification of the process		🟥	🟧	🟦🟩		
Assembiying				🟥🟧🟩🟦		
Testing and Corrections					🟥🟧🟩🟦	
Elaboration of the operation Manual				🟥🟧🟩🟦	🟥🟧🟩🟦	
Delivery of the prototype						🟦

Responsible: 🟥 Ivan Nolivos 🟧 Gabriel Gallo 🟦 Martin Davila 🟩 Andi Viliacis ⬛ Fernandez/Moreno CIA. LTDA

Piping System

Table # 18: Piping system part list

Part	Quantity	Length [mm]	L Tolerance[mm]	Width [mm]	Diameter [mm]	D Tolerance [mm]	Measurement Instrument	Measurement Responsible
Pump-Elbow Pipe	2	97.15	±1	2.00	15.87	±0.1	Tape Measure & Caliper	Martín Dávila & Gabriel Gallo
Piping Elbow	4	125.70	±1	2.00	15.87	±0.1	Tape Measure & Caliper	Martín Dávila & Gabriel Gallo
Elbow-Tank Pipe	2	194.46	±1	2.00	15.87	±0.1	Tape Measure & Caliper	Martín Dávila & Gabriel Gallo
Tank-Elbow Pipe	2	80.65	±1	2.00	15.87	±0.1	Tape Measure & Caliper	Martín Dávila & Gabriel Gallo

Tank-Pump Pipe	2	50.00	±1	2.00	31,75	±0.1	Tape Measure & Caliper	Martín Dávila & Gabriel Gallo
Vertical Distribution Pipe	8	50.00	±1	1.52	25.40	±0.1	Tape Measure & Caliper	Martín Dávila & Gabriel Gallo
Horizontal Distribution Pipe	2	580.00	±1	1.52	25.40	±0.1	Tape Measure & Caliper	Martín Dávila & Gabriel Gallo
Nozzle	48	25.00	±0.5	1.50	5.25	±0.5	Caliper	Martín Dávila & Gabriel Gallo
Valve	2	-	-	-	31,75	-	Caliper	Martín Dávila & Gabriel Gallo
Grid Basket	2	8920.00	±1	-	4.00	±0.1	Tape Measure & Caliper	Martín Dávila & Gabriel Gallo
Bottle-Holder Rack	2	2986.68	±1	-	7.00	±0.1	Tape Measure & Caliper	Martín Dávila & Gabriel Gallo

Reservoir System

<div align="center">

Table # 19: Reservoir system part list

</div>

Part	Quantity	Length [mm]	Width [mm]	Height [mm]	Tolerance [mm]	Measurement Instrument	Measurement Responsible
Tank	1	820.00	620.00	500.00	±1	Tape Measure	Martín Dávila & Gabriel Gallo
Divider plank	1	580.00	10 ±0.1	480.00	±1	Tape Measure & Caliper	Martín Dávila & Gabriel Gallo

Pump

Table # 20: Pump Part List

Part	Quantity	Power Input [kW]	RPM	Flow Rate [L/min]	Tolerance [L/min]	Measurement Instrument	Measurement Responsible
Pump	2	0.40	1750	99.6	±1	Flowmeter	Ivan Nolivos

Water Heating System

Table # 21: Composed by two parts that contains all the parameters to be measure and controlled by the manufacturers

Stainless Steel Resistance				
Parameters to consider	**Value**	**Tolerance**	**Measurement Instrument**	**Measurement Responsible**
Diameter	25.4 mm	+/- 0.1 mm	Caliper	Andi Villacis
Length	250 mm	+1%	Caliper	Andi Villacis
Voltage input (Max)	415 V	-	Multimeter	Andi Villacis
Current Input (Max)	14 A	-	Multimeter	Andi Villacis
Power input (>100W)	6000 W	+/- 5-10 %	-	Andi Villacis
Maximum Temperature	700 C	-	Pyrometer	Andi Villacis
Maximum Pressure	15 Bar	-	-	N/A

Pyrometer				
Measure Magnitudes	Value	Tolerance	Measurement Instrument	Measurement Responsible
Temperature (max)	100-300 C	0,5 % ± 5°C	-	-
Voltage	DC 24 V	± 10 %	Multimeter	Andi Villacis
Current	< 100 mA		Multimeter	Andi Villacis

Pump Controller

Table # 22: Pump Controller part list

Part #	Name	Installation Responsible
1	Display	Ivan Nolivos
2	Wires	Ivan Nolivos
3	PLC	Ivan Nolivos

4	Stop Button	Ivan Nolivos

Manufacturing Diagram

Appendix B.4: Manufacturing Diagram
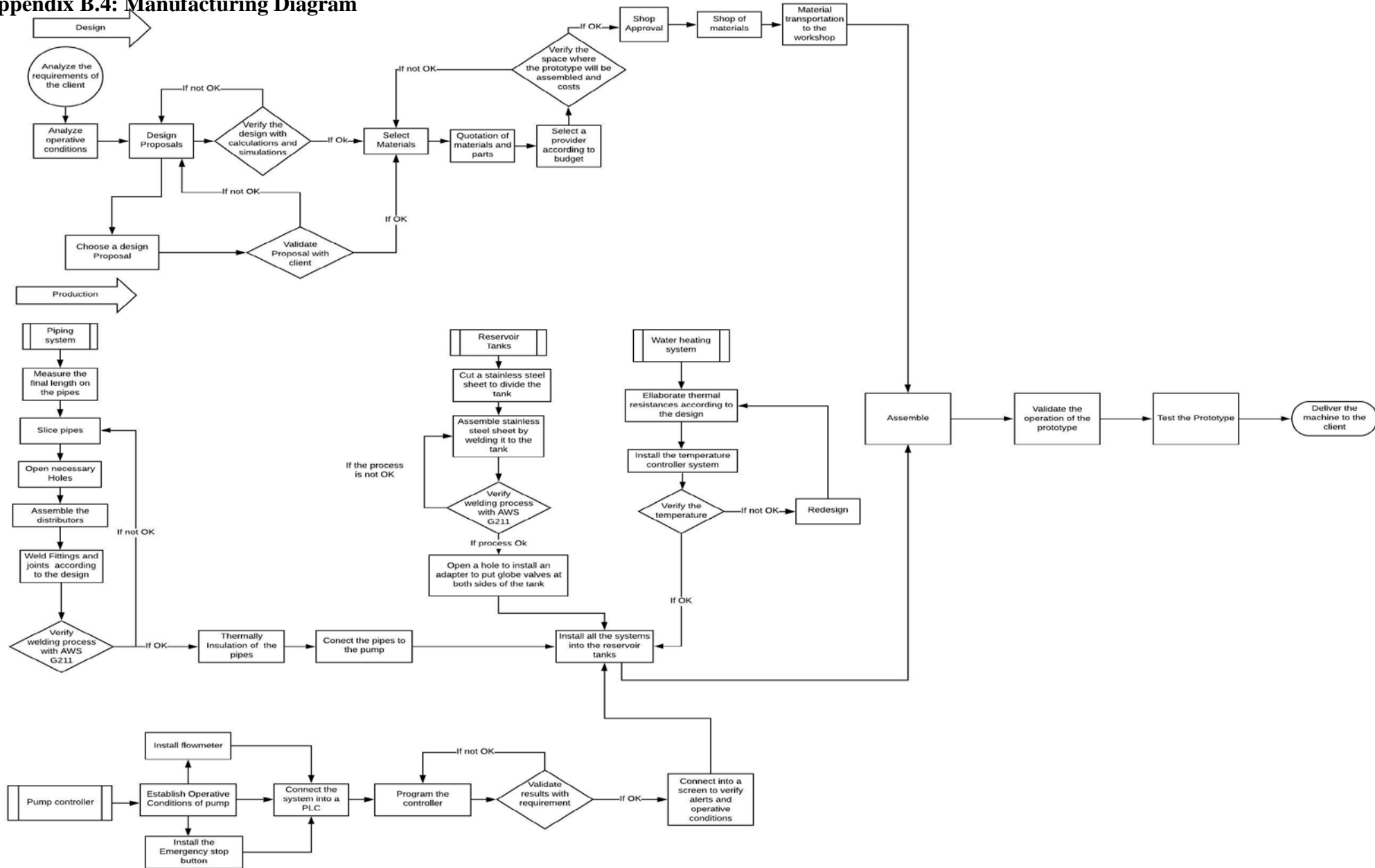
Leak Testing

Table # 23: *Leak Test Parameters*

Data	Description	Relevance	Parameters applied by the designers for the testing
Test circuit number	Allows the designer to know how much tests will be taken	When applying experimental methods, it is important that the results obtained at the tests show a pattern that repeats and matches with other tests. If the pattern repeats, the system will have the same behavior during its operation.	10 Iterations by each fluid
Piping Instrumentation and diagrams	A list that shows an identification of pipes and also the fittings added to the pipelines. Also, the hydraulic planes and the flux diagrams must be considered.	The hydraulic plane illustrates all the pipes and fittings in the system. In case of a leaking detection, this part must be considered in the plane for the designers to make a review of what happened during the process and effectuate the appropriate corrections.	Hydraulic Planes, Mechanical planes, and manufacturing diagram

Tests days	Shows which day the test has been taken	The date is important because, in case of failures or good behavior, designers could archive and interpret pattern along the time.	April 24, 2020 April 27, 2020 May 1, 2020
Location within facility	Shows specific place where the test will be taken	Location is an important fact to analyze because the results of the tests could vary according to the place where the tests are performed. If the location where the test is taken does not affect to the system, then, the system is developing its tasks properly.	USFQ workshop Open field (soccer court) USFQ Food Plant
Design Pressure	The average pressure for which the machine has been designed	This pressure will allow the designer to know how much the pressure could variate from its designed values and also for how much it will increase up to the test	32.39 kPa.g
Test Pressure	Pressure which is going to be applied to the system for testing	This pressure will exceed the standard levels of the designed values. This is to test if the system can resist to an additional amount of pressure. Accidents could happen and in case of a failure, system must support this failure with no leaking or sealing failures.	50 kPa

Test fluid	Different fluids considered for testing	For the bottle washing machine, there are two fluids of interests, it is important that the system does not fail using any of these fluids.	Water NaOH
Test fluid temperature	Temperature that will be applied for fluids	When the bottle Washing machine is working, it flows hot water over the pipelines, this could produce thermal stresses producing changes on the results	20 ℃ (5 tests with water and 5 tests with NaOH) 85 ℃ (5 tests with water) 30 ℃ (5 tests with NaOH)
Time	How much time does the test will be carried out	Time is an important variable to verify how long does the system supports the elevation of the pressure.	5 tests of 5 minutes 5 tests of 10 minutes (For each fluid)

Differential of pressure	Shows how much has the pressure has been risen or reduced	This allows to know how much pressure has been incremented from the designed values.	17.61 kPa.g
Comments	Comments about the pipelines, pump, fittings and others	If leaks appear, they must be commented with its intensity. Also, if the system does not show leaks, a positive commentary about the well behavior of the system should be done.	-
Signatures	Responsible of the tests must sign	During the test, responsible personal will be assigned to supervise and to operate the system in case of a failure	Ivan Nolivos Gabriel Gallo Martin Davila Andi Villacis

Pressure Testing

Table # 24: *Pressure Testing Parameters*

Data	Description	Relevance	Parameters applied by the designers for the testing
Test circuit number	Allows the designer to know how much tests will be taken	When applying experimental methods, it is important that the results obtained at the tests show a pattern that repeats and matches with other tests. If the pattern repeats, the system will have the same behavior during its operation.	10 Iterations by each fluid
Instrumentation and diagrams	A list showing the components that interact in the test such as pumps. In addition, it should be considered a pressure plane of the pumps	It is important these planes since it compares the initial pressure to us and to be able to compare the experimental data with the theoretical ones	Pressure Planes, Performance Plane

Date of tests	Shows which day the test has been taken	Dates is important for a time comparison to find out if there is a problem with the system	April 15, 2020. May 25, 2020 May 1, 2020
Location	Shows a specific place the test was performed	Location helps us know if the test performance varies according to location. It allows us to analyze and compare whether or not the location affects the development of the system	-USFQ workshop -USFQ Food processing plant
Design Pressure	The average pressure for which the machine has been designed	Design pressure helps us get an idea of the result we expect and compare for further analysis	32.39 kPa.g
Test Pressure	Pressure which is going to be applied to the system for testing	Higher pressure should be tested to verify that the system may have and observe its effects in the event the system fails. The system can fail and increase the pressure at the system outlet causing accidents	50 kPa
Test fluid	Different fluids considered for testing	For the bottle washing machine, there are two fluids of interests, it is important that the system does not fail by using any of these fluids.	Water NaOH

Test fluid temperature	Temperature to be applied to the fluid	The temperature can be a factor for changing the pressures and therefore the results	20 ℃ (5 tests with water and 5 tests with NaOH) 85 ℃ (5 tests with water) 30 ℃ (5 tests with NaOH)
Time	How much time does the test will be carried out	The time to observe if there is any variation in height is considered.	5 tests of 5 minutes 5 tests of 10 minutes (For each fluid)
Differential of heights	Shows how much has the heights has been risen or reduced	The height difference allows to know if there is a reduction or increase in pressure	5 cm 10cm
Comments	Comments about the results, heights, variables to take into account	If the system shows height difference in the jet, it must be notified to analyze what happens. Also comment if the system works correctly	-

| **Signatures** | Responsible of the tests must sign | During the test will be always assigned responsible persons to supervise and to operate the system in case of a failure | Ivan Nolivos, Gabriel Gallo Martin Davila, Andi Villacis |

Troubleshooting

Table # 25: *Troubleshooting Solutions*

Problem	Detail	Solution
Alignment	Bottle not correctly fastened	When this occurs, operator must verify that the tension cables are correctly fastened to the structure and verify that there is not any interference between the cables and the set of bottles situated. Always follow the instructions detailed on the datasheet for the type of bottles designed. If the problem persists, verify if the cable is joined to the base structure of the rack, if the cable is separated, the operator must contact the designers to fix the welding failure.
	Bottle not compatible with the rack	Operator must respect the shapes of the bottles that are specified on the data sheet. If a different bottle is used, accidents will occur. If the bottle is not aligned, hot water could spill over people causing second grade burnings on the skin or damaging objects near. Additional, if the bottle does not fit in its specific place do not force it, because it could damage the structure.
	Bottle-holder rack	Fasten the bolts to adjust the tensor cables or verify if the welding points of the structure are still functional.

Clamping	Piping joints	Always, operator must test the system with cold water at both sides to verify if there is any clamping trouble. If any of the joints is not well secured, separate the part and join it again by applying an adequate torque (enough to secure the bolts but not too much to damage the thread). If the clamps are still failing, the designers must check the system and verify if it is necessary to replace the clamp or effectuate a procedure of material wear.
Leaking	Joints	When the prototype is tested, leaking must be verified. If the system is leaking, try to verify exactly which points have this problem and disarm up to the failure point. If the system persists, take all the parts out and assemble the entire system again. If the problem is still present, welding or corrosion problems could be present on the system, if this is the case, contact with the designers to fix the problem.
Corrosion	Corrosion Points	Even if we are working with stainless steel, corrosion will affect at any moment of the life time operation of the bottle washing machine. Periodical inspections must be effectuated (at least every 3 months) to check if there is any problem. If the corroded point is not too big, the operator could grind the surface with sandpaper until this point is disappeared. If this corrosion point growths or if there is any big point of corrosion, the pipe should be replaced or take out a surface treatment to solve this problem.

Cavitation	Pump impeller	The system is designed to avoid cavitation but with the pass of the time and depending on the usage of the machine, cavitation could erode the internal surface of the impeller. Operator must check if the impellers are not showing erosion problems, if this happens, contact to the designers to effectuate adjustments into the flow rate of fluid and also at the pressure. This will keep the system functional for a longer period of time.
Erosion	Internal surface of pipes	Always keep the tanks clean, verify that there are not solids that comes inside the piping system. When solids crashes with the walls, they could wear out the system and it could cause leaking problems and orifices on the pipe in extreme cases. In case of advanced erosion, the pipe must be immediately replaced. The inspection of the pipe must be taken at least each 3 months.
Water Heating System	Overheating	Too much power input into the resistance could damage it, but before this happens, the relay system must this by shooting off the water heating system. If the relay jumps, immediately the operator must turn off all the system by using the emergency stop button. Wait at least 30 minutes until the system colds and test the system by preheating the water. If the pyrometer shows atypical data, do not use the equipment and contact with the designers.
	Circuit damage	If the system is not working, do not force it, do not manipulate it, contact with the designer to replace the necessary parts and effectuate the necessary corrections

| Electrical | System does not run | If the system is not running, verify the connection of the pump with the pump controller. Verify also if the system connector to the power source is well connected. If all the connections are verified and the system is still not running, do not manipulate, contact with the designers to replace the necessary parts and solve the electrical problems. |

Design, Concepts and Selections

Water heating

Table # 26: *Selection Criterion for water heating*

Weight < Operating Safety <   Precision = Cost

Requirements and criteria suggested for heating water					
CRITERIA	**Weight**	**Cost**	**Precision**	**Operating Safety**	**E+1**	**Weighted**
Weight		0	0	0	0	0,00
Cost	1		0,5	0	1,5	0,27
Precision	1	0.5		0	1	0,18
Operating Safety	1	1	1		3	0,55
				Total	**5,5**	**1,00**

Cost

Hybrid < Gain Heater < Resistance Heater

Cost analysis					
CRITERIA	Resistance Heater	Gain Heater	Hybrid	E+1	Weighted
Resistance Heater		1	1	2	0,67
Gain Heater	0		1	1	0,33
Hybrid	0	0		0	0
			Total	3	1

Weight

Hybrid < Gain Heater < Resistance Heater

Weight analysis					
CRITERIA	Resistance Heater	Gain Heater	Hybrid	E+1	Weighted
Resistance Heater		1	1	2	0,67
Gain Heater	0		1	1	0,33
Hybrid	0	0		0	0
			Total	3	1

Beer Bottle Rack

Table # 27: *Criteria applied for the selection of beer bottle rack*

Cost > Size > Precision > Weight = Operating Safety

Requirements and criteria suggested for Beer Bottle Rack							
CRITERIA	Cost	Size	Precision	Weight	Operating Safety	E+1	Weighted
Cost		1	1	1	1	4	0,4
Size	0		1	1	1	3	0,3
Precision	0	0		1	1	2	0,2
Weight	0	0	0		0,5	0,5	0,05
Operating Safety	0	0	0	0,5		0,5	0,05
					Total	10	1

Table # 28: *Conclusion of the selection of the Rack*

Conclusion							
CRITERIA	Cost	Size	Precision	Weight	Operating Safety	E+1	Priority
Rack	0,40	0,00	0,10	0,00	0,05	0,55	1,00
Crate	0,00	0,30	0,10	0,05	0,00	0,45	2,00
					Total	1	

Precision

Hybrid > Gain Heater > Resistance Heater

Operation precision analysis					
CRITERIA	Resistance Heater	Gain Heater	Hybrid	E+1	Weighted
Resistance Heater		0	0	0	0
Gain Heater	1		0	1	0,33
Hybrid	1	1		2	0,67
			Total	3	1

Safety

Hybrid = Gain Heater < Resistance Heater

Operation safety analysis					
CRITERIA	Resistance Heater	Gain Heater	Hybrid	E+1	Weighted
Resistance Heater		1	1	2	0,67
Gain Heater	0		0,5	0,5	0,17
Hybrid	0	0,5		0,5	0,17
			Total	3	1

Conclusion

			Conclusion			
CRITERIA	**Weight**	**Cost**	**Precision**	**Operating Safety**	**E+1**	**Weighted**
Resistance Heater	0,00	0,18	0,00	0,36	0,55	1
Gain Heater	0,00	0,09	0,06	0,09	0,24	2
Hybrid	0,00	0,00	0,12	0,09	0,21	3

Pipe Selection

Table # 29: *Criteria applied for the selection of the piping system*

Weight < Cost < Thermal Conductivity					
Table 15: Requirements and criteria suggested for pipes					
CRITERIA	Weight	Cost	Thermal Conductivity	E+1	Weighted
Weight		0	0	0	0,00
Cost	1		0	1	0,33
Thermal Conductivity	1	1		2	0,67
			Total	3	1,00

Table # 30: *Conclusion of the piping system selection*

Conclusion					
Table 19: Conclusion					
CRITERIA	Weight	Cost	Thermal Conductivity	E+1	Weighted
Stainless Steel	0,00	0,00	0,67	0,67	1
Copper	0,00	0,33	0,00	0,33	2

Engineering Analysis

Milestone #1: Bottle-holder rack design

Problem: The structural basket has 24 cavities for holding different size glass bottles for their washing process. The basket holds the beer bottle by their upper part, since there are placed upside down. The bottom of the bottle is hold by another adjustable bar in the top of the basket, this way the bottle is secured for the washing process. It is necessary to analyze if the basket design is the appropriate for the process, since it must support the loads and the stresses produced by them on and off the procedure.
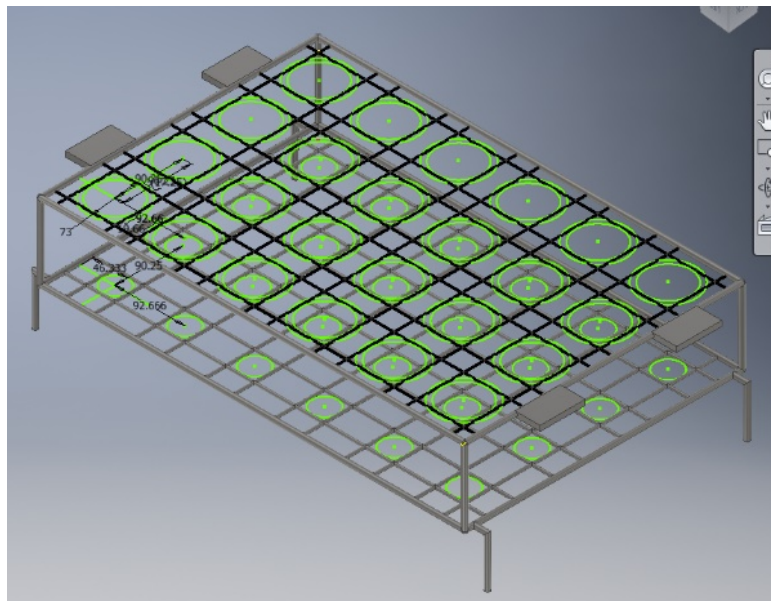
Figure # 36: Bottle holder basket

For the analysis the lower bars, which support the bottle weight during the process, will be analyzed for the most critical situations. This scenario will be when the entire bottle is supported by only one of the bars -the bottle normally should be supported in 4 points, two in the bars located lengthwise and two located breadthways the basket. The bar located lengthwise is the one chosen for the analysis due to it is longer and holds more

bottles tan the one located breadthways. Also, the spaces where the upper part of the bottle is located are more spaced in lengthwise than Breadthways.
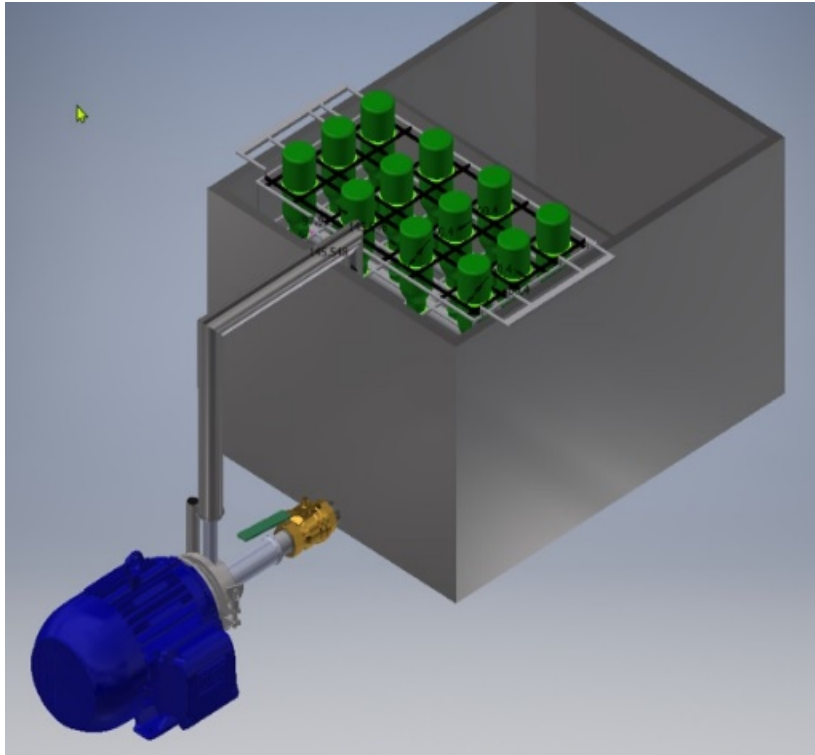
Figure # 37: Final Assembly

Also, the analysis will be done at the moment the basket is in more stress and this is when the system is off, but the basket is charged with bottles. This is because when the system is on the water or caustic soda jet pumped into the bottle will relieve, in a small scale, the weight of the bottle from their supporting points.

Known:

Material: Stainless Steel AISI 304

$F_Y = 205 \ [MPa]$

$r = 3,5 \ [mm]$ (still bar radius)

$$w_{bottle} = w_b = 83 \ [N]$$

Procedure:

Simplified System:
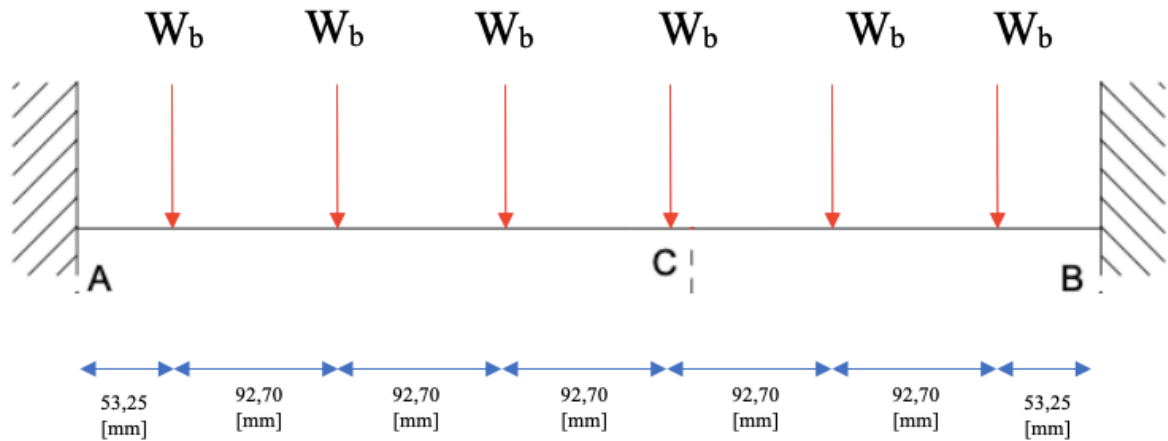
Figure # 38: Simplified structural system

Free body Diagram:
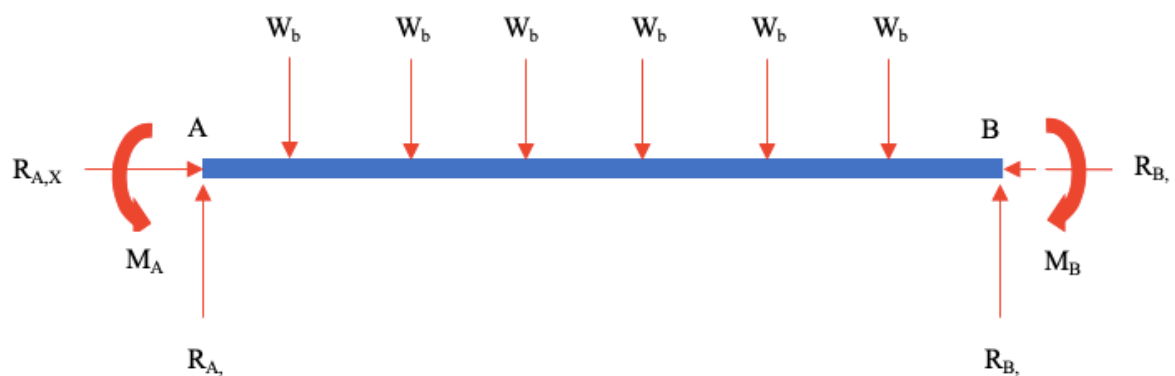
Figure # 39: Simplified structural system's free body diagram

Since there are no forces in the x-axis direction:

$$R_{A,x} = R_{B,x} = 0 \ [N]$$

Due to symmetry:

$$R_{A,y} = R_{B,y}$$

$$M_A = -M_B = M$$

After force analysis:

$$\sum F_y = 0$$

$$R_{A,y} = R_{B,y} = 11{,}49 \ [N]$$

The overlay method is applied. This method helps simplify the analysis for the bar, this way we can divide the initial system into the equivalent sum of different equivalent-sub systems. The following equivalation is made:
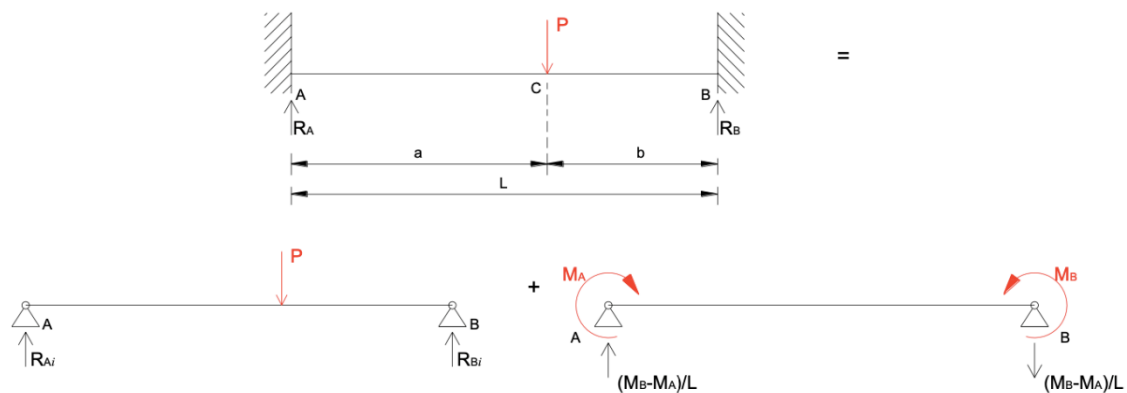
Figure # 40: Equivalent system for a beam fixed at both ends

Figure # 49 Figure # 40 shows the equivalent system for a beam fixed at both ends and with a force applied at any distance in the beam length. Since the structural system has been simplified to a beam fixed at both ends with six forces located at some point of the beam, the system can be analyzed as follows:
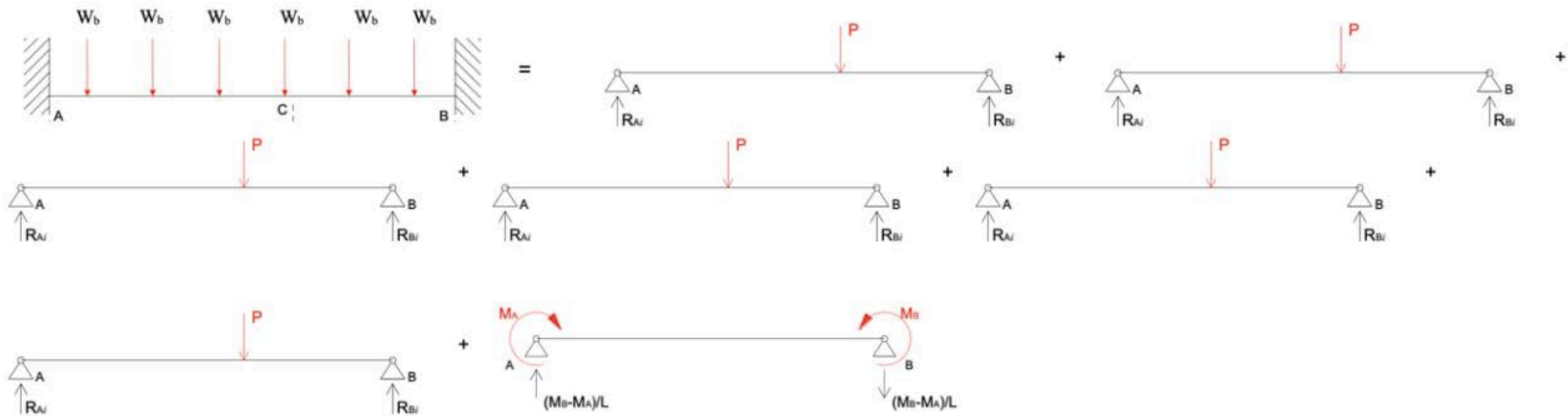
Figure # 41: Decomposition into sub-systems for the analyzed beam

Each of these systems has a same magnitude force **"W$_b$"** applied at a different distance **"a"** distance from the end **"A"** and a **"b"** distance of the end **"B".** As the ***Figure # 41*** shows a sum of 7 sub-systems, six simple supported beam systems with one force applied and a simple supported beam with momentum at both ends, are needed emulate the original beam to be analyzed. The first 6 systems are very similar to each other and they only differ by the distances **"a"** and **"b"** where the load is applied

For all the systems:

$$L = 570 \times 10^{-3} \ [m]$$

$$P = w_b = 3{,}83 \ [N]$$

For case **[1]**

$$\mathbf{a} = 53{,}25 \times 10^{-3} \ [m]$$

$$\mathbf{b} = 516{,}75 \times 10^{-3} \ [m]$$

For case **[2]**

$$\mathbf{a} = 145{,}95 \times 10^{-3} \ [m]$$

$$\mathbf{b} = 424{,}05 \times 10^{-3} \ [m]$$

For case **[3]**

$$\mathbf{a} = 238{,}65 \times 10^{-3} \ [m]$$

$$\mathbf{b} = 331{,}35 \times 10^{-3} \ [m]$$

For case **[4]**

$$\mathbf{a} = 331{,}35 \times 10^{-3} \ [m]$$

$$\mathbf{b} = 238{,}65 \times 10^{-3} \ [m]$$

For case **[5]**

$$\mathbf{a} = 424{,}05 \times 10^{-3} \ [m]$$

$$\mathbf{b} = 145{,}95 \times 10^{-3} \ [m]$$

For case **[6]**

$$\mathbf{a}= 516{,}75 \times 10^{-3} \; [m]$$

$$\mathbf{b}= 53{,}25 \times 10^{-3} \; [m]$$

The literature gives, for each sub system the specific formula for the momentum at "*A*" and "*B*", as it follows:

$$M_A = \frac{-Pab^2}{L^2}$$

$$M_B = \frac{-Pa^2 b}{L^2}$$

Since the momentum at **A** and **B** will be the same due symmetry "***M_A***" is picked to be calculated. Making the respective calculation, each momentum is gotten as it follows:

Case **[1]:**

$$M_{A,1} = -0{,}168 \; [N.m]$$

Case **[2]:**

$$M_{2,2} = -0{,}309 \; [N.m]$$

Case **[3]:**

$$M_{2,3} = -0{,}309 \; [N.m]$$

Case **[4]:**

$$M_{2,4} = -0{,}222 \; [N.m]$$

Case **[5]:**

$$M_{2,4} = -0{,}106 \; [N.m]$$

Case **[6]:**

$$M_{2,4} = -0,017 \, [N.m]$$

This way, using the first equality relation we have that:

$$M_A = M_B = M = M_{2,1} + M_{2,2} + M_{2,3} + M_{2,4} = -1,131 \ [N.m]$$

$$|M| = 1,131 \ [N.m]$$

Having the value of the momentum at the fixed points it's possible to calculate the stress at this point points using the following equation:

$$\sigma = \frac{|M|}{S}$$

Where **S** is the section modulus. Since the section modulus for a bar is a circulus:

$$S = \frac{\pi r^3}{4}$$

$$S = 3,37 \times 10^{-8} [m]$$

$$\therefore \ \sigma_m = 33,59 \ [MPa]$$

Now with both, the maximum stress in the bar and the yield strength of the material, it is possible to calculate the safety factor for the design system:

$$\eta = \frac{F_y}{\sigma_m}$$

$$\eta = 6,1$$

Since the most critical element in the structural system was analyzed and since the safety factor found in the analysis is bigger than 6; it is possible to observe that the structural element is not a critical one in the entire system design. In fact, for this design is possible to reduce de geometry dimensions of the bars and it would still be a reliable design, reducing weight and costs, both very important parameters discussed before in the report.

Milestone #2: *Water Heating*

Problem: For Designing a Bottle Washing, it must heat the water contained in the thank considering that at the beginning, the water will be between 15 °C – 18 °C (**Hint:** consider an average temperature of 16.5 °C). However, that water should be heated up to 90 °C before start recirculating. Once it recirculates along the piping, you have to ensure that after getting out of the nozzle, water should be at least at 75 °C in order to follow Sanitizing Standards. With this in mind, consider that water heating will be made by a commercial electrical resistance and provide a calculation for heat transferred on the system.

Known:

$$T_{F_{Water}} = 90 \,°C$$

$$C_{P_{Water}} = 4.186 \, \frac{kJ}{kg \, K} \, (@ \, 1 \, atm)$$

$$\forall_{water} = 83.52 \, L \quad (assuming \ height \ of \ 40 \ cm)$$

$$t_{preheating} = 40 \, min$$

$$\rho_{water} = 998.84 \, \frac{kg}{m^3}$$

Assumptions:

$$T_{0_{Water}} = 15 \,°C - 18 \,°C \, (\textbf{Avg: } 16.5 \, °C)$$

$$\textbf{\textit{Pressure}} = 1 \, atm$$

Constant Properties

➤ **Heat needed for Preheating:**

Heat needed for preheating water from **16.5 °C** to **90 °C,** can be estimated by using this equation:

$$\boldsymbol{Q} = m\left(C_p \right) (\Delta T)$$

$$\boldsymbol{\rho} = \frac{m}{\forall_{water}}$$

$$\boldsymbol{m} = \boldsymbol{\rho} \left(\forall_{water} \right)$$

$$\boldsymbol{Q} = \boldsymbol{\rho} \left(\forall_{water} \right)\left(C_p \right) (\Delta T)$$

$$\boldsymbol{Q} = (998.84) \frac{kg}{m^3} \, (0.0835) m^3 \, (4.186) \frac{kJ}{kg \, °C} (90 - 16.5)°C$$

$$\boldsymbol{Q} = (25666.87) \, kJ$$

➤ **Power needed for Preheating:**

Power needed for preheating water from **16.5 °C** to **90 °C,** can be estimated by using this equation:

$$\dot{\boldsymbol{Q}} = \frac{Q}{t}$$

$$\dot{\boldsymbol{Q}} = \frac{(25666.87)kJ}{(3600) \, s}$$

$$\dot{\boldsymbol{Q}} = (7.13)kW$$

➢ **Simulation**

<u>Steady State</u>

In order to do the simulation of Water Heating, the Beer Bottle Washing Machine Design was moved to **Autodesk Fusion 360**. Using this software, a New Body for the Water and the
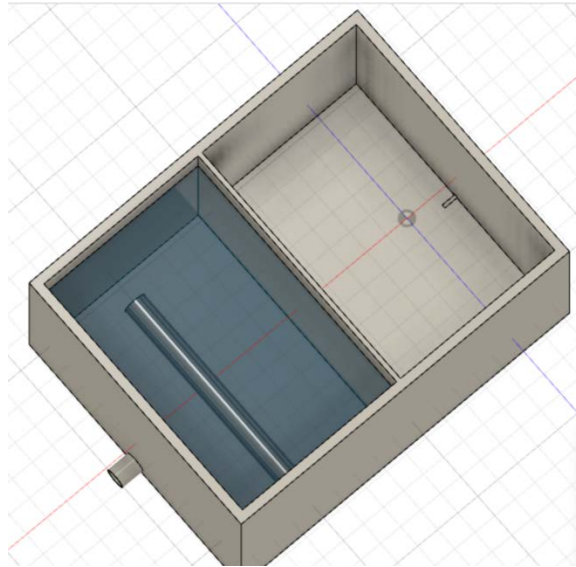
Heating Element had to be drawn. It is important to say that all the other elements that do not act during the preheating of water were removed. The results got can be seen as follows:
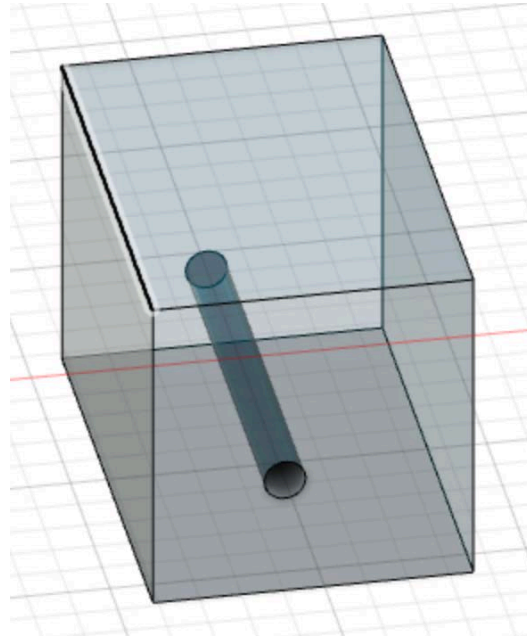
Figure # 42: Water body drawn for simulation Analysis

The Heating Element was simulated as a Cylinder with a ***Diameter*** of **2.54 cm** and a ***Height*** of **25 cm.** This because the Stainless-Steel Resistance found in the Ecuadorian Market has this specifications. However, it is J Shaped and it is formed by some other small tubes, but it is a good approximation if a cylinder is used. Specially because the Heat input will be the same independent of how the heating element is shaped.
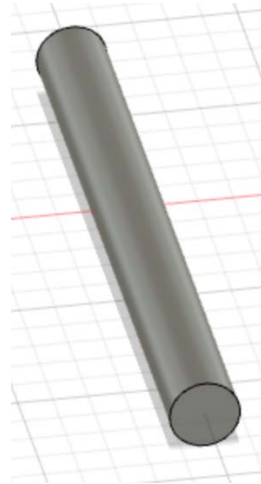
Figure # 43: Heating Element Drawn for Simulation Analysis

The Material Properties used for all the elements used during Simulation were chosen from

Autodesk Fusion 360 Library, as follows:

Water Thank: Stainless Steel
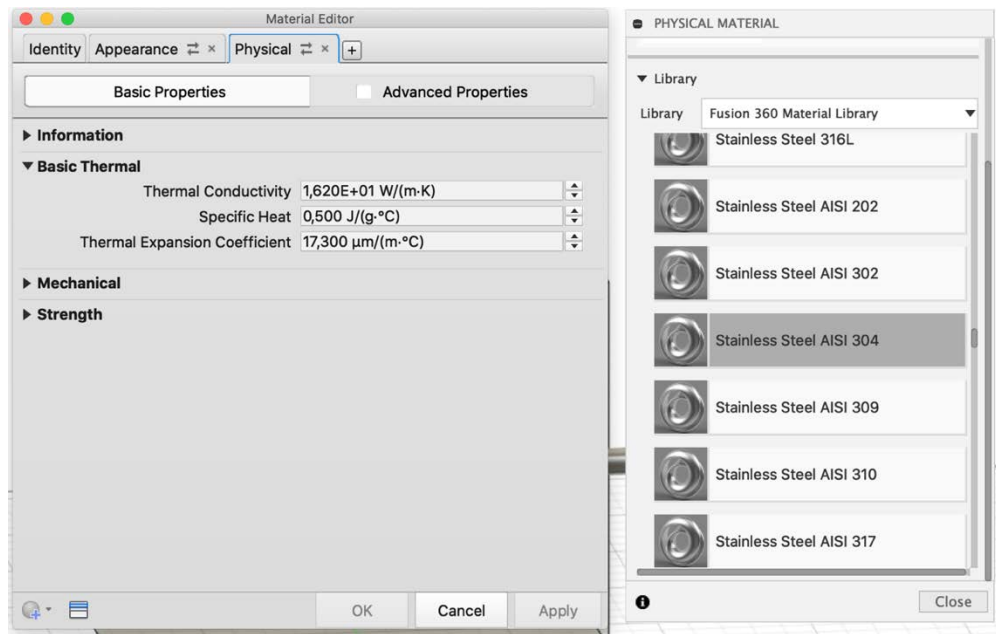
Figure # 44: Stainless Steel Properties used during Simulation

Water:
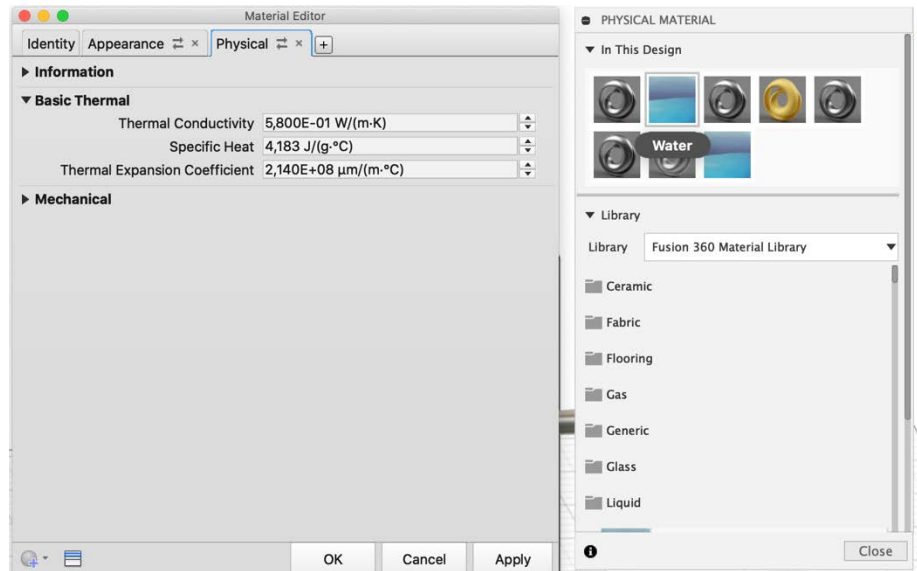
Figure # 45: Water Properties used during Simulation

For simulating the Water Heating, there were some inputs entered, as follows:
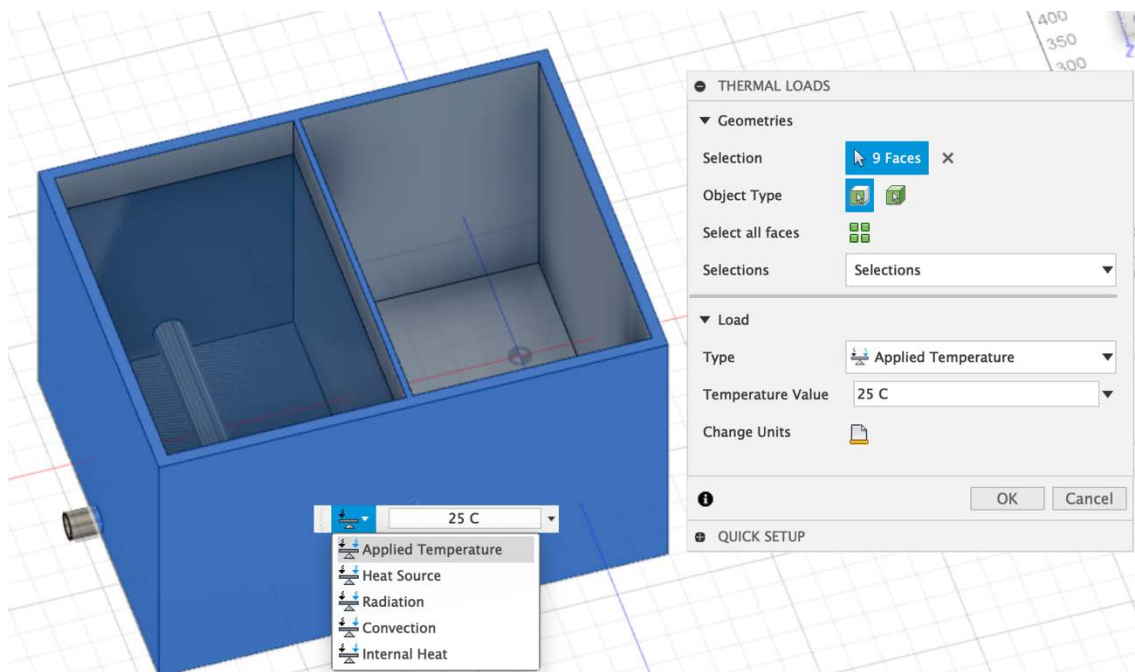
Figure # 46: Water Tank (Top View) was supposed to be at Room Temperature
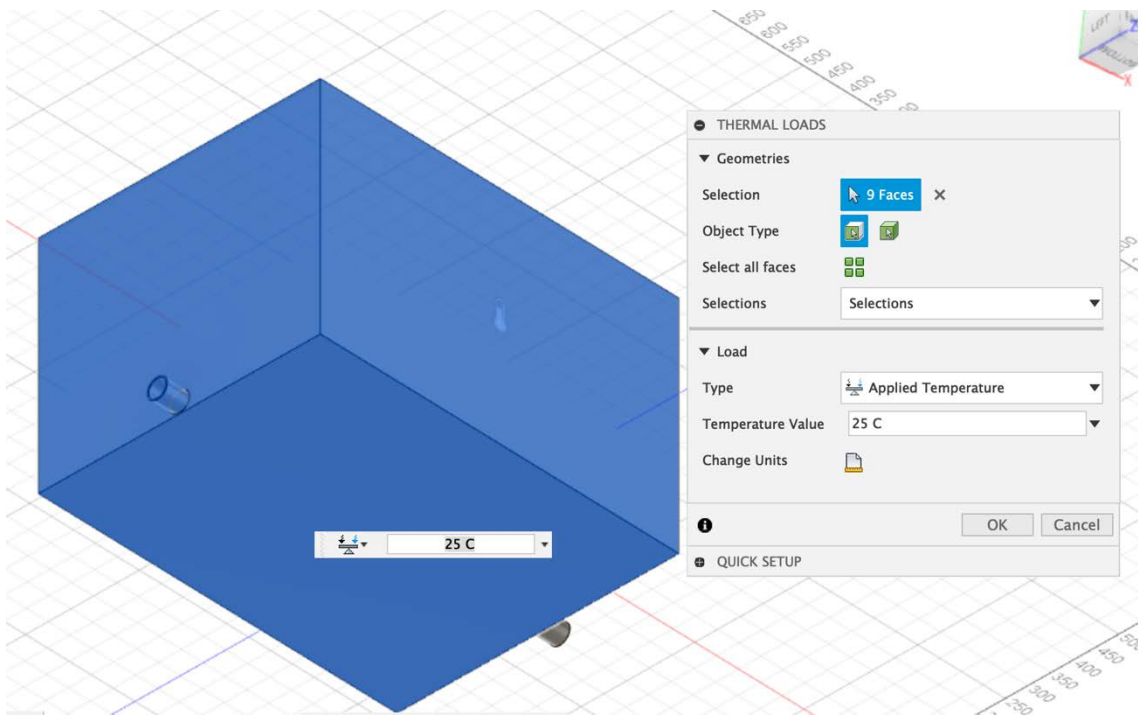
Figure # 47: Water Tank (Isometric View) was supposed to be at Room Temperature
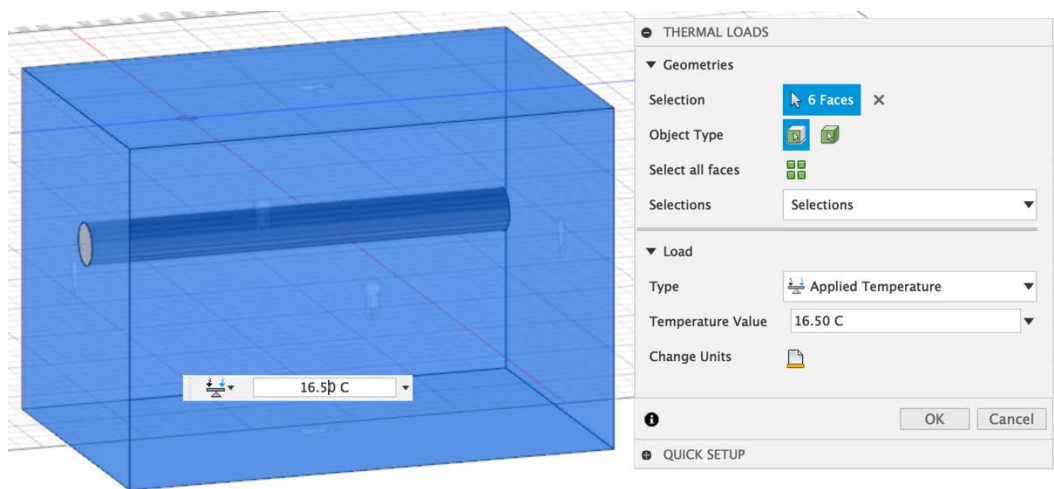
Figure # 48: Water was supposed to be at an average Temperature of 16.5 C
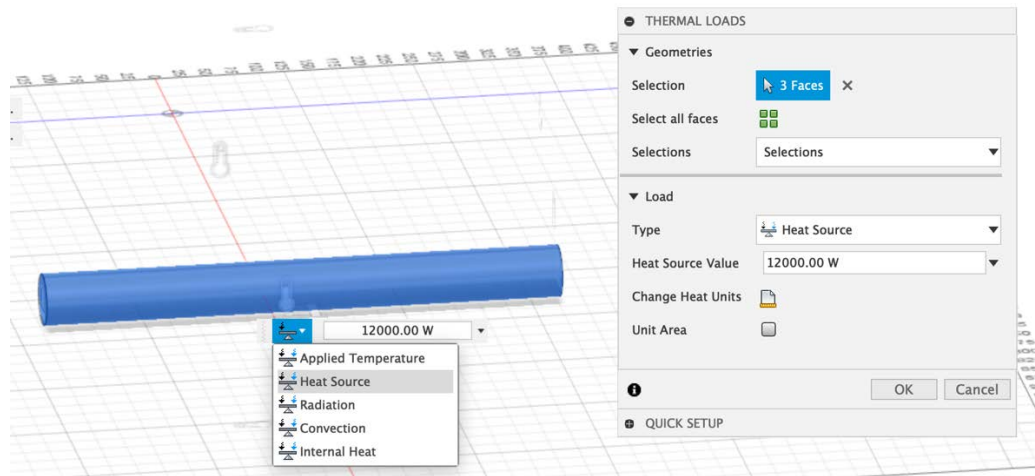
Figure # 49: The Heating Element was supposed to give 12 kW to the System

The mesh was automatically generated by the System as can be seen in the following picture:
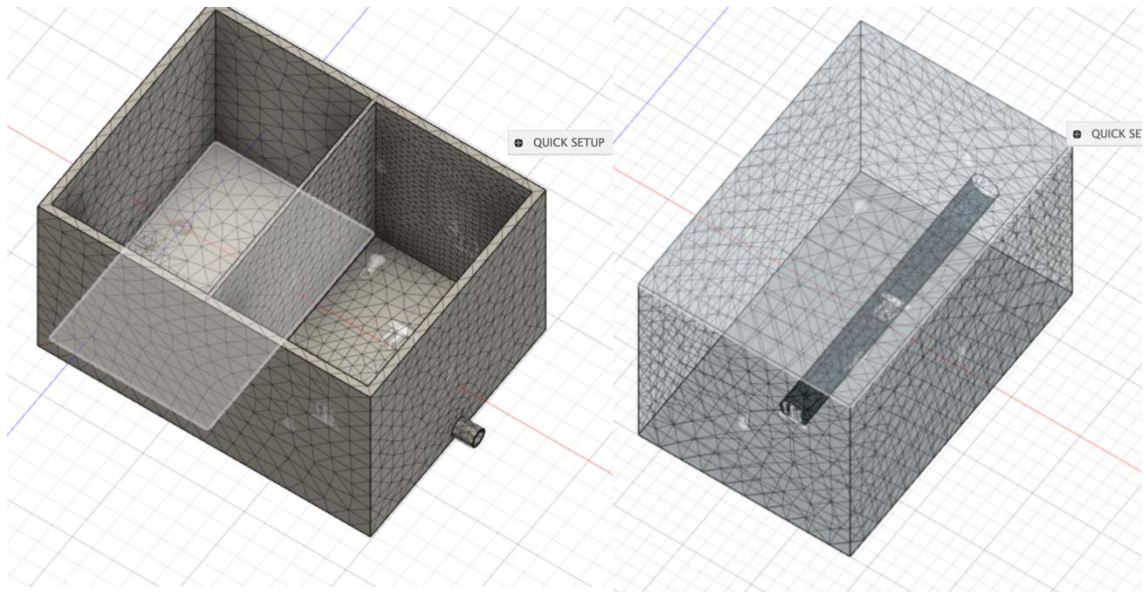
Figure # 50: Mesh generated by the Software

Applying previous Inputs, the results got for **Steady State** are as follow
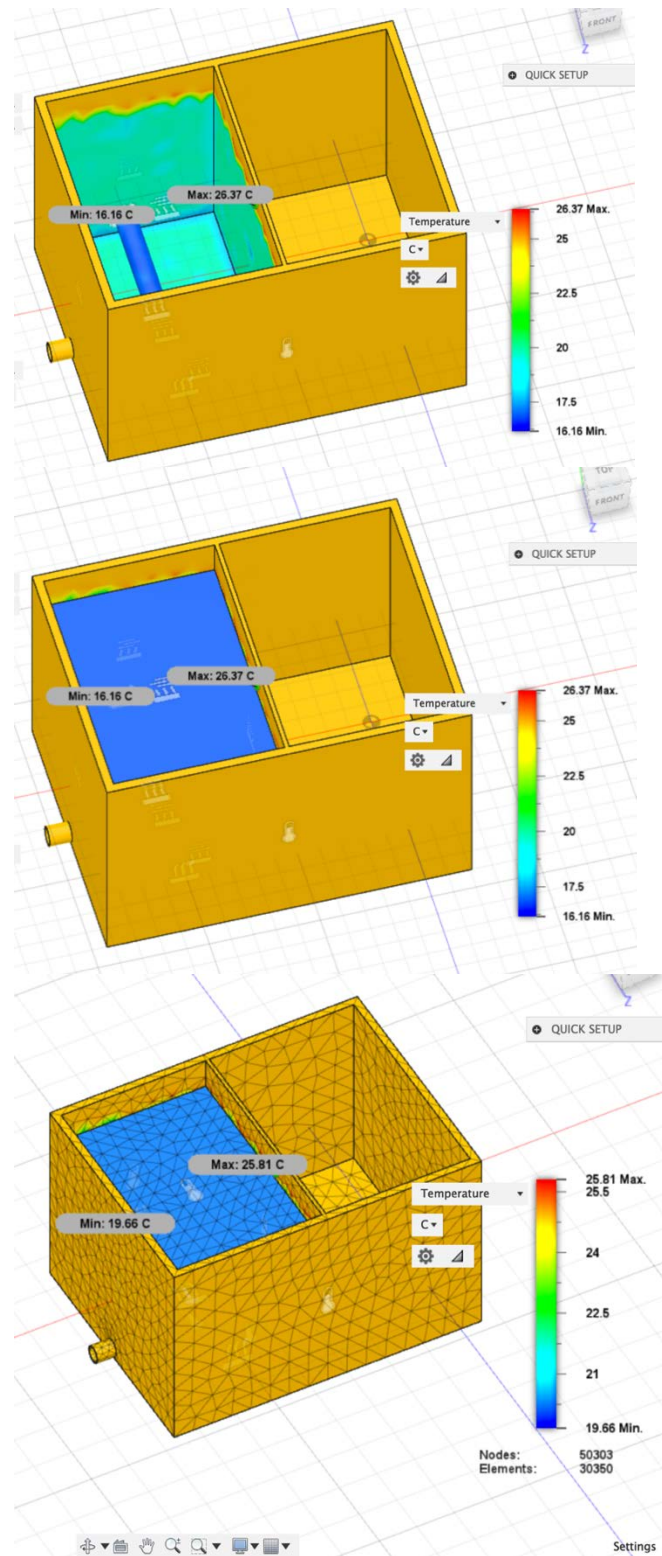
If the Inputs for the water are changed, in order to simulate convection of water with

standard properties, *Figure # 51:* Results got from Simulation
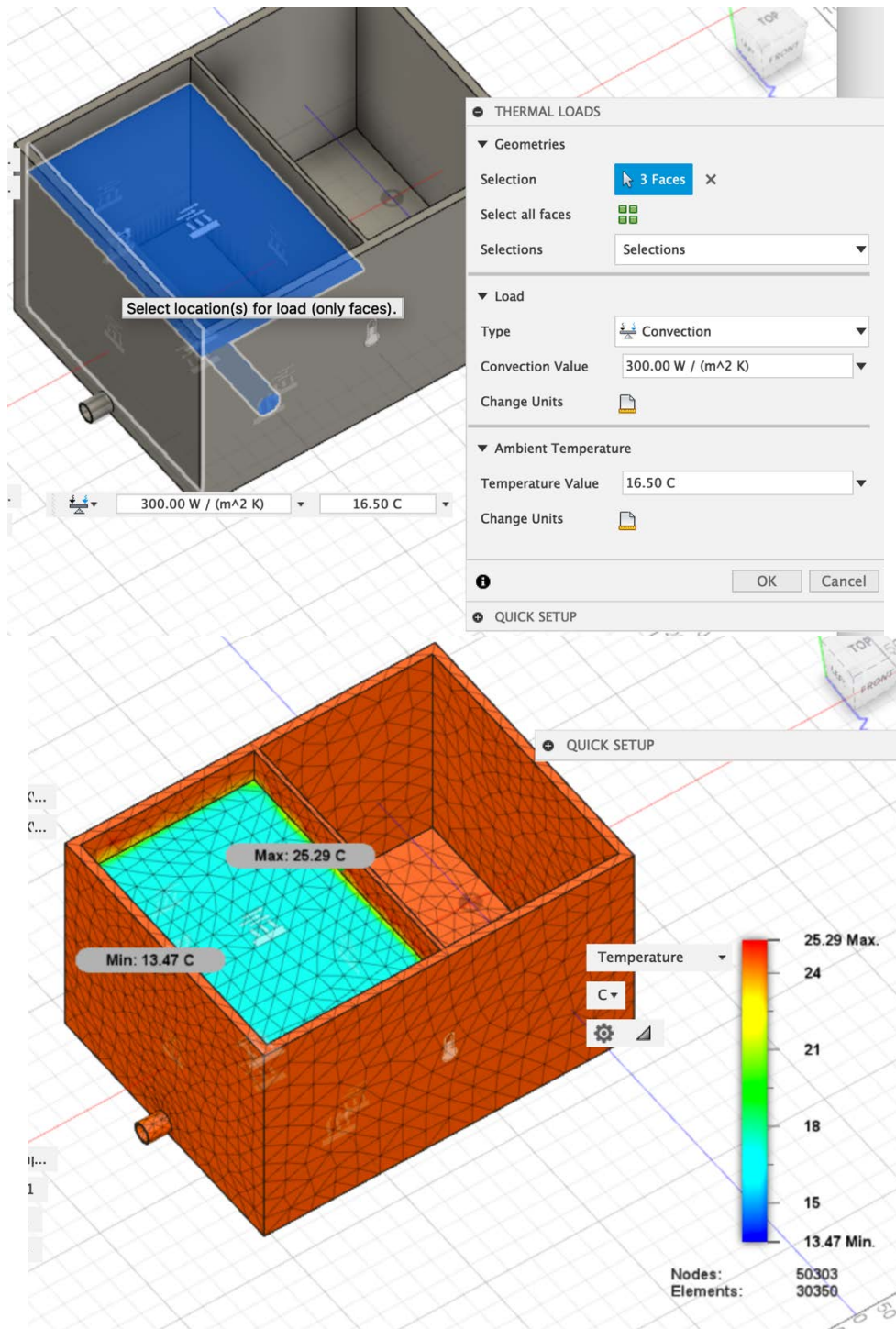
Figure # 52: Results got after using convection of water

As it can be seen in the results got during the simulation of the Water Heating, the water is not heated enough even using a **12 kW** Stainless Resistance, as it was supposed from the previous analyzes. This is why, a coil induction system was suggested in the **DESIGN FOR MANUFACTURING** Section.

<u>Transient State</u>

When trying to do the simulation for Transient State, **ANSYS FLUENT** was used with the same conditions described before. After running the simulation Considering a Single-Phase case, there was an error after 52 Seconds. This error was caused because the water film near the Heating Element evaporates as soon as the Resistance starts to put some power in the system. So, as the simulation considered a single-phase system because that was the only one learned during class, the error was caused and results cannot got.
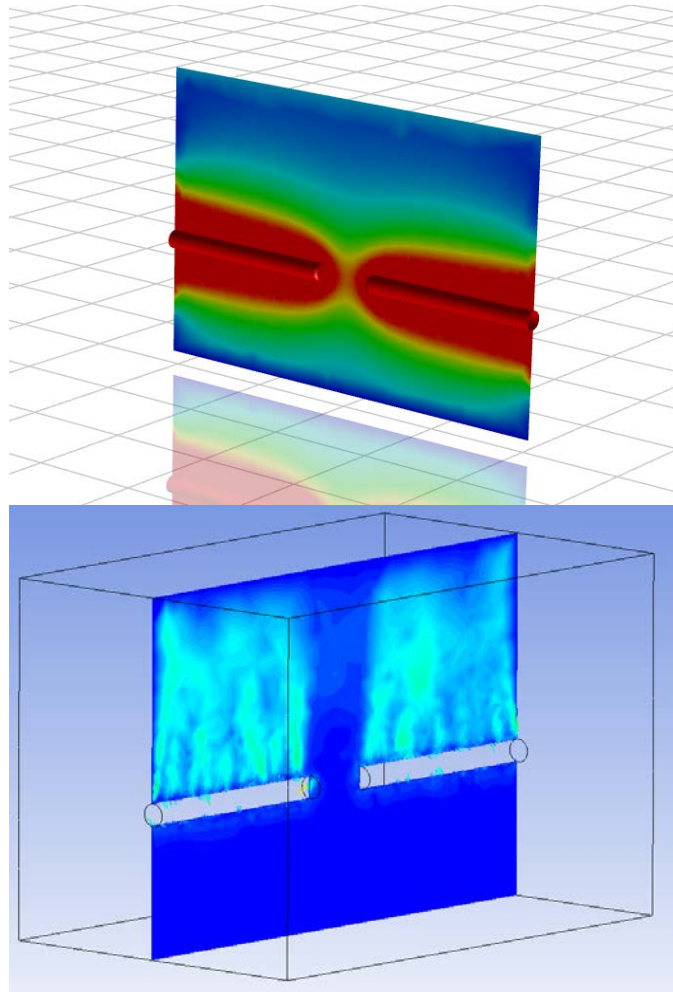
Figure # 53: Error caused due to the consideration of Single Phase Simulation.

Heat Loss during Water Recirculation

For determining the Heat Loss during Water Recirculation, a simulation using **ANSYS FLUENT** was performed. For this, it was necessary to Create a watertight Geometry from the 3D model of the Beer Bottle Washing Machine.
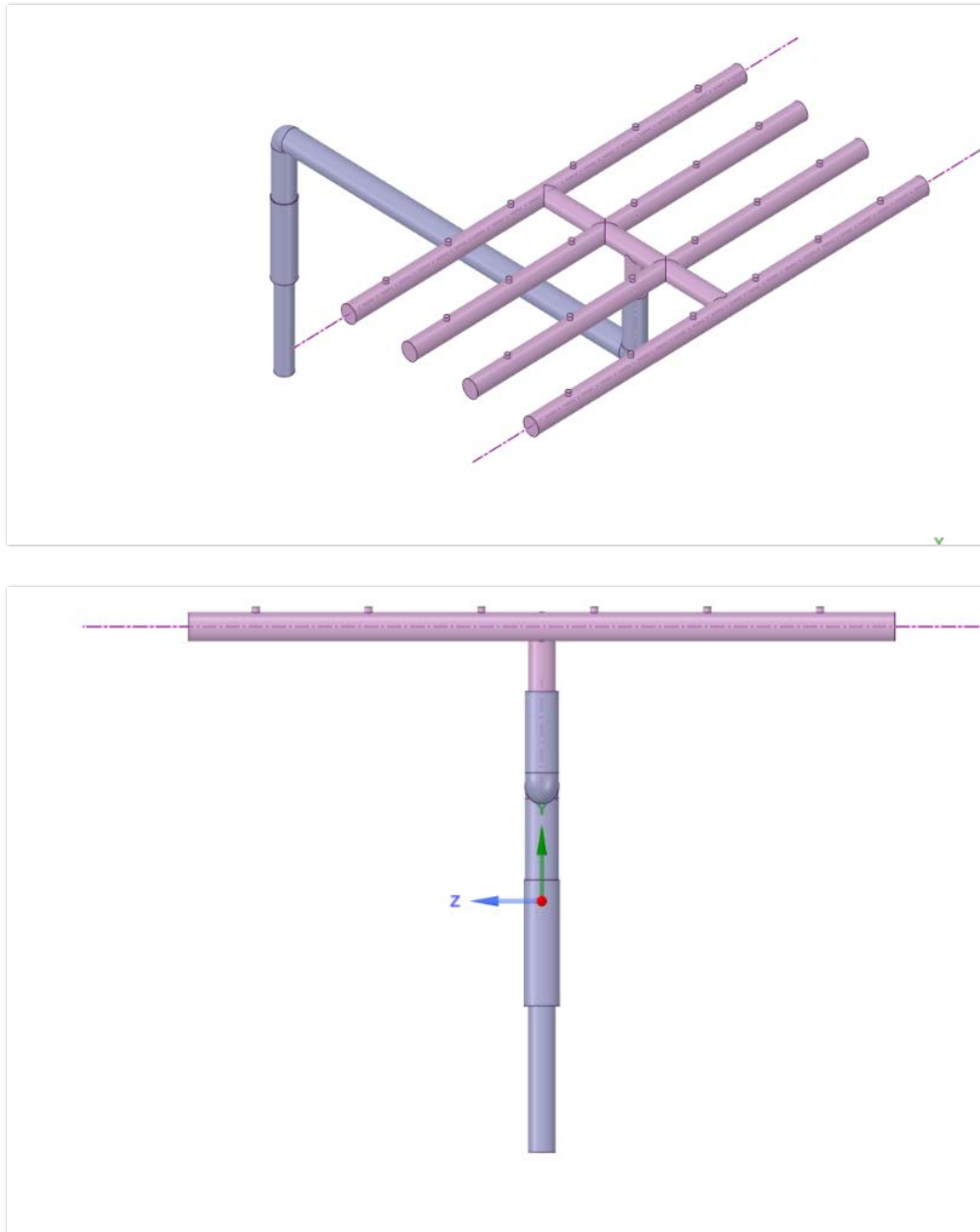
Figure # 54: Watertight Geometry created from the CAD files

The Stainless-Steel Material Properties used during the simulation of the water tank were also used for the Simulation of the Piping System as it will be made from Stainless Steel. These Properties are as follows:

Piping System: Stainless Steel
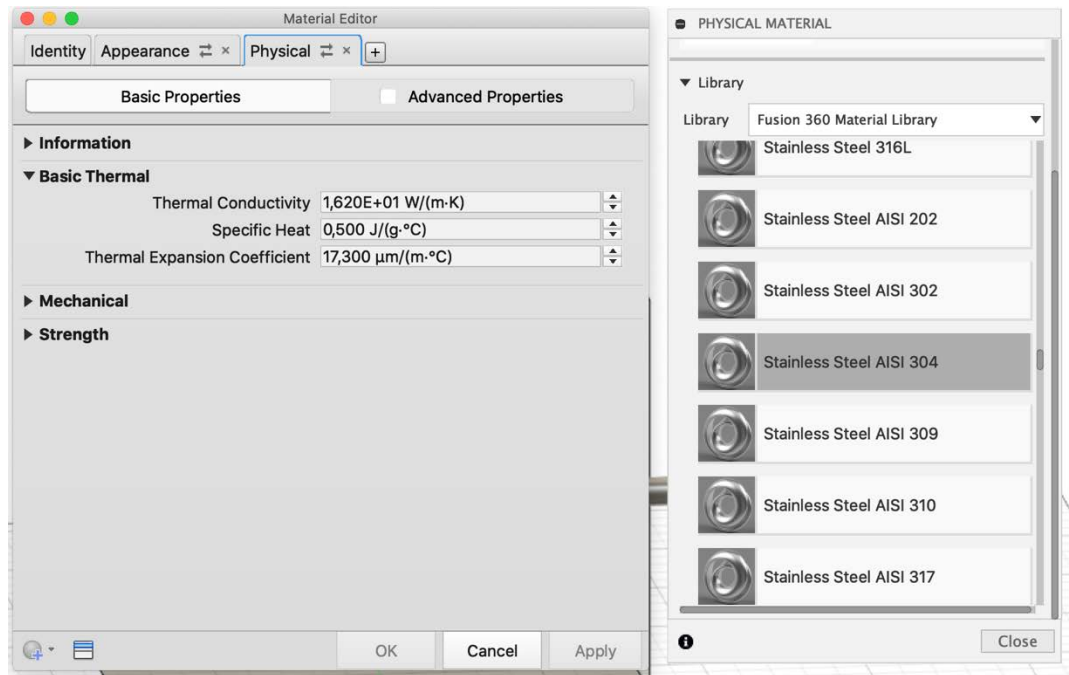
Figure # 55: Stainless Steel Properties used during Simulation of the Water Distributor System

The properties of the water used during the simulation of the Piping System were the same as the ones presented in *Figure # 46*. The Boundary Conditions used for this simulation were taken from the results got in the Section .

Milestone #4: Pressure drops and losses *inside the* pipe. These conditions are described

as follows:

- *Inlet Flow* from the pump = **151.04** [L/min]

- *Flow velocity* at Inlet = **27.24** [m/s]

- *Heat Transfer* to the surroundings from the steel pipes = **25** [W/m^{2}K]

- *Average Temperature* in the Surroundings= **295.65** [K]

- *Average Pressure* in the Surroundings = **0.715** [atm]

The Properties for the Fluid used for this simulation were taken from Chemical Engineering

Essentials (Huitt, 2008) and they are described as follows:

- *Density* of the Water = **1031.07** [kg/m^3]

- *Viscosity* of the water = **0.97804** [mPas]

- *Specific Heat* was chosen as a constant = **4182** [kJ/kgK]

- *Surface Roughness of Wall =* **0.001211**

A mesh was generated for the Watertight Geometry presented in *Figure # 43*. The
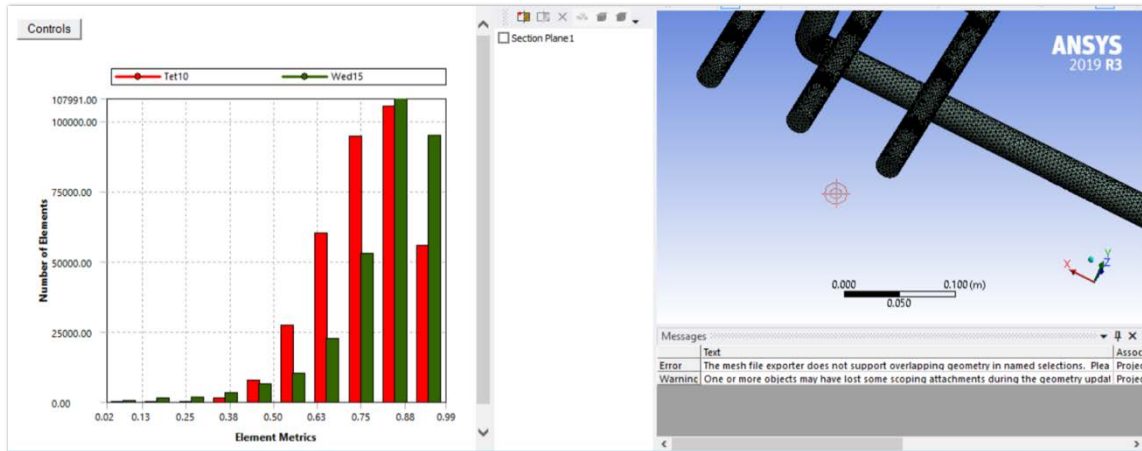
Figure # 56: Statistics of the Watertight Mesh

following statistics was obtained:

As it can be seen on *Figure # 45*, the statistics of the Watertight are converging fast when generating the mesh. This is a good signal when starting to for the simulation because it means that there are no problems with the Geometry

The final Mesh obtained was as follows:
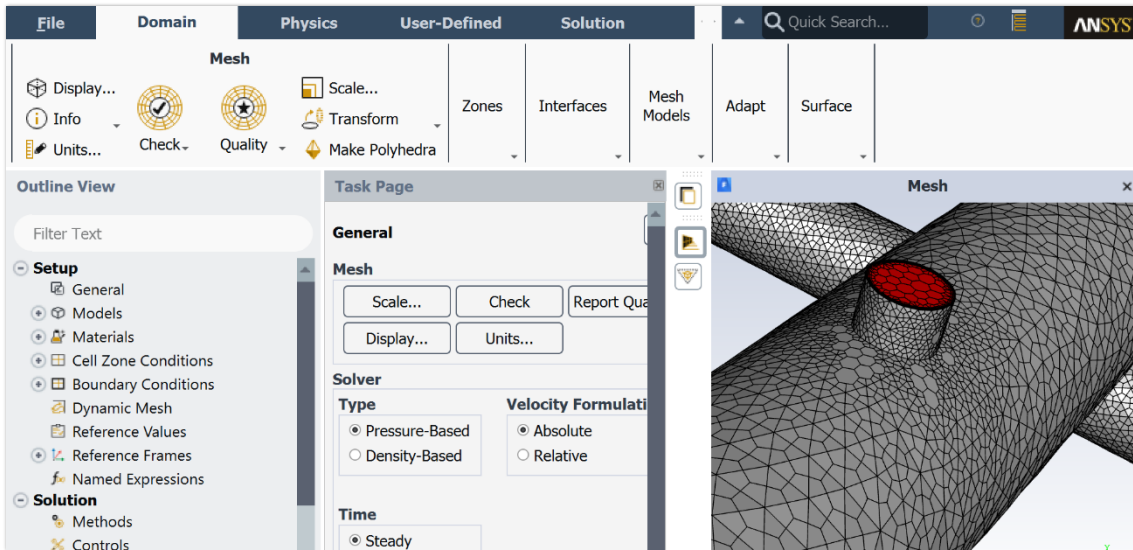
Figure # 57: Final Mesh Obtained

As it can be seen on ***Figure # 46***, the mesh generated for the Watertight is a combination of triangles and hexagons distributed in the most efficient way possible.

After running the simulation with the conditions described before, the following results were got:

Residuals after 1100 Iterations are shown below:
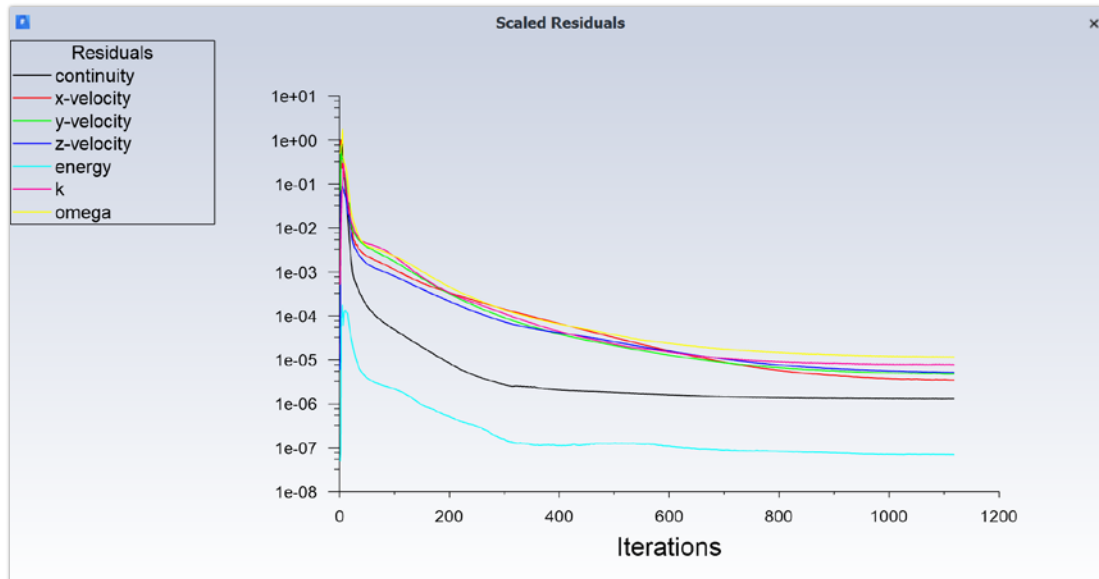
Figure # 58: Residuals after 1100 Iterations

As it can be seen on *Figure # 59*, the mesh generated for the residuals start to converge after 1100 iterations, which means that the software is finding a solution for the specific conditions of the problem.

The *Average Temperature at the Outlet* is shown below:
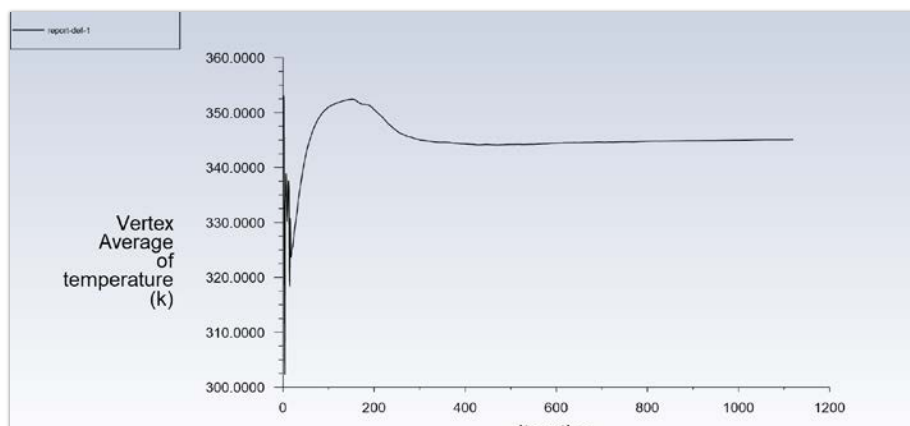
Figure # 59: Average Temperature at the Outlet

As it can be seen on *Figure # 48*, the Temperature at the Outlet doesn't change after

400

Contours of Static Temperature (k)   Apr 14, 202
                                   ANSYS Fluent 2019 R3 (3d, pbns, sstkw

thro

Fur...
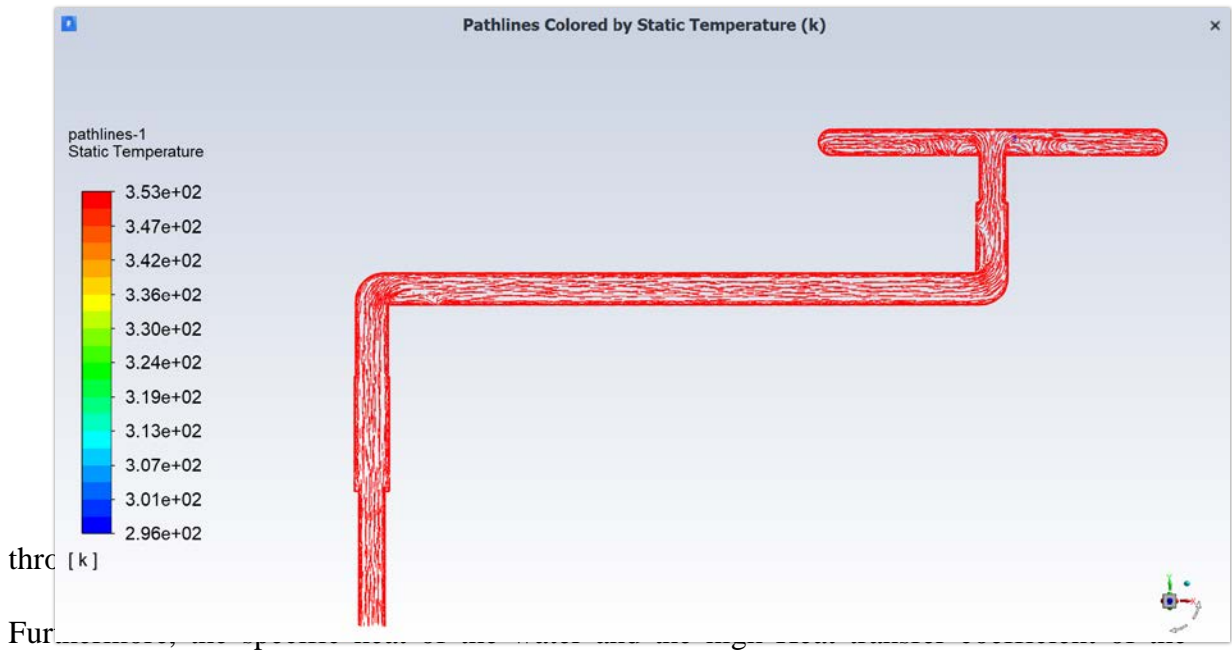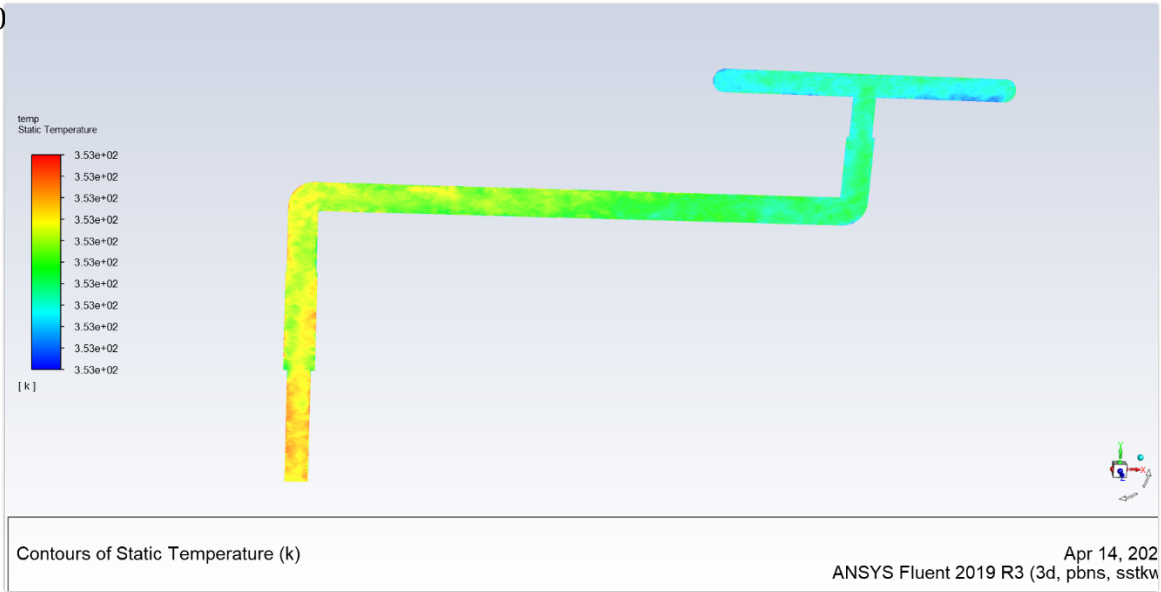
Stainless Steel make this possible
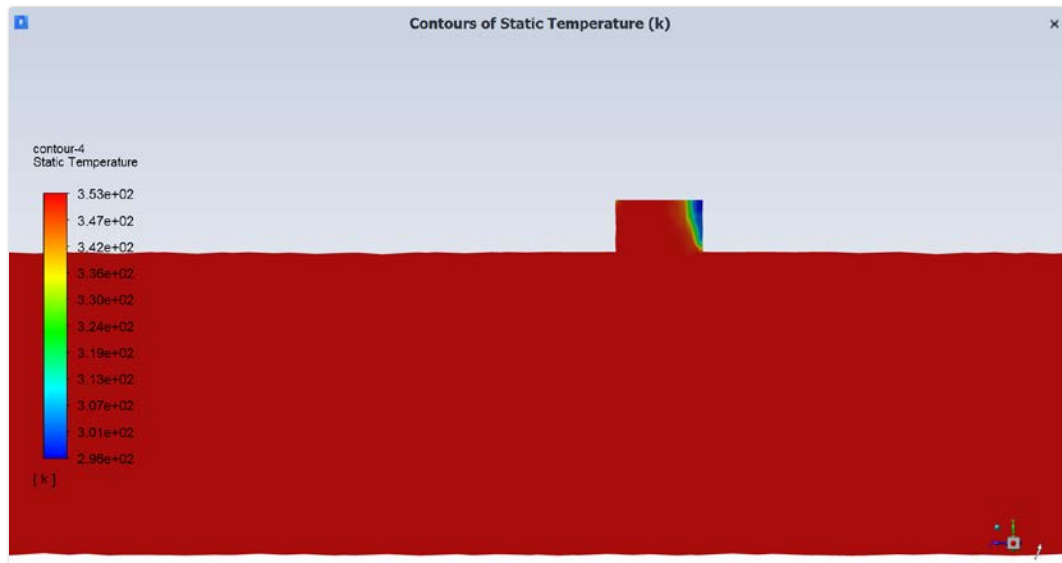
Figure # 61: Contours of Static Temperature through the Water Distributor System

As it can be seen on **Figure # 50Figure # 49**, the Temperature of the Fluid is almost the same through the Water Distributor System. The temperature experiments a little decrease near the nozzle because in this part there are atmospheric conditions and a Temperature Variation. However, this difference is not that high and lets the fluids to stand at the desired temperature.
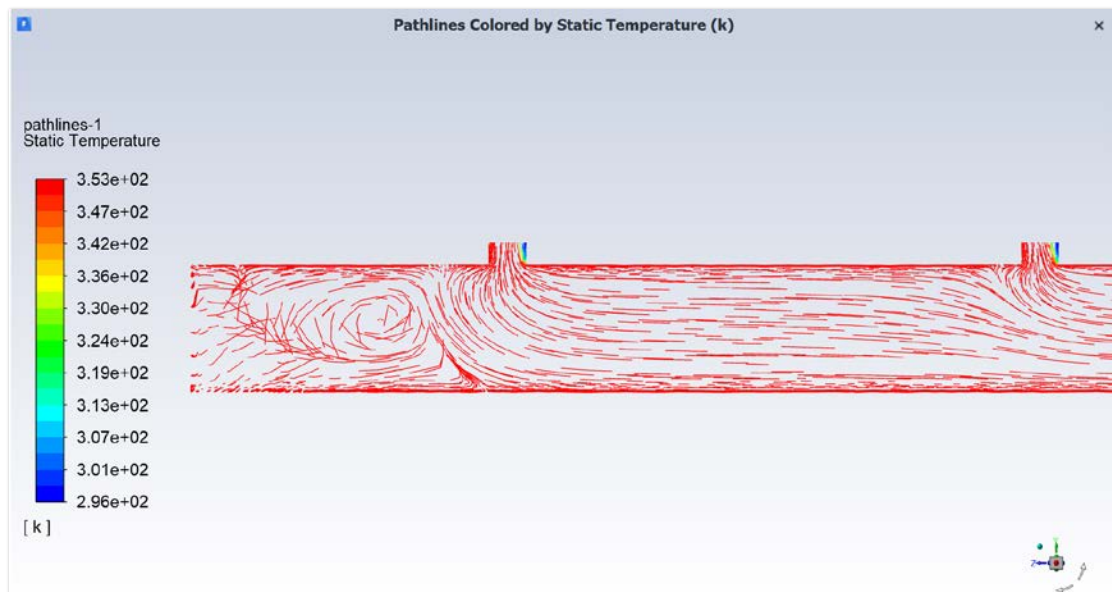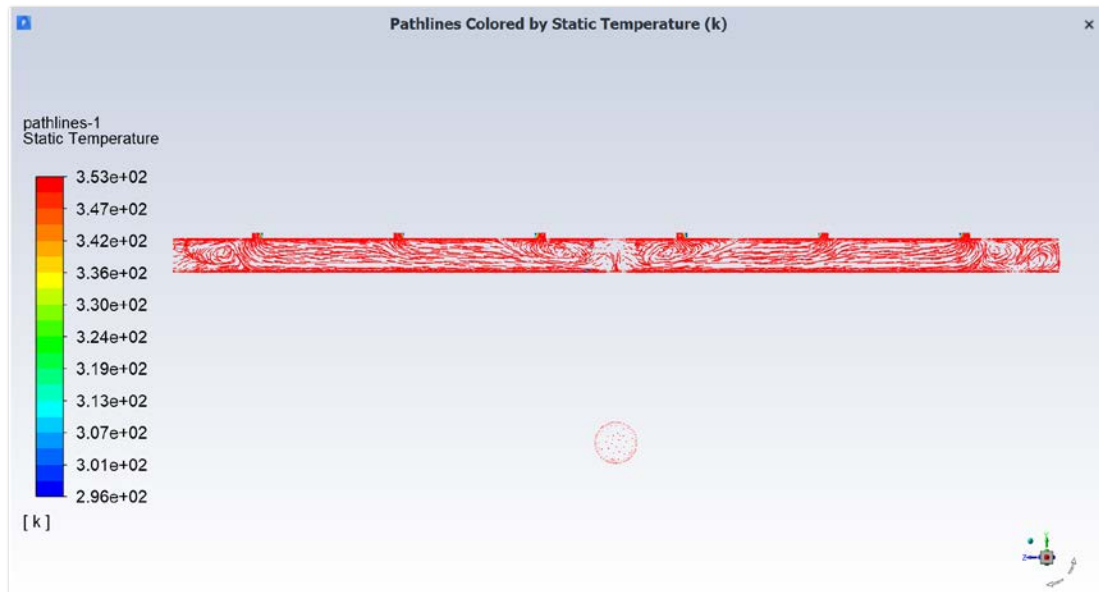
Figure # 62: Pathlines of Static Temperature through the Water Distributor System

As it can be seen on *Figure # 51Figure # 50Figure # 49*, the Temperature of the Fluid is almost the same through the Water Distributor System even tough that this fluid is running at high velocity and high pressure.
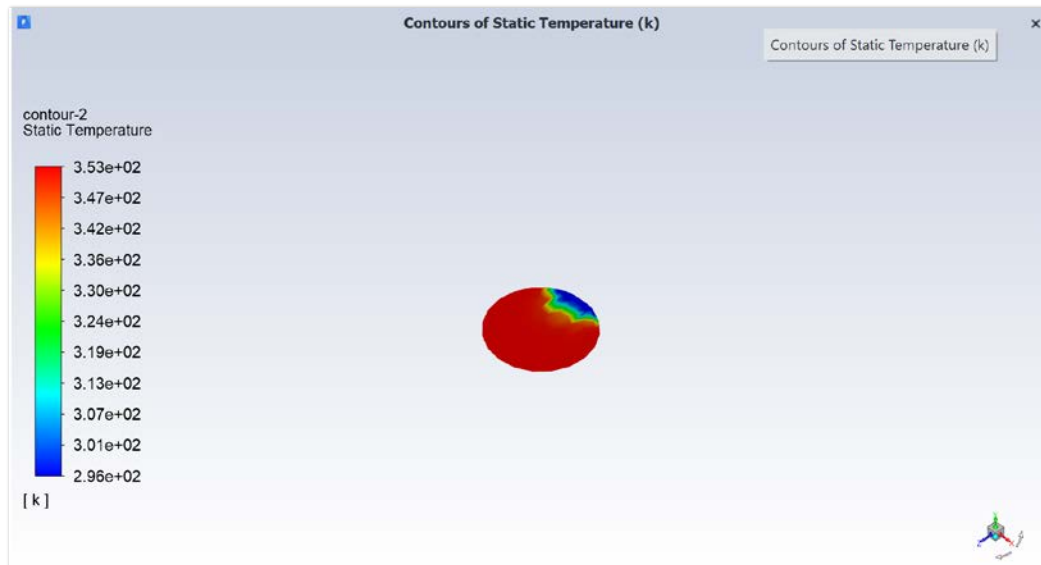
Figure # 63: Average Temperature at the Outlet

As it can be seen on **Figure # 52***Figure # 50Figure # 49***,** the Temperature of the fluid at the outlet is uniformly except for the part near the exit. This because that spot is formed mostly by air due to the high velocity of the water at reaching the nozzle.

The *Average Flow Rate at the Outlet* is shown below:
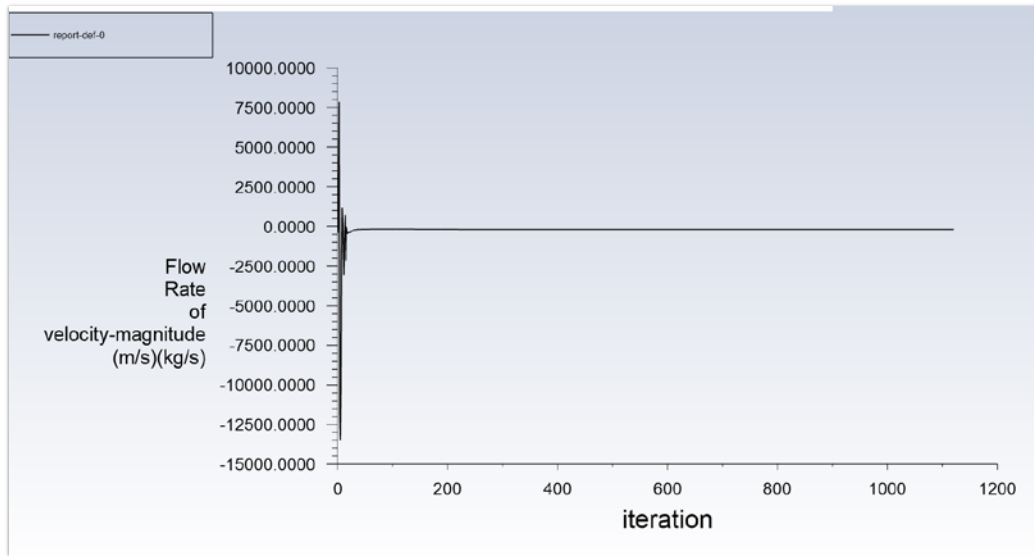
Figure # 64: Average Flow Rate at the nozzle

As it can be seen on *Figure # 53,* the Average Flow Rate at the Outlet doesn't change after 50 Iterations, which means that the problem was solved very fast.
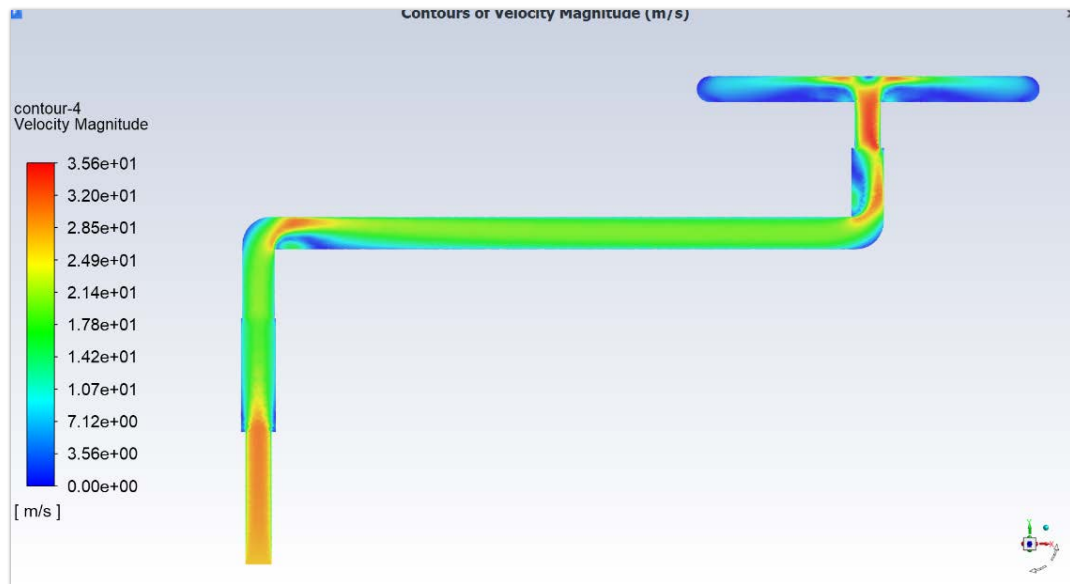
Figure # 65: Contours of Static Velocity through the Piping System

As it can be seen on *Figure # 66Figure # 49*, the Velocity of the Fluid is very high at the inlet because it is pumped up with high pressure. Then, the Fluid reaches the first elbow with lower velocity due to the losses caused by Potential Energy. After that, the fluid reaches the Water Distributor System with a lower velocity and the is pumped at the outlet. The Even though there are a lot of losses through the system, the outlet velocity of the fluid is very high. The Velocity Vectors can be seen at *Figure # 55*, where it is possible to appreciate how fast the fluid is moving through the system. For this reason, some vortices are created on the spots were the fluid changes its direction.
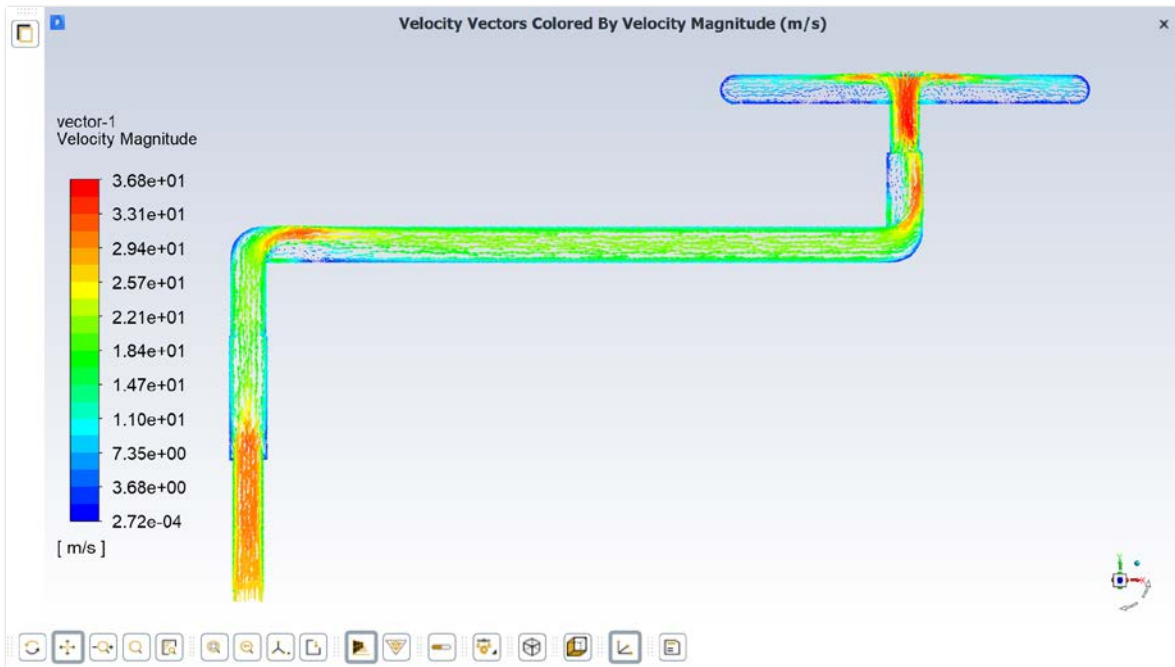
Figure # 66: Velocity Vectors through the Piping System

Figure # 67: Contours of Static Velocity through the Water Distributor System
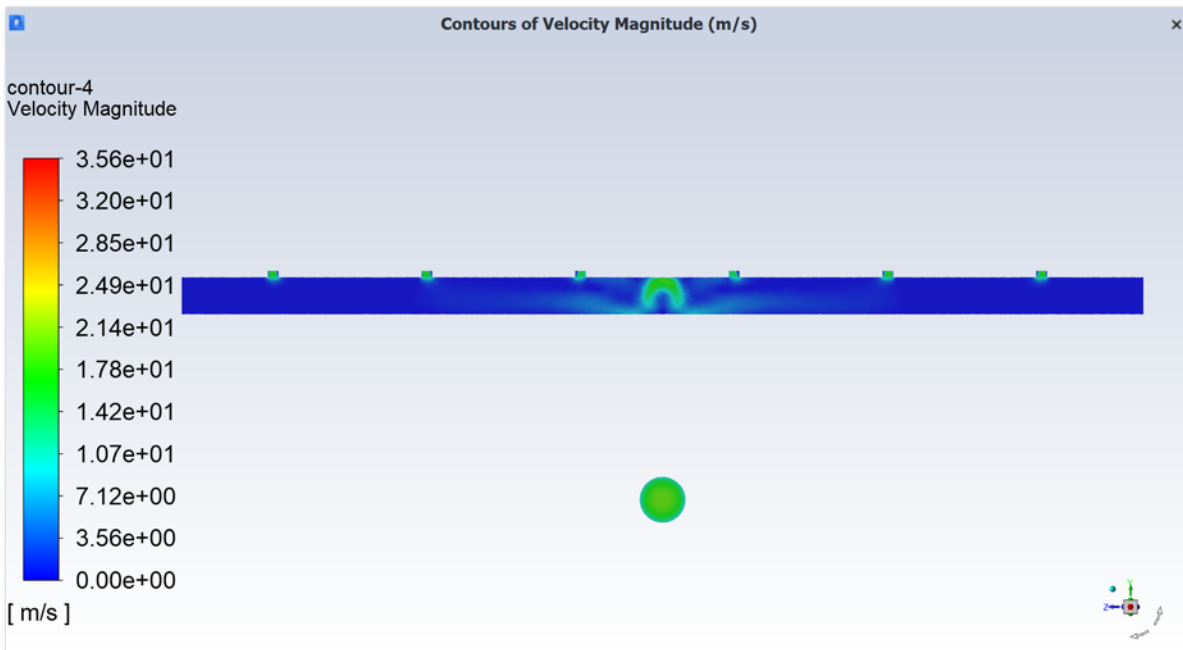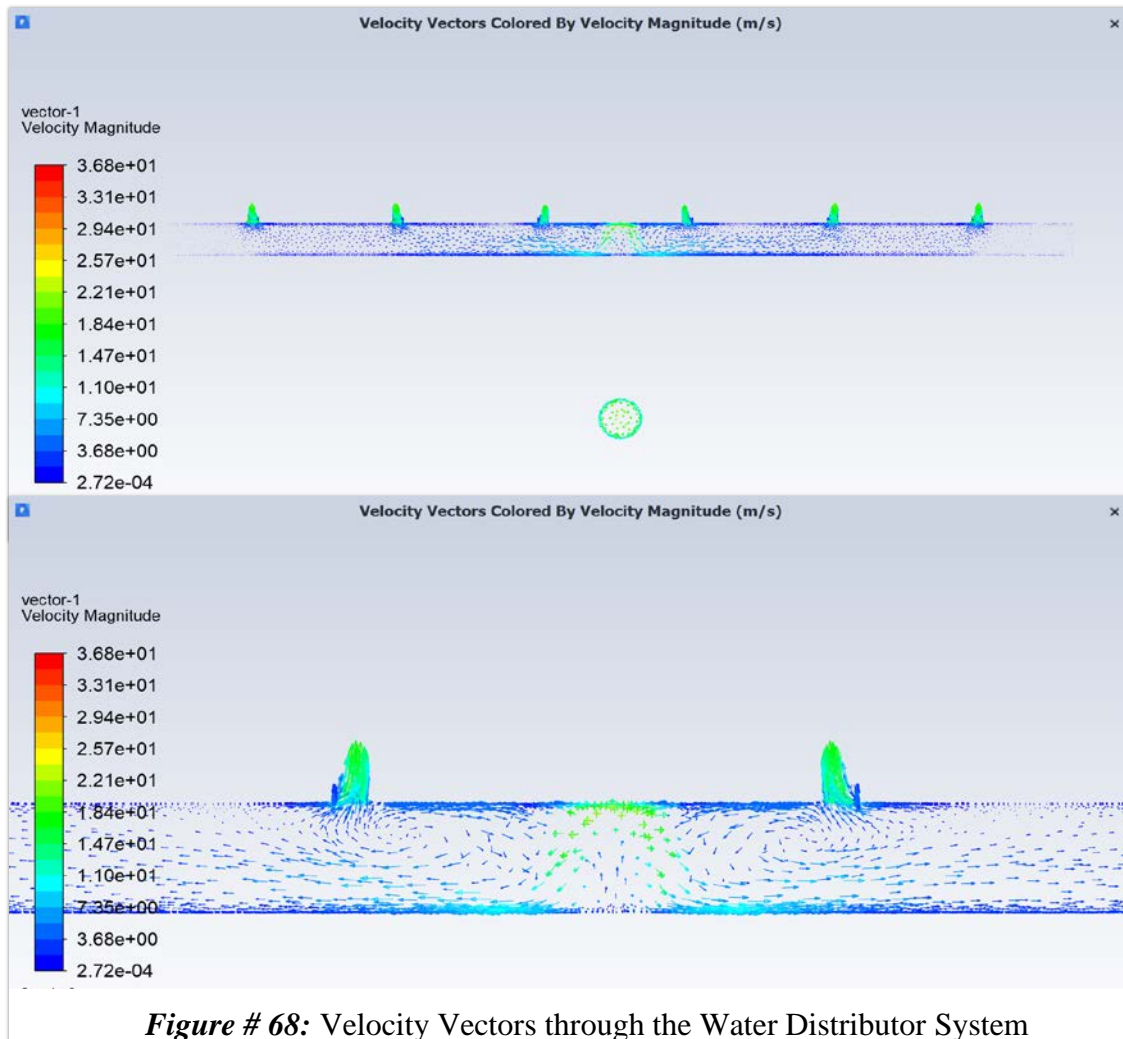
Figure # 68: Velocity Vectors through the Water Distributor System

As it can be seen on ***Figure # 56***, the Velocity of the Fluid is almost the same through

the Water Distributor System. This because the fluid flows smoothly is this part after

experimenting the majority of the losses through the piping system. However, this velocity

increases at the nozzle due to the change of the diameter. The Velocity Vectors through the

Water Distributor System can be seen at ***Figure # 57***, where it is possible to appreciate how

the fluid is moving through this system. There are some vortices were the fluid changes its

direction and that is because of the high velocity at which the fluid is moving.
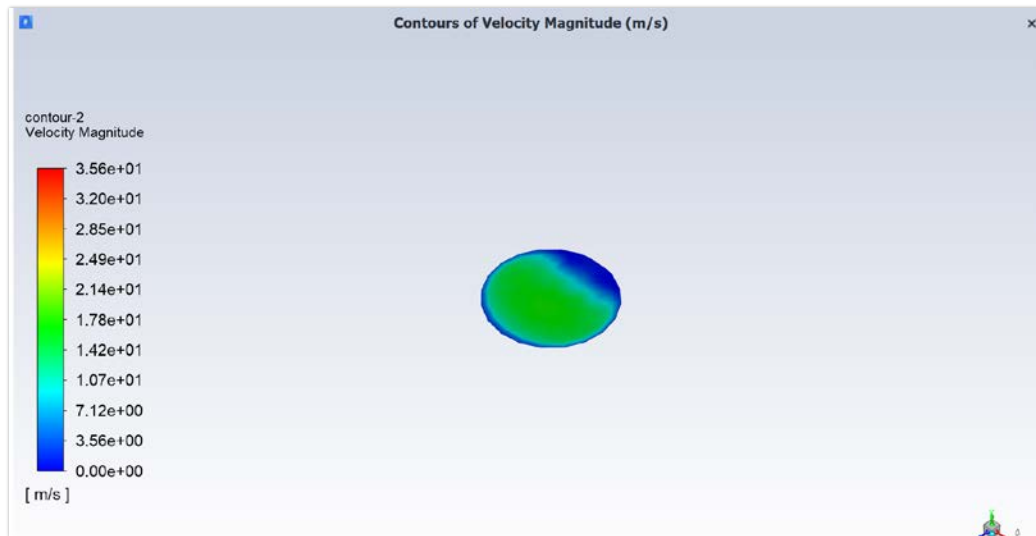
Figure # 69: Velocity Contours at the Nozzle

As it can be seen on ***Figure # 58Figure # 50Figure # 49,*** the Velocity of the fluid at the outlet is uniformly except for the part near the exit. This because that spot is formed mostly by air due to the high velocity of the water at reaching the nozzle.

From the results shown before, the following conclusions were obtained:

- ***Average Velocity*** at outlet = **(15)** m/s

- ***Height*** to which the Water is pumped out through nozzles = **(11.47**) m

- ***Average Temperature*** at outlet = **(347)** K

These results are accurate because the Pump has a lot of power, so the Water is pumped out the nozzle with high velocity and pressure. Furthermore, the specific heat of the water is very high, so, there is not a big difference temperature between inlet and outlet.

Milestone #3: *Automation*

Problem: The Heating Element will remain on for a long time, how can energy be saved if it is known that the customer wishes to maintain the water temperature in a certain range?

➢ **Temperature Control**

A conditioning circuit was considered for temperature control. This circuit works through signals, if 0.5 V is sent our machine will be turned off, but if we send more than one volt our machine will turn on. "The signal conditioner is a data collector that converts mechanical or electrical signals into another output signal. "Amplifies the signal and converts it into another easy-to-read format that is compatible with data acquisition or machine control purposes." (HBM, s/f). The signal conditioner is responsible for signal conversion, linearization, amplification, filtering, evaluation, various interfaces (***Figure # 71***)

$$V_{out} = \frac{R_2}{R_1}(V_2 - V_1)$$
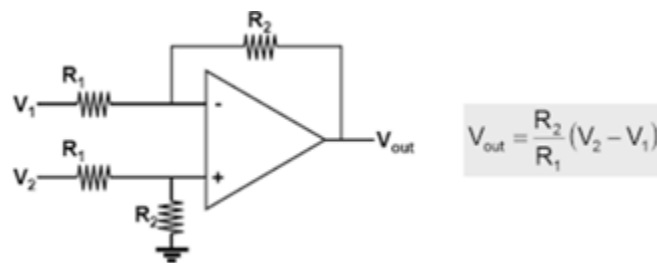
Figure # 70: Conditioning circuit model**.** Reprinted form Electronic Instrumentation.

Miguel A. Perez and others, Ed. Thomson-Paraninfo

This system will allow us to control the temperature range in which the induction heater works and thus save energy in the bottle rinse. If the water is in the allowed hot range, it will turn off; if it is below the range, it will turn on.

Milestone #4: Pressure drops and losses inside the pipe.

At this point we want to analyze the pressure drops produced into the system and we want to analyze the pressure losses given by accessories and by friction over our pipe system.

We have subdivided the bottle washer machine in 3 subsystems to execute this calculation.

➢ **First subsystem**

Data obtained by the system:

Table # 31: Data obtained from the system

$P_A = 0.715\ [atm] = 71.99[kPa]$ Atmospheric pressure in Cumbayá	$T_{water,hot} = 85[°C]$
$\dot{W}_{pump} = 1\ [Hp] = 0.746\ [kW]$	$Q_1 = 99.6\dfrac{L}{min} = 0.00166\left[\dfrac{m^3}{s}\right]$
$D_{pipe} = 1.5\ [in]=0.038\ [m]$	$\rho_{water}@\mathbf{85}°C = 968.6\left[\dfrac{kg}{m^3}\right]$
$\mu_{water}@\ \mathbf{85}°C = 1.200\left[\dfrac{kg}{m*hr}\right]$ $= 3.35*10^{-4}\left[\dfrac{kg}{m*s}\right]$	$\gamma_{water}@\mathbf{85}\ °C = 9501.97\left[\dfrac{N}{m^3}\right]$ $L = 0.30\ [m]$

At *Figure # 72* it is illustrated the problem that is going to be analyzed. The first analysis is executed from point **A** to point **B.** The **Point A** is at **30 cm** of *height* from **B** and **30 cm** of horizontal length **from B.**
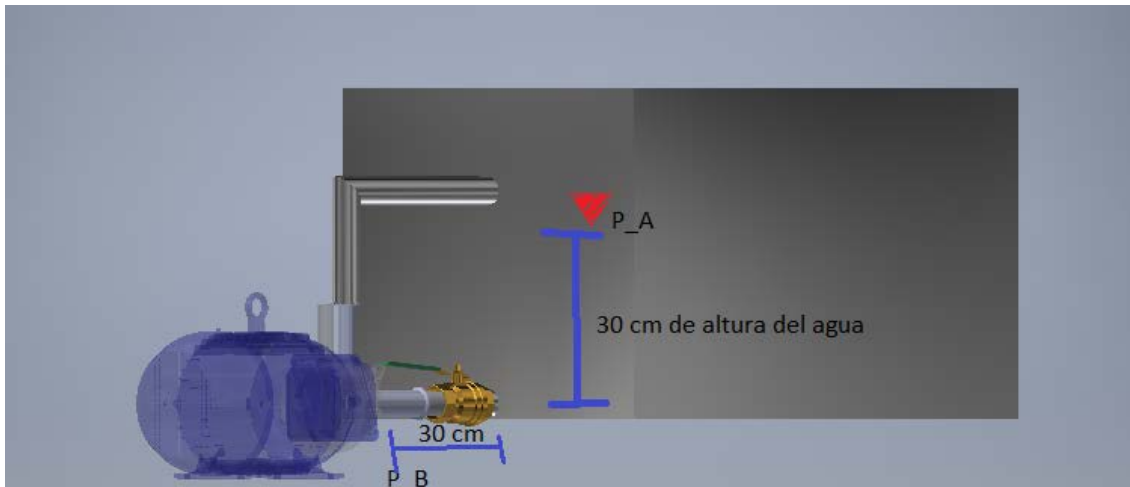
Figure # 71: First subsystem considered to solve the problem

Equations:

First analysis by Bernoulli is considered to obtain the pressure drop between A and B.

$$\frac{P_A}{\gamma_w} + \frac{v_A^2}{2*g} + z_A = \frac{P_B}{\gamma_w} + \frac{v_B^2}{2*g} + z_B + H_{lost} \qquad (1)$$

Where the lost considered are by friction, by the valve and also for the entrance of the tank.

To obtain the constant of the minor losses of the valve and the entrance, consider **Figure #** *61* and **Figure #** *74*

BALL VALVES

If: $\beta = 1$, $\theta = 0$ .... $K_1 = 3 f_T$
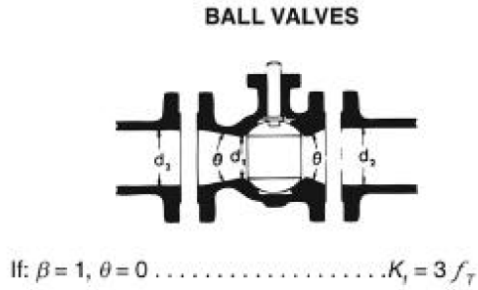
r/d	K
0.00*	0.5
0.02	0.28
0.04	0.24
0.06	0.15
0.10	0.09
0.15 & up	0.04

*Sharp-edged

Flush

For K,
see table
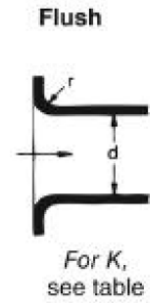
Figure # 73: Valve constant for minor losses. Reprinted from *Thermal Energy Systems,* S. Penoncello, 2014.

Figure # 72: Constant for the entrance of the pipe. Reprinted from *Thermal Energy Systems,* S. Penoncello, 2014.

Where f_T is defined as:

$$f_T = \frac{0.25}{\left(\log\left(\frac{\frac{\varepsilon}{D}}{3.7}\right)\right)^2} \quad (2)$$

$$f_T = 0.020537$$

The lost constant of the valve and of the entrance are:

$$K_e = 0.5 \text{ and}$$

$$K_{Valve} = 0.0615$$

To obtain the velocity over the pipeline, consider the following formula:

$$v = \frac{Q}{A}$$

Considering the area as:

$$\frac{\pi}{4} * D^2$$

So velocity is obtained:

$$v = 1.464\frac{m}{s}$$

The formula for the losses is as follows:

$$H_{lost} = \left(f * \frac{L}{D} + \sum K\right) * \frac{v^2}{2*g} \quad (3)$$

The constant f is defined as the moody constant and obtained with the moody chart illustrated at *Figure # 75*. To obtain this constant is necessary to obtain Reynolds number and the relative roughness.

Reynolds Number

$$Re = \frac{\rho * v * g}{\mu} = 4.141 * 10^7$$

Relative roughness

$$R_R = \frac{\varepsilon}{D}$$

Where epsilon ε is obtained from the *Figure # 76*.
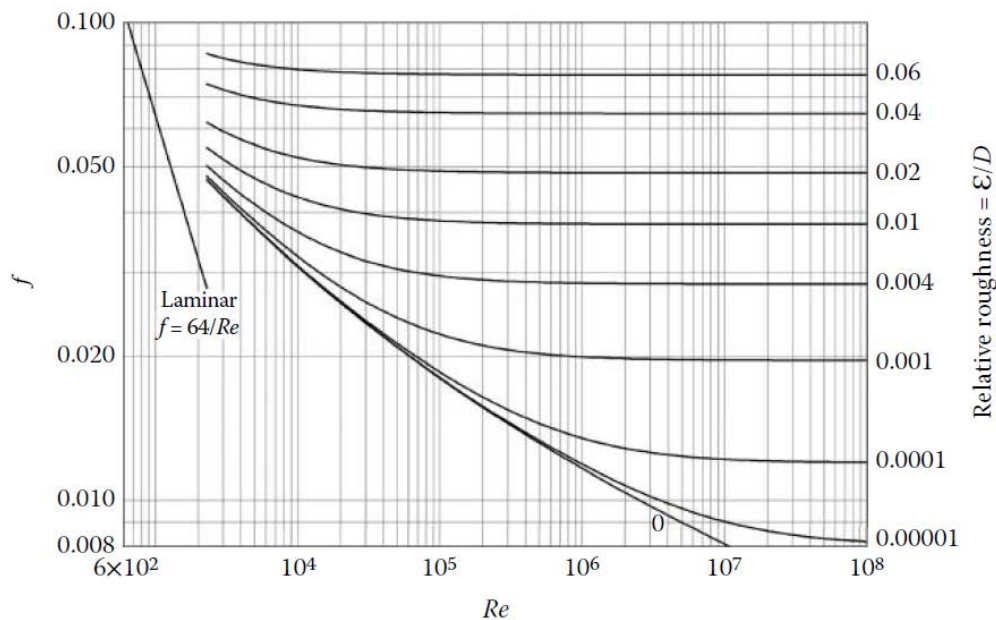
Figure # 74: Moody Chart. Reprinted from: *Fundamental of Fluid Mechanics.* Munson, B.,

Young, D., & Okiishi, 2017.

Typical Absolute Roughness Values (ε) for Pipes

Pipe Material	foot	centimeter
Drawn tubing	0.000005	0.00015
Commercial steel or wrought iron	0.00015	0.0046
Asphalted cast iron	0.004	0.12
Galvanized iron	0.005	0.15
Cast iron	0.0085	0.26
Wood stave	0.0006–0.003	0.18–0.09
Concrete	0.001–0.01	0.031–0.31
Riveted steel	0.003–0.03	0.091–0.91

Source: Moody, L. F., *Trans. ASME*, 66, 8, 671–684, 1944.

Figure # 75: Roughness defined for different materials. Reprinted from *Thermal Energy*

Systems, S. Penoncello, 2014.

Having a relative roughness of:

$$R_R = 0.001211$$

And taking in consideration the *Figure # 75*, he following value of *f* was obtained:

$$f = 0.02059$$

Thus, the losses are obtained

$$H_{lost} = 0.08897 \, [m]$$

Then, the pressure at **point B** results:

72.95 [kPa]

➢ **Second Subsystem**
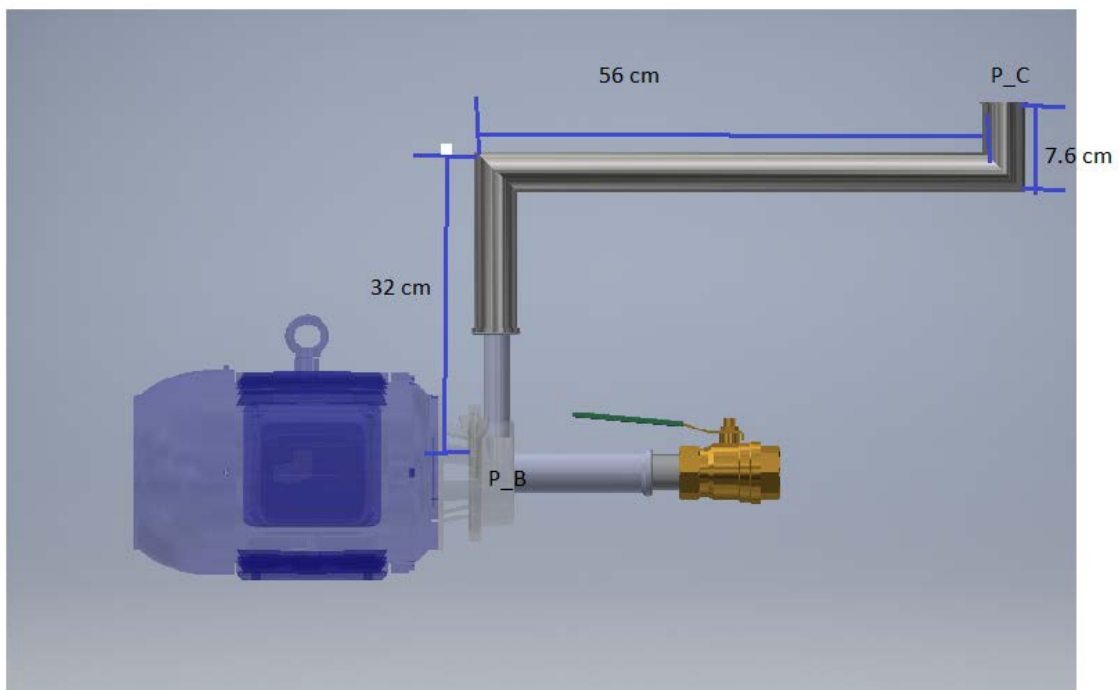
Figure # 76: Illustration of subsystem 2.

Here, the same flow rate will be assumed, given the fact that the losses by friction and by accessories are minimum. So, we obtain: $Q_2 = Q_1$

What is desired to obtain at this subsystem is the head given by the pump to the system, for then obtaining the pressure at the point C and also the velocity that is going to be the entrance velocity to the subsystem number 3.

Based on the data considered at *Table # 31* the following equations allow us to compute the results:

$$H_p = \frac{\dot{W}_{pump}}{\gamma_{water} * Q_2} = 47.35\ [m]$$

The Pressure at point **C** could be obtained. With this, enough information is gotten to have the velocity at point **C.**

Considering Bernoulli between points **B** and **C,** the following equations are obtained":

$$\frac{P_B}{\gamma_w} + \frac{v_B^2}{2*g} + z_B + H_p = \frac{P_C}{\gamma_w} + \frac{v_C^2}{2*g} + z_C + H_{lost}$$

Considering **Point B** as reference, then:

$$z_B = 0$$

Also, the velocity inside of the pipes is going to be the same at each point given that the pump gives to the system a big head and the losses compared to the height gains are minimum. So, the expression reduces to:

$$\frac{P_B}{\gamma_w} + H_p = \frac{P_C}{\gamma_w} + z_C + H_{lost}$$

The height, where **point C** is located is:

$$z_C = 0.396 \, [m]$$

The losses formula is the same considered at subsystem 1.

$$H_{lost} = \left(f * \frac{L}{D} + \sum K\right) * \frac{v^2}{2 * g}$$

For the minor losses, this time, 2 elbows are considered, and for major losses consider a length of:

$$L_2 = 0.956 \, [m]$$

The friction factor, f value is going to be the same considered in subsystem 1 because Reynolds number is the same given that the velocity of the fluid inside the pipe was assumed to be the same in this part, also, the diameter of the pipe is the same, so the relative roughness does not alter its value, with all this considerations

$$f = 0.02059$$

The **constant K** of the elbows are obtained from the *Figure # 78*:

STANDARD ELBOWS

90°   45°

$K = 30 \, f_T$ $K = 16 \, f_T$
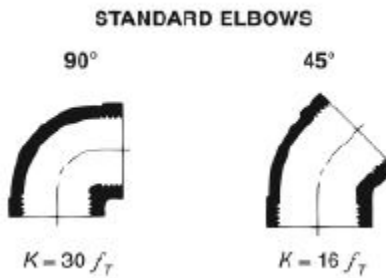
Figure # 77: Elbow friction data. Reprinted from *Thermal Energy Systems,* S. Penoncello,

2014

With $f_T = 0.020537$ obtained at subsystem number one. The elbow constant is:

$$K_{elbow} = 0.6161$$

With all these considerations and the values obtained, pressure at point **C** is:

$$P_C = 518.48 \, [kPa].$$

It is important to say that the pressure value obtained is considerably bigger than the pressure at point **B,** but the pump used at this system delivers a big head gain, so it is acceptable to gain a lot of pressure too.

➤ **Third subsystem**
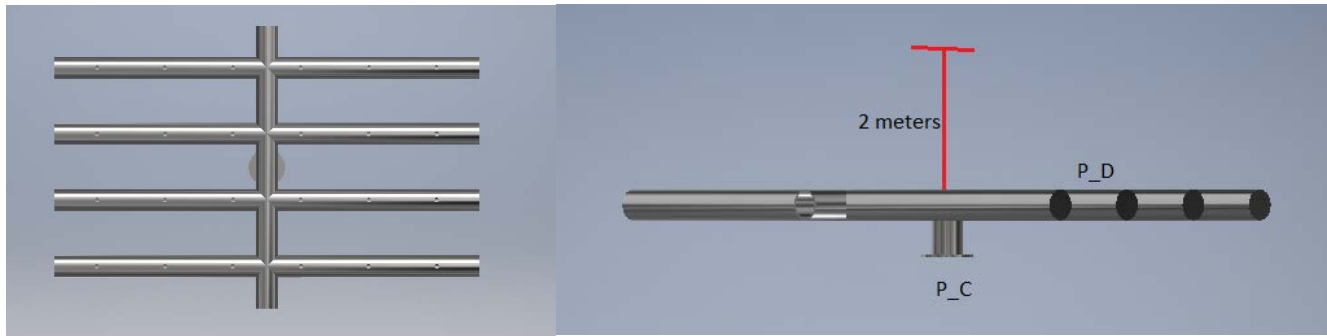
Figure # 78: Illustration of subsystem 3

Now, the exit velocity by the nozzles is of interest. Also, the pressure exit, that's why, having two unknown variables, it is needed to have the following assumptions:

- According to the calculations done, **47.35 meters** are won from the exit of the pump. What is desired is to have a final water height of **2 meters** as it is illustrated in *Figure # 67*. From the exit, to the last point of the water distributor, there are **3.67 meters of pipes.** Adding extra **2 meters** of jet height is obtained **5.67 meters** of water path. Considering this, the following lost at this system is:

$$H_{lost,s3} = 47.35 \, [m] - 5.97 \, [m]$$

$$H_{lost,s3} = 41.38 \, [m]$$

This pressure and height losses are going to be obtained by putting a system of valves that reduces the water flux and that allows to avoid the excessive height over the pipe exits.

Given these considerations, equations are computed between points **C** and **D:**

$$\frac{P_C}{\gamma_W} + \frac{v_c^2}{2*g} + z_c = \frac{P_D}{\gamma_W} + \frac{v_D^2}{2*g} + z_D + H_{lost}$$

Considering that the velocities of **C** and **D** are the same given that the losses are minimum compared with the pump height gain, and that the difference of height is minimum, the expression simplifies to:

$$H_{lost} = \frac{P_C - P_D}{\gamma_W}$$

The only unknown value here is pressure **D,** so it results:

$$P_D = 125.32 \, [kPa]$$

Here, a problem of **type 2** in *fluid mechanics* is identified, in which, the unknown variable is the exit velocity and the flow rate. For this, an iterative process is needed, that's why a system of 3 equations is assembled:

$$(1) \ H_{lost} = \left(f * \frac{L}{D} + \sum K\right) * \frac{v^2}{2*g}$$

$$(2) \ R_e = \frac{\rho * v * D}{\mu}$$

The f value that is considered as the third relation but is not going to be obtained by correlations, this value will be obtained by the moody chart.

The lost constant **(K's)** of the accessories considered for the minor losses are 5 T's and 24 projecting pipe exits, all these values are illustrated at *Figure # 80* and *Figure # 69*:

PIPE EXIT

Projecting	Sharp-Edged	Rounded
$K = 1.0$	$K = 1.0$	$K = 1.0$
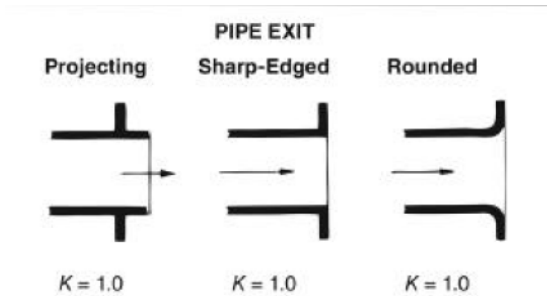
Figure # 79: Pipe exit K constant value Reprinted from *Thermal Energy Systems,* S.

Penoncello, 2014.

c. Tees

Line flow, flanged	0.2
Line flow, threaded	0.9
Branch flow, flanged	1.0
Branch flow, threaded	2.0
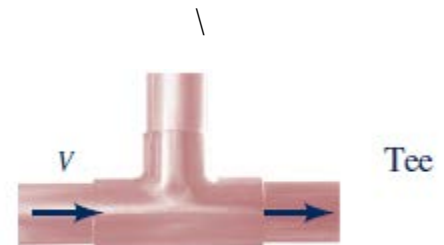
Figure # 80: T's loss constant considered for minor losses. Reprinted from: *Fundamental of*

Fluid Mechanics. Munson, B., Young, D., & Okiishi, 2017.

The minor constant for the exit is the projecting exit and for the T, flanged is the chosen one.

Table # 32: Iterations table obtained with the equations system

f	$v = \left(\frac{5.97}{1.47+f*4.36}\right)^{\frac{1}{2}}$ [m/s]	$R_e = 1.09 * 10^5 * v$	f obtained
Assume 0.02	1.95	$2.13423*10^5$	0.02174
0.02174	1.953	$2.12905*10^5$	0.02175
0.02175	1.953		

After 3 iterations to verify the calculations, the exit velocity obtained is:

$$v = 1.95 \left[\frac{m}{s}\right]$$

And the flow rate is considering a diameter of **1 cm** of exit is:

$$Q_{exit} = 1.53 * 10^{-4} \left[\frac{m^3}{s}\right]$$

To validate our calculations, the system is solving by **EES**, obtaining the following result about the graphics of the system:

Table # 33: Head result of the system solved for different flow rates.

$\blacktriangleright$ 1..12	H_{p2} [cm]	V_2 [cm³/s]
Run 1	214,3	0
Run 2	214,4	45,45
Run 3	214,5	90,91
Run 4	214,7	136,4
Run 5	215	181,8
Run 6	215,4	227,3
Run 7	215,9	272,7
Run 8	216,4	318,2
Run 9	217,1	363,6
Run 10	217,8	409,1
Run 11	218,6	454,5
Run 12	219,6	500
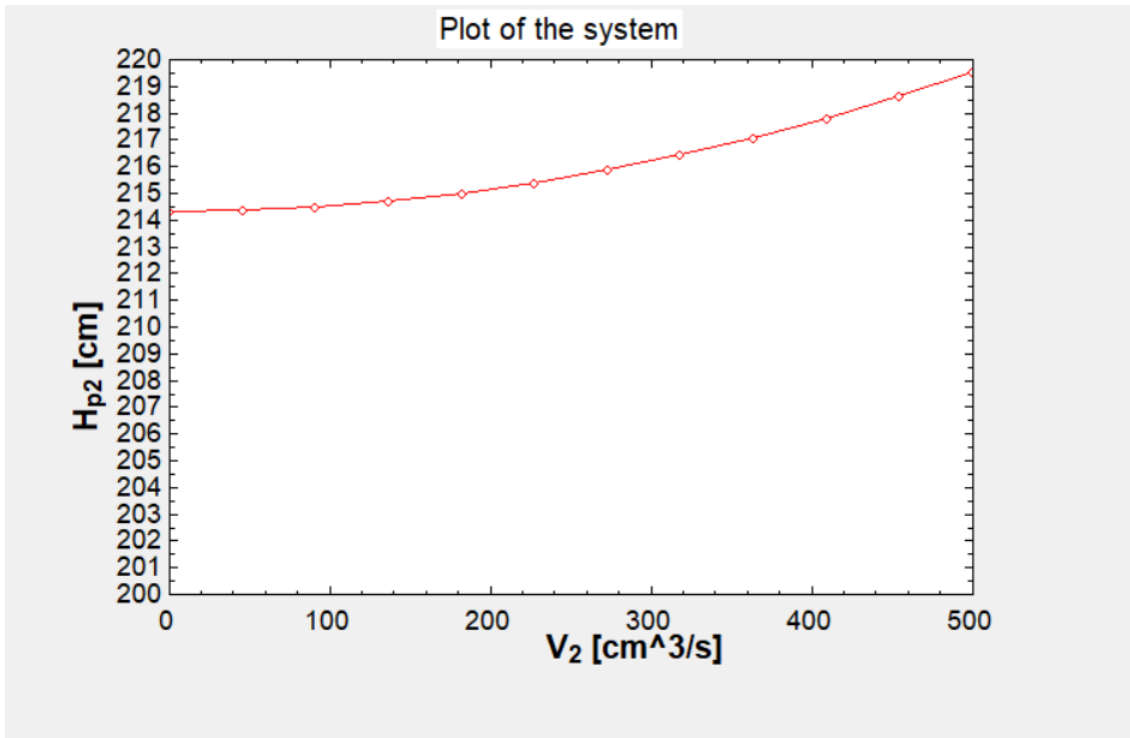
Figure # 81: Plot result of the piping system

Maintenance and Operation Manual

Data sheet

Table # 34: *Data Sheet of the Beer Bottle Washer Machine*

Parameters	Description
Production Rate	290 bottles and 2 barrels per day. (Minimum required 80 bottles and 2 barrels per day)
Bottle type	Major diameters glass bottles from 60 to 73 millimeters
Rinsing time (Water)	5 minutes
Rinsing time (NaOH)	5 minutes
Water temperature	85 ℃ ± 5 ℃
NaOH Temperature	30℃ ± 5℃
Pump	• Power: 0.4024 kilowatts

	• Speed: 1750 RPM • Type: End Suction • Size: 1-1/2 X 1-6 AA • Impeller Size: $\emptyset \ 5 \ inches$ • 1 pump per washing station
Water and NaOH Flow Rate	$99.6 \dfrac{L}{min} \pm 1 \dfrac{L}{min}$
Water Average Pressure	0.077 kilopascal
NaOH Average Pressure	0.055 kilopascal
Dimensions of the machine	• Width: 2170.65 millimeters • Depth: 620 millimeters • Height: 756.26 millimeters
Water pipes	Stainless steel 440C $\emptyset \ 1.25 \ inches$
Water distributor pipes	Stainless steel 440C $\emptyset \ 1 \ inch$

NaOH pipes	Stainless steel 440C Ø 1.25 *inches*
NaOH distributor pipes	Stainless steel 440C Ø 1 *inch*
Rack Height	107 mm
Rack Dimensions	374 x 507 mm
Equipment	2 Bottle-holder racks
Electrical Connection	220V AC
Tank volume (Water and NaOH)	66.99 Liters
Water Heater	2 Electrical resistances of Stainless Steel 304 with an input power of 6 Kilowatts

Part Description

Table # 35: *List of Parts*

Part Number	Quantity	Part Name
1	1	Reservoir Tank
2	2	Pipe Pump-Elbow
3	4	Piping Elbow
4	2	Pump
5	2	Pipe Elbow-Tank
6	2	Pipe Tank-Elbow
7	2	Pipe Pump-Elbow
8	2	Water Distributor Pipe
9	2	Parker Brass Ball Valve XV520P
10	2	Bottle Rack
11	24	Glass Bottle
12	34	Ferrule
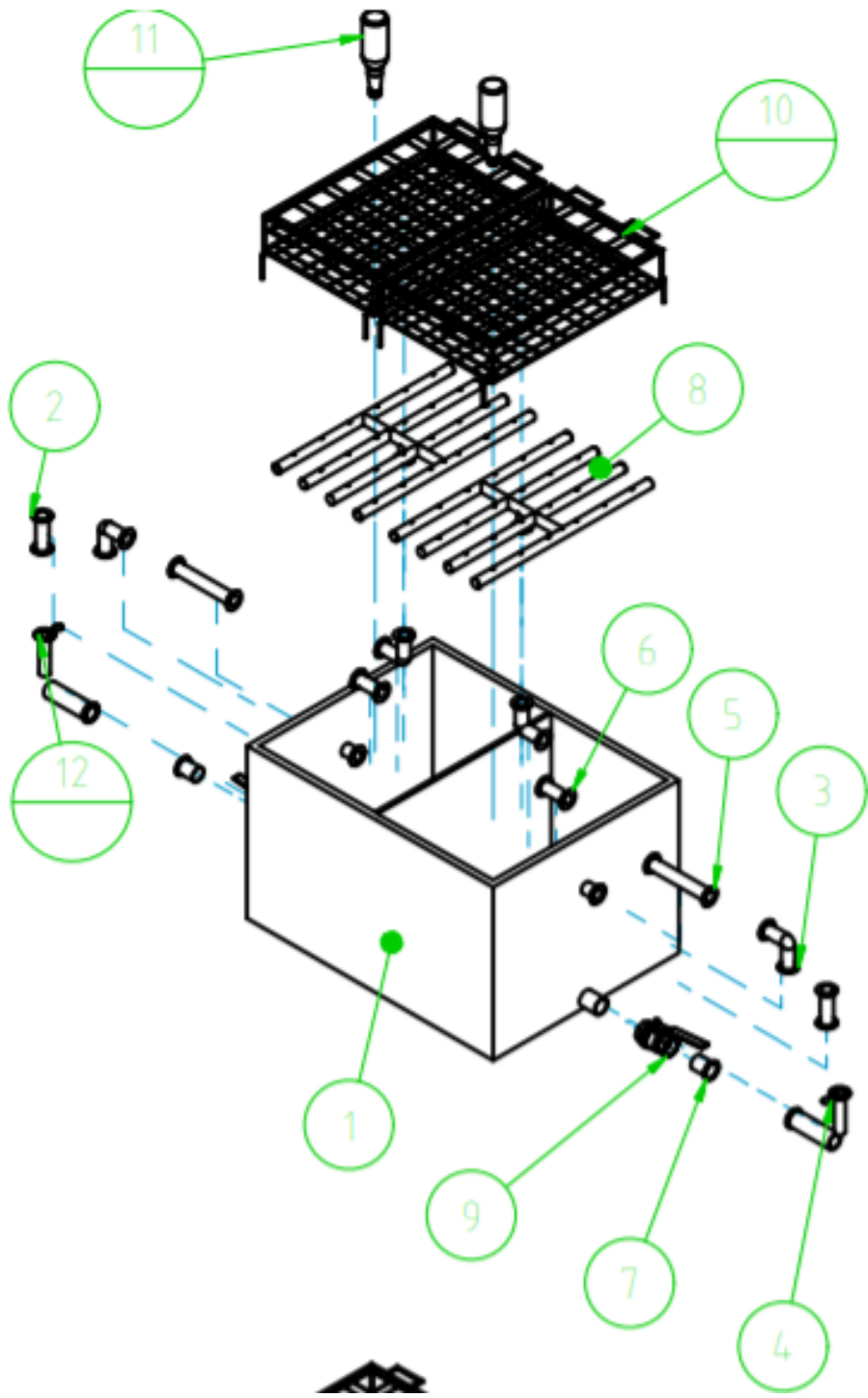
Figure # 82: *List of parts of Bottle Washer Machine*

Installation

The bottle washing machine is made up of the following parts

- 820 mm x 620 mm x 500 mm Stainless Steel Tank

- 4 - Ø 1 ¼ in Piping elbows

- 2 - Ø 1 ¼ in x 91.75 mm pump – elbow pipes.

- 2 - Ø 1 ¼ in x 194 mm elbow - tank pipes.

- 2 Ø 1 ¼ in x 80.65 mm tank-elbow internal pipes.

- 2 - Ø 1 in water Distributor Pipes

- 16 - Gaskets (Plus 16 spare gaskets)

- 14 - Clamps

- 2 - Racks

- 40 - Elastic cords

- 48 - Ø 5.23 mm x 25 mm Nozzles

- 1 - 0.4024 kW Pump, 99.6 L/min

- 2 - 6kW Stainless steel coils

- 2 - ¼ in Ball Valves 1

- Electronic control system

- Panel control box

- 2 - 1 ¼ Hoses with a ferrule adapted

The following conditions described on the installation piping plan are necessary:

- The pump has to be 15 mm above the ground. This height is necessary to obtain a correct alignment and connection of the pipes

- Install the equipment on a flat surface for an adequate water level

- Make sure the electric system (heating and automation) is correctly connected

Connect the respective pipes with a gasket and a clamp through the ferrules. The order is as follows:

- Connect the "pump-elbow" pipe to the "elbow" pipe and this to the "elbow-tank" pipe. (*Figure # 84*)

- Connect this sub-assembly to the pump and tank as shown in the *Figure # 84*.
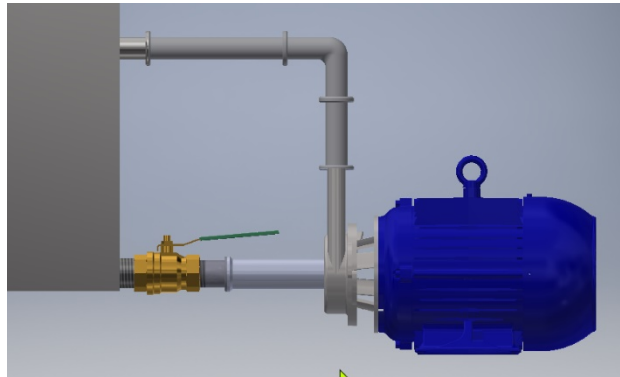
Figure # 83: Steps 1 and 2

- Place 24 nozzles in the water distributor using Teflon tape in the threaded section
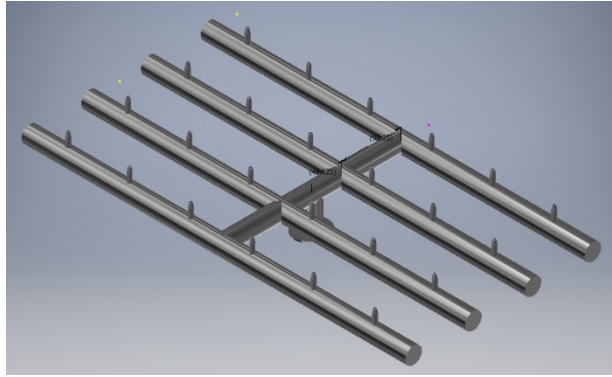
Figure # 84: Colocation of Nozzles

- Connect the "tank-elbow" pipe to the "elbow" pipe and this on the inside of the tank (*Figure # 86*)
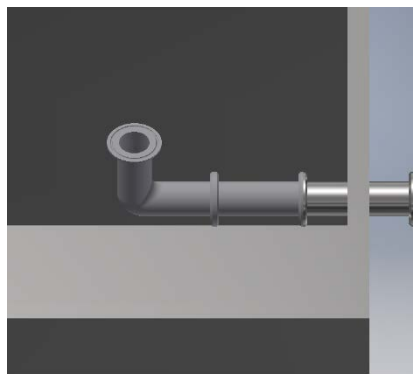
Figure # 85: Step 4

- Connect the water distributor to the previous sub-assembly (*Figure # 87*)

- Connect the elastic cables to the eyebolts incorporated in the rack (*Figure # 87*)

- Place the rack in the tank by inserting its four rods into the four holes in the top of the tank (*Figure # 87*)
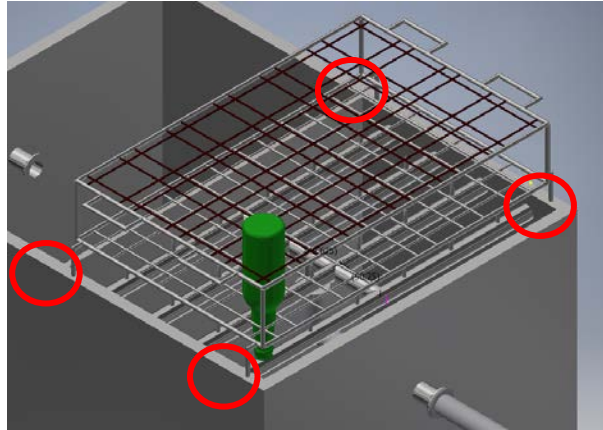
Figure # 86: Steps 5, 6, 7

- ▪ Repeat these steps for the other side of the tank

Attention: Electrical installations need to be performed by a licensed technician!

Preheating Process

The preheating process is the final step prior the operation of the Beer Bottle Washing Machine. This process is quite important due to the necessity of using water heated up to 85 degrees Celsius during the Washing process. The BRC standard suggests using hot water during the disinfection and washing process of any bottles in the Food Industry. This because hot water can easily clean and remove some of the most common food scraps. The preheating process ***must*** take place once the user has already finished all the steps described in the **¡Error! No se encuentra el origen de la referencia.** section. This because the Beer Bottle Washing Machine has to be totally assembled before starts operating. It is recommended for the user to double check if the installation process was made in a proper way in order to avoid any kind of leaking trough the piping system. Double checking the correct installation of the device will also avoid losing heated water during the operation of the Beer Bottle Washing Machine.

Before starting the preheating process, it is also important to check if the electronic devices such as the Pyrometer, Control Panel and the Power Source are in optimal conditions to operate. You can check this by doing a fast inspection of its exterior and pushing their on/off buttons to see if they are working.

Figure # 87: Pyrometer and Panel Control. Reprinted

from *Alibaba, 2020,* https://www.alibaba.com/product-

Once you confirm that the electronic devices are properly working, then you have to make sure that you have a constant water supply. This because the left compartment of the Tank has to be filled out with water. You must fill out the Water Compartment of the Tank up to **0.4 m.** There should be a mark in the compartment that will show the appropriate level of the water that has to be used.
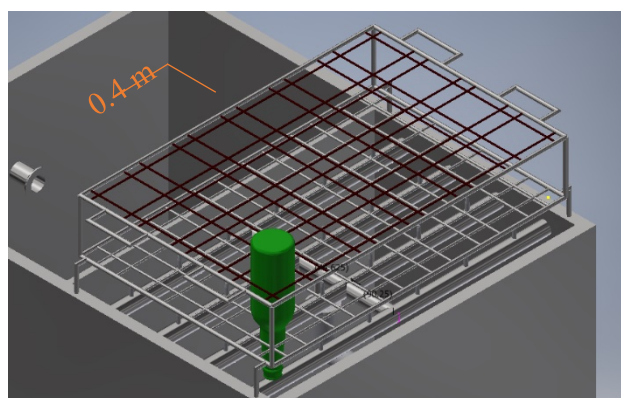
In case that the water mark is not legible, you can measure a height of **0.4 m** from the bottom of the Tank in order to assure the proper water volume i.e. **84 L.** This is quite important because all the parameters are based in this water volume. So, in order to have a proper operation of the device, the user must guarantee a Volume of Water of **84 L.**
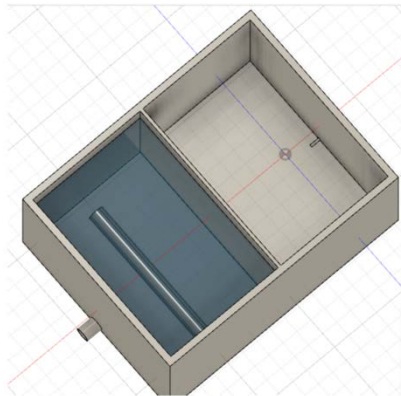
Figure # 89: Water tank

When the Water Container is filled out with **84 L** of Water, the user should wait for **5 minutes** before turning on the Preheating system. During this time, the user must check the device in order to find any place with water leaking. If there is no one, then, the user must

Figure # 90: Start Button . Reprinted from *Alibaba, 2020,*

https://www.alibaba.com/product-detail/Custom-high-accuracy-indoor-control-

panel_62408482217.html?spm=a2700.galleryofferlist.0.0.70931d03sa0Hnn&s=p

turn on the Preheating System. This can be done by pushing the blue button of the control panel:

The preheating process will be performed for *45 minutes.* So, the user must take in consideration this time in order to plan his/her activities in a proper way.

As said before, the preheating process is going to take *45 minutes.* This time is needed to heat water from its original temperature up to 85 Degrees Celsius. Their power input is controlled by the temperature of the water. An Electronic Control System was set up in a PLC contained in the Control panel. This system is connected with a pyrometer in order to

Figure # 91: Timer. Reprinted from *Alibaba, 2020,*

https://www.alibaba.com/product-detail/Custom-high-accuracy-indoor-control-

panel_62408482217.html?spm=a2700.galleryofferlist.0.0.70931d03sa0Hnn&s=

p

know the water temperature at the very top. There is also a timer in the Control Panel that

lets the user know the time required for the Water to reach the desired temperature.

Attention: Do not touch the Surface of the Tank!!

During the preheating process, the user has to be aware that the Surface of the Tank

will be very hot. Even if the Electric Resistances are located at the bottom part of the Tank,

the surfaces near them will be very hot. For this reason, it is important for the user to not

touch these parts.

Once the temperature of the Water reaches **85 Degrees Celsius,** an alarm will sound

in order to let the user know that the Preheating process has ended. Then the user can start

operating the device and wash the beer bottles. But, before that, the user has to follow the

steps described in the next section.

Pump and flow rate setting

When the user wants to start the pump, first must verify that the entire system is tightened in all its joints and fittings. It is important to verify at least twice that the pump connector is adjusted because in case of a failure in this connector, accidents could be produced.

Figure # 92: Pump controller System. Reprinted from *Alibaba, 2020,* https://www.alibaba.com/product-detail/Development-board-Arduinos-UNO-R3-atmega328p_60838481820.html?spm=a2700.galleryofferlist.0.0.2dfd7d0ff8PjA9 &s=p

Once all the evaluations are done, the tanks must be filled up to 40 cm (Where a red line must be marked), if the system is not filled up to this level, the water inlet will not be enough to support the desired flow rate specified at the data sheet. Also, the adequate quantity of water will avoid the system to cavitate and maintain the impeller of the pump in good conditions for a long time.

The pump controller is a user-interface system that allows to set the Rinsing time and also has an emergency stop system that in case of failure must be actioned by the operator.

The control interface contains **3 blocks.** The first block A (illustrated with blue) is the interface that allows to set the time. The times comes from a minimum of 1 minute and a maximum of **99 minutes.** The increments of time are programmed to increase or decrease by **30 seconds.** In the **LCD** minutes and seconds are showed. Time goes decreasing according to the time programmed at the beginning. **Block B** (illustrated with orange) has the emergency stop button that will stop the pump in case that the operator detects a failure on the system. Block C (illustrated with green) contains a switch and a light. When the system is operating, the red light at Block C, will be ON. At the high state (ON), the pump will be working at the flow rate of **99.6 [L/min].**

Notes: Consider fixing the pump to the floor or at least adjust the pump because in some occasions, pump could be started very hard and push the system and have unnecessary movements that could put in danger the integrity of the operators.

Troubleshooting

The bottle washer machine is design for easy use. However, there are some problems the machine could suffer during or prior its operation. There are two types of failures this machine may go through. Procedure problems and operational problems. The firs problem type occurs when the operator missed the correct process to ensemble or handle the machine. In the other hand, the operational problems may occur when a machine accessory is in failure. This can happen when an item has reached a certain level of ware and it has to be replaced or has be under maintenance.

Under this differentiation, five problems have been analyzed and cataloged as primordial for the operation of the bottle water machine:

Alignment problem

An alignment problem refers specifically to the bottle-nozzle alignment. It is considered a procedure problem. The distributor pipe, where the nozzles are located, has been design so the part of the nozzles enter exactly, with very small tolerance, into the bottles mouth. There are various bottle types that can fit into the bottle-holder rack. However, the design was made for the **335 ml** and **750 ml** long neck beer bottles. This doesn't mean that other bottles won't be compatible with the structure.

If an alignment problem presents it can occur because of two different factors. The first one is that the bottle is not correctly fastened, this occurs because in the upper part of the rack the tension cables are too loose avoiding the bottle can be placed in the correct position to be aligned with the nozzles. The tension cables allow that different kinds of bottles can be placed and secured to the structure, if any of these are loose could involve alignment problems or a more serious one which is the abandonment of a bottle of its position due of the water pressure during the washing process.

The second factor of the alignment problem is the bottle is not compatible with the rack. There is a significant amount of different glass bottles for the beverage industry. Some of them may not adapt to the structure because of geometry problems like the bottle neck or its body inhibit the bottle to be correctly placed in the structure. If the procedure to place the bottles in the rack has been done correctly, reviewed and no problem has been found then the rack is not compatible with that kind of bottle shape.

Clamping problems

The clamping problems can occur in two different systems: at the bottle-holder rack and in the piping systems and at the piping system. It is considered a procedure problem. The first failure was already mentioned in the previous sections. This occur when the tension cables used to fasten the bottle for the process is too loose. Each cable along and breadthways the structure has, at its both ends, screw mechanisms to adjust the cable to the correct tension so it can correctly hold the bottle for the process.

The second problem, at the piping system, occurs at the piping joints. Since all the pipe is detachable, in every joint it has a clamp which allows the accessories to remain together while operating and enable a very easy and fast dismantling process for cleaning or maintenance operations. The clamp is secured by torque pressure in the screw each clamp has. If a joint is not correctly clamped, it can provoke leaking in the system or an abrupt rupture in the joints which can be very dangerous for the operation personal.

Leaking problems

The leaking problem, as mention, is part of the procedure problems. Leaking may occur when a clamp is not well secured as a result of a lack of torque while securing the screw mechanism in the clamps. However, if clamping procedure after a cleaning or maintenance process is the correct, then a problem can be caused by a defective clamp. Damage can occur in the screw mechanism with time because of usage, applying a very excessive force on it, or because heavy blows or falls suffered, which can deform the mechanism avoiding it can mate as it should to the joint.

Corrosion problems

Consider as an operational problem, the corrosion in the material can be a very serious problem if not properly taken care off. The pipes will be operating with two different kind of liquids, caustic soda and water, at high temperatures that can variety between 75-90 ℃. Although the material used at the pipes is stainless-steel, a very high corrosion resistant material, a little bit of corrosion is expected in a long-term use. With time, the pipes will have to enter to maintenance process for corrosion elimination. This phenomenon will depend on the cycles quantity the machine will be exposed to and how frequent the pipes are cleaned. With good maintenance, the pipes wont's suffer any important wear during a significant amount of time.

Pump problems

Another possible operational problem can be suffered at the pump. Wear is a problem most materials and machines suffer. The pumps used at the system will suffer wear at different levels depending on the operation conditions and the operating cycles. If the machine is constantly operating at its maximum capacities, the wear will occur before than if the machine is operating at normal and controlled conditions. However, this mechanical phenomenon will occur sooner or later in long-term. The pumps should be maintained and analyzed for possible damage every three months. A wear in the pump can cause cavitation in the system damaging the pipes and its joints accessories. Each pump has its own operational and maintenance manual which should be followed for every process.

Heating failure

A heating problem is considered as operational. It may occur when the heating resistance has reached a certain level of were due to usage. Depending on the washing cycles

the machine will perform, the resistance will have a higher or lower wear level. However, a resistance failure is not expected to occur in a short time term since the design of the heating system was considering for a high stress during the cycles.

The heating system can also fail because of a circuit damage. This process is all automatized so there is the possibility that one of the many accessories incorporated into the circuit may fail because of overheating, wear, or any accident that may damage the control electrics.

Electric problems

Electric failures are another kind of problems considered as operational. Process like water heating or the pump control are all automatized which involves a considerable number of electronic items. Any component is exposed to suffer wear with use, some components are made to last longer than others but eventually the components will have to be maintained if possible or replaced for new ones. Also, damage can occur in internal components due to overheating caused by bad connections or external accidents which involve any electrical component.

The machine has to be installed in a place were any connection or electrical component is well secured to avoid any accident which can potentially damage the automatized system. Having loose cables in the flor can produce accidents like people tripping on them harming themselves and damaging the system. Also, if having leaks, the loose cables could produce short-circuit which can cause terrible safety problems for the personal.

Troubleshooting Solutions

The Troubleshooting solutions can be seen at *Table # 25* at the **Appendix B – Project Management.**

Maintenance of the piping system and identification of leaks

The stainless-steel piping system is made up of several sections due to the continuous cleaning that must be carried out. The parts of this system are connected by means of ferrules and clamps that allow their adjustment. Rubber gaskets are placed in the middle of these two components that do not allow the liquid to filter and escape to the outdoors. These gaskets can wear out over time and allow liquid to pass through. The set of spare parts includes a set of 16 packages that must be replaced if this problem occurs. If there are water leaks on the tank divider plate or pipes. Contact the designer.1

It is possible find another water leak in the thread of the nozzles. Therefore, it is recommended to use Teflon tape to avoid this problem. If this problem occurs in the future, replace the Teflon tape. It is important to carry out the internal cleaning of the pipes using a chemical cleaner that is available in the hardware stores, making sure that there are no solids and residue layers that can cause corrosion of the material. Perform this cleaning periodically. Change the caustic soda every week or depending on the number of cleaning cycles performed If the leaking is located at the inside, consult a specialist technician for repair (Not at the joints)

Structural management

The bottle-holder rack is the simplest system of the machine. The structure can easily resist more than 10 [kg] in terms of bottles weight or a stress of more than 33 [MPa]. The structure is design for a certain bottle type (335 ml and 750 ml long neck beer

bottles). However, it can easily hold a large number of different bottle types. For a correct use of this component, follow the next steps:

- Each bottle placed in its individual compartment has to be positioned upside-down. This means the bottle neck has to be facing the floor.

- To secure ta bottle to the structure tremble the cables at the top of the rack making sure they are being adjusted around the bottle body.

- To adjust the cables, use the screw device placed at the sides of the structure, turn them until the cables are trembled. Don't overstrain the screw this could damage the device and the bottles.

- Confirm that each bottle is well secured by trying to move it or gently trying to lift it. If well secured the bottle should be stay still in its place.

Note: When a new and different bottle is going to be tested at the rack it is important to do it as gently as possible. Under no circumstances a bottle has to be forced to fit in a compartment. This can deform part of the structure making it useless until its fixed.

Once the structure is loaded with bottles, it has to be placed over the tank for the washing process. The structure has four legs which fit exactly in the four holes placed in the top sides of the tank. There are two handles in each side of the structure, so it has been placed over the tank by two people. The rack can be manipulated by only one person, but for safety reasons it is not recommended to do so.

Once the structure is placed over the tank follow these instructions:

- Make sure it is well settled in the corresponding spots. The handles should be pointing to the sides of the tank, breadthways.

- Re-check the bottles are still well secured to the rack.

If the procedure is carefully done with this criteria and safety steps, the structure is ready for operation.

Heating System Maintenance

Please read all the information attached to this manual that corresponds to the technical information from the providers of each electronic component of the heating system. Besides that, it is suggested for the user to follow each of the recommendations below in order to guarantee the proper operation of the heating system.

➢ **Control Panel**

The Control panel has to be cleaned once a month. For this, it is necessary to use a wire cleaner 3M in order to remove dust and any kind of dust inside the Control Panel and the wires.

Furthermore, it is important to do a fast check of the connections made inside the Control Panel and review the current, voltage and phases. For this, the user can ask for a licensed technician in order to guarantee the proper functioning of the device.

Figure # 93: Control Panel Box. Reprinted from *Alibaba 2020,*

https://www.alibaba.com/trade/search?fsb=y&IndexArea=product

_en&CatId=&SearchText=control+panel

Attention: Do not open the control panel when it is on!!

➢ **Resistances**

The Stainless-Steel Resistances have to be cleaned once a week with a Stainless-Steel cleaner. For doing this, it is important to turn off the device and drain the water. Stainless Steel cleaner will help to clean the resistances and maintain it surface free of

Figure # 94: Stainless Steel Cleaner. . Reprinted from *Alibaba 2020,*

https://www.alibaba.com/product-detail/stainless-steel-cleaner-polish-spray-

water_62545455142.html?spm=a2700.galleryofferlist.0.0.72175621brbcJx&s=p

rust.

Attention: Please use PPE while using the Stainless-Steel Cleaner!!

The electric connections have to been reviewed once a month by the same electric technician that will check the control panel.

Figure # 95: Stainless Steel Resistance. Reprinted from *Alibaba 2020,*

https://www.alibaba.com/product-detail/electrical-resistance-tubular-for-water-

heater_60023836658.html?spm=a2700.galleryofferlist.0.0.5925e4abxDOJI2&s=p

Attention: Do not touch the surfaces located near the Resistances!!

The resistance can reach a temperature of 500 Degrees Celsius, so please use a

Figure # 96: PPE Needed. Reprinted from *Alibaba 2020,*

https://www.alibaba.com/product-detail/electrical-resistance-tubular-for-water-

heater_60023836658.html?spm=a2700.galleryofferlist.0.0.5925e4abxDOJI2&s=p

PPE for hot surfaces during the operation of the equipment

➢ **Pyrometer**

The Pyrometer has to be reviewed and calibrated every 6 months. For this, it is

necessary to bring it to a licensed calibration center. Also, when cleaning, please do not

touch the front surfaces where the laser is located.

Safety operation

A safe operation is very important, mainly in this machine which works with very high temperature and has important electrical risks which can cause serious problems to the operator's wellness. To avoid and reduce to its maximum the risks, the operator has to follow the next steps.

- The following safety equipment has to be used all times during the machine operation:

  - Thermal gloves, to manipulate the structure after use.

  - Protective glasses

  - Apron

  - Industrial boots

- The bottle-rack has to be full loaded for every cycle. The 24 bottles have to be inside the rack. There is not possible no leave a nozzle without a bottle because, while operation, a hot water jet will be out freely, and it can reach the operator or the electrical system causing serious damage.

- Prior the preheating procedure, make sure the nozzles are all aligned with the bottles in the rack, and part of them are inside the bottles. This avoid the risks of having hot water jets uncontrolled during the washing process.

- Before the preheating procedure, run both systems to make sure the water jets are hitting bottles at their inside and there are no leaks in the system.

- Make sure there are no loose cables or water under the machine. This can cause short-circuits.

- Assure the bottles are well fastened to the structure and make a one-minute run test before the preheating process to certify the bottles won't come off.

- Secure the pump to the floor so it won't move during operation. Consider that the system will operate under high pressure values.
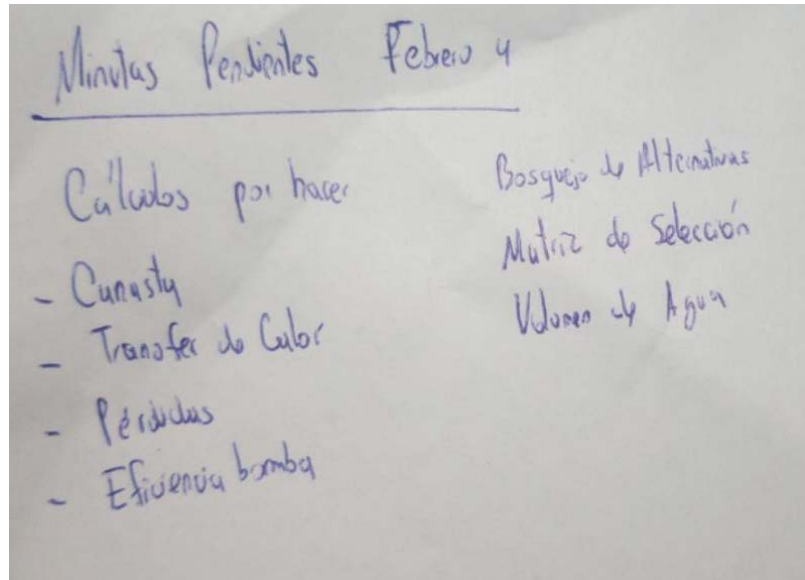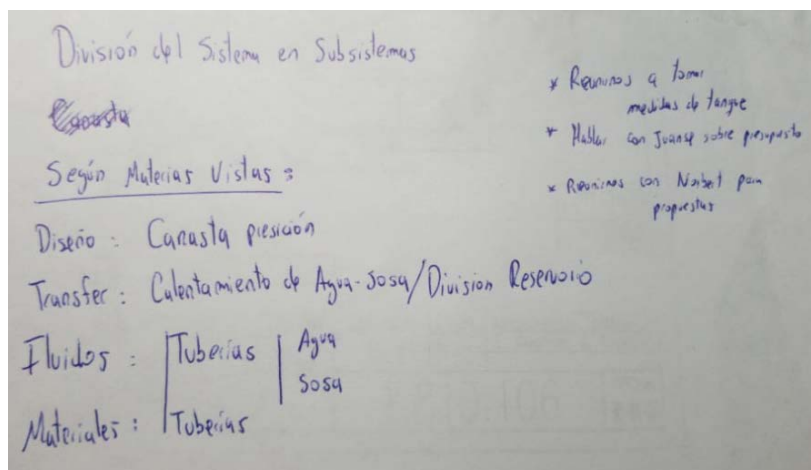
Meeting Minutes

Figure # 97: first meeting minute

Figure # 989: second meeting minute