UNIVERSIDAD DE INVESTIGACIÓN DE

TECNOLOGÍA EXPERIMENTAL YACHAY

Escuela de Ciencias Químicas e Ingeniería

TÍTULO: 3D Design of Experimental Setup for High Pressure and Variable Temperature Studies

Trabajo de integración curricular presentado como requisito para la obtención del título de Ingeniero en Polímeros

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Urcuquí, septiembre 2021

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DEDICATION

This work is dedicated to my parents Enma and Segundo. I hope this achievement will complete part of the dream that they had for me all those years ago when they decided to give me the best education they could.

And finally, this work is dedicated to myself, for despite, the self-doubt, lack of confidence and unrelenting frustration, I was able to be kind enough to myself to complete this thesis and achieve this dream I have nurtured throughout these years in university.

Evelyn Andrea Callataxi Suárez

ACKNOWLEDGEMENTS

I would like to thank the following people without whom the development of this project would have not been possible.

First of all, I would like to thank Yachay Tech University for allowing me to grow as a professional and as an individual and also for giving me a second home for the past few years.

Thanks to every single of my teachers, for every class, for every encouraging conversation, for the passion they showed me. And a special thanks to my thesis tutor Ph.D. Marvin Ricaurte for giving me this opportunity to work with him, for challenging my knowledge, for the dedication, enthusiasm, patience, and guidance offered through the development of this project. All of these will accompany me on my new journey.

Thank you to my classmates with whom I have shared many hours of learning, and laughing. Thanks to my friends and roommate who made my stay in university better by giving me a familiar hand to hold onto. And a big thanks to my best friend who even though was at a long distance still felt close to me.

To my uncles, aunts, and grandparents who have acted as second parents to me, all of their encouraging words and support I hold close to my heart.

Finally, the biggest and warmest thank you to my parents and brother who are my safe place. For reaching to me through the phone to offer kind words when I needed them the most. For welcoming me at home with such love and enthusiasm every time I needed to take a breath. I cannot thank them enough for the numerous times they showed me their unconditional love and trust. The joy I feel now, this one victory I have achieved is theirs too.

Evelyn Andrea Callataxi Suárez

RESUMEN

El siguiente trabajo presenta el diseño 3D de dos montajes experimentales para estudios de alta presión y temperatura variable. El primer montaje experimental está diseñado para su instalación futura en el Laboratorio E2/E3 y está compuesto por dos reactores sin agitación, unidades de calefacción, controladores, tuberías, accesorios y válvulas. Mientras que le segundo montaje experimental está diseñado para una instalación futura en la terraza del Laboratorio de Docencia y está compuesto por dos reactores agitados, controladores, baños térmicos, tuberías, accesorios y válvulas. Para diseñar los montajes experimentales, fue necesaria la aplicación de principios de ingeniería, desde la conceptualización, hasta el modelaje final. Los diseños 3D se modelaron a través de AutoCAD, para lo cual se necesitaron los conceptos básicos de uso de software CAD. El modelado en 3D ayuda a visualizar los requisitos de espacio para la futura instalación y puesta en servicio de los montajes experimentales. Además, la procura de los materiales necesarios para ambos diseños se llevó a cabo como un paso previo a la futura instalación. Una vez obtenidos los modelos 3D y la lista de todos los componentes, se realizó el análisis económico para determinar el costo total estimado del proyecto. La instalación de estos montajes experimentales será de amplia utilidad para futuras investigaciones realizadas dentro de la Universidad Yachay Tech.

Palabras clave: alta presión, montajes experimentales, diseño 3D

ABSTRACT

The following work presents the 3D design of two experimental setups for high-pressure and variable temperature studies. The first experimental setup is designed for future installment in the Laboratory E2/E3, and is composed of two non-stirred reactors, heating units, controllers, piping, fittings and valves. While the second experimental setup is designed for future installment in the Teaching Laboratory's terrace, and is composed of two stirred reactors, controllers, refrigerated circulators, piping, fittings and valves. The design of the experimental setups required the application of engineering principles, from the conceptualization to the modeling. The final 3D designs were modeled through AutoCAD, for which the basics of how to use CAD software were needed. The modeling of the experimental setups aids the visualization of space requirements for future installation and commissioning of the equipments. Additionally, the procure of the materials needed for each of the designs was carry out as an early step before the actual installation. Once both designs and the list of all components was developed, the economic analysis was done to determine the estimated total cost of the project. The experimental setups serve as a tool for future research done within Yachay Tech University.

Keywords: high-pressure, experimental setup, 3D design

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CHAPTER I

INTRODUCTION

Since the beginning of the industrial period, high pressure processes have been of utmost importance for the chemical and mechanical industry. During this time, as a result of accidents caused by bursting pressure vessels, safer and tight seal pressure vessels were developed. However, the chemical industry continued fast growing and with it came the requirement for more components aside from pressure vessels, such as compressors, heat transfer devices, high-pressure pumps, tubes, fittings, improved sealing systems and complete pressure systems. Nowadays, high-pressures approaches keep on being applied to multiple industries within a diverse range of processes (Eggers, 2012). And within those process constant development and innovation is expected. Furthermore, the implementation of new technologies is most often tested through a science-based approach in a laboratory before it is scaled up to industrial level.

In this context, high pressure systems in laboratories are often used for discovering, testing or improving different process, like the use of supercritical fluids, catalytic chemical synthesis of ammonia, production of low-density polyethylene. Homogenization for the production of emulsions used specially in pharmaceutical, cosmetic, chemical, and food industry. In the enhancement of crude oil recovery there are specially many processes carried out at high pressure like miscibility testing, reservoir's fluids characterization (density, rheology, interfacial tension, wetting, diffusivity, permeability), capture and storage of carbon dioxide (CCS) for gas injection and hydrates formation (Eggers, 2012).

The present work shows the 3D design of experimental setup for diverse studies at high pressure and variable temperature. It is structured in three main parts. Chapter I is an introductory section dealing with the approach to the problem at hand and the objectives of this work. Chapter II presents a compilation of basic knowledge and theorical background tied to this work. Chapter III shows the methodology used to achieved the proposed objectives. Chapter IV shows an economic analysis of the project. This work ends with its corresponding conclusions and recommendations.

1.1 Problem Approach

Nowadays, the engine for growth and welfare for societies are research, development, and innovation activities (R&D&i) (Moreno-Navarro et al., 2014). In developing countries such as Ecuador, the progress of R&D&i implies strengthening research capability and the ability to adapt technology to local conditions. To achieve these goals is necessary to acknowledge high education institutions as the crucial components for research and development because they not only train future scientists and engineers but also carry out research in their own laboratories becoming ideal environments for new talents to bloom (World Bank, 2010). Thus the quality of high education institutions' infrastructure and equipment is of utmost importance. Aware of this reality Ecuadorian universities constantly make efforts to produce research, develop adequate equipment and adapt technology to their country's conditions.

In Yachay University, professors, students, and technicians alike have come together to increase the input of research and development. Some of these efforts relevant to the present work are: a state-of-the-art review on additives that improve the CO_2 capture process (Loachamin, 2021) ; a state-of-art review on evaluation of clays in the CO_2 capture process (Carrión, 2021) ; the installation and commissioning of high-pressure experimental setups for CO_2 capture testing using EDA (Villarroel et al., 2021), among others. As projects like the aforementioned have been developed, more equipment needs to be designed, installed, and commissioned to carry out basic and applied research studies. The present work proposes two preliminary 3D designs of experimental setups for high-pressure and variable temperature analysis studies considering two possible locations within Yachay Tech university: Fume hood in Laboratory E2/E3 and Teaching Lab's terrace. Each of these setups consist of two reactors, accessories, pipelines, fittings, pressure gauges, and multiple valves. The modeling of these designs was done with CAD software.

The designs would provide a guide for the future installation of experimental setups that once implemented can serve as a tool for high pressure and variable temperature studies at the university such as:

- The capture of acid gases (CO_2, H_2S).
- Flow assurance studies.

- Development of new formulations and new materials.
- Evaluation of corrosion inhibitors.
- Studies at extreme conditions of pressure and temperature with different applications.
- Gas hydrates as an alternative for transportation and storage

Later, the experimental setup can be used to provide services to the industry in the province of Imbabura.

1.2 Objectives

1.2.1 General Objective:

To develop preliminary 3D designs of experimental setups for high pressure and variable temperature studies.

1.2.2 Specific Objectives:

- Conceptualize designs according to engineering principles.
- Model the designs using CAD software to visualize the space requirements for future installation and commissioning of the equipment.
- Procure of the equipment and material needed to ensemble the experimental setups.
- Develop an economic analysis to determine the associated cost to each of the two experimental setups.

CHAPTER II

BACKGROUND AND LITERATURE REVIEW

This chapter intends to summarize the related literature for the development of the 3D design of high-pressure experimental setups through CAD software. The most important points to mention may be high-pressure common processes, experimental setups, its components, characteristics and applications and finally, the characteristics of CAD software which make it fitting for this project.

2.1 High pressure processes

The development of high-pressure processes is tied to the mechanical and chemical industry due to the need for safe and tight seal vessels working at very demanding conditions. Figure 1 shows the different pressure ranges at which some high-pressure processes operate. In the literature there are many high-pressure processes that have been developed further or new ones that have been introduced overtime. Some examples of these processes are in material's science which uses high pressure to form ceramics, polymers or crystal with special properties. The oil and gas industry uses high pressure for enhanced recovery. Also, the liquid natural gas industry (LNG) has increased significantly due to high pressure systems (Eggers, 2012).

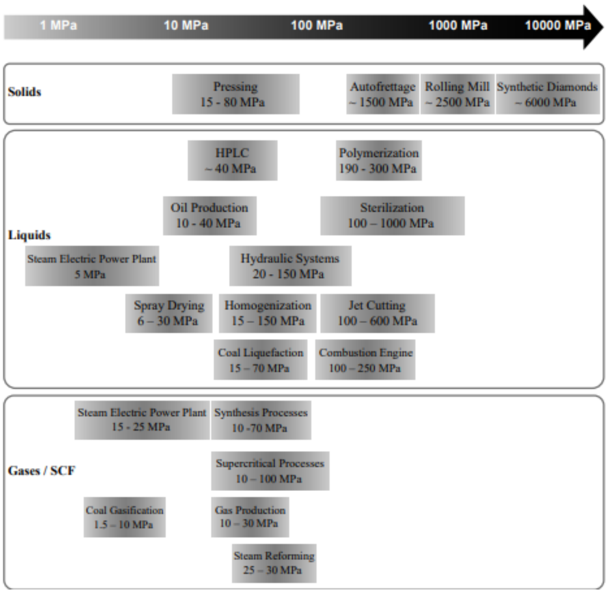

***Figure 1**. Pressure ranges for common pressure processes* (Eggers, 2012).

2.2 High-pressure experimental setup

A pressure system comprises one or more pressure vessels of rigid construction, associated piping, valves, fittings, accessories and protecting devices; which contains a fluid such as steam, gas, etc. (Great Britain. Health and Safety Commission., 2000). According to the Great Britain. Health and Safety Commission (2000): pressure systems can be divided into three categories: Minor systems which can contain steam, pressurized hot water, compressed air, inert gases and do not include pipeline. The pressure in the system should be less than 20 bar (2.0 MPa) if there is not a direct-fired source, while the temperature should be between -20°C and 250°C except for systems with refrigeration operating a lower temperature. In the other hand, major systems may include steam generating systems where individual generators can produce more than 10 MW. These types of systems also include the ones where the pressure-volume product for the biggest vessel is more than 10^6 bar liters (100 Pa m^3). Finally, the intermediate systems include storage systems and pressure systems that do not fit into the other categories. They may also be considered intermediate if they include pipelines unless the system has other aspects of the major category.

There are different examples of pressure systems, for instance, pressurized process plant and piping, stem boilers and steam heating systems, refrigeration systems and compressed air systems, simple pressure cookers, vacuum autoclaves for sterilization, bioreactors, fermenters and small bench equipment for research purposes. (Great Britain. Health and Safety Commission., 2000).

The high-pressure experimental setups proposed in this work would be considered intermediate systems, since they are designed to perform processes at higher pressures than 2 MPa and also the systems include pipelines.

2.3 High-pressure experimental setups applications

In accordance to the previously reported information, high pressure processes take place in several fields, and in consequence, the uses of laboratory equipment to continue developing these processes are also diverse. In the literature there are few examples of experimental setups and its applications at high-pressure.

- *Carbon dioxide capture*

Out of the global power generation, 42% comes from coal power plants and compared to the other fossil fuels, this type of energy generation causes a high emission of carbon dioxide that ranges from 750 to 1100g/kWh. To reduce these emissions, one of the approaches taken by the industries is the capture and underground storage of CO_2 known as CCS technologies. Furthermore, while capturing CO_2 emissions, research has taken an advantage of the high miscibility of CO_2 and has made efforts to concentrate it from flue gases and store it in smaller volumes as a condensed or supercritical phase that could be used for enhanced oil recovery (Eggers, 2012). However, the most developed and most viable technology for CO_2 capture might be chemical absorption. In their work, Villaroel et al. (2021) point out, that, in this field, many studies at laboratory scale are carried out to improve and identify new solvents for chemical absorption of CO_2, however many of them are carried out at low-pressure when most of these processes are operate at high pressure conditions at industry level. As consequence their work present the installation and commissioning of a high-pressure experimental setup in Yachay University (Figure 2) for CO_2 capture testing using EDA aqueous solutions at different concentrations.

Figure 2*. Final result of the experimental equipment after assembly* (Villarroel, 2020) .

Figure 3 illustrates the scheme of the experimental setup used to perform kinetic and thermodynamic analysis of high-pressure CO_2 capture with EDA. This setup consists of a non-stirred pressure vessel with a capacity of 98.7 cm^3 supplied by a CO_2 store cylinder that is in turn connected to a pressure regulator. These units are coupled together by seamless tube. Additionally, there is a heating unit and a temperature controller. The setup has connection to SpecView 32 SCADA software to record temperature and pressure measurements in the computer.

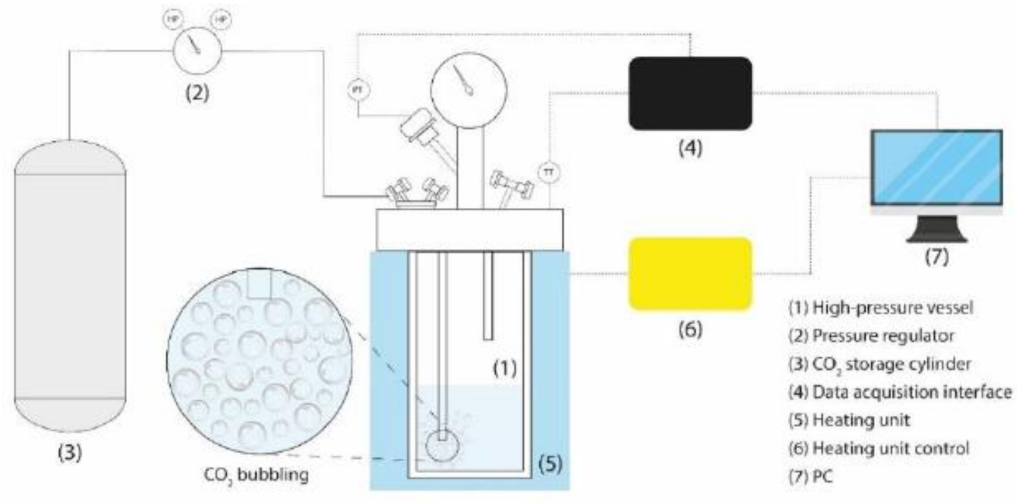

Figure 3. *Schematic diagram of the high-pressure setup* (Villarroel et al., 2021).

Also in the same field is the work by Wang et al., (2013) which studied CO_2 capture by selective hydrate formation. In this process CO_2 is separated by the engagement of its molecules in the cages of the hydrate. The proposed model to carry out this process is fairly simple. There two parts, during the first one a mixture of CO_2 and more gases enters the system into hydrate reactor and CO_2 goes through selective hydrate formation and is caged into the hydrate. Also, CO_2 can be recovered by depressuring (Figure 4a) and during the second part of the process CO_2 is prepared for an easy disposal since it was stored in solid form (Figure 4b) (Wang et al., 2013).

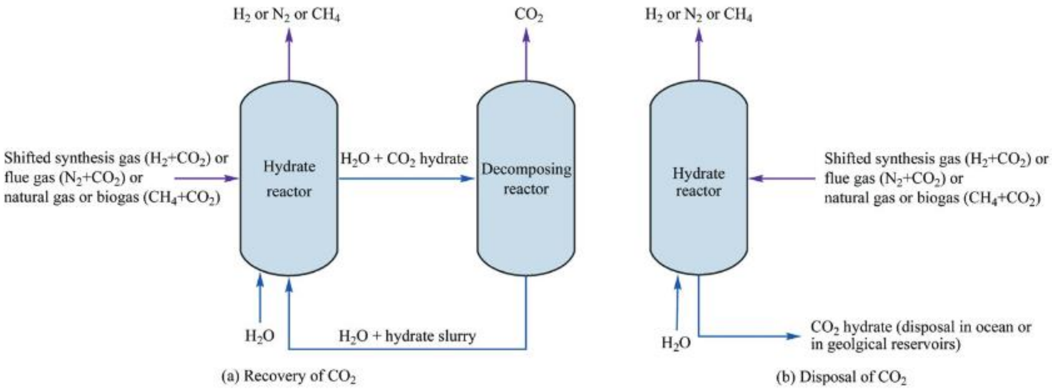

Figure 4. *Schematic diagram of CO2 capture by hydrate formation* (Wang et al., 2013).

This proposed setup is at laboratory scale and, in this case, according to Wang et al. (2013) it is relatively easy to carry out CO_2 capture due to the huge hydration pressure difference between CO_2 and the other gas in the mixture.

- *Flow assurance*

Modern society heavily depends on hydrocarbon industry, which in consequence has led to the rise of a variety of challenges in the exploration, production, and transportation and storage technologies of hydrocarbons. One of the most severe challenging aspects are the risks associated with the transportation of multiphase fluids through pipelines. The fluid flow must go from the deposit to the surface facilities, without being halted in any way. These interruptions could take place because of water, oil and gas flowing simultaneously and the potential risks are pipelines' obstruction because of the formation of solids due to a variation in the composition of the fluid under specific pressure and temperature conditions. Corrosion may occur when the water cut is high. Formation and deposit of scales inside the pipeline might also halt the flow and facilitate the formation of slugs, causing operational problems. To present a solution to this challenge, studies to identify and quantify flow assurance risks are needed. At laboratory scale PVT studies for flow assurance can be performed. For this type of analysis, the samples of the deposit's fluids are studied to determine their composition, potential for wax and asphaltene deposition, corrosivity, its overall characteristics and behavior in function of temperature and pressure. Commonly, this analysis is carried out by simulating the drop of the deposit's pressure. Once the analysis is carried out, information about the physical properties of the fluids' behavior in a wide range of conditions is obtained, along with information of how the composition of the fluid varies (Guo et al., 2014).

- *Hydrates characterization and analysis*

Gas hydrates are low molecular weight molecules with crystalline structures which contain small water and gas molecules at high pressure and low-temperature conditions (Dong et al., 2021). Research in the field of gas hydrates has shown they can be used as potential sources of methane, gas transport, and storage, flow assurance, desalinization of seawater, gas separation, and CO_2 capture. For these technologies to continue maturing, experimental setups were developed using reactors of different types and auxiliary equipment (Figure 5). These experimental setups enable the analysis and characterization of hydrates. For this purpose, a few studies take place: a study of the effect of water's enclosure in small pores of gas hydrates at high pressure over equilibrium conditions and tensiometry studies to understand phenomena at the interface (Díaz & Ricaurte, 2021).

Figure 5. *Experimental setup for the analysis and characterization of hydrates (Díaz & Ricaurte, 2021).*

2.4 Materials, accessories and fittings for experimental setups

The most used material of construction for gas systems piping is 316 L stainless steel. It has been proved to be adequate in applications that work with most of the gases including some with relative inertness. Moreover, this material is chosen because of its good weldability, availability in different sizes and forms, and the large range of products like tube fitting, valves, etc. For a high-pressure system, the operating pressure is higher than the standard service pressure delivered to the user by the source. In these types of setups, a service regulator is needed on each service line to control the pressure. To ensure a tight seal between pipes and tube fitting, valves, gauges, etc., the use of compression fittings (front ferrule, back ferrule and nut) is encouraged. Another main advantage of the use of these fittings is the ease with which the components of the experimental setup connect. There are quite a lot of types of valves in the market and each can have different applications in a high-pressure experimental setup (Bolmen, 1998). To mention some examples, needle valves are used in the pressure systems to regulate pressure and precise control flow like control of flow direction and open and close status (Qian et al., 2019), and ball valves are used in fully open or fully closed positions, for quick opening and closing. They are used for isolating sections of the pipeline, in case of emergency (Shashi Menon, 2015).

2.5 Challenges for developing high-pressure experimental set-ups

In the developing process, there are many strategies to produce the main components, accessories, fittings, etc. One of the most common decisions for the developing process is the question of whether to produce these elements in-house or outsourcing them. An in-house strategy gives full control over the aspects of the developing process. This strategy may make the developing quicker since it reduces delays between stages. Some challenges of establishing an efficient in-house strategy for developing a project is to acquire a variety of information for the whole production and design. Equipment, hand-labor and facilities are needed for every step of the developing process which represent higher costs. In the other hand, an outsourcing strategy consists on transferring a complete section of the production or service to subcontractors, that is acquiring services or buying equipment from suppliers. The benefits of this strategy are the possibility to focus in the most important part of the process and the reduce in operational costs. Some of the challenges of this approach is the evaluation of the best subcontractors or suppliers, according the requirements. Outsourcing can completement an in-house production (Qi, 2008); (Liberty Electronics, 2021).

2.6 Computer-aided design (CAD)

2.6.1 Definition

CAD is a group of applied techniques that enable engineers and design professionals to model a two- or three-dimensional entity. Some of the advantages of working with CAD software are quicker design analysis and calculations, an increase in the adaptability of the product to the new market challenges, the interaction and facility to create new designs. The possibility of modeling the behavior before its construction, the model serves as a database for future construction. Improves the detailing of final products and provides direct transfer of database from CAD to an external software (Gómez & Tubón, 2017).

2.6.2 Considerations for the use of CAD

The first consideration is to develop a draft or conceptualization of the needed product, this step will help visualize the product in early stages of production. To make the best use of a CAD software a good computing power PC may be required, with good enough processing speed, considerable RAM, and many times, quality of the display of the results delivered by the software. Another consideration to work with a CAD software is to get acquainted with the basics, since this software can be used through programming languages and application packages. The former one implies broad knowledge of the determined language, mathematic, geometric, and vectorial analysis while application packages have become more used and assimilated because of its constant development, specialization in different applied areas, and the open architecture design graphic interface (Rojas & Rojas, 2006).

2.6.3 Application areas of CAD software

CAD software is constantly used by engineers and designers in different fields such as:

- Chemical engineering
- Mechanical engineering
- Industrial engineering
- Electrical and electronic engineering
- Aerospace engineering
- Animation production
- Artistic digital design, among others (Gómez & Tubón, 2017).

CHAPTER III

METHODOLOGY

This chapter presents the methodology used to develop the 3D design of two experimental set-ups. Design A is a non-stirred high-pressure and high-temperature experimental setup. Design B is a stirred high-pressure and low-temperature experimental setup. The possible installation places for these setups are the Laboratory E2/E3 and the Teaching Laboratory's Terrace, respectively. To fulfill the stated objectives of this work, a standard methodology for design was established (Figure 6). This process consists of four levels: conceptualization, modeling and detailing, procurement of materials and economic analysis.

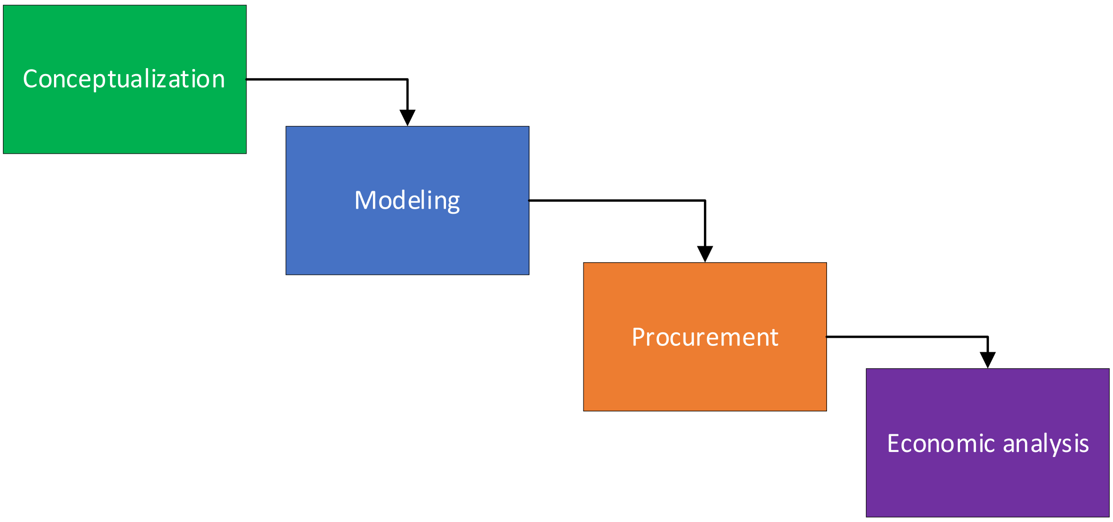

Figure 6. *Schematic diagram of the methodology*

3.1 Conceptualization

During this stage, many aspects were considered for the development of the experimental setups. To start the design process, the purpose of the experimental setups was determined. In this case, the experimental setups are pressure systems expected to perform studies at high pressure and variable temperature. The general high-pressure processes to be carried out in these systems are gas injection into a liquid phase type of reactions, and with a low level of production since they will be used for research purposes mainly. Hence, the setups' main components are non-stirred and stirred batch reactors for design A and B, respectively.

The conceptualization of design A starts with the idea to expand the applications and functionality range of the experimental setup designed, installed and commissioned by Villarroel et al., (2021). By conceptualizing another non-stirred batch reactor in this system, the possibility to have both reactors operate in series and parallel is opened. This physical configuration is also enabled by adding an adequate arrangement of piping, fittings and valves. The reactors also need accessories like a heating unit for the pressure vessel, controllers to facilitate the precise temperature control and that allow the user to visualize data through a PC. Furthermore, for design A, space requirements were especially important since the possible installation is the fume hood in the Laboratory E2/E3. The fume hood's dimensions are 1.37m length and 0.5 width. In the other hand, for design B two stirred reactors were conceptualized. The stirring helps to mix uniformly the composition and temperature of the contents of the vessel. To make up for energy effects caused by the chemical reactions, the reactors may have jacketed walls or internal heat exchangers. Other accessories for the reactors are external refrigerated circulators and energy suppliers. In the same manner as design A, the physical configuration of the main components, accessories, fittings and valves is visualized so the reactors can operate as connected in series or parallel.

3.2 Modeling with AutoCAD

For this stage, the overall layout design is obtained which encompasses the general arrangement, spatial compatibility, the preliminary form design, and provides solutions for any auxiliary functions. To achieve this purpose an exhaustive effort was made to collect technical information on the components of the design, the accessories, fittings, valves, etc. The modeling of the 3D design was made through the CAD software AutoCAD.

For this work, the most important requirement was the space constraints. For the experimental setup designed for the Laboratory E2/E3, first, the fume hood was molded using the geometric, structural, and dimensional information (Figure 7).

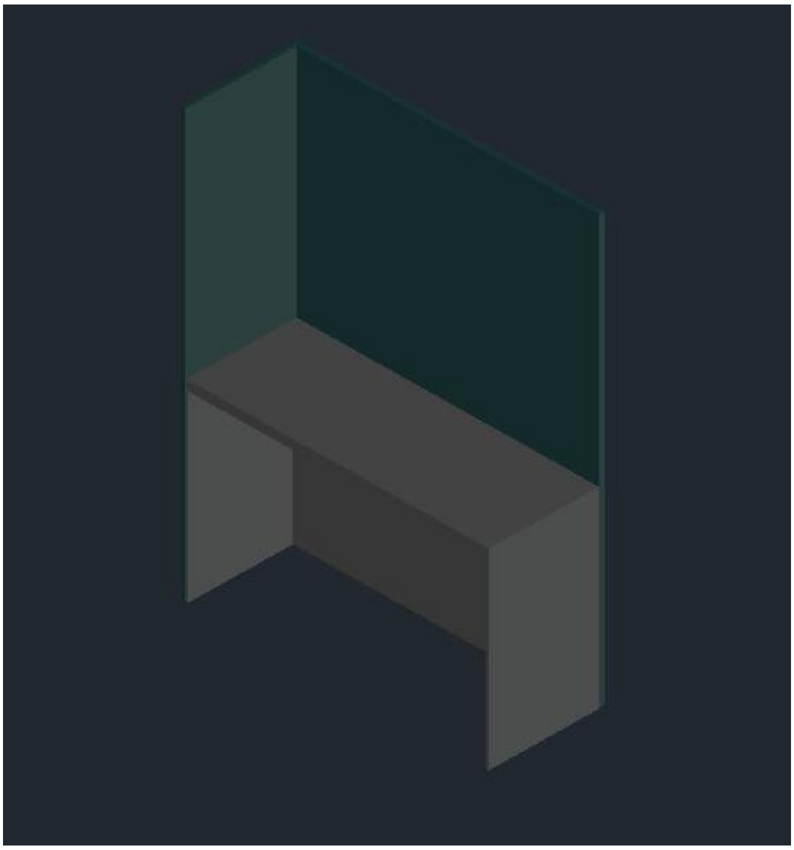

Figure 7. *SE isometrical view of the fume hood.*

For the experimental setup designed for the Teaching's laboratory terrace, two tables were conceptualized, they have the following dimensions: 1500 x 750 x 900 mm (Figure 8).

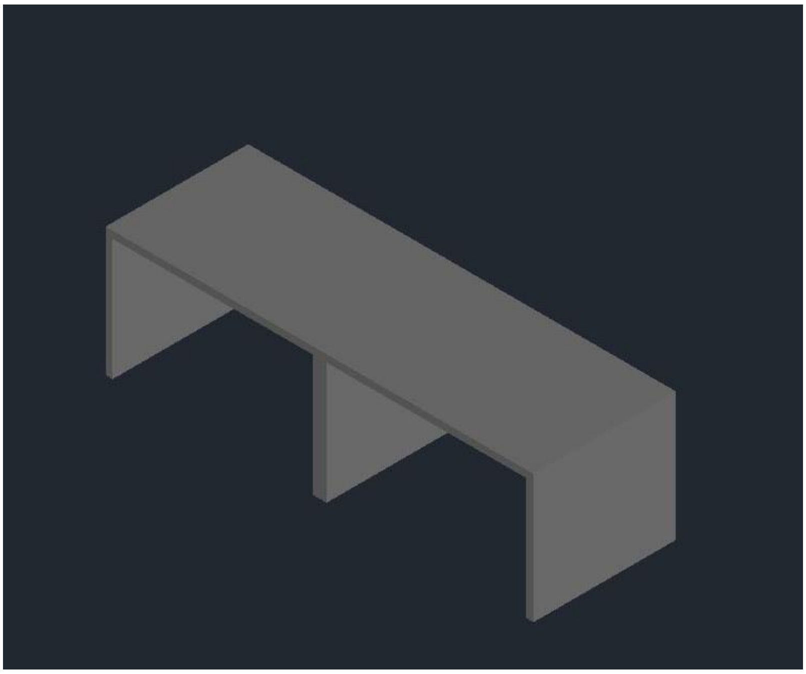

Figure 8. *SE isometrical view of the tables in the Teachings Laboratory.*

With the space requirements covered, the arrangement-determining requirements must be met. In this case, twisted pipelines were designed to aid the motion of the reactors, furthermore pipelines and relief valves in the direction of the ceiling to make use of the fume hood and for protection against accidental overpressure. The next step was to acquire, from the official supplier's catalogs, the available templates for the tube fittings, valves, and pressure gauges. They were dimensioned and placed according to the scheme obtained from the conceptualization phase (Figure 9).

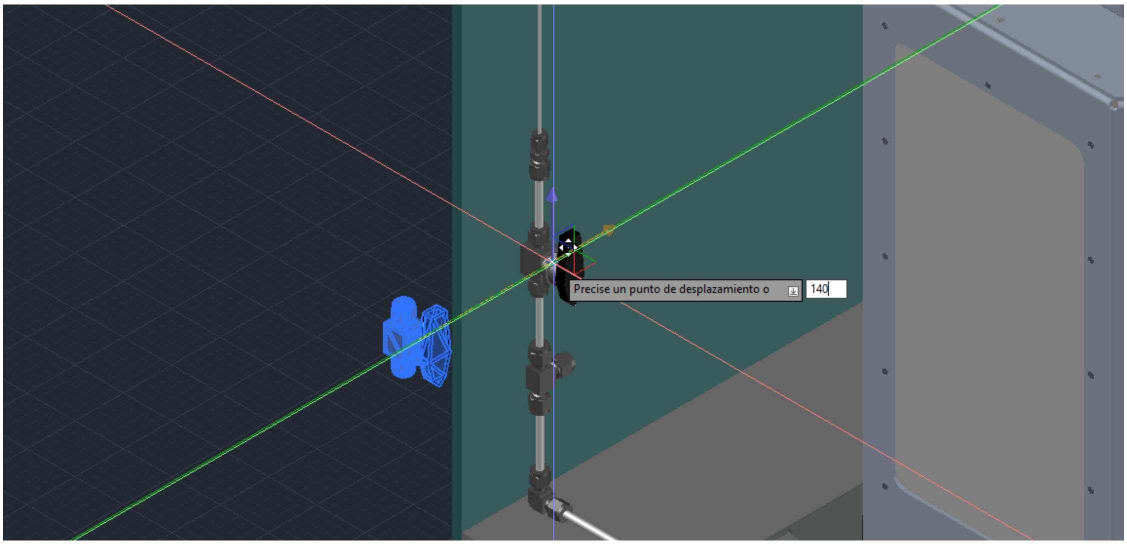

Figure 9. *Spatial placement and dimensionnement of the valve template*

In the same manner, the templates for the reactors were obtained, dimensioned, and placed accordingly. Pipelines, gas storage tanks, controllers, regulators, and components without an official template were designed and modeled.

3.3 Detailing and procurement of materials

This project is considered to have an in-house and outsourcing approach. The complete design is developed in-house and all the materials are considered to be outsources from suppliers. To procure the materials and get an estimated cost, it is necessary to specify all the components to more detail. The dimensions, properties, codification, technical specifications, construction materials. As a result, the final layouts for the experimental setups are obtained, which also functions as a construction manual for the future ensemble. To evaluate a list of possible suppliers, the most important aspects taken into account

were: the competitive costs, quality of the products, shortest delivery times, technical services, among others.
The main suppliers determined for this work were Swagelok and Parr which are two companies specialized in manufacturing high-pressure piping, fittings, etc. and reactors, respectively.

3.4 Economic analysis

To develop the economic analysis, the first step is to curate a list of the main components, accessories, fittings and valves needed for each of the designs. After this stage is concluded, the estimated costs from the suppliers are obtained.

CHAPTER IV

3D DESIGN OF EXPERIMENTAL SETUPS

This chapter presents the technical descriptions of the main components, connections and accessories. The process flow diagram (PFD), the equipment detailed description, the 3D designs, the list of materials for design A and design B.

4.1 Design components

4.1.1 Main components

- *Non-stirred Reactor*

The reactor is a batch Parr HPS - model 4793 (Figure 10) which employs a 100 ml pressure vessel, a benchtop stand, and ceramic fiber heater. It is adequate for working with expensive materials or in small amounts, which makes it ideal for the process of using hazardous materials that need to be limited to a minimum to reduce risks. Additionally, it reduces the number of waste products. The vessel's standard maximum operating temperature is 500K and a pressure up to 20685 KPa.

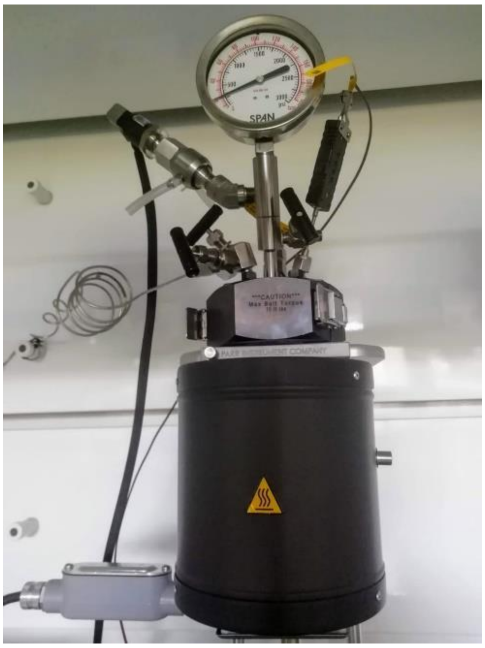

***Figure 10**. Reactor Parr HPS - model 4793.*

The reactor consists of a moveable head with different fittings. A differential pressure gauge, a thermocouple, and three valves that allow gas release, liquid sampling, and gas injection into the liquid phase. The head is clamped to the cylinder by a split-ring with cap screws. To load the liquid phase into the vessel the two rings are removed. To close it, the head is locked with an encircling drop band (Parr Instrument Company, 2021).

- *Stirred reactor*

The stirred reactor is a batch Parr 5100 model (Figure 11) which employs a 160 ml capacity vessel, a bench top stand and a glass/metal jacketed wall. It is ideal for a pressure system running reactions that need stirring, convenient for operation at relatively high pressure and where resistance for corrosion is needed. The reactor possesses an electrical supply and positive agitation is supplied by high torque magnetic drives. The head fittings include valves for gas inlet, gas release and liquid sampling, internal thermocouple for temperature control. The reactor includes an O-ring and a split-ring closure to clamp the head and the vessel. When opened, a gasket groove retains the O-ring on the head (Parr Instrument Company, 2021).

Figure 11. *Reactor Parr 5100 model.*

4.1.2 Connections and accessories

- *Temperature controller*

The Parr 4838 reactor controller (Figure 12) offers features such as a PID controller for precise temperature control, pressure display module, heating, and cooling control loops, motor speed control, high and low power heater switch. Also, all the modules are equipped with bidirectional digital communications that enable the user to log all current readings to a PC and to send setpoints, stirrer speeds, and alarm values from the PC to the 4848 Controller. This model allows the addition of expansion modules for tachometer, pressure, and high-temperature alarm.

Figure 12. *Temperature controller Parr 4848.*

- *Refrigerated circulator*

The PolyScience Circulating Bath (Figure 13) is a simple unit intended for the precise temperature control of suitable liquids. The equipment’s capacity is 15 liters, its tank is made of stainless steel, has a working temperature range of -40° to 200°C. It possesses a powerful pressure/suction pump and its process connection is a 1/4" female NPT (Polyscience, 2014).

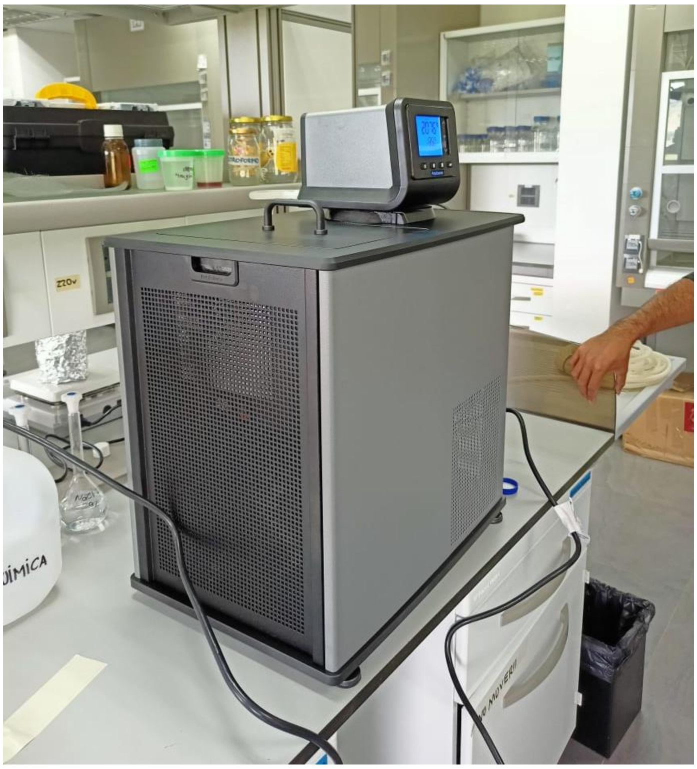

Figure 13. *PolyScience circulating bath.*

- *Valves*

The design of the experimental setup is composed of needle and ball valves. The integral bonnet needle valve is made of 316 L stainless steel with a connection of 1/4 in. Swagelok (Figure 14a). It has a compact design and its working pressure goes up to 6000 psig and temperatures go up to 315°C which makes it ideal for precise flow control and high-temperature applications. The needle valves (Figure 14b) in the experimental setup are a 2-way straight pattern type made of stainless steel with connections of 1/4 in. Swagelok on both sides and 1/8 in. Swagelok on both sides, depending the case. The working pressures go up to 3000 psig (206 bar) and temperatures ranging from –65 to 300°F (–53 to 148°C). They are used widely in many applications since they are practical and economical.

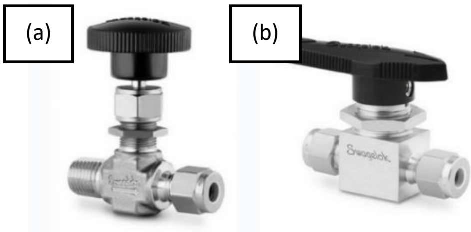

Figure 14. *Valves types: (a) Needle valve - (b) Ball valve*

- *Tube fittings*

The tube fittings present in the experimental setups are elbows, tees and unions. See Appendix 1 for each of their descriptions.

- *Software*

SpecView is a supervisory control and data acquisition (SCADA) software that enables the connection between industrial instrumentation and a PC, it monitors, displays and stores the received information. Additional features of the software include recording of log process parameters, operation of a graphical user interface to visualize the process, operation of a strategy controller logic engine for process automation, display of machine performance, review process operating parameters, replay process conditions, among others (SpecView Inc, 2021). The experimental setup design serves as the communication between the controllers and PCs.

4.2 Physical configuration

The two experimental setups designs have pipelines, fittings and valves arrangement which enables the combination of two reactors that can be operated in parallel or series (Figure 15).

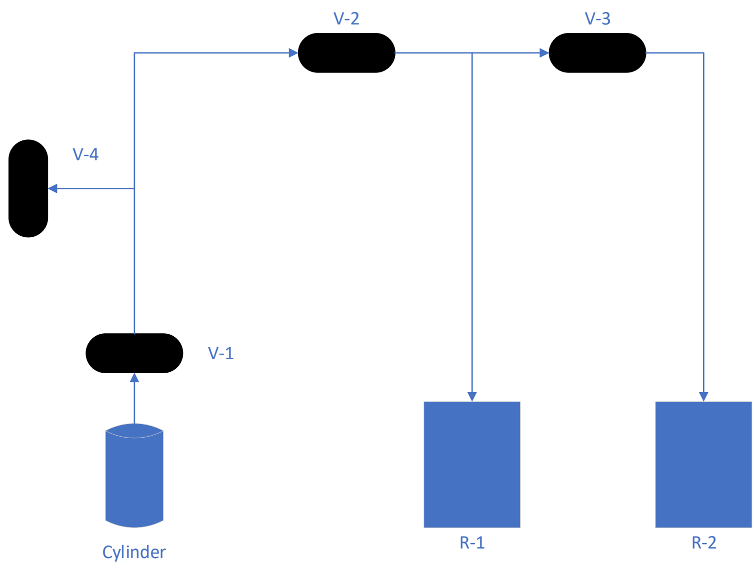

Figure 15. *Physical configuration of two batch reactors, piping and valves.*

In a process where it is preferable to use the reactors connected in parallel, the valve V-1 is opened to supply gas. Valves V-2 and V-3 are opened to allow the gas injection into the liquid phase in the reactors R-1 and R-2, while V-4 is closed since the valve is only used as relief. Additionally, the release and liquid sampling valves in the head fittings of the reactors would be closed, while the inlet valves are open to allow the injection of gas. In the other hand, for a process where it is preferable to use the reactors connected in series, the process could be separated in two parts. For the first part, the valve V-1 is opened to supply gas, the valve V-2 is opened too and the valve V-3 is closed to stop the gas from going into the reactor R-2. For the second part, once the reaction has been carried out in the reactor R-1, the valve V-2 is closed to stop the gas and valve V-3 is opened to allow the gas coming from reactor R-1 to enter the reactor R-2. Additionally, valve V-4 is closed as it is used only for relief or release of gas. Table 1 summarizes the general conditions for the system to operate in series or parallels. These conditions are identical for the two designs presented in this work.

Table 1. *General conditions for operating in series or parallel.*

Conditions	Open Valves	Closed valves
R-01	V-1; V-2	V-3; V-4
R-02	V-1; V-2; V-3	V-4
R-01 and R-02 in parallel	V-1; V-2; V-3	V-4
R-01 and R-02 in series	V-1; V-3	V-2, V-4

4.3 Design A

Design A corresponds to the design of a non-stirred high-pressure and high-temperature experimental setup considering its possible installation in the fume hood of the Laboratory E2/E3.

4.3.1 Process flow diagram

The general process to be carried out in this equipment is the injection of gas from a cylinder T-101 into the non-stirred reactors R-101 and R-102 where a liquid phase is loaded (Figure 16).

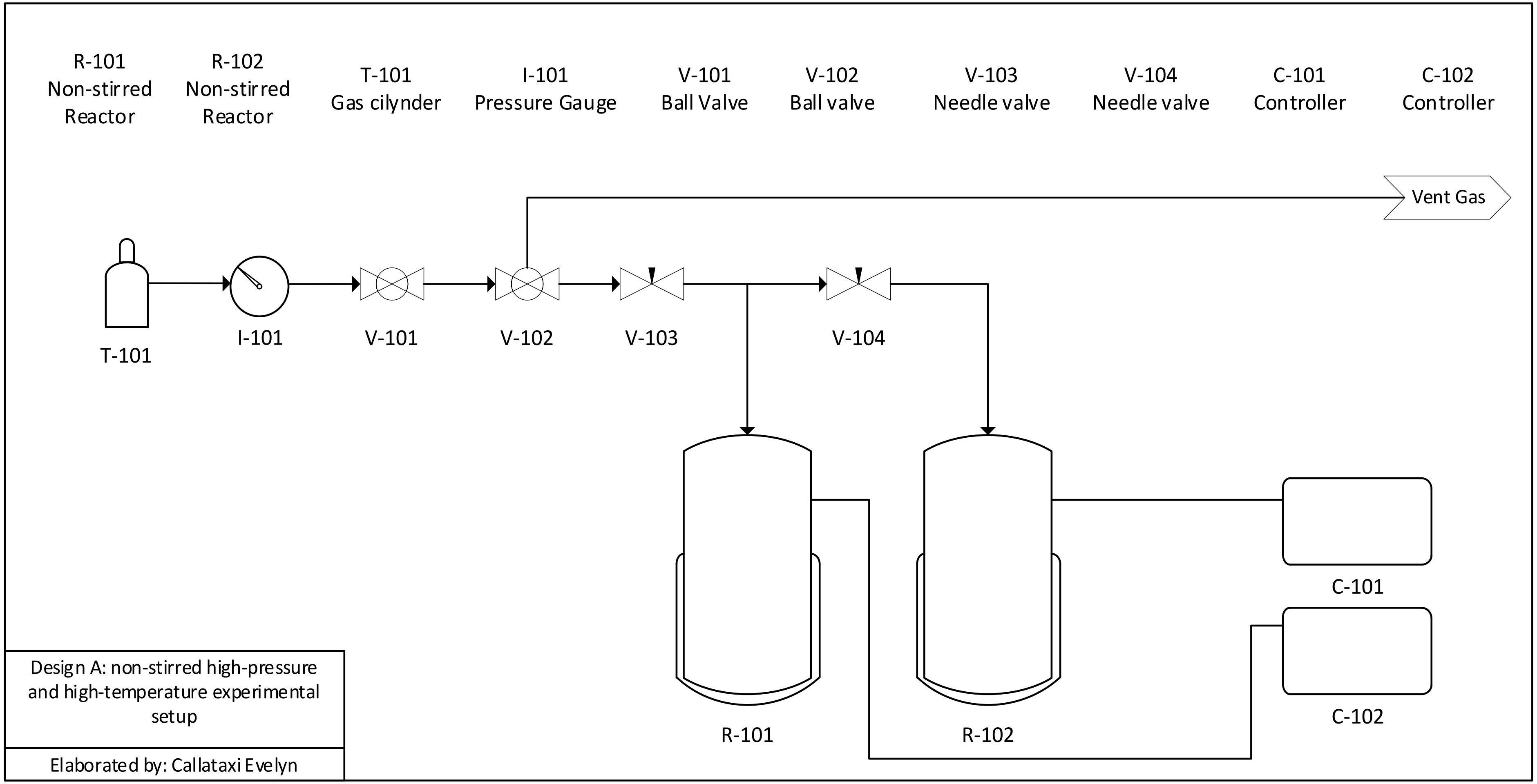

Figure 16. *Flowchart for the process in the non-stirred experimental setup*

4.3.2 3D design

Figure 17 shows the diffent views in AutoCAD for the design A. (a) is the NE isometric view of the equipment. (b) is the E frontal view of the equipment and (c) shows the frontal view of the equipment.

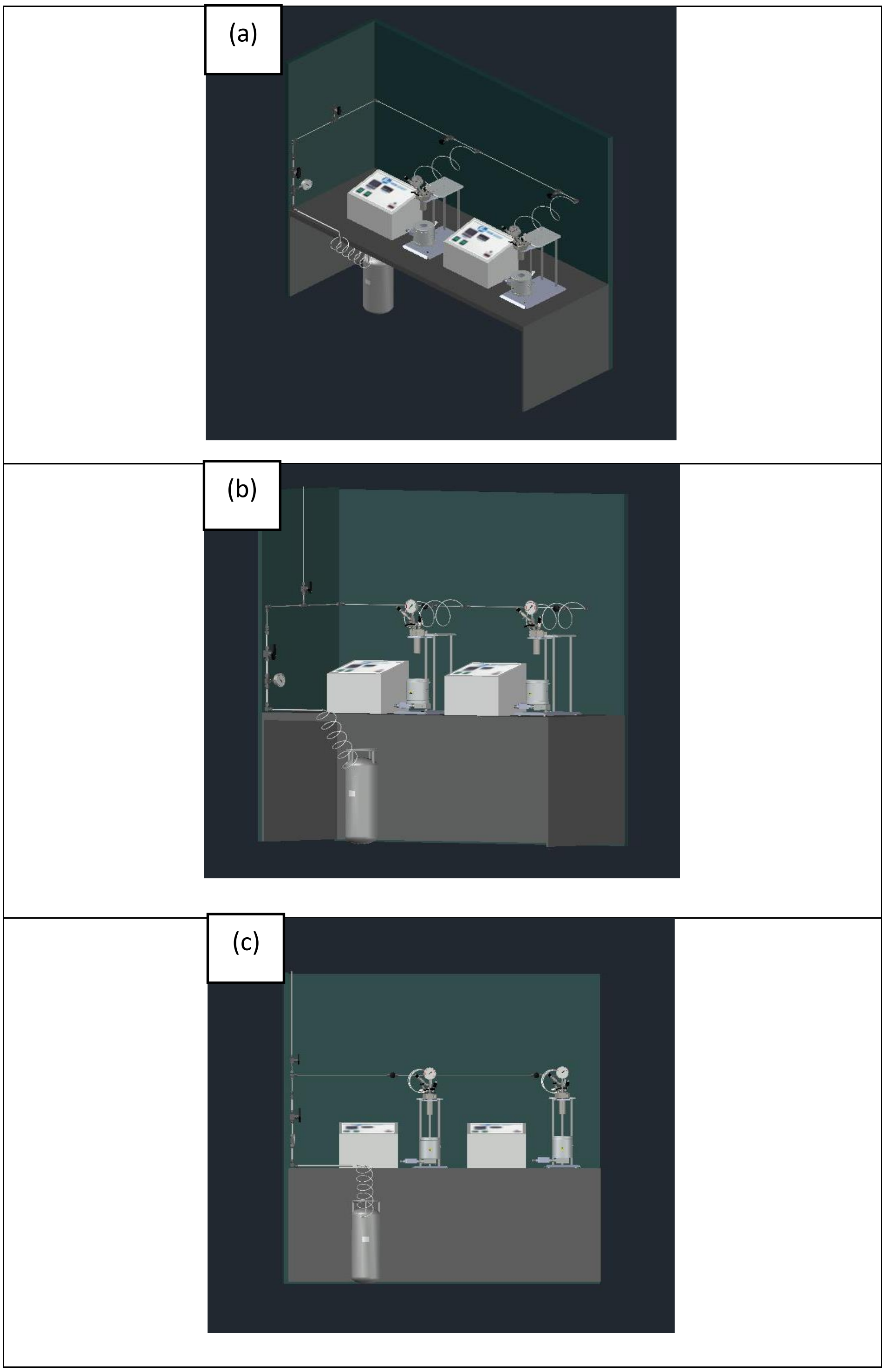

Figure 17. *3D modeling in AutoCAD for Design A.*

4.3.3 Equipment description

The high-pressure experimental setup is composed of two reactors R-101 and R-102, two controllers C-101 and C-102, four valves V-101 to V-104, a pressure gauge I-101, seamless pipeline, tube fittings, a gas cylinder T-101, and a service regulator. A stainless steel backplate sized to match the length and width of the fume hood is conceptualized to cover the left and back walls. The pipeline, tube fittings, valves, and pressure gauge are fixed to the backplate with clamps.

In the first place, the cylinder T-101 inlet connects to a pressure regulator, which has an outlet connection of 1/4”, this outlet fits 300 mm in length stainless steel seamless tubing of 1/4”. Continuing the flow of the gas, a pressure gauge I-101 of 1/4” is connected to display the pressure of the line, after that the ball valve V-101 is used as a shutoff valve to give protection should there be a leak. Afterwards, a reducing unit is used to reduce the pipeline from 1/4” to 1/8”. Using a 90° elbow of 1/8”, the pipeline is redirected to continue parallel to the left wall through a length of 200 mm, then a tee of 1/8” branches the pipeline in two lines. The upstream outlet is connected to the ball valve V-102 is as a vent valve. The other outlet is fitted to a tube section of 100 mm in length and consequently, the pipeline is redirected to continue parallel to the back wall, using a 90° elbow of 1/8”. Then a pipe section of 400 mm is connected to the regulator needle valve V-103, whose outlet is fitted to a tee of 1/8”. One of the outlets of the tee will be fitted to a twisted tubing of 560 mm in length.

The other outlet fits a 400 mm pipe section, then a reducing union is used to change the pipe cross-section from 1/8” to 1/4”, which is connected to the 1/4” reducing union needle valve V-104, another reducing union is used to change the pipe cross-section from 1/4” to 1/8”, then the pipeline is fitted to a 90° elbow of 1/8”. The outlet is then fitted to a twisted tubing of 560 mm in length. Finally, both twisted pipelines are directly connected to their corresponding reactors R-101 and R-102.

4.3.4 Materials

The complete list of main components, accessories, fittings, valves, tubing used for design A is shown in Table 2.

***Table 2**. Complete list of materials for Design A.*

Item	Material description	Quantity
1	HPS - model 4793-100 ml vessel	2
2	Parr 4838 reactor controller	2
3	1-Piece Ball Valve, 1/4 in. Swagelok	1
4	1-Piece Ball Valve, 1/8 in. Swagelok	1
5	Integral Bonnet Needle Valve, 1/8 in. Swagelok	2
6	Union Elbow, 1/4 in. Tube OD	1
7	Union Tee, 1/4 in. Tube OD	1
8	Union Elbow, 1/8 in. Tube OD	3
9	Union Tee, 1/8 in. Tube OD	2
10	Reducing Union, 1/4 in. x 1/8 in. Tube OD	1
11	Industrial Pressure Gauge, 0 to 600 psi, kPa secondary, 1/4 in. tube adapter	1
12	Seamless Tubing, 1/8 in. OD x 0.028 in. Wall x 2.96m	1
13	Seamless Tubing, 1/4 in. OD x 0.035 in. Wall x 1m	1
14	Nut and Ferrule Set for 1/8 in. Tube Fitting	10
15	Nut and Ferrule Set for 1/4 in. Tube Fitting	10

4.3.5 Optimization

For the analysis of optimization, the core parameter to be considered was the length of the pipeline in comparison to the volume of the reactors, to determine the dead volume of gas lost in the pipes that does not contribute to the system (Table 3).

Table 3. *Death volume in the design A.*

Reactors’ volume (Vr)	200	ml
Pipeline volume (Vp)	23.36	ml
Death Volume	**11.68**	**%**

4.4 Design B

Design B corresponds to the design of a stirred high-pressure and high-temperature experimental setup considering its possible installation in the terrace of the Teaching’s Laboratory.

4.4.1 Process flow diagram

The general process to be carried out in this equipment is the injection of gas from a cylinder T-201 into the stirred reactors R-201 and R-202 where a liquid phase is loaded (Figure 18).

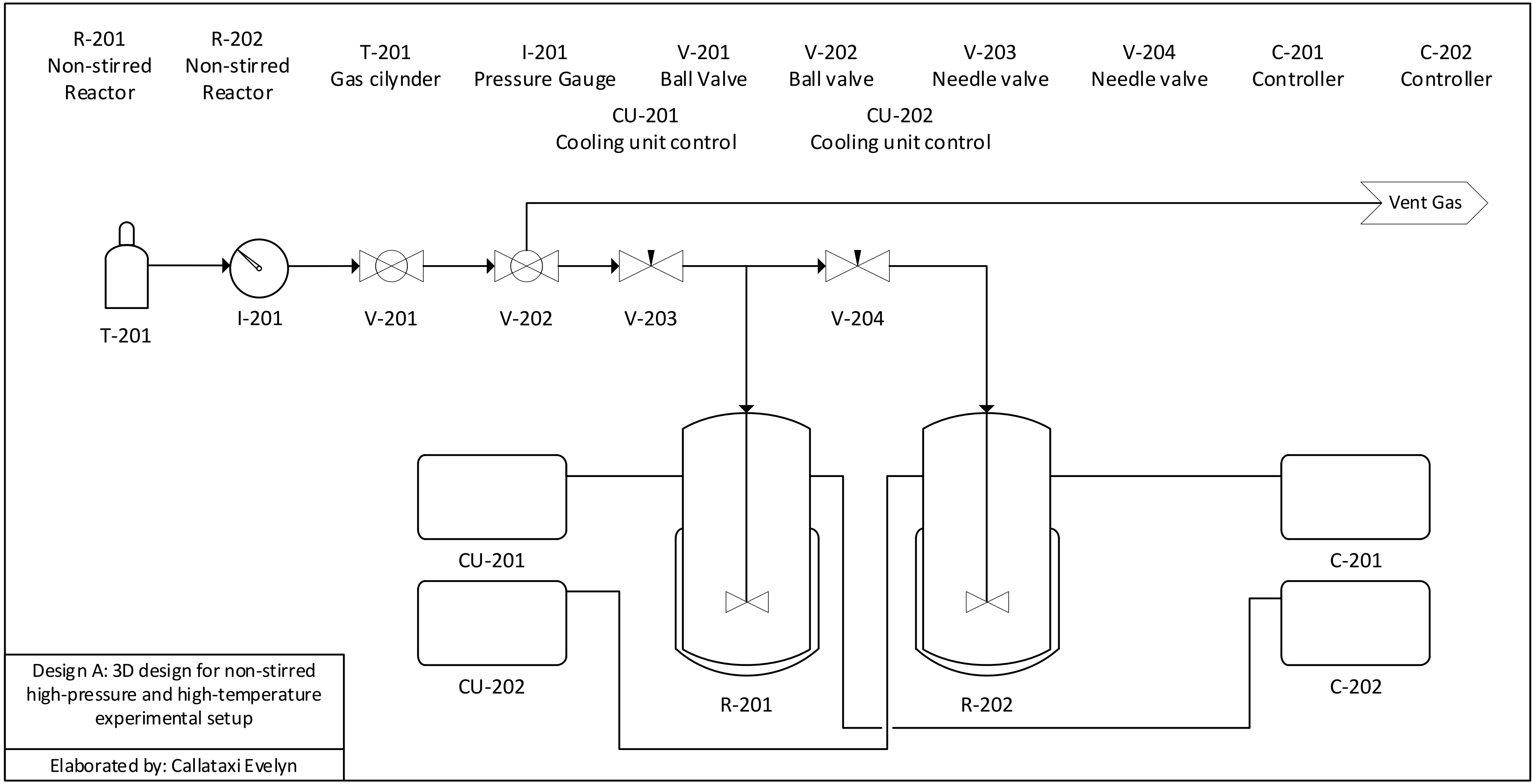

Figure 18. *Flowchart for the process in the stirred experimental setup*

4.4.2 3D design

Figure 19 shows the diffent views in AutoCAD for the design B. (a) is the NE isometric view of the equipment. (b) is the E frontal view of the equipment and (c) shows the S frontal view of the equipment.

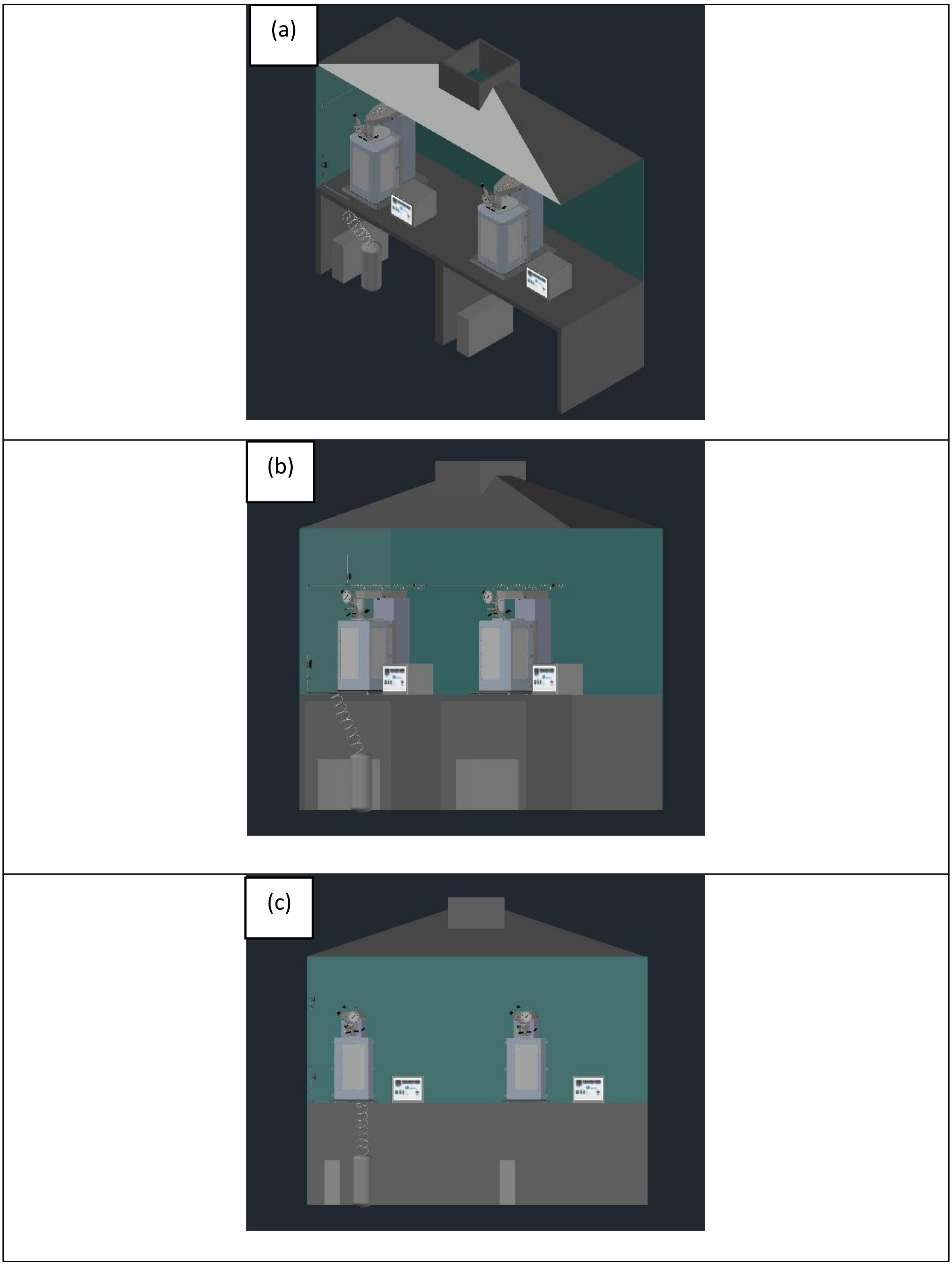

Figure 19. *3D modeling in AutoCAD of design B*

4.4.3 Equipment description

The high-pressure experimental setup is composed of two reactors R-201 and R-202, two temperature controllers C-201 and C-202, two refrigerated circulators RC-201 and RC-202, four valves V-201 to V-204, a pressure gauge M-201, seamless pipeline, tube fittings, a gas cylinder T-201, and a service regulator.

A stainless steel backplate sized to match the length and width of the tables is conceptualized on the left and back walls. The pipeline, tube fittings, valves, and pressure gauge are fixed to the backplate with clamps.

In the first place, the cylinder T-201 inlet connects to the pressure regulator SR-201, which has an outlet connection of 1/4", this outlet fits 300 mm in length of stainless-steel seamless tubing of 1/4". Continuing the flow of the gas, a pressure gauge M-201 of 1/4" is connected to display the pressure of the line, after that the ball valve V-201 is used as a shutoff valve to give protection should there be a leak. Afterward, a reducing union is used to reduce the pipeline from 1/4" to 1/8". Using a 90° elbow of 1/8", the pipeline is redirected to continue parallel to the left wall through a length of 400 mm, then a tee of 1/8" branches the pipeline in two lines. The upstream outlet is connected to the ball valve V-202 it works as a vent valve. The other outlet is fitted to a tube section of 460 mm in length and consequently, the pipeline is redirected to continue parallel to the back wall, using a 90° elbow of 1/8". Then a pipe section of 250 mm is connected to the regulator needle valve V-203, whose outlet is fitted to a tee of 1/8". One of the outlets of the tee will be fitted to a twisted tubing of 1500 mm in length. The other outlet fits a 1400 mm pipe section, which is connected to the regulator needle valve V-204, whose outlet is fitted to a 90° elbow of 1/8". The outlet is then fitted to a twisted tubing of 1500 mm in length. Finally, both twisted pipelines are directly connected to their corresponding reactors R-201 and R-202.

To ensure a tight seal throughout the experimental setups, the compression fittings use front ferrule, back ferrule, and a nut.

4.4.4 Materials

The complete list of main components, accessories, fittings, valves, tubing used for design B is shown in Table 4.

Table 4. *Complete list of materials for Design B.*

Item	Material description	Quantity
1	5100 - model 60 ml vessel	2
2	Parr 4838 reactor controller	2
3	15 Liter Refrigerated Circulator, -40°C	2
4	1-Piece Ball Valve, 1/4 in. Swagelok	1
5	1-Piece Ball Valve, 1/8 in. Swagelok	1
6	Integral Bonnet Needle Valve, 1/8 in. Swagelok	1
7	Integral Bonnet Needle Valve, 1/4 in. Swagelok	1
8	Union Elbow, 1/4 in. Tube OD	1
9	Union Tee, 1/4 in. Tube OD	1
10	Union Elbow, 1/8 in. Tube OD	3
11	Union Tee, 1/8 in. Tube OD	2
12	Reducing Union, 1/4 in. x 1/8 in. Tube OD	3
13	Industrial Pressure Gauge, 0 to 600 psi, bar secondary, 1/4 in. MNPT	1
14	Female Connector, 1/4 in. Tube OD x 1/4 in. Female NPT	1
15	Seamless Tubing, 1/8 in. OD x 0.028 in. Wall x 5.75m	1
16	Seamless Tubing, 1/4 in. OD x 0.035 in. Wall x 1m	1
17	Nut and Ferrule Set for 1/8 in. Tube Fitting	10
18	Nut and Ferrule Set for 1/4 in. Tube Fitting	10

While each of the materials is unique, spare units may be kept at facility. For this reason, in the procure stage, additional materials were added to the final list. See Appendix 2 and 3 for the final lists of procured materials.

CHAPTER V

ECONOMIC ANALYSIS

This chapter presents the estimated cost for the design A and design B taking into account the direct cost corresponding to materials and indirect cost of installation. Moreover, the estimated total for the future installation of both experimental setups is presented.

5.1 Direct costs

Encompasses all cost associated with the implementation of the experimental setup, in this case, the cost of all components of the setup.

5.1.1 Materials costs

They are the main resources used in production, these are transformed into a finished good with the aid of direct labor and indirect costs of production.

For design A: non-stirred high-pressure and high-temperature experimental setup, the total cost of the materials is shown in Table 5.

For design B: stirred high-pressure and low-temperature experimental setup, the total cost of the materials is shown in Table 6.

***Table 5**. Total cost of the materials for design A.*

Item	Material description	Quantity	Unit price	Total
1	HPS - model 4793-100 ml vessel	2	15,440	30,880
2	Parr 4838 reactor controller	2	1,250	2,500
3	1-Piece Ball Valve, 1/4 in. Swagelok	1	108.28	108.28
4	1-Piece Ball Valve, 1/8 in. Swagelok	1	91.34	91.34
5	Integral Bonnet Needle Valve, 1/8 in. Swagelok	2	90.37	180.74
6	Union Elbow, 1/4 in. Tube OD	1	18.52	18.52
7	Union Tee, 1/4 in. Tube OD	1	26.26	26.26
8	Union Elbow, 1/8 in. Tube OD	3	17.46	52.38
9	Union Tee, 1/8 in. Tube OD	2	28.24	56.48
10	Reducing Union, 1/4 in. x 1/8 in. Tube OD	1	13.51	13.51
11	Industrial Pressure Gauge, 0 to 600 psi, kPa secondary, 1/4 in. tube adapter	1	155.58	155.58
12	Seamless Tubing, 1/8 in. OD x 0.028 in. Wall x 2.96m	1	84.12	84.12
13	Seamless Tubing, 1/4 in. OD x 0.035 in. Wall x 1m	1	69.4	69.4
14	Nut and Ferrule Set for 1/8 in. Tube Fitting	10	5.39	53.9
15	Nut and Ferrule Set for 1/4 in. Tube Fitting	10	4.43	44.3
TOTAL				**$34,334.81**

Table 6. *Total cost of the materials for design B.*

Item	Material description	Quantity	Unit price	Total
1	5100 - model 60 ml vessel	2	43,495.20	86,990.40
2	Parr 4838 reactor controller	2	1,250.00	2,500.00
3	15 Liter Refrigerated Circulator, -40°C	2	5,471.50	10,943.00
4	1-Piece Ball Valve, 1/4 in. Swagelok	1	108.28	108.28
5	1-Piece Ball Valve, 1/8 in. Swagelok	1	91.34	91.34
6	Integral Bonnet Needle Valve, 1/8 in. Swagelok	1	90.37	90.37
7	Integral Bonnet Needle Valve, 1/4 in. Swagelok	1	84.35	84.35
8	Union Elbow, 1/4 in. Tube OD	1	18.52	18.52
9	Union Tee, 1/4 in. Tube OD	1	26.26	26.26
10	Union Elbow, 1/8 in. Tube OD	3	17.46	52.38
11	Union Tee, 1/8 in. Tube OD	2	28.24	56.48
12	Reducing Union, 1/4 in. x 1/8 in. Tube OD	3	13.51	40.53
13	Industrial Pressure Gauge, 0 to 600 psi, bar secondary, 1/4 in. MNPT	1	155.58	155.58
14	Female Connector, 1/4 in. Tube OD x 1/4 in. Female NPT	1	13.36	13.36
15	Seamless Tubing, 1/8 in. OD x 0.028 in. Wall x 5.75m	1	84.12	84.12
16	Seamless Tubing, 1/4 in. OD x 0.035 in. Wall x 1m	1	69.40	69.40
17	Nut and Ferrule Set for 1/8 in. Tube Fitting	10	5.39	53.90
18	Nut and Ferrule Set for 1/4 in. Tube Fitting	10	4.43	44.30
TOTAL				**$101,422.57**

5.2 Indirect costs

Table 7 shows all the indirect materials and machine-tools involved in the implementation of the experimental setups. See Appendix 2 and Appendix 4.

Table 7. *Indirect costs for the implementation of the setups.*

Item	Material	Unit Price	Cost
1	Hand Tube Bender, 1/4 in. Tube OD, 3/4 in. Bend Radius	193.12	193.12
2	Hand Tube Bender, 1/8 in. Tube OD, 9/16 in. Bend Radius	397.71	397.71
3	Tube Cutter for Stainless Steel, Soft Copper, and Aluminum Tubing	70.17	70.17
4	Tube Deburring Tool	44.48	44.48
6	Ratchet Wrench, 1/8 in. Tube Fitting Size	35.08	35.08
7	Ratchet Wrench, 1/4 in. Tube Fitting Size	35.08	35.08
8	Stainless Steel Backplate	80.8	404
TOTAL			**$1,179.64**

5.3 Total cost

The toral cost of both high-pressure experimental designs is shown in Table 8.

Table 8. *Estimated total cost of the installation of both experimental setups.*

Direct Cost	Design A	34,334.81
	Design B	101,422.57
Indirect cost		1,179.64
TOTAL		**$136,937.02**

As of today, October 10, 2021, 62% of the total cost is covered. See Appendix 2 for the already acquired materials.

CONCLUSIONS

- The design A is an experimental setup which allows studies at high-pressure and high-temperature, with the possible installation in the Laboratory E2/E3, while the design B is an experimental setup which allows studies at high-pressure and low-temperature, with the possible installation in the Teaching Laboratory's Terrace.

- The purpose, the physical configuration of the reactors, the space requirements, the main necessary components, accessories, fittings, etc. were the major considerations for the design of both experimental setups.

- The use of software CAD allowed the efficient 3D modeling of the experimental setups to provide a visualization the space requirements for future installation and commissioning of the equipment.

- Once the design, list of components, and possible suppliers were determined, the procurement of all the materials was carried out to aid the future installation and commissioning of the equipments.

- The economic analysis provided the estimated cost for the design A and design B materials, the indirect cost of installation, and the total cost of the project. Out of this total valor, the 62% is already covered.

RECOMMENDATIONS

- The experimental setups are general designs conceptualized to carry out a number of different processes. Since Yachay University has produced several research projects for which these experimental setups are useful, it is recommended to carry on with the next stage of the project: installation and commissioning.

- Consider this designing project as a guide for the future installation of high-pressure and variable temperature experimental setups.

- For the future installation and commissioning it is important to consider the safety measures presented in this project which are the installation of relief valves in case of emergency, use of pressure regulators and the maximum operating pressures and temperatures of each of the components.

- It is recommended to capacitate the students, teachers and laboratory staff on the correct use of these equipments to avoid any possible risk related to operating with high pressure and temperatures.

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APPENDIX

APPENDIX 1.

TUBE FITTINGS DESCRIPTIONS

Tube fittings are components used in a pipeline system. According to their specific functions, there are different types of fittings:

- Tee: is a three-way outlet fitting used to make perpendicular connections to pipe, create a branch from the main pipe. The tees used in the experimental setup design are made of 316-stainless steels, all of its connections are 1/4 or 1/8 in Swagelok (Figure 20).

***Figure 20**. Union tee*

- Elbow: component used to change the direction of the pipe. The 90° elbows used in the experimental setup design are made of 316 stainless steel and have connections on both sides of 1/4 in Swagelok or 1/8 in Swagelok (Figure 21).

***Figure 21**. Union Elbow*

- Reducer union: component used to reduce the diameter of the pipe. The reducer proposed in the experimental setup design is made of 316 stainless steel and its connections are 1/4 in Swagelok x 1/8 in Swagelok (Figure 22). (Parisher & Rhea, 2012).

***Figure 22**. Reducing Union*

APPENDIX 2

NEW MATERIALS' QUOTATION

R.U.C: 1791743164001

FACTURA

No. 001-001-000032213

NÚMERO DE AUTORIZACIÓN

0809202001179174316400120010010000322134316400112

FECHA Y HORA DE AUTORIZACIÓN 08/09/2020

AMBIENTE: PRODUCCIÓN

ENTREGA NORMAL

CLAVE DE ACCESO

0809202001179174316400120010010000322134316400112

BOLIVAR INTERNATIONAL SUPPLY BIS S.A.

Dir. Matriz: Av. de los Shyris N35-174 y Suecia, Edificio RENAZZO PLAZA, 6to Piso Oficina 605A

Dir. Sucursal: Av. de los Shyris N35-174 y Suecia, Edificio RENAZZO PLAZA, 6to Piso Oficina 605A

OBLIGADO A LLEVAR CONTABILIDAD SI

Razon Social / Nombres y Apellidos: PROGRAMA DE LAS NACIONES UNIDAS PARA EL DESARROLLO - PNUD

RUC/CI: 1791746791001

Fecha Emisión: 08/09/2020

Referencia: ECU10-0000011061

Guia Remisión: 001-001-000008980

Cod. Principal	Cant.	Descripción	Precio Unitario	Descuento	Precio Total
304L-HDF4-500	1.00	Sample Cylinder 1/4"FNPT, 500 cm3	190.04	0.00	190.04
MS-5K-CY-2"	1.00	Sample Cylinder Carrying Handle	49.58	0.00	49.58
SS-1RM4-S4	1.00	Needle Valve 1/4"MNPT x 1/4"OD	91.38	0.00	91.38
SS-ORS2	2.00	Needle Valve 1/8"OD	90.37	0.00	180.74
SS-1RS4	2.00	Needle Valve 1/4"OD	84.35	0.00	168.70
SS-ORS2-A	2.00	Needle Valve 1/8"OD	105.10	0.00	210.20
SS-1RS4-A	2.00	Needle Valve 1/4"OD	101.25	0.00	202.50
PGI-63B-PG100-LAQX-J	1.00	Pressure Gauge 63 mm, 0 to 100 psi	155.58	0.00	155.58
PGI-63B-PG160-LAQX-J	1.00	Pressure Gauge 63 mm, 0 to 160 psi	155.58	0.00	155.58
PGI-63B-OG600-LAQX-J	1.00	Pressure Gauge 63 mm, 0 to 600 bar	155.58	0.00	155.58
PGI-63B-PG100-LAOX-J	2.00	Pressure Gauge 63 mm, 0 to 100 psi	155.58	0.00	311.16

R.U.C: 1791743164001

FACTURA

No. 001-001-000032213

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0809202001179174316400120010010000322134316400112

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AMBIENTE: PRODUCCIÓN

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0809202001179174316400120010010000322134316400112

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Razon Social / Nombres y Apellidos PROGRAMA DE LAS NACIONES UNIDAS PARA EL DESARROLLO - PNUD

RUC/CI: 1791746791001

Fecha Emisión: 08/09/2020

Referencia: ECU10-0000011061

Guia Remisión: 001-001-000008980

Cod. Principal	Cant.	Descripción	Precio Unitario	Descuento	Precio Total
PGI-63B-PG300-LAOX-J	2.00	Pressure Gauge 63 mm, 0 to 300 psi	155.58	0.00	311.16
PGI-63B-PG600-LAOX-J	2.00	Pressure Gauge 63 mm, 0 to 600 psi	155.58	0.00	311.16
SS-QC4-S-400	3.00	Quick-Connect Stem 1/4"OD	27.88	0.00	83.64
SS-QC4-B-400	3.00	Quick-Connect 1/4"OD	45.54	0.00	136.62
MS-HTB-4	1.00	Hand Tube Bender 1/4"OD	193.12	0.00	193.12
MS-HTB-2	1.00	Hand Tube Bender 1/8"OD	397.71	0.00	397.71
SS-43GS4	2.00	Ball Valve 1/4"OD	108.28	0.00	216.56
SS-41GS2	2.00	Ball Valve 1/8"OD	91.34	0.00	182.68
SS-400-9	4.00	Union Elbow 1/4"OD	18.52	0.00	74.08
SS-200-9	4.00	Union Elbow 1/8"OD	17.46	0.00	69.84
SS-400-3	4.00	Union Tee 1/4"OD	26.26	0.00	105.04
SS-200-3	4.00	Union Tee 1/8"OD	28.24	0.00	112.96

R.U.C: 1791743164001

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RUC/CI: 1791746791001

Fecha Emisión: 08/09/2020

Referencia: ECU10-0000011061

Guia Remisión: 001-001-000008980

Cod. Principal	Cant.	Descripción	Precio Unitario	Descuento	Precio Total
SS-400-4	2.00	Union Cross 1/4"OD	47.52	0.00	95.04
SS-200-4	4.00	Union Cross 1/8"OD	50.71	0.00	202.84
SS-400-6	6.00	Union 1/4"OD	12.75	0.00	76.50
SS-200-6	6.00	Union 1/8"OD	12.90	0.00	77.40
SS-400-7-4	6.00	Connector 1/4"OD x 1/4"FNPT	13.36	0.00	80.16
SS-400-6-2	6.00	Red. Union 1/4" x 1/8"OD	13.51	0.00	81.06
SS-400-1-4	6.00	Connector 1/4"OD x 1/4"MNPT	8.20	0.00	49.20
SS-T4-S-035-20	1.00	Tubing 1/4"OD x 0,035"Wall x 20 Ft	69.40	0.00	69.40
SS-T2-S-028-20	1.00	Tubing 1/8"OD x 0,028"Wall x 20 Ft	84.12	0.00	84.12
MS-TC-308	1.00	Tube Cutter from 3/16 to 1"OD	70.17	0.00	70.17
MS-TDT-24	1.00	Deburring Tool 3/16" to 1 1/2 ", 4 to 38 mm OD	44.48	0.00	44.48
304-S1-PP-4T	6.00	Plastic Clamp Tube Support 1/4"	4.71	0.00	28.26

BOLIVAR INTERNATIONAL SUPPLY BIS S.A.

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OBLIGADO A LLEVAR CONTABILIDAD SI

R.U.C: 1791743164001

FACTURA

No. 001-001-000032213

NÚMERO DE AUTORIZACIÓN

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FECHA Y HORA DE AUTORIZACIÓN 08/09/2020

AMBIENTE: PRODUCCIÓN

ENTREGA NORMAL

CLAVE DE ACCESO

0809202001179174316400120010010000322134316400112

Razon Social / Nombres y Apellidos PROGRAMA DE LAS NACIONES UNIDAS PARA EL DESARROLLO - PNUD

RUC/CI: 1791746791001

Fecha Emisión: 08/09/2020

Referencia: ECU10-0000011061

Guia Remisión: 001-001-000008980

Cod. Principal	Cant.	Descripción	Precio Unitario	Descuento	Precio Total
304-S1T-PP-4T	6.00	Plastic Clamp Tube Support 1/4"	5.96	0.00	35.76
MS-RW-200	1.00	Ratchet Wrench 1/8"	35.08	0.00	35.08
MS-RW-400	1.00	Ratchet Wrench 1/4"	35.08	0.00	35.08
SS-200-NFSET	10.00	Nut and Ferrule Set 1/8"OD	5.39	0.00	53.90
SS-400-NFSET	10.00	Nut and Ferrule Set 1/4"OD	4.43	0.00	44.30
SS-400-SET-10	1.00	Ferrule Set 1/4"OD	22.01	0.00	22.01
SS-200-P	6.00	Plug 1/8"OD	8.05	0.00	48.30
SS-400-P	6.00	Plug 1/4"OD	6.38	0.00	38.28

Información Adicional

Dirección	Vía a Nayón S/N
Teléfono	02 3824240
Email	alexandra.reyes@undp.org
Guías Remisión	001-001-000008980

SUBTOTAL 12.00 %	5336.95
SUBTOTAL 0%	
SUBTOTAL NO SUJETO DE IVA	
SUBTOTAL SIN IMPUESTOS	5336.95
DESCUENTO	0.00
ICE	
IVA 12.00 %	640.43
PROPINA	0.00
VALOR TOTAL	5977.38

APPENDIX 3

NEW MATERIALS' QUOTATION

COTIZACION No. BIS-487-VAR-21 / REV. 1

Página: 1 de 2

A: UNIVERSIDAD DE INVESTIGACION DE TECNOLOGÍA EXPERIMENTAL YACHAY — Su Referencia: EMAIL

Attn. MARVIN RICAURTE — Fecha: 25/08/2021

ITEM	CANT	UNID	REFERENCIA	DESCRIPCION	PRECIO UNITARIO	PRECIO TOTAL
1	5	EA	SS-2C-25	Stainless Steel Poppet Check Valve, Fixed Pressure, 1/8 in. Swagelok Tube Fitting, 25 psig (1.8 bar) TE: 10 SEMANAS	67,46	337,30
2	4	EA	SS-4CA-350	Stainless Steel Poppet Check Valve, Adjustable Pressure, 1/4 in. Swagelok Tube Fitting, 350 to 600 psig (24.2 to 41.4 bar) TE: 10 SEMANAS	78,27	313,08
3	4	EA	SS-200-9	SS Swagelok Tube Fitting, Union Elbow, 1/8 in. Tube OD TE: 1 A 2 SEMANAS	17,46	69,84
4	4	EA	SS-200-3	SS Swagelok Tube Fitting, Union Tee, 1/8 in. Tube OD TE: 1 A 2 SEMANAS	28,24	112,96
5	2	EA	SS-41GS2	SS 1-Piece 40 Series Ball Valve, 0.2 Cv, 1/8 in. Swagelok Tube Fitting TE: 1 A 2 SEMANAS	91,34	182,68
6	2	EA	SS-ORS2	SS Integral Bonnet Needle Valve, 0.09 Cv, 1/8 in. Swagelok Tube Fitting, Regulating Stem Max Temperature with Pressure Rating 450°F @ 3435 PSIG /232°C @ 236 BAR Orifice .080 in Room Temperature Pressure Rating 5000 PSIG @ 100°F /344 BAR @ 37°C TE: 1 EA 1 A 2 SEMANAS / 1 EA 10 SEMANAS	90,37	180,74
7	2	EA	SS-QC4-S-400	SS Instrumentation Quick-Connect Stem w/o Valve, 0.3 Cv, 1/4 in. Swagelok Tube Fitting TE: 10 SEMANAS	22,77	45,54
8	2	EA	SS-QC4-B-400	SS Instrumentation Quick-Connect Body, 0.2 Cv, 1/4 in. Swagelok Tube Fitting TE: 1 A 2 SEMANAS	45,54	91,08
9	1	EA	SS-T4-S-035-20	316/316L SS Seamless Tubing, 1/4 in. OD x 0.035 in. Wall x 20 Feet (Order in 20 foot increments) max. Workin pressure 5100 psig TE: 1 A 2 SEMANAS	69,40	69,40
10	1	EA	SS-T2-S-028-20	316/316L SS Seamless Tubing, 1/8 in. OD x 0.028 in. Wall x 20 Feet (Order in 20 foot increments) max working pressure 8500 psig TE: 1 A 2 SEMANAS	84,12	84,12
11	10	EA	SS-200-NFSET	SS Nut and Ferrule Set (1 Nut/1 Front Ferrule/1 Back Ferrule) for 1/8 in. Tube Fitting, Please order in multiples of five ESTA REFERENCIA SE COMERCIALIZA EN MULTIPLOS DE 5. / TE: 1 A 2 SEMANAS	5,39	53,90
12	10	EA	SS-400-NFSET	SS Nut and Ferrule Set (1 Nut/1 Front Ferrule/1 Back Ferrule) for 1/4 in. Tube Fitting, Please order in multiples of five ESTA REFERENCIA SE COMERCIALIZA EN MULTIPLOS DE 5. / TE: 1 A 2 SEMANAS	4,43	44,30

COTIZACION No. BIS-487-VAR-21 / REV. 1

A: UNIVERSIDAD DE INVESTIGACION DE TECNOLOGÍA EXPERIMENTAL YACHAY | Su Referencia: EMAIL

Attn. MARVIN RICAURTE | Fecha: 25/08/2021

SUBTOTAL	USD.	1.584,94
12 % IVA		190,19
TOTAL DDP QUITO		1.775,13

VALIDEZ: 30 DIAS

ENTREGA: INDICADO EN CADA ÍTEM / BASADO EN EXISTENCIAS A LA FECHA.

STOCK SUJETO A VENTA PREVIA

TERMINO DE PAGO: 100% CON LA ORDEN DE COMPRA

POR FAVOR, COLOCAR LA ORDEN DE COMPRA A:
BOLIVAR INTERNATIONAL SUPPLY BIS S.A.

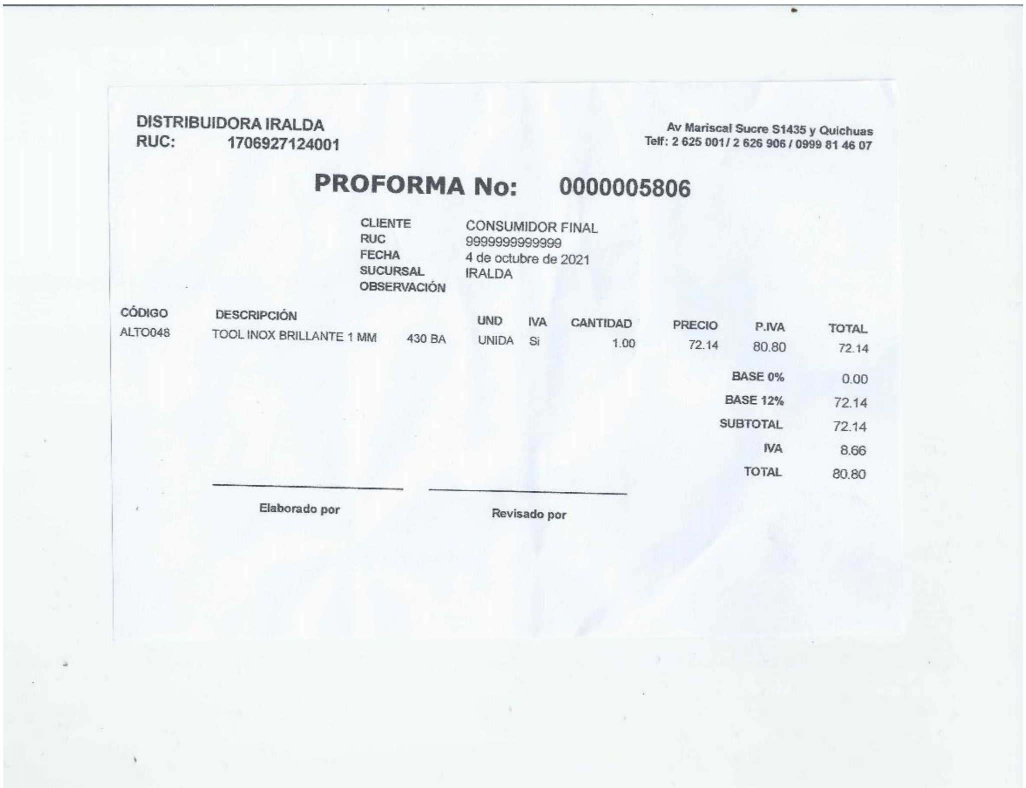
OBSERVACIONES:
PRECIOS VÁLIDOS PARA LA OFERTA TOTAL
CASO CONTRARIO SE RECOTIZARA.
LUGAR DE ENTREGA: BODEGA DE BIS (COTIZACIÓN DDP QUITO ÚNICAMENTE)
POR LA EMERGENCIA SANITARIA, LAS ENTREGAS DEBERÁN COORDINARSE CON ANTICIPACIÓN DEBIDO A LAS RESTRICCIONES DE MOVILIDAD.
NO SE ACEPTAN DEVOLUCIONES DE MATERIALES

Ivan Molina

IVAN MOLINA
GERENTE GENERAL

APPENDIX 4

STAINLESS STEEL SHEET'S QUOTATION



DISTRIBUIDORA IRALDA
RUC: 1706927124001

Av Mariscal Sucre S1435 y Quichuas
Telf: 2 625 001/ 2 626 906 / 0999 81 46 07

PROFORMA No: 0000005806

CLIENTE CONSUMIDOR FINAL
RUC 9999999999999
FECHA 4 de octubre de 2021
SUCURSAL IRALDA
OBSERVACIÓN

CÓDIGO	DESCRIPCIÓN		UND	IVA	CANTIDAD	PRECIO	P.IVA	TOTAL
ALTO048	TOOL INOX BRILLANTE 1 MM	430 BA	UNIDA	Si	1.00	72.14	80.80	72.14

BASE 0%	0.00
BASE 12%	72.14
SUBTOTAL	72.14
IVA	8.66
TOTAL	80.80

Elaborado por

Revisado por