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ACADEMIC MASTER'S END STUDIES

Section: PROCESS ENGINEERING

Option: ENVIRONMENTAL PROCESS ENGINEERING

Theme

Technical Feasibility Study of recovering rejected gas from decarbonization section in GNL2/Z complex BETHIOUA

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Supported on 24 /06 / 2024 In front of a jury composed of:

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ملخص

يبحث هذا العمل فى جدوى تركيب وحدة استرجاع الغاز المنطلق، بهدف النقاط غاز ثاني اكسيد الكربون المنطلق في الغلاف الجوي , منهجيتنا تتضمن تحليل مركبات الغاز كما انها تتضمن تحديد الابعاد الاجهزة يدويا و التي اكدتها عمليات المحاكاة باستخدام برنامج Aspen hysysV11. تظهر النتائج ان ارتفاع و قطر عمود الفصل هي 4,267 متر، 1,219 متر على التوالي والضاغط بقوة 112,2 كيلوواط النتائج تؤكد لنا جدوى المشروع تقنيا مع امكانية التسويق مع مراعاة خصائص الغاز

الكلمات المفتاحية : ثاني اكسيد الكربون ,Aspen HysysV11, تركيب.

Résumé

Ce travail propose une installation pour récupérer le gaz rejeté, avec l'objectif de capter le CO2 rejeté dans l'atmosphère, la méthodologie comprend les analyses de gaz rejeté, ainsi qu'un dimensionnement d'équipements manuel, confirmé par des simulations avec Le Logiciel Aspen HysysV11. Les résultats montrent que la hauteur et diamètre de colonne de séparation sont respectivement de 4.267 m, 1.219 m et le compresseur avec pouvoir de compressions 112.2 kwatt.

Mots clés: CO2, Aspen HysysV11 ,installation.

Abstract

This work examines the rejected gas recovery installation, with the objective of capturing CO2 rejectedinto the atmosphere, the methodology includes analyzes of rejected gas, as well as manual equipment sizing, Confirmed by simulations with the (Aspen HysysV11 software). The results show that the height and diameter of the separation column are respectively 4.267 meters, 1.219 meters, the compressor with compression power 112.2 kilowatts. The results confirm the technical viability of the project.

Keywords: CO2 , Aspen HysysV11, installation.

Acknowledgments

In the first place we thank our god who has given us the strength and patience to complete this work.

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We would like to express our gratitude to all those who have participated in this project from close or far, through advice, support and encouragement.

Dedications

I dedicate my work to

My dear parents, there no dedication be able to express my sincere feelings for their unlimited patient, their constant encouragement, their help and testimony of my deep love and respect for their great sacrifices.

My brother and my cousin and Strangers who i met at University who became my best friends and even my brothers and sisters.

My professors and my lectrurs during these five years in the university especially my supervisor Dr. BENHOURIA Assia for her guide, tutoring and encouragement during the preparation of memory.

My brother Oussama

To my friends and all my family members and to those I love

Delmi abderrahmane.

Djilali ayad oussama

summary

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General introduction

General introduction

Pollution can be defined as the introduction of harmful substances or contaminants into the environment, which can lead to adverse effects on human health, ecosystems and the quality of air, water and soil. These substances can come from various sources such as industrial activities, vehicles, domestic waste, intensive agriculture, among others. Pollution is a global problem that requires concerted efforts to reduce its impact and preserve our planet for future generations [1].

In this context, natural gas, often considered as a cleaner alternative to traditional fossil fuels such as coal and oil, plays a complex role in the global energy landscape. While natural gas produces fewer air pollutants per unit of energy than other fossil fuels, its exploitation, transport and use are not without consequences for the environment.

Natural gas is considered a cleaner and more environmentally friendly fuel than most other fossil fuels. Its comparative advantage in terms of the environment compared to coal or oil lies in the fact that sulfur dioxide emissions are negligible and that the levels of nitrogen oxide and carbon dioxide are lower [2].

One of the main reasons for this pollution is Burning fuels that shows fine and ultrafine particulates long-lived greenhouse gases, and short- lived climate pollutants (SLCPs).

The report also shows that human actions still have the potential to determine the future course of climate. The evidence is clear that carbon dioxide (CO_2) is the main driver of climate change, even as other greenhouse gases and air pollutants also affect the climate [3]. Stabilizing the climate will require strong, rapid, and sustained reductions in greenhouse gas emissions [4].

There is an excessive volume of greenhouse gases in the atmospheric system and a broad consensus that this will have serious consequences in terms of climate change. Industrial flue gas emissions include carbon dioxide (CO_2), nitrogen oxides (NOx), hydrocarbons, carbon monoxide (CO), particulate matter and sulfur dioxide (SO2), almost all of these emissions are greenhouse gases. These emissions endanger human health, agricultural crops, forest species, various ecosystems and the general environment because they enhance the greenhouse effect and thus contribute to global climate changes. Greenhouse gas emissions contain about 77 % CO_2. According to recent IPCC reports, the average global concentration of CO_2 in the atmosphere is now approaching 400 ppm; however, more extensive research states that the safe level of CO_2 concentration is below 350 ppm [5].

Capture, isolation and use of CO_2 emissions from flue gas are now familiar all over the world. These methods are a promising solution for promoting sustainability for the benefit of future generations. Previously, many researchers focused on the capture and storage of CO_2; However, less effort has been spent on finding ways to take advantage of flue gas emissions. Moreover, many issues have to be overcome in the field of carbon capture and sequestration technology, in particular regarding the cost, capacity and durability of the storage tank [6].

The main objective of this work is to use Hysys to propose a system to recovery the rejected gas in the air of the second natural gas liquefaction zone (GNL2) in Arzew.

Our memory is therefore structured according to the following order:

- ✓ Chapter I present the GL2/Z complex, the definition of gas and its uses, the definition of heating gases and their impact, and information on the devices used to equipment rejected carbon dioxide in the air.
- ✓ Chapter II devised in two parts, the first part about the laboratory method: we explore the rejected gas by capture a sample and discussion of their results by realized the compositions and the second part: about the simulation method which we install a process of recovery and simulate it and discussion of their results we make a comparison of Hysys dimension's process and calculated dimensions for realized the equipment.

Chapter I
Bibliography part

Chapter I: Bibliography part

This chapter is devoted to the presentation of the GL2Z complex, its mode of operation, the definition of gas and its uses, explaining how to remove carbon dioxide from natural gas, the definition of heating gases and their impact, the most important of which is carbon dioxide, and information on the devices used to equipment rejected carbon dioxide in the air

I.1 Presentation of the complex

I.1.1 Historical reminder

The GL2 / Z complex is an industrial site for the production of liquefied natural gas (LNG) located in the Arzew industrial zone in the village of BETHIOUA, it is located in bordering the sea and distant 40 km west of Oran and 450 km from Algiers, it extends over an area of 72 hectares. It is carried out by the American company "Pullman Kellogg Plant service Alegria Incorporation”. The construction of the plant began in 1977 and its commissioning dates back to 1981 [7].

I.1.2 Description and operation of the GL2/Z complex

Among the liquefaction units, the GL2/Z complex was built on the basis of high-performance technology. It is composed of six (06) liquefaction trains which work in parallel but connected to each other by transfer lines. The Natural Gas supply to each train is carried out by pipe networks.

The plant is composed of three areas:

- A process area.
- A utility area.
- An area for storage and loading.

The A.P.C.I (Air Products and Chemicals - Incorporation) process used in the GL2/Z complex works with two refrigerants, propane and MCR (Multi Refrigerant Component).

The liquefaction of Natural Gas requires four essential steps which will be described later and uses two refrigerant systems (propane and MCR mixed refrigerant) [8].

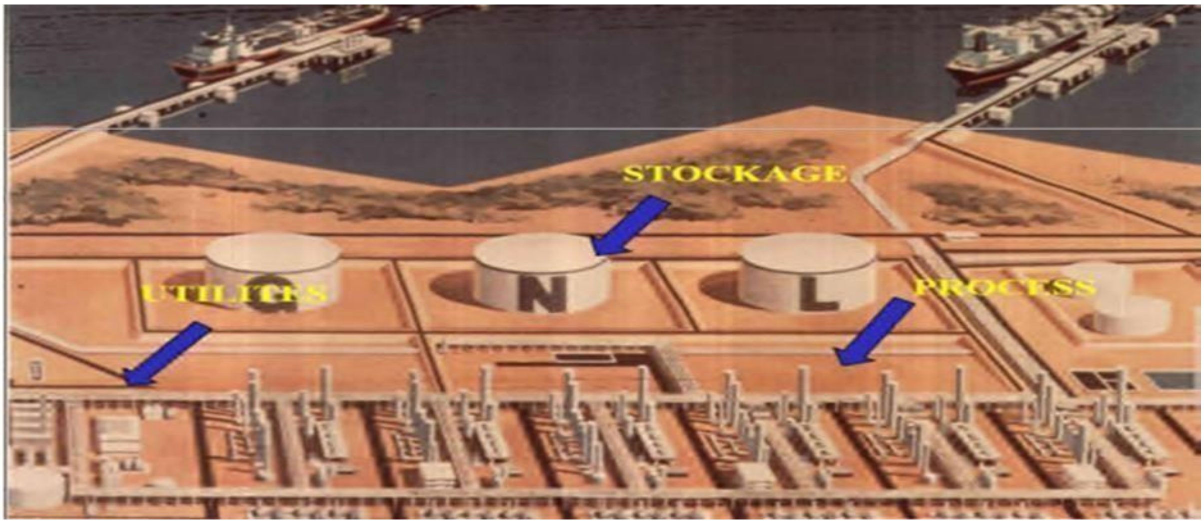


Figure I.1. Complex GL2/Z [9].

I.1.2.1 Process area

The process area consists of six identical trains operating in parallel. They are powered by LARP which comes from Hassi-R'mel at a pressure of 46 bars and at room temperatures, each train is composed of the following sections:

- Demercurization
- Decarbonization.
- Deshydratation.
- Fractionation of hydrocarbons.
- Liquefaction.

LARP contains heavy and light hydrocarbons as well as oils, water (H_2O), carbon dioxide (CO_2), nitrogen (N_2), helium (He) and mercury (Hg) [8].

I.1.2.2 Utilities area

This area is essentially autonomous and ensures the supply of all utilities during the start-up and start-up of the six (06) liquefaction trains, and all production facilities. It consists mainly in the production and supply of this which follows: Electric power, steam, desalinated water, air, cooling water [8].

I.1.2.3 Storage and loading area

The LNG is stored at -162°C in 3 tanks with a unit capacity of 100,000 m^3 each. The loading of the product is ensured at the level of 2 loading docks that can receive LNG carriers with a capacity of 40,000 to 145,000 m^3 LNG. The storage of the produced gas oil is provided by two (02) bins of 14.500 m^3 each [8].

I.2 Natural Gas

I.2.1 The origin of natural gas

It is generally accepted that the carbon and hydrogen contained in natural gas comes from the remains of plants and animals that have accumulated at the bottom of lakes and oceans for millions of years. After being covered by thick layers of other sediments, the organic material was transformed into crude oil into natural gas under the effect of the pressure exerted by these different layers and the heat emitted by the Earth's core. The oil and gas were then expelled out of the marine clayey shales in which they had been deposited and from there penetrated the porous sedimentary rocks. The oil and gas then rise through the rock, because it is less dense than water, which fill the pores [10,11].

I.2.2 Definition of natural gas

Natural gas is a fossil fuel naturally present in gaseous form in the porous rocks of the subsoil. Used as an energy source, gas is composed of hydrocarbon [12].

I.2.3 The characteristics of natural gas

Natural gas is colorless, odorless and tasteless, without any particular shape and lighter than air. It is in its gaseous form at -161 ° C. For safety reasons, a chemical fragrance, mercaptan, which gives it a rotten egg smell, is often added to it in order to detect a possible gas leak [10,13].

The greenhouse effect is a natural phenomenon by which part of the solar energy that is emitted by the earth is absorbed and retained in the form of heat in the lower atmosphere. The greenhouse effect is caused by gases contained in the atmosphere, mainly water vapor. Other gases play a role in the greenhouse effect: carbon dioxide, methane, nitrogen oxides, ozone and hydrocarbons. There are two types of greenhouse effect (Natural and Reinforced).

I.3 Decarbonization

I.3.1 Principle

The carbon dioxide CO_2 is removed from the natural gas (NG) according to the conventional process by absorption / desorption with an amine solution.

For this, a 15% aqueous solution of mono ethanolamine (MEA) is used, the section is essentially composed:

- A natural gas absorption column.

- A quiet regeneration of the aqueous mono ethanolamine solution: column, exchangers, pumps, storage tank.
- Auxiliary installations for purification and preparation of the amine solution.

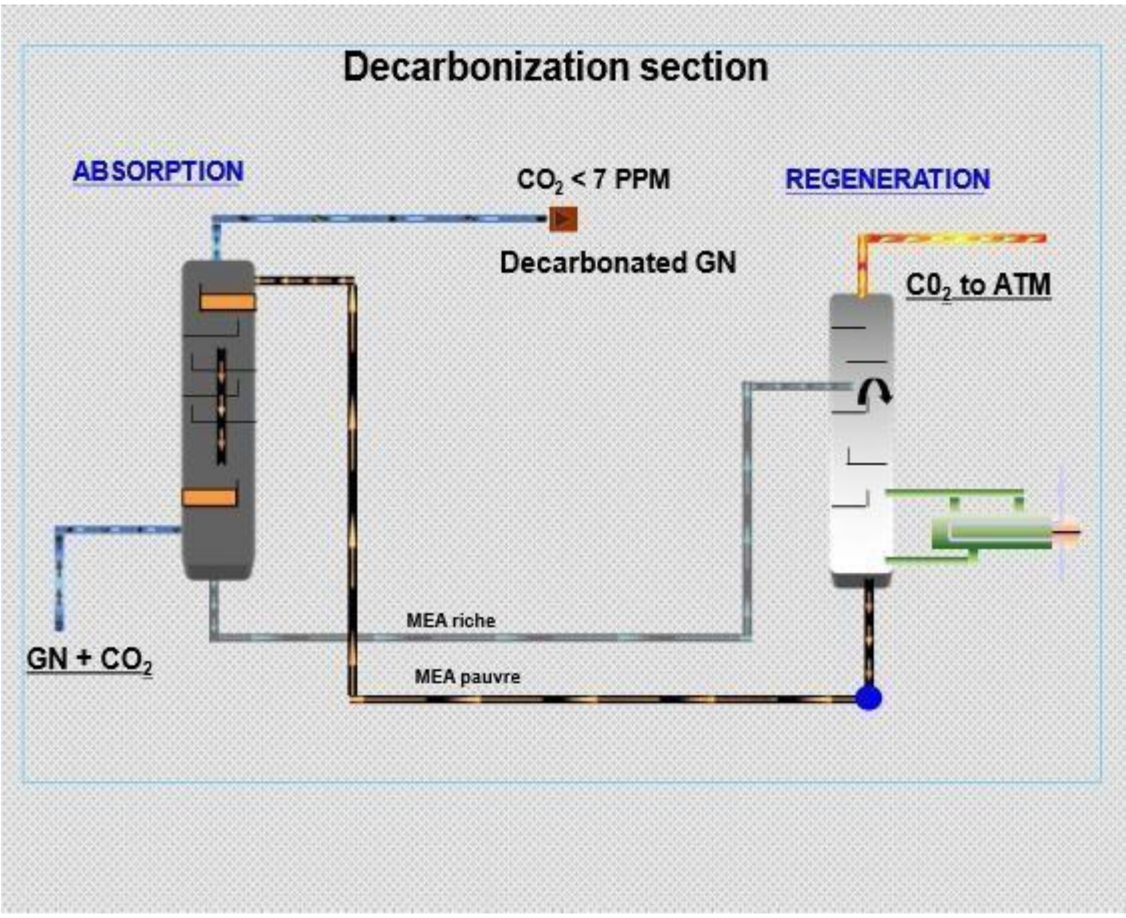


Figure I.2. Decarbonization section (basic schemes) [14].

I.4 Greenhouse

I.4.1 Definition

Greenhouse gases (GHGs) are gases whose physical properties are such that their presence in the Earth's atmosphere contributes to a greenhouse effect on the Earth's surface.

The main greenhouse gases [15]

- Water vapor
- Carbon dioxide
- Methane
- Ozone

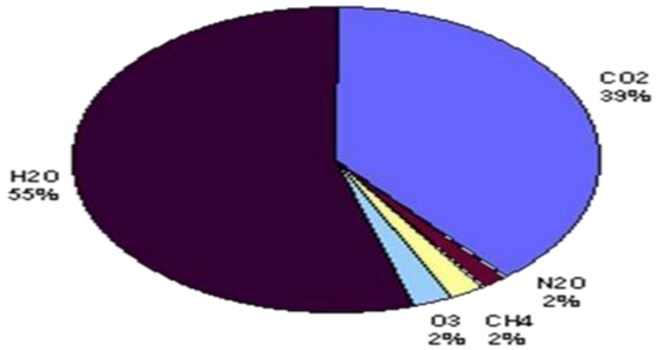


Figure I.3. Representation of the main greenhouse [14].

I.4.2 The impact of greenhouse gases

Human activities generate large volumes of greenhouse gases (GHGs): carbon dioxide, from the combustion of fossil fuels (oil, coal...); methane, rather from agricultural activities; nitrous oxide, emitted by certain fertilizers or by certain chemical processes; fluorinated gases from air conditioners.

The greenhouse effect is a phenomenon very sensitive to variations in the composition of the atmosphere. The increase in GHG emissions modifies this composition, causing an increase in the greenhouse effect.

This imbalance leads to global warming which modifies climates [15].

I.4.3 Main methods to reduce the GHG content (industry)

There are several methods to reduce greenhouse gas emissions, in particular in the industrial environment [16]. Here are some examples:

I.4.3.1 Energy efficiency

By improving the energy efficiency of industrial processes, we can reduce the amount of energy required to produce one unit of product, which also reduces emissions of greenhouse gases.

I.4.3.2 Renewable energies

The replacement of fossil energy sources by renewable energies (as solar, wind or hydraulic energy) significantly reduces greenhouse gas emissions.

I.4.3.3 Carbon capture and storage

This technology makes it possible to capture the greenhouse gas emissions produced by the industrial processes and to store them in geological reservoirs or in forms solid.

I.4.4 The main greenhouse gases (GHG) at the level of the GL2Zcomplex

The main greenhouse gases (GHGs) emitted by the GL2Z complex are carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). CO2 is emitted during the combustion of fossil fuels to provide energy for the liquefaction process of natural gas. CH4 is emitted during the production, transportation and handling of liquefied natural gas, since natural gas contains a significant amount of methane. Nitrous oxide is also emitted during the combustion of fossil fuels and can be produced during the decomposition of materials.

I.4.5 The sources of greenhouse gas (GHG) emissions at the level of the GL2Z complex

I.4.5.1 Direct source [17]

- Emissions from process-related operations.
- Emissions related to local electricity production.
- Emissions from infrastructure/security operations and transport machines/cars.

I.4.5.2 Indirect source

This category includes GHG emissions from the import of electricity, steam, demineralized water purchased from SONELGAZ and KAHRAMA and consumed by the GL2Z Complex [17].

I.5 Equipment

I.5.1.1 exchanger

I.5.1.1.1 Tube and shell exchanger

Shell and Tube Heat Exchangers are one of the most popular types of exchangers due to the flexibility the designer has to allow for a wide range of pressures and temperatures.

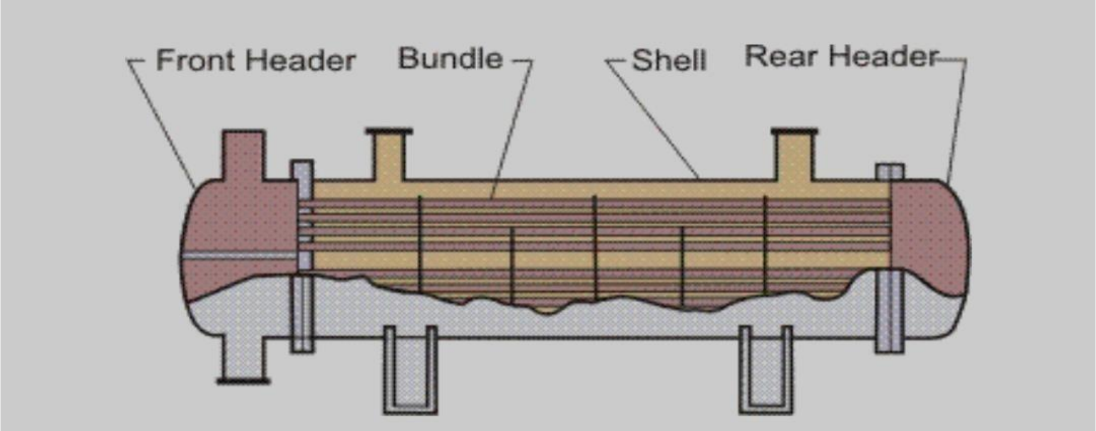


Figure I.4. Tube and shell exchanger [18].

I.5.1.2 . The separation column

I.5.1.2.1 principle

A separator is a tank which operates at constant pressure thanks to a valve system with adjustable opening on the oil and gas outlets by a system of screens and baffles suitably arranged inside, the flow of the mixture is delayed so as to avoid entrainment of liquid droplets in the gas and gas bubbles in the oil. The degassing is due solely to variations in pressure and temperature [19].

The separation operation is intended to separate the oil from the gas and water in order to allow the delivery to the customer of products.

Moreover, in treatment plants, it is essential to protect certain equipment against certain fluids such as:

- All gases containing liquid or solid particles at the suction of centrifugal compressors which risk cavities in the presence of gas bubbles in the pumped liquid
- All Centrifugal pumps are at risk of cavities in the presence of gas bubbles in the pumped liquid.

The role of a separator is limited to removing the gas from the liquid already vaporized in the tubing and the collection network and to eliminating the liquid droplets that could be entrained by the gas.

I.5.1.2.1.1 The vertical column

The vertical separator consists of a cylindrical steel body, closed at each end by a domed bottom. The two phases to be separated enter tangentially and meet a deflector; a first separation is thus carried out by gravity, centrifugation and collision effect.

The drops of liquid fall by gravity into the liquid collection zone which is separated from the gas phase by a conical screen, in order to obtain an interface that is sufficiently undisturbed and a stable liquid level. The drops entrained by the gas are eliminated in the upper section by means of baffles which induce a centrifugal movement and a droplet separator which makes it possible to stop and coalesce the small drops. The capacity of the vertical separators reaches between 500 and 850 m^3/d with pressures up to (420 Bar) [19].

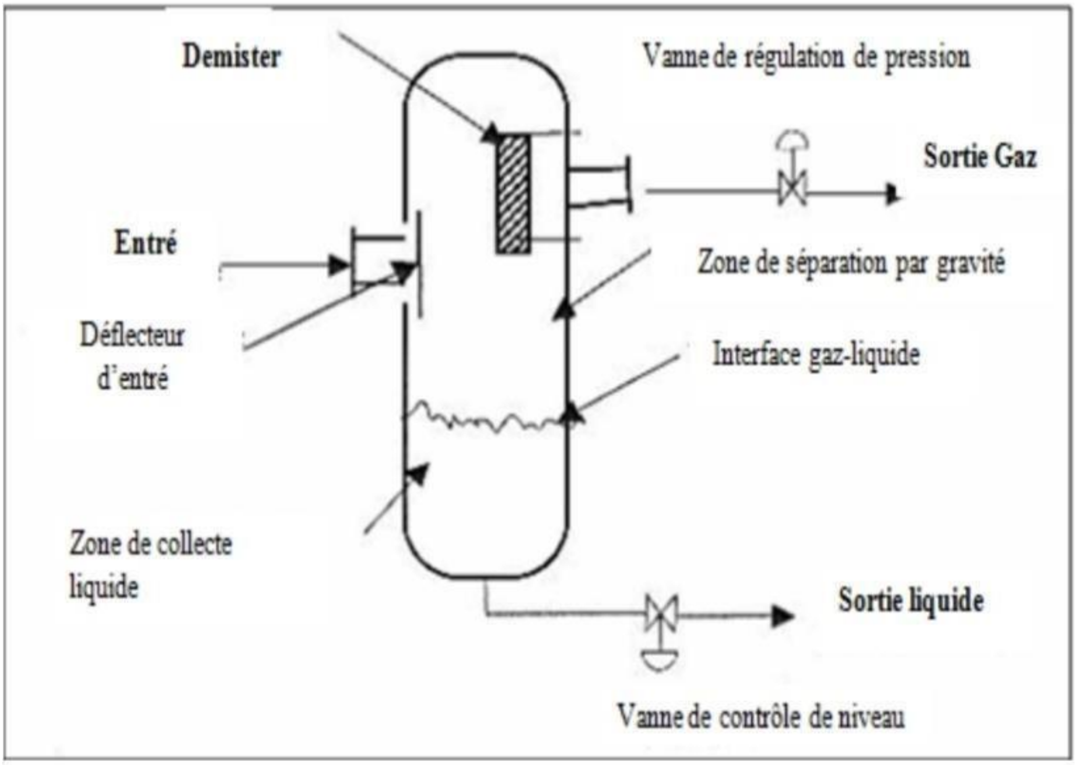


Figure I.5. Vertical column with a vertical demister [20]

The vertical separator with two compartments has a greater separation capacity in view of the flow rate of the liquid phase, the lower compartment being used as a liquid collection zone and the upper compartment as a separation zone. The capacity of vertical separators generally goes up to 5000 m3/day, with pressures up to 420 bar. In the Middle East, there are vertical separators with a very large capacity of up to 20,000 m3 / day [19].

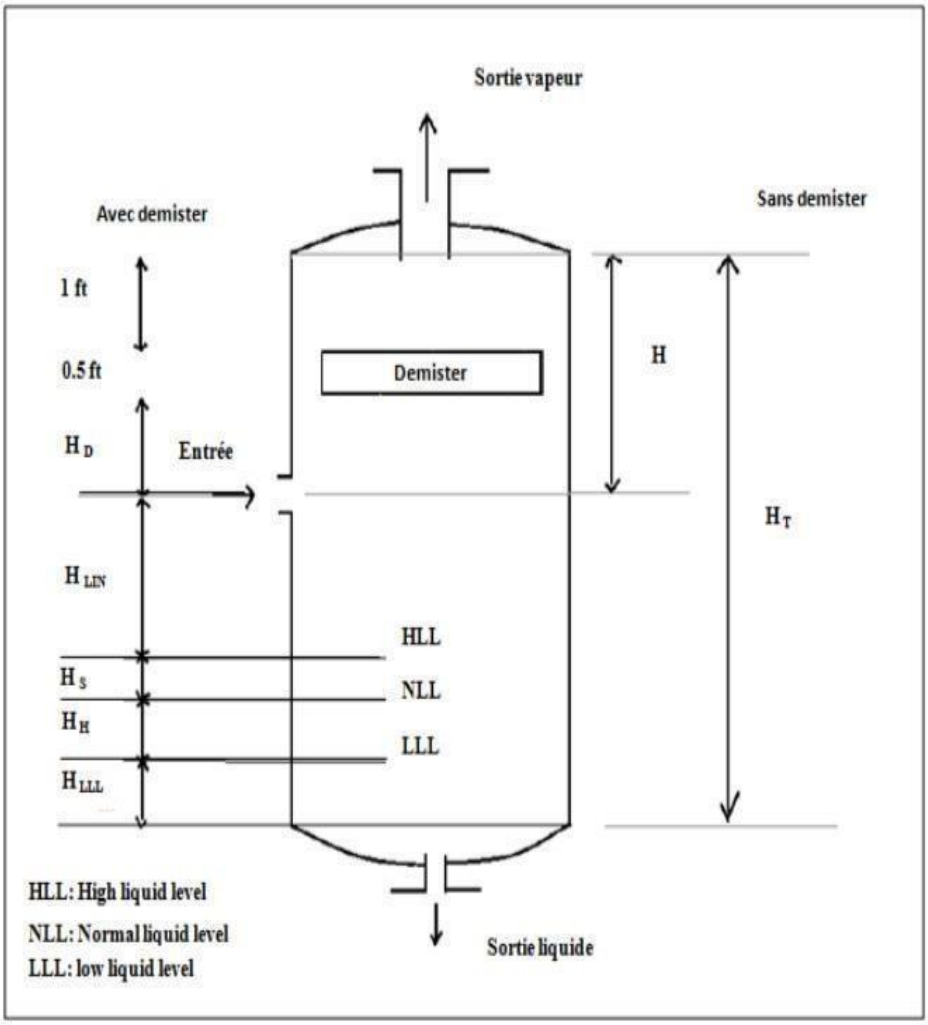


Figure I.6. The different of heights of the vertical separation column [21].

I.5.1.3 The compressors

I.5.1.3.1 principle

A compressor is a machine that reduces the volume and thus increases the pressure of a given amount of air by mechanical means. The air thus compressed has a high potential energy when the external pressure is removed, the air expands rapidly. The expansion force of compressed air has many applications.

We can choose our compressor as follows:

- Minimization of capital investment costs
- Minimization of maintenance costs
- Required output power
- Flexibility
- Environmental considerations.

I.5.1.3.2 compressor

I.5.1.3.2.1 Liquid ring compressor

Liquid ring compressors compress gases from a low pressure to a high pression. the most gases can be compressed, even those containing dust or a liquid phase. Due to the technology used and the presence of a liquid ring; the compression is almost isothermal.

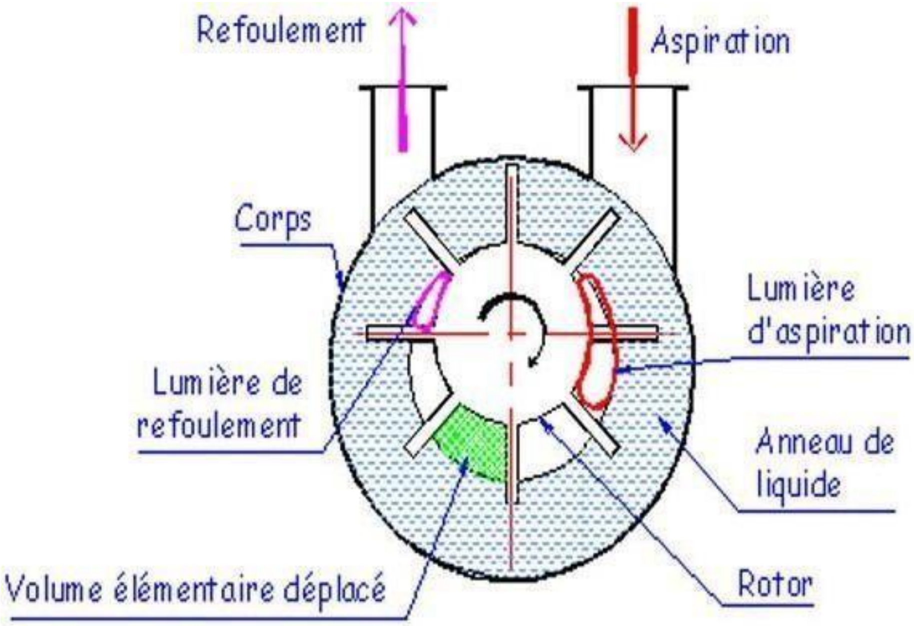


Figure I.7. Liquid ring compressor [22].

Chapter II
Experimental Part

Chapter II: Experimental Part

This chapter is devoted to the presentation of standardized test materials and methods and to the discussion of the results obtained from laboratory part and simulation part. Present of a system for the recovery of rejected gas in air by Hysys V11 and calculate the dimension of all the equipment's system that's been proposed for gas recovery.

II.1 Materials and methods

II.1.1 Materials

II.1.1.1 Laboratory materials

A faucet with a stainless-steel tube 40 cm long and 10 mm in diameter, and a plastic sample bag with a capacity of 2 m^3 presented in figure II-1

Figure II.1. Capture equipment, a) faucet with a pipe, b) sample bag.

The gas chromatograph GC03 (CP-3800) and GC02 (CP-3800) used in this work were obtained from VARIAN 3800 and created in 1997. Chromatograph GC02 and GC03 presented in figure II.2.

The chromatograph (CP-3800) is easily configured to perform on-line analyses for monitoring critical gas and liquid process streams. The CP-3800's flexible platform lets you start with a basic configuration and add a wide variety of options in the field. These options include additional channels, gas and liquid sampling valves, and external sampling devices.

Future upgrades guarantee that you can meet changing requirements at a moment's notice. Unleash the full potential of the CP-3800 gas chromatograph 02 (GC02) and gas chromatograph 03 (GC03) with the Galaxie chromatography data System. Galaxie dramatically improves daily workflow with intuitive, easy-to-use graphical interfaces for instrument control, data acquisition, processing, and standard and custom reporting. From a simple stand-alone GC system, to an automated simulated distillation package.

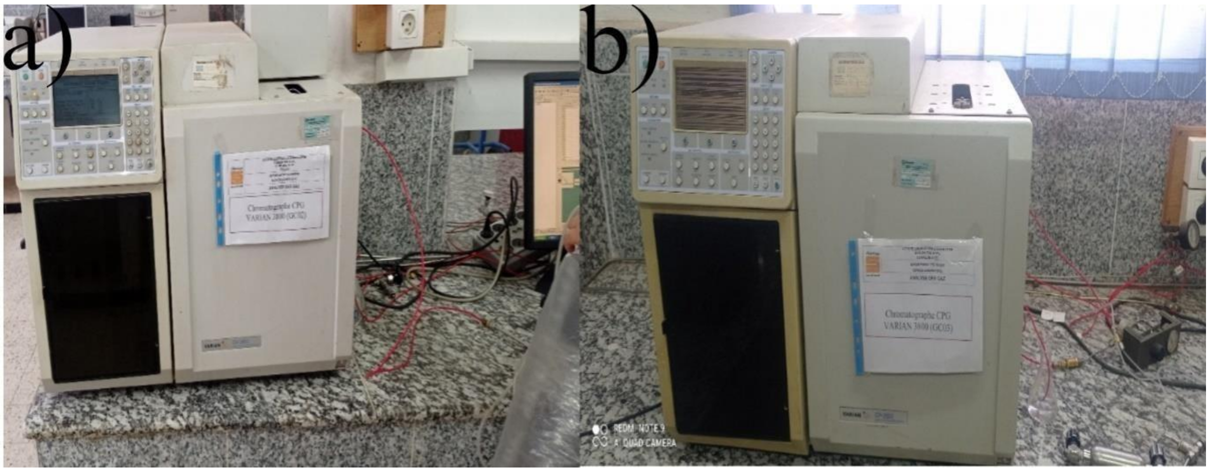
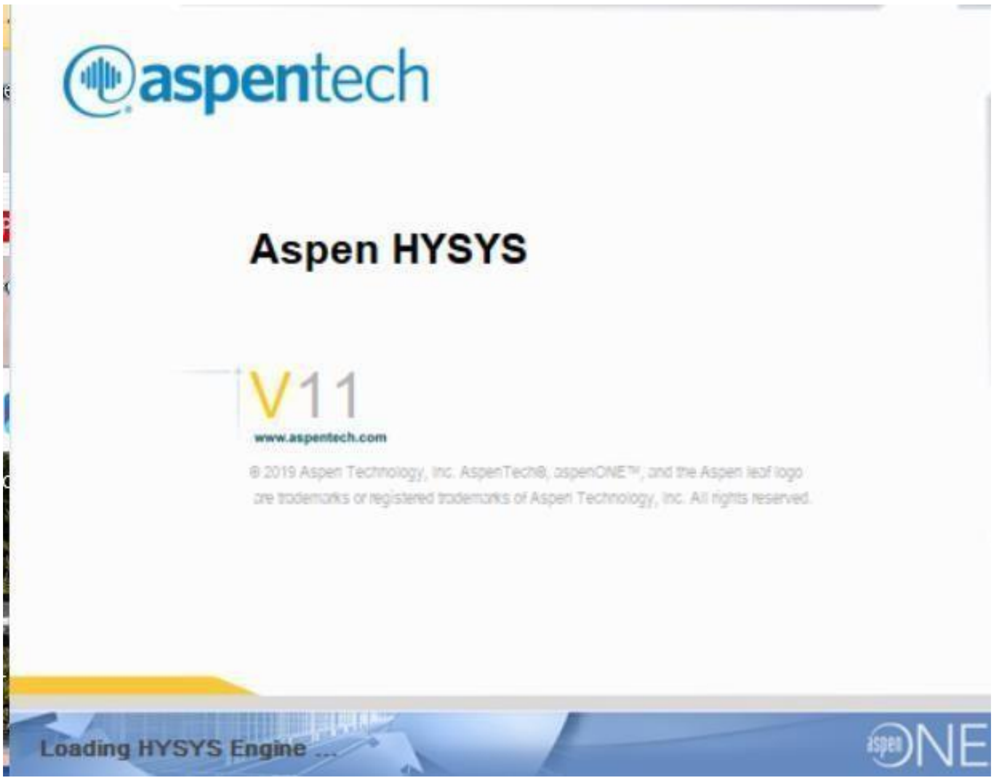


Figure II.2. Chromatograph (CP-3800), a) gas chromatograph 2 (GC02), b) gas chromatograph 3 (GC03).

II.1.1.1.1 Simulation materials

Our work aims to recovering the gas rejected into the air, we employed several components and methodologies. Leveraging the HYSYS V11 program, we utilized the Peng-Robinson system to model and simulate the process intricacies. We integrated key elements such as coolers, compressors, and column separation techniques to effectively capture and reclaim the emitted gas. This comprehensive approach allowed us to analyze the behavior of the gas mixture under various conditions and optimize the recovery process for maximum efficiency and sustainability.



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Loading HYSYS Engine ...

Figure II.3. Aspen HYSYS V11 program.

II.1.2 Methods

II.1.2.1 Laboratory part

To analyze the rejected gas, we utilized several steps presented in Figure II.4

Firstly, the carbon dioxide is removed from the natural gas in the absorption column by introducing gas at the bottom of the column and mono ethanolamine MEA from the top, so that the carbon dioxide is removed in a regeneration column of MEA to go to the balloon X33F to be released directly into the air with temperature 59.99 °C.

Secondly, this rejected gas contains other compositions; to find out these compositions, we took a sample of the gas in a custom bag by manually installing a stainless-steel tube at the outlet of the X33F balloon valve.

Finally, the rejected gas was brought to the laboratory to analyze it and to know all their compositions by connecting the sample bag with the chromatograph (CP-3800) GC02 and GC03.

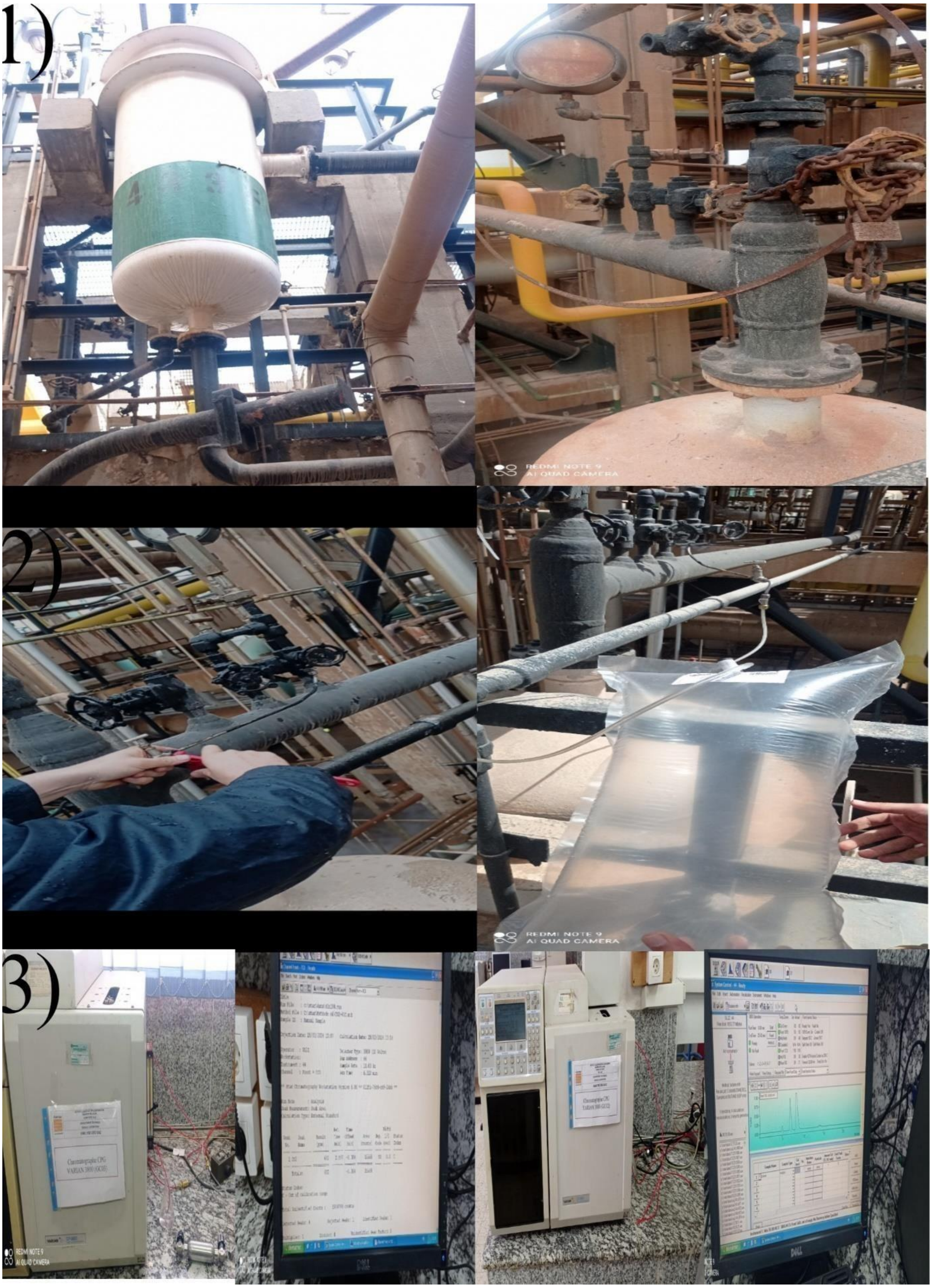


Figure II.4. Analysis gas’s steps 1) Explore reflux balloon, 2) Capture the gas, 3) rejected gas compositions.

II.1.2.2 Simulation part

The rejected gas in decarbonization section make us simulate the proposal process in the three zones which we have two trains in each zone so for each three trains, connecting the outlets of the X33F with lines. These lines go and supplies the cooler to eliminate the humidity produced by the gas in the separation column, thereby, condensing the water content in the rejected gas. Finally, the outlet liquid will end up in the hydrocarbon decantation system and the vapor at the top of the separator supplies a compressor to increase the pressure as presented in figure II.5.

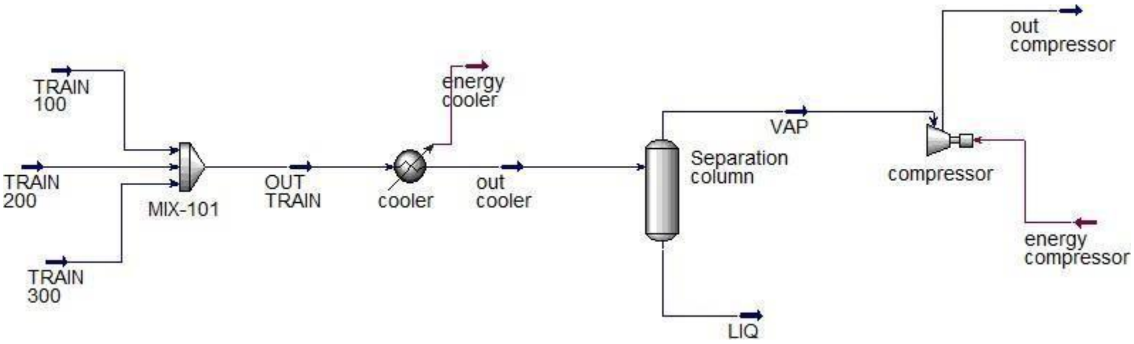


Figure II.5. Installation process by Hysys V11.

In our work, we used the cooler in place of the exchanger as proposed from technical department because the Hysys V11 doesn't have the seawater, and we used the same temperature proposed (89.6°F). This temperature was calculated by using the equation II.1.

Calculation of the outlet temperature of cooler

$Q=m.Cp(T_1-T_2)$ ....(Equation II.1)

where Q was heat of the device (btu), m was the mass (lb), Cp was the specific heat of fluid (btu/lb°F) and T1 and T2 were the inlet and the outlet temperature (°F), respectively.

The exchanger used should be shell and tube heat exchanger with a counter-current system. We consider that the tube side and the shells side have the same amount of heat.

$m_1.Cp_1(T_1-T_2)=m_1.Cp_2(T_3-T_4)$...........................(Equation II.2)

where m_1 (lb) represent mass of gas,

where m_2(lb) represent mass of H_2O.

T1, T2, T3 and T4 were the temperatures of entered tube, outlet tube, entered shell and outlet shell (°F), respectively, and T_2 = 89.6°F.

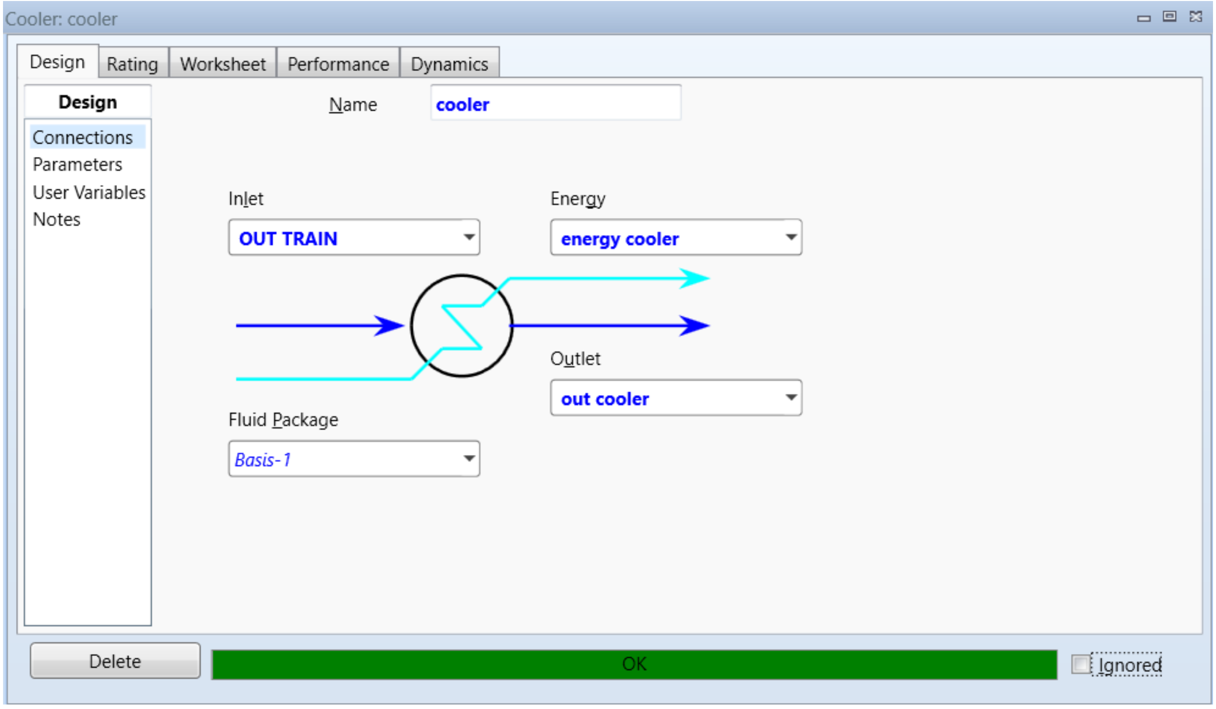
The table II.1 presented the several parameters of model exchanger used in complex GNL2Z.

Table II.1. Exchanger parameters.

Fluid	**Gas**	**H_2O**
Mass (lb)	12960.000	4817.610
Entered temperature (°F)	T_1=139.982	T3=75.020
Outlet temperature(°F)	--	T4=131.000
C_P(BTU/lb °F)	0.383	1.000

II.1.2.2.1 Cooler

The cooler reduces the temperature of the gas to 32.2°C, which condense all the humidity exist in the rejected gas to liquid. The cooler design used presented in figure II.6.



Name: cooler

Inlet: OUT TRAIN

Energy: energy cooler

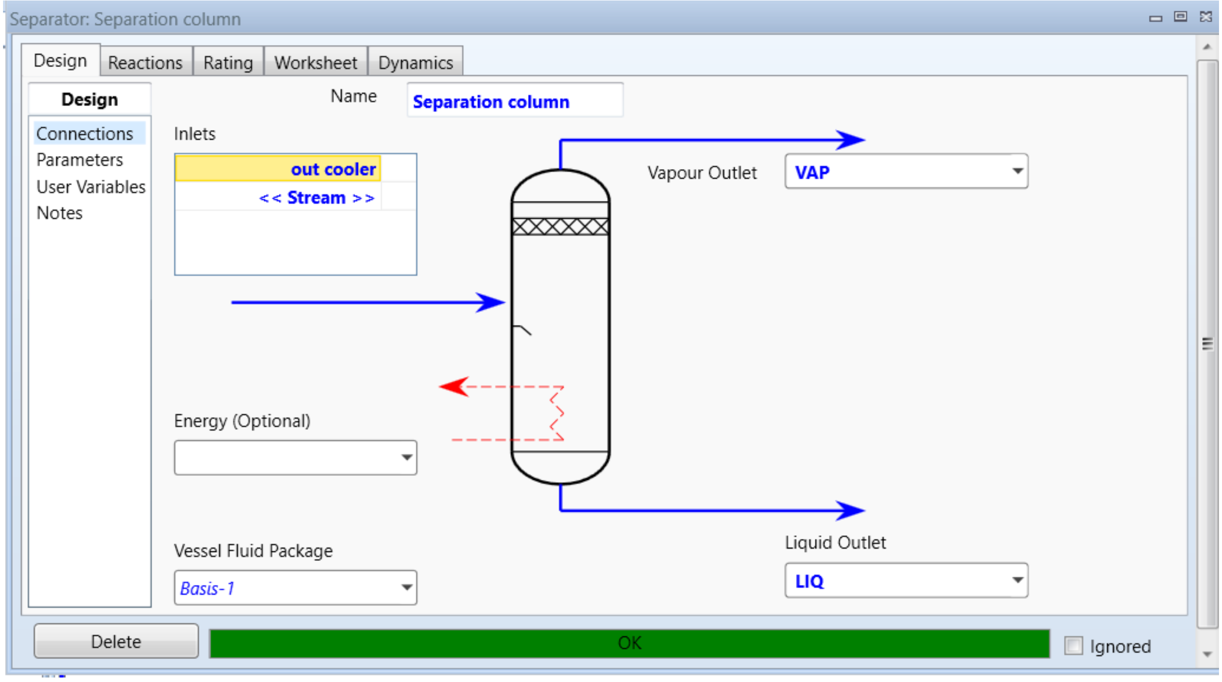
Outlet: out cooler

Fluid Package: Basis-1

Figure II.6. Cooler design.

II.1.2.2.2 Separation column

The separation column was chosen to separate the gas from the liquid in order to protectthe compressor from water droplets. The separation column design used presented in figure II.7.



Separator: Separation column

Name: Separation column

Inlets: out cooler, << Stream >>

Vapour Outlet: VAP

Energy (Optional):

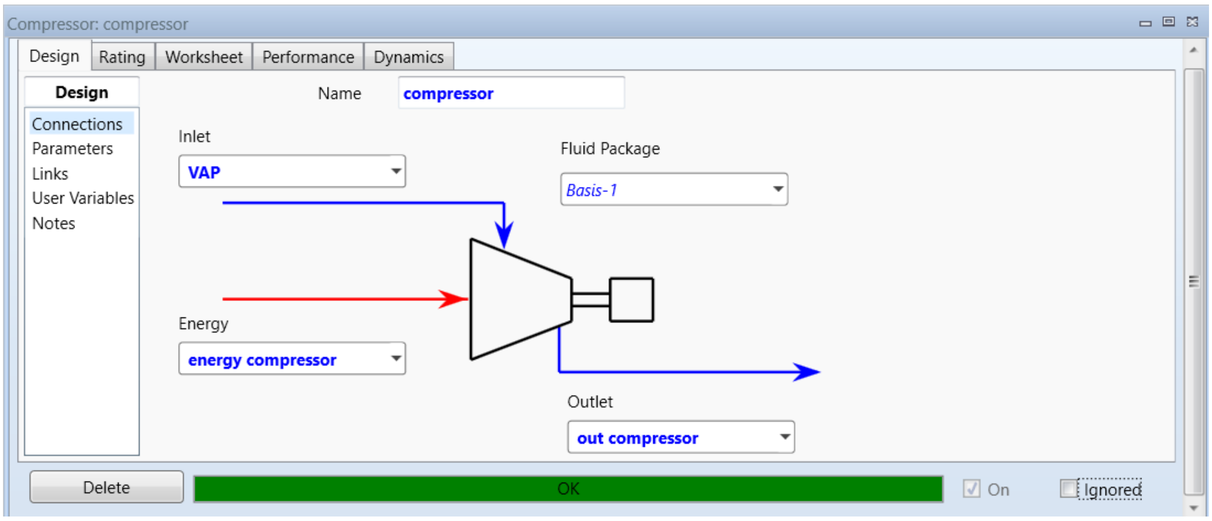
Vessel Fluid Package: Basis-1

Liquid Outlet: LIQ

Figure II.7. Separator design.

II.1.2.2.3 Compressor

This rejected gas will be sucked by a compressor to increase the pressure to 3 bars so that it can be transported and evacuated. The compressor design used presented in figure II.8.



Compressor: compressor

Name: compressor

Inlet: VAP

Fluid Package: Basis-1

Energy: energy compressor

Outlet: out compressor

Figure II.8. Compressor design.

II.1 Results and discussions

II.1.1 Laboratory

Based on the analysis experiment, the results of gas chromatograph (02) and (03) the compositions of rejected gas is presented in table II.2 and figure II.9.

Table II.2. Compositions of the rejected gas to atmosphere.

Compositions	Molar fraction	Molar percentage (%)
Carbon dioxide (CO_2)	0.8368	83.68
Nitrogen (N_2)	0.0001	0.01
Methane (CH_4)	0.0077	0.77
Ethane (C2)	0.0009	0.09
Propane (C3)	0.0002	0.02
Water (H_2O)	0.1544	15.44

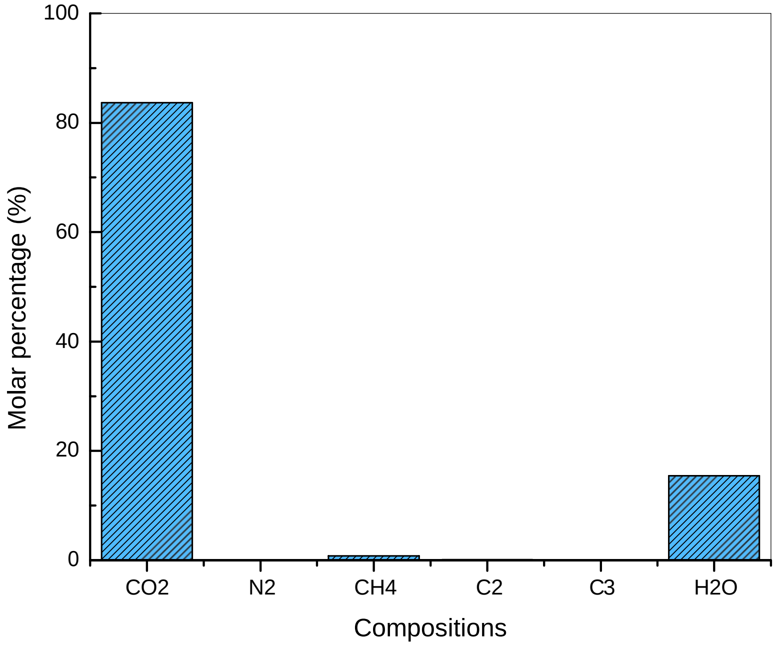


Figure II.9. Molar percentage of different compositions of rejected gas.

As shown in figure.II.8, the molar percentage of the carbon dioxide and the water are 83.68% and 15.44%, respectively, which represented the high percentage of the elements of this gas. Moreover, this gas contains very low percentages of methane, ethane, propane and nitrogen were 0.77%, 0.09%, 0.02 % and 0.01%, respectively.

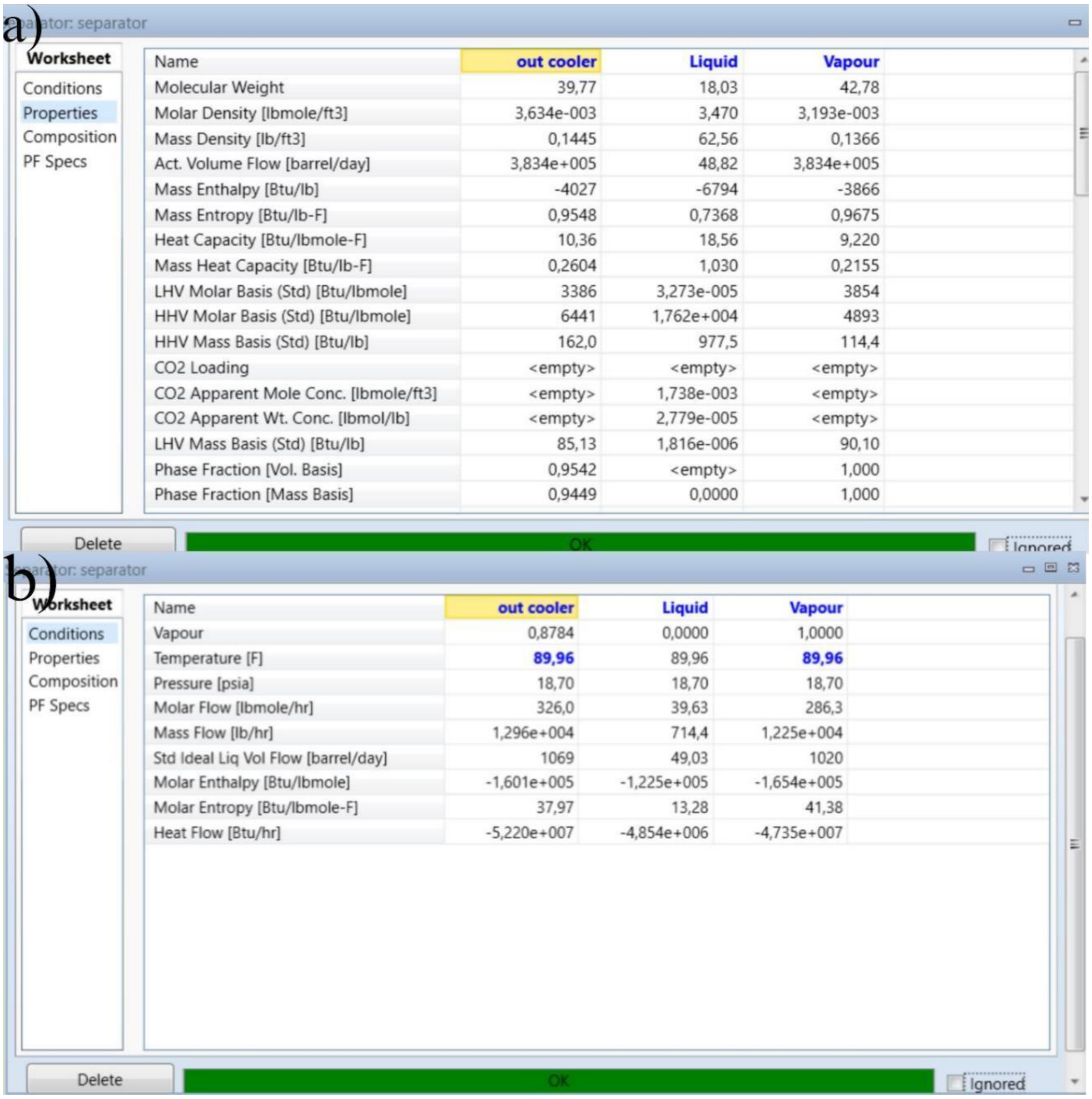
We conclude that the rejected gas will be a big environmental pollution, for this reason, we have to resolve this problem by creating an installation to stop this pollution, firstly, we get a design example as well as simulate the recovery equipment and calculate their dimensions to embody it in reality.

II.1.2 Simulation

II.1.2.1 Dimension

II.1.2.1.1 Separation column

To calculate the dimensions of separator column the properties used in this work were the liquid mass density (lb/ft^3) and vapor mass density (lb/ft^3). These proprieties presented in figure II.10.a. In addition, the conditions used were the pressure (psia), the liquid mass flow (lb/h)and the vapor mass flow (lb/h). These conditions were presented in figure II.10.b.



a)

Name	out cooler	Liquid	Vapour
Molecular Weight	39,77	18,03	42,78
Molar Density [lbmole/ft3]	3,634e-003	3,470	3,193e-003
Mass Density [lb/ft3]	0,1445	62,56	0,1366
Act. Volume Flow [barrel/day]	3,834e+005	48,82	3,834e+005
Mass Enthalpy [Btu/lb]	-4027	-6794	-3866
Mass Entropy [Btu/lb-F]	0,9548	0,7368	0,9675
Heat Capacity [Btu/lbmole-F]	10,36	18,56	9,220
Mass Heat Capacity [Btu/lb-F]	0,2604	1,030	0,2155
LHV Molar Basis (Std) [Btu/lbmole]	3386	3,273e-005	3854
HHV Molar Basis (Std) [Btu/lbmole]	6441	1,762e+004	4893
HHV Mass Basis (Std) [Btu/lb]	162,0	977,5	114,4
CO2 Loading	<empty>	<empty>	<empty>
CO2 Apparent Mole Conc. [lbmole/ft3]	<empty>	1,738e-003	<empty>
CO2 Apparent Wt. Conc. [lbmol/lb]	<empty>	2,779e-005	<empty>
LHV Mass Basis (Std) [Btu/lb]	85,13	1,816e-006	90,10
Phase Fraction [Vol. Basis]	0,9542	<empty>	1,000
Phase Fraction [Mass Basis]	0,9449	0,0000	1,000

b)

Name	out cooler	Liquid	Vapour
Vapour	0,8784	0,0000	1,0000
Temperature [F]	89,96	89,96	89,96
Pressure [psia]	18,70	18,70	18,70
Molar Flow [lbmole/hr]	326,0	39,63	286,3
Mass Flow [lb/hr]	1,296e+004	714,4	1,225e+004
Std Ideal Liq Vol Flow [barrel/day]	1069	49,03	1020
Molar Enthalpy [Btu/lbmole]	-1,601e+005	-1,225e+005	-1,654e+005
Molar Entropy [Btu/lbmole-F]	37,97	13,28	41,38
Heat Flow [Btu/hr]	-5,220e+007	-4,854e+006	-4,735e+007

Figure II.10. Separator worksheet, a) properties, b) conditions.

a) Critical speed [14]

To calculate the critical speed of the steam (ft/sec), we used the equation II.3 as following:

$U_t = k\sqrt{\frac{(\rho L - \rho v)}{\rho v}}$..(Equation II.3)

Where ρL(lb/ft^3) and ρv (lb/ft^3) are the gas phase and liquid phase densities, respectively.

K (ft/sec) is the Souder's brown, it was calculated by the equation II.4.

$K=0.430-(0.023 * \ln P)$.........................(Equation II.4)

Where P (Psia) is the pressure.

b) Steam speed [14]

$U_V = 0.750\ U_t$....................................(Equation II.5)

Where U_V and Ut (ft/sec) represent steam speed and critical, respectively.

c) Separator diameter [14]

To calculate the diameter of the separator D (ft), we used the equation II.6 as following:

$D = D_{VD} + 0.5$......................... (Equation II.6)

To calculate demister D_{VD} (ft), we used the equation II.7 II.8 as following:

$D_{vd} = \sqrt{\frac{4 * Qv}{3.14 * Uv}}$....................................... (Equation II.7)

Where Q_V (lb/h) represent the mass flow rate, Q_v was determined using the following equation:

$Q_v = \frac{Wv}{3600 * \rho v}$..(Equation II.8)

Where Wv is the mass flow of vapor (lb/hr)

d) Retention volume [14]

To calculate the retention volume U_V(ft^3), we used the equation II.9 as following:

$U_V = T_H * Q_L$.......................................(Equation II.9)

Where T_H (min) retention time and Q_L (ft^3/min) volume flow rate of the liquid.

e) **Alarm volume** [14]

To calculate the alarm volume (ft^3), we used the equation II.10 as following:

$V_S=T_S*Q_L$……………………………(Equation II.10)

Where Ts is alarm time (min), Ts was determined using the following equation:

$T_S= T_H/2$ ....(Equation II.11)

where T_H (min) is retention time.

Q_L (ft^3/min) volume flow rate of the liquid, Q_L was determined using the following equation:

$QL = \frac{wL}{3600*\rho L}$…......................(Equation II.12)

f) **Retention height** [14]

To calculate the retention height H_H (ft), we used the equation II.13 as following:

$H_H=\frac{4*VH}{3.14*D^2}$…………………………(Equation II.13)

Where V_H represent retention volume (ft^3)

g) **Alarm height** [14]

To calculate the alarm height Hs (ft), we used the equation II.14 as following:

$H_S=\frac{4*VS}{3.14*D^2}$………………………… (Equation II.14)

Where V_S (ft^3) represent alarm volume.

h) **Mass flow rate** [14]

To calculate the mass flow rate Qm (ft^3/ min), we used the equation II.15 as following:

$Q_m= Q_L+Q_V$…………………………(Equation II.15)

i) **Mass density**

To calculate the mass density ρ_m (lb/ft^3), we used the equation II.16 as following:

$\rho_m= \rho_L*h_+ \rho_V*(1-h)$......................... (Equation II.16)

Where ρL(lb/ft^3) and ρv (lb/ft^3) are the gas phase and liquid phase densities, respectively.

j) **Tubular diameter** [14]

To calculate D_N(ft), we used the equation II.17 as following:

$DN = \frac{4*Qm}{3.14*60*\rho m}$ ….................... (Equation II.17)

Where Q_m (ft^3/ min) and ρ_m (lb/ft^3) is mass flow rate and mass density, respectively

k) **Center height** [14]

To calculate center height (ft), we used the equation II.18 as following:

H_{LIN}= DN+12… ....(Equation II.18)

Where DN (ft) is the tubular diameter.

l) **Height of disengagement of the steam** [14]

To calculate the height of disengagement of the steam H_D (ft), we used the equation II.19 as following:

H_D=0.5*D......................... (Equation II.19)

H_{LLL} = 1.25ft (see annex 2)

a) **Total height** [14]

To calculate the total height H_T (ft), we used the equation II.20 as following:

$H_T = H_{LIN} + H_D + H_S + H_H + H_{LLL}$ .... (Equation II.20)

Where H_{LIN} (ft), H_D (ft), H_S (ft), H_H (ft) and H_{LLL} represent center height, height of disengagement, alarm height, retention height and high liquid level, respectively.
All the values calculated of the separator column are presented in table II.3.

Table II.3. Dimension results of separator column.

Parameters	**Results**	**Unites**
Critical speed Ut	7.744	ft/sec
Coefficient of brown Welders(K)	0.362	ft/sec
Steam speed U_V	7.808	ft/sec
Diameter of separator D	2.836	ft
Demister D_{VD}	2.336	ft
Liquid flow rate Q_L	0.003	ft^3/ min
Retention volume V_H	0.009	ft^3
Retention time T_H	3.000	min
Alarm volume Vs	0.004	ft^3
Alarm time T_S	1.500	min
Retention height H_H	0.001	ft
Alarm height H_S	0.006	ft

Mass flow rate Q_M	24.913	ft^3/ min
Mass Density ρm	24.959	lb/ft^3
Tubular diameter D_N	27.888	ft
Center height power supply H_{LIN}	15.888	ft
Height of disengagement from the steam H_D	1.418	ft
Total height H_T	20.149	ft
H_T/D	7.105	/

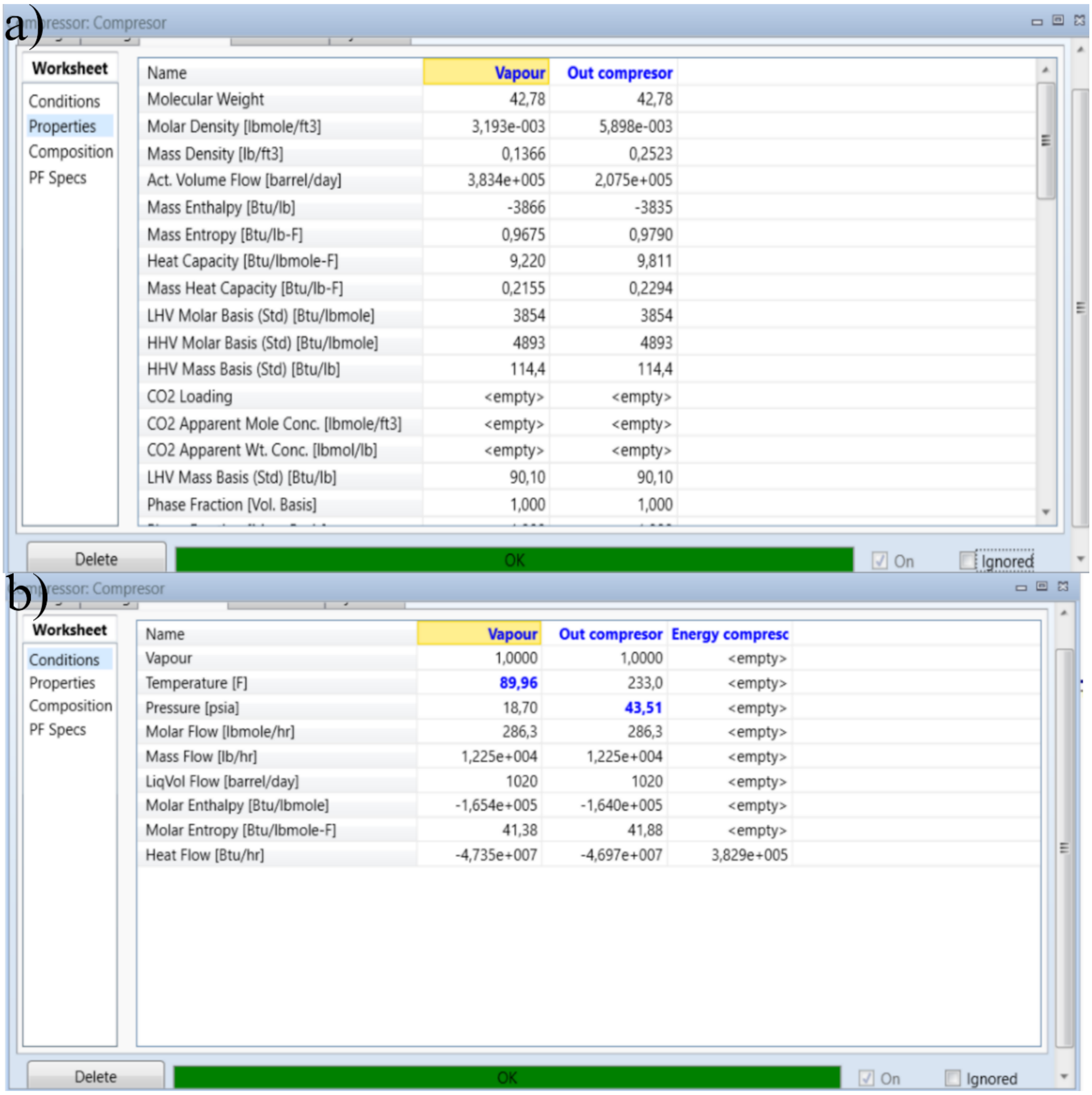
Table II.4. Comparison of Hysys and calculated results of separator column.

Dimensions	Calculated results	Hysys results
Diameter of separator D(ft)	2.836	3.280
Total height H_T (ft)	20.149	13.130
H_T/ D	7.105	4.003

The results obtained by manual calculation and by the Hysys simulator show a noticeable difference. This difference observed is not acceptable and this goes back to the precision in calculated part.

II.1.2.1.2 Compressor

To calculate dimensions of compressor the property used in this work was the mass density (lb/ft3), this property presented in figure II.10.a. In addition, the conditions used were entered temperature (℉), entered pressure (psia), out pressure (psia) and mass flow rate (lb/hr) , these conditions were presented in figure II.11.b.



Name	Vapour	Out compresor
Molecular Weight	42,78	42,78
Molar Density [lbmole/ft3]	3,193e-003	5,898e-003
Mass Density [lb/ft3]	0,1366	0,2523
Act. Volume Flow [barrel/day]	3,834e+005	2,075e+005
Mass Enthalpy [Btu/lb]	-3866	-3835
Mass Entropy [Btu/lb-F]	0,9675	0,9790
Heat Capacity [Btu/lbmole-F]	9,220	9,811
Mass Heat Capacity [Btu/lb-F]	0,2155	0,2294
LHV Molar Basis (Std) [Btu/lbmole]	3854	3854
HHV Molar Basis (Std) [Btu/lbmole]	4893	4893
HHV Mass Basis (Std) [Btu/lb]	114,4	114,4
CO2 Loading	<empty>	<empty>
CO2 Apparent Mole Conc. [lbmole/ft3]	<empty>	<empty>
CO2 Apparent Wt. Conc. [lbmol/lb]	<empty>	<empty>
LHV Mass Basis (Std) [Btu/lb]	90,10	90,10
Phase Fraction [Vol. Basis]	1,000	1,000

Name	Vapour	Out compresor	Energy compresc
Vapour	1,0000	1,0000	<empty>
Temperature [F]	89,96	233,0	<empty>
Pressure [psia]	18,70	43,51	<empty>
Molar Flow [lbmole/hr]	286,3	286,3	<empty>
Mass Flow [lb/hr]	1,225e+004	1,225e+004	<empty>
LiqVol Flow [barrel/day]	1020	1020	<empty>
Molar Enthalpy [Btu/lbmole]	-1,654e+005	-1,640e+005	<empty>
Molar Entropy [Btu/lbmole-F]	41,38	41,88	<empty>
Heat Flow [Btu/hr]	-4,735e+007	-4,697e+007	3,829e+005

Figure II.11. Compressor worksheet, a) properties, b) conditions.

a) **Number of floors** [14]

To calculate the number of floors, we used the equation II.21 as following:

$S=1.43 \log (P_O / P_E)$..........................(Equation II.21)

Where P_O(psia) and P_E(psia) is pressure out and entered, respectively.

b) **Pressure and reduces temperature** [14]

To calculate reduced pressure and reduced temperature, we used the following values:

T_C=304.060 °K

P_C=7503.400 psia

Where T_C (°K) is the critical temperature and P_C (psia) is the critical pressure, these parameters were calculated by using the following equations:

$P_R = P_E/P_C$ .... (Equation II.22)

$T_R = T_1/T_C$ ....(Equation II.23)

c) **Capacity coefficient** [14]

To calculate the capacity coefficient K, we used the equation II.24 as following:

$K=\frac{cp}{cp-R}$ ….....................(Equation II.24)

Where R (8.314 J/mol K) is the universal gas constant and cp is specific heat (37.240 btu/lb°F)

d) **Adiabatic coefficient** [14]

To calculate the adiabatic coefficient C_a, we used the equation II.25 as following:

$C_a=(K-1)/K$ .... (Equation II.25)

e) **Compression ratio** [14]

To calculate the compression ratio, we used the equation II.26 as following:

$r = \frac{PO}{PE}$ ....(Equation II.26)

Where Po and P_E were the outlet and entered pressure (psia), respectively.

f) **Temperature repair** [14]

To calculate the temperature repair (K), we used the equation II.27 as following:

$T_2=T_E+(T_E/Nad)[r^{Ca}-1]$ .... (Equation II.27)

Where T_E(K), Nad, r^{Ca} and Ca represent entered temperature (°K), adiabatic yield and compression ratio and coefficient adiabatic, respectively.

g) **Work polytropic** [14]

To calculate the work polytropic (kJ/kg), we used the equation II.28 as following

$W_P=\frac{Z* R*T2*K}{M*(K-1)}$ .... (Equation II.28)

Where Z, R, T_2 and K represent compressibility coefficient, universal gas constant (J/mol. K), temperature repair (K) and capacity coefficient, respectively.

The compressibility coefficient Z=0.98. (See annex 3)

a) **Work adiabatic** [14]

To calculate the work adiabatic (kJ/kg), we used the equation II.29 as following:

$$W_{ad}=\frac{WP*Nad}{NP} \text{.....................................} \text{(Equation II.29)}$$

Polytropic and adiabatic yield N_P=0.700, N_{ad}=0.740. respectively (see annexe 3)

b) **Adiabatic head H_A** [14]

To calculate the Adiabatic head (ft), we used the equation II.30 as following:

$$H_c=\frac{WP*1000}{g} \text{.....................................} \text{(Equation II.30)}$$

Where g represents gravity (ft/s²)

c) **Polytropic head H_p** [14]

To calculate the permissible height (ft), we used the equation II.31 as following:

$$H_p=\frac{Wad*1000}{g} \text{.....................................} \text{(Equation II.31)}$$

d) **Power of compression** [14]

To calculate the power of compression (kJ/h) we used the equation II.32 as following

$$P=\frac{Qm*Wad}{1000*Nad} \text{...} \text{(Equation II.32)}$$

Where Qm mass flow rate (kg/sec), W_{ad} Work adiabatic (Nm/kg), N_{ad} adiabatic yield.

Table II.5. Compressor dimensions results

Parameters	Results	Unites
Number of floor S	0.524	/
Reduced pressure P_R	0.041	/
Reduced temperature T_R	1.003	/
Capacity ratio K	1.280	/
Coefficient adiabatic C_a	0.220	/
Compression ratio r	2.320	/
Repair temperature T_2	389.080	K
Polytropic work W_P	54.920	kj/kg
Adiabatic work W_{ad}	58.050	kj/kg
Adiabatic head H_A	5598.396	m

Polytropic head H_p	5917.431	m
Power of compression P	404800.140	kj/h

Table II.6. Comparison of Hysys and calculated results of compressor

Dimensions	Calculated results	Hysys results
Capacity ratio K	1.280	1.275
Adiabatic yield N_{ad}	74.000	75.000
Polytropic yield N_P	70.000	77.000
Adiabatic head H_A (m)	5598.396	5561.000
Polytropic head H_p (m)	5917.431	5713.000
Power of compression P (kW)	112.450	112.200

The dimension results obtained by calculation and Hysys simulator show a small difference. This discrepancy can be attributed to Hysys's advanced modeling, which uses stronger thermodynamic models and an integrated database. These tools allow Hysys to provide slightly different results compared to simplified manual method.

General conclusion

General conclusion

The objective of this work was focused mainly on the elimination of carbon dioxide from rejected gas of GNL2/Z complex at the Algerian Arzew refinery for the protection of the environment. As well as the study of recovery the carbon gas released in the decarburization section. This study was carried out by using tow methods:

- Laboratory part which we capture a sample of the rejected gas from reflux balloon and analyze it to explore the rejected gas’s compositions.
- Simulation part where we propose cooler, separator and a compressor for capture these rejected gas and simulate the installation by hysysV11 and calculate the dimensions of the process equipments.

The results obtained showed that the rejected gas contain the carbon dioxide and the water with high molar percentage. Moreover, a low molar percentage of nitrogen, methane, ethane and propane. These results were obtained by using gas chromatograph. For realize the proposed installation we calculate the equipment’s dimensions and compare it with Hysys dimensions.

The amounts quantity of methane in the rejected gas made us to install an incinerator to burn these quantity for two reasons:

- Firstly, The global warming potential of methane is 25 times higher than the global warming potential
- Secondly, raising the quality of gas in order to increase the financial value.

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Annexes

Annexes

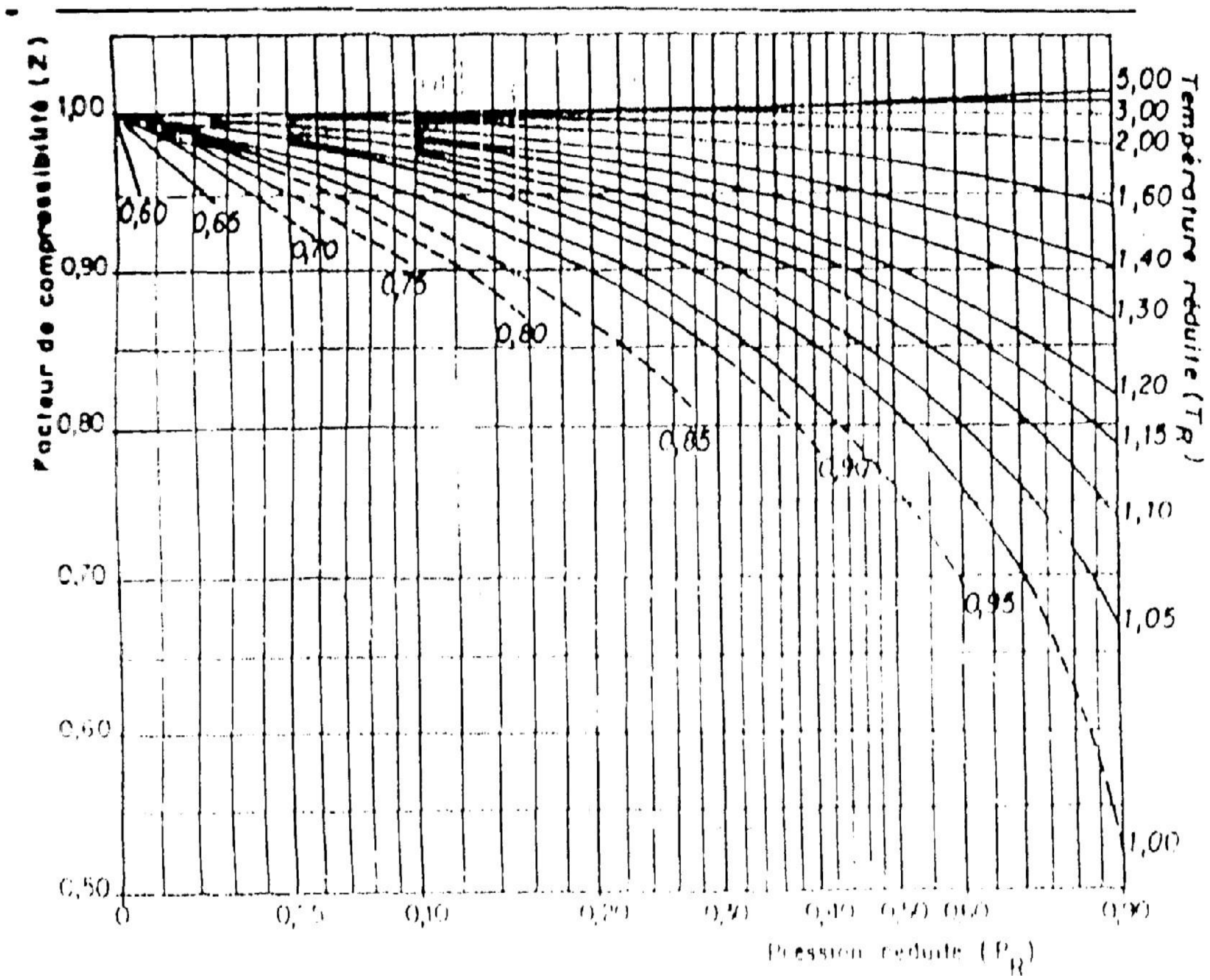
Annexes.1. Retention time.

	Retention time (min)	Alarm time (min)
Feeding balloon of a unit	10	5
Separator balloon feeding 1 - a column 2 - a tank a) with a pump through a exchanger b) without pump 3 - power supply of an oven	5 5 2 10	5 2 1 3
Accumulator balloon 1- reflux only 2 - reflux more product	3 3	2 2
Column background 1 -feeding a column 2 - feeding another column	5	2
suction balloon of a compressor	3 between alarm and closing 10between welding linefrom the bottom and the alarm	

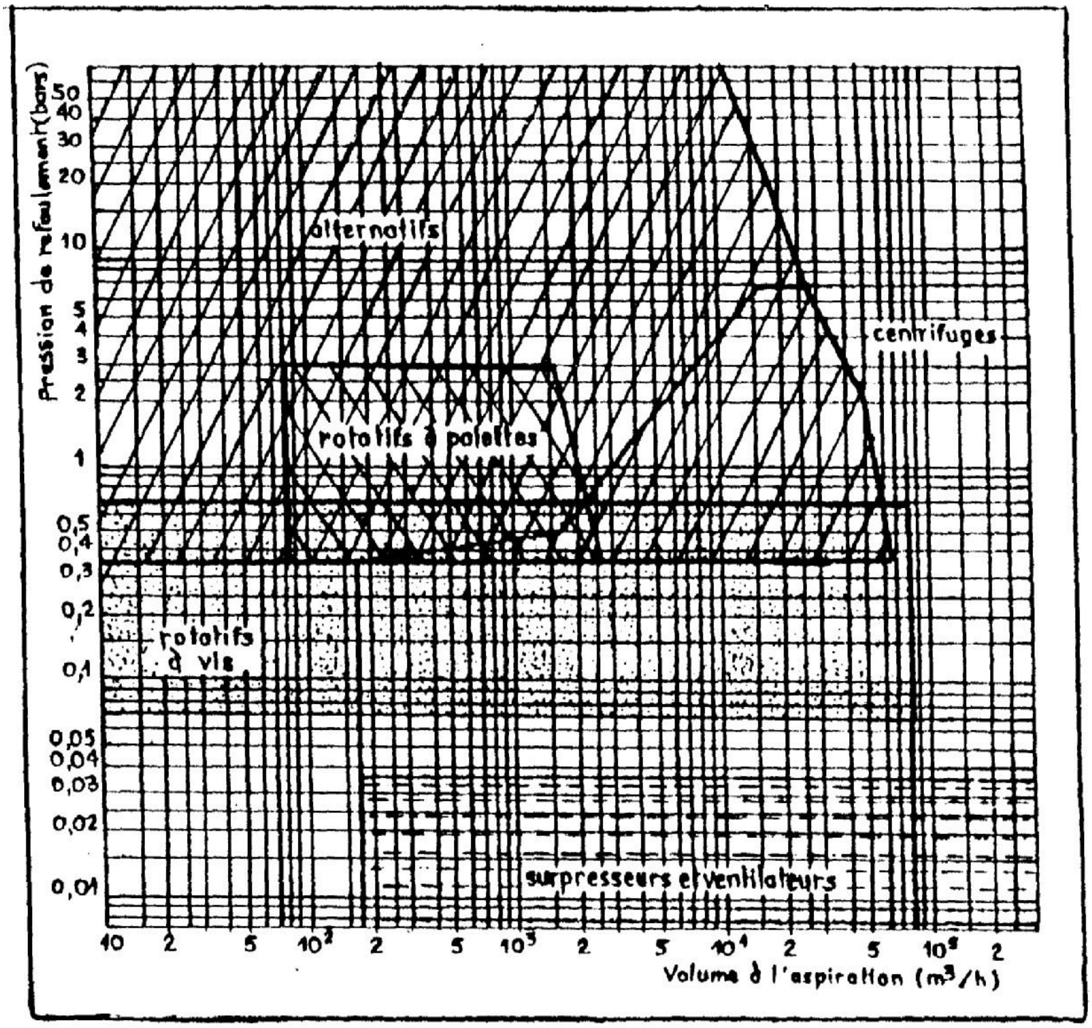
Annexes2. HIII values.

Diameter (ft)	vertical balloon		horizontal balloon
	< 300 psi	> 300psi	
< 4	15 in	6in	9in
6	15in	6in	10in
8	15in	6in	11in
10	6in	6in	12in
12	6in	6in	13in

ANNEXE 3. Choix du compresseur



Polytropic and adiabatic yield annexe
NP=0.700
Nad=0.740


Pression de refoulement (bars)
50
40
30
20
10
5
4
3
2
1
0,5
0,4
0,3
0,2
0,1
0,05
0,04
0,03
0,02
0,01
alternatifs
centrifuges
rotatifs à palettes
rotatifs à vis
surpresseurs et ventilateurs
10
2
5
10^2
2
5
10^3
2
5
10^4
2
5
10^5
2
Volume à l'aspiration (m^3/h)