The 2021 – 2022 TIChE National Chemical Engineering

Student Plant Design Competition

The Cold Energy Utilization of LNG

coupled with Liquid Air Energy Storage: fully recovery

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ABSTRACT

In Thailand, there will be a growing demand for liquefied natural gas (LNG) due to the increase of population and energy requirement, leading to the study of cold energy utilization from LNG regasification. The objective of this project is to utilize the wasted cold energy of LNG by coupling it with liquid air energy storage (LAES) to improve the efficiency of power generation. The proposed Liquefied Natural Gas-Liquid Air Energy Storage-Ranking Cycle (LNG-LAES-RC) operates as peak-off peak hours. During on-peak times, power is generated by air expansion while cold energy from LNG and liquid air is recovered and stored in liquid Propane. During off-peak times, cold energy from both LNG and Propane is used to liquefy air. The double cold energy is capable of reducing power consumption. In addition, a low-grade portion of cold energy is then fully utilized by the additional Rankine cycle, which heat source is from NG combustion to improve the performance of power generation. This conceptual design could achieve the electrical round-trip efficiency of 196.69% which is the highest compared with previous studies. To make the process become more realistic, pressure drop in heat exchangers are calculated and air pretreatment section is concerned, resulting in the dramatically drop in electrical round-trip efficiency to 120.91%. In economic terms, this study achieved negative NVP with no IRR and payback period. Even this study obtained negative NVP and has less amount of cold energy that the LNG inlet temperature is only -129.3 °C, but still reached the highest electrical round-trip efficiency.

Keywords: Cold energy utilization; Liquid air energy storage; LNG regasification; Process design

Department Reference No.:[redacted]

ABBREVIATIONS

CES	Cryogenic energy storage
d_j	Depreciation
DCA	Direct Contact Aftercooler
FCI	Fixed capital investment
IRR	Internal Rate of Return
LAES	Liquid air energy storage
LNG	Liquefied natural gas
NG	Natural gas
NPV	Net Present Value
ORC	Organic Rankine Cycle
ORV	Open rack vaporizer
PCAES	Pressurized cryogenic energy storage system
RC	Rankine Cycle
TCI	Total capital Investment cost
TPC	Total product cost

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CHAPTER 1

INTRODUCTION

Currently, in Thailand, there is a growing demand for energy due to the increase in population and economic growth, so natural gas (NG) will be a new supplying energy resource because of its properties and reliability, which are clear, colorless, odorless, non-corrosive and non-toxic.

To transport NG safely, it has been cooled down to liquid at approximately -162 °C that called liquefied natural gas (LNG). After receiving LNG, it has to be changed its phase in the regasification process before being delivered to the natural gas pipeline network. In general, in the process of regasification, seawater is being used as a heat source to heat the LNG, then it will be directly discharged to the sea. It causes a wasted huge amount of cold energy (which is released by natural gas in liquid form) and leads to the study of cold energy utilization.

The energy of LNG can be utilized in several different industrial processes that require cooling and power generation. To have the cooling in industry process, the specific industry has to be located very close to the LNG terminal. Due to this, the application options are limited. There is a higher interest in power generation from LNG cold energy. This can be done by integrating different power cycles with LNG regasification. However, a study of the economic efficiency of using cold energy utilization from LNG with general cold power generating plants was analyzed in South Korea (Kim *et al.,* 2006), the result was found to be much lower compared with air separation, cryogenic crushing, and frozen food storage. Therefore, the process of power generation should be improved or combined with other methods.

Recently, the integration of liquid air energy storage (LAES) and cold energy utilization from LNG has been developed as an alternative option to generate power. In LAES, a period is divided into peak (high-priced electricity) and off-peak (low-priced electricity) hours. During off-peak times, cold energy is used to liquify air for energy storage. During peak times, liquid air releases stored energy by air expansion, and the power is generated. This process aims to minimize energy consumption over the energy storage period while maximizing energy generation during the energy released period. To do that, cold energy from LNG comes in handy as a significant cold energy source in the part of air liquefaction.

Consequently, this study is mainly focused on using cold energy utilization from LNG regasification combine with liquid air energy storage and power cycles to generate power along with improving the ability to fully utilize cold energy from LNG to increase its efficiency. The process simulation was performed by using Aspen Hysys V.12. Furthermore, economic analysis, safety consideration and environmental consideration are presented in this report.

1.1 Purpose

1.1.1 To design the power generation process from cold energy utilization of LNG regasification.

1.1.2 To analysis the economic and technical feasibility of this process simulation.

1.2 Project scope statement

1.2.1 Plant shall be available for 24 hours/day and 365 days/year operation

1.2.2 Supply high pressure of LNG 90.5 – 105.5 barg

1.2.3 Supply LNG temperature -129.3 to -154.5 °C

1.2.4 Available of LNG flow which will be utilized cold energy utilization is 100 t/h

1.2.5 Overall allowable pressure drop 10 bar

1.2.6 The returned temperature shall be 15.6 – 48.9 °C

1.2.7 Tie in point for HP LNG and HP NG header is 12 and 16 inches, respectively.

1.2.8 The recommendation limit of velocity in the pipeline for liquid and gas is 3 – 6 m/s and 15 – 20 m/s, respectively.

1.2.9 The plant is designed for a lifetime of 25 years. An automatic plant control system may be installed and complied with Thai regulations and international standards.

1.2.10 In consideration of economic analysis, if LNG is totally from the system, the LNG price will be charged 300 baht per MMBTU. In case, NG is returned to the existing terminal grid, the cost of cold energy utilization is 10 baht per ton of LNG

1.2.11 The rental cost of a filled land in the industrial estate is at 100,000 baht/rai/year

1.2.12 Discount rate shall be assumed at 10%

1.2.13 Plant sitting layout can be designed for both areas as shown in figure 1.1

- 20 Rai area is available on the west side of the LNG terminal.

  (The piping length from tie-in point up to battery limit is 460 m.)

- 60 m x 50 m area is available inside of LNG terminal.

  (The piping length from tie-in point up to battery limit is 330 m.)

Figure 1.1. Plant sitting layout

CHAPTER 2

REVIEW OF LITERATURE

2.1 Theory and related concepts

2.1.1 Natural gas

Natural gas is a type of petroleum from a fossil beneath the earth's surface. It contains many different compounds. The largest component is Methane and it usually also contains a variable percentage of Ethane, Propane, Hexane, and non-hydrocarbon such as Nitrogen and Carbon dioxide. These components can be separated and useful in many branches of production. (PTTPLC, 2012)

2.1.2 Liquefied natural gas (LNG)

Generally, Natural gas is delivered by pipeline, however in the case of long-distance transportation, it can be liquefied, by cooling the gas down to approximately -160 °C, the gas will condense and becomes liquid then delivered by ship, called Liquefied natural gas (LNG). Shipping is a preferable way to deliver LNG compared with pipeline especially for international transport since it takes less volume, which is about 600 times less than Natural gas (PTTPLC, 2012). Making it easier for shipment and storage, and also reduce the cost of transportation. After being liquefied and transported to the area of demand, LNG is returned to the gas phase in the regasification process at the terminal (Mayorets *et al.,* 2014).

As mentioned before, natural gas is a complex mixture, thus the mole percentage of each composition consisting of LNG is vary. According to Thai Institute of Chemical Engineering and Applied Chemistry (TIChE) Plant Design Competition Year 2021-2022, LNG composition can be divided into 3 cases as shown in table 2.1.

Table 2.1: LNG composition (TIChE, 2021)

Composition (mol %)	Lean Case	Rich Case	High N_2 Case
CH_4	99.84	87.24	93.40
C_2H_6	0.01	8.45	3.90
C_3H_8	0.00	3.15	1.12
i-C_4H_{10}	0.00	1.11	0.58
n-C_4H_{10}	0.00	0.00	0.00
i-C_5H_{12}	0.00	0.05	0.00
n-C_5H_{12}	0.00	0.00	0.00
CO_2	0.00	0.00	0.00
N_2	0.15	0.00	1.00
Total	100.0	100.0	100.0
Molecular Weight	16.06	18.61	17.27
Density (kg/m3) @ b.p. at 1 atm	424.7	469.5	451.9

2.1.3 Liquid air energy storage (LAES)

Liquid Air Energy Storage (LAES) systems are energy storage systems that take electrical and thermal energy as inputs to regenerate electrical energy output on demand. These systems have been suggested for use in grid-scale energy storage, demand-side management, and facilitating an increase in renewable power integration into the current power network.

The process of Liquid air Energy Storage (LAES)

Form figure 2.1, Liquid air Energy Storage (LAES) systems are divided into 2 main parts that are liquefaction system and power generation system.

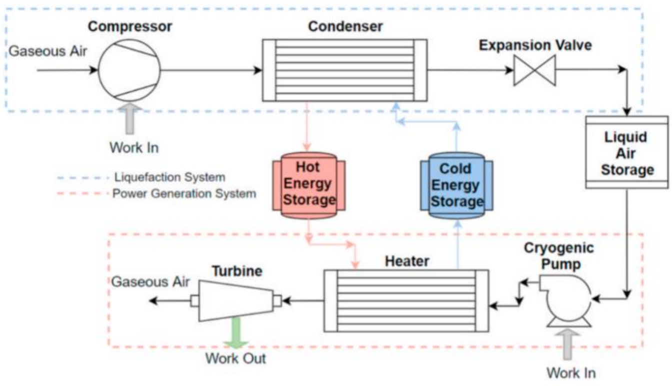


Figure 2.1. Baseline LAES system. (O'Callaghan *et al.,* 2021)

Liquefaction system

In part of a liquid faction, cycles are an air liquefier, which uses electrical energy to draw air from the surrounding environment, clean it and then cool the air to subzero temperatures until the air liquefies. The condition of liquid air depends on the T-S diagram and the initial temperature of cold energy storage (Janssen, 2018).

Power generation system

In part of power generation cycles, when power is required, liquid air is drawn from the tanks and pumped to high pressure. The air is evaporated to ambient temperature. This produces a high-pressure gas, which is then used to drive a turbine (Janssen, 2018).

2.2 Literature Review

Kim *et al.* (2006) analyzed economic efficiency of LNG cold energy use in South Korea, which are cold power generation, air separation, cryogenic crushing, frozen food storage, and carbonic acid. The result showed that payback periods each process as follows. The power generation, PPM is 18.6 years. The cold crushing business, PPM is 8.7 years. The frozen food storage, PPM is 7.7 years and the carbonic acid, PPM is 6.6 years.

Li *et al.* (2010) reviewed the use of cryogen as an energy carrier. It was shown that cryogens are better than other used thermal storage media. They concluded that Brayton cycle is a good option to extract energy from cryogens if high-grade heat source is available while Rankine cycle is more suitable when low-grade heat is available.

Bernd *et al.* (2013) analyzed the performance of Rankine cycle and heat waste recovery. Result in the energy efficiency can be improved 36.8% with Ranking cycle and 43.3% in combined cycle for recovery of the wasted heat.

Lee *et al.* (2017) proposed the combination of LNG regasification process and cryogenic energy storage (CES) which used air as its working fluid. The cold energy of LNG is transferred in form of cold transfer in heat exchanger and shaft work transfer by direct expansion of LNG to compress the air. This system can store and release energy concurrently as LNG operates full-time that dependently with CES. Resulting in the increase of daily produced energy by CES system more than double compared to the studies which have divided operating modes for energy storage and release.

Tholander *et al.* (2018) calculated the electrical round-trip efficiency of liquid air energy storage (LAES), a novel technology that liquefies air and stores. When electricity is needed, liquid air is expanded in a turbine to generate electricity. The liquid air is stored at 1 bar, -198 **°C**. This process was concluded that the round-trip efficiency of LAES is 21.6% without heat and cold recycle but the round-trip efficiency of LAES can be increased with heat and cold recycle. Moreover, LAES is high energy density which is comparable to other processes.

Kim *et al.* (2018) proposed pressurized cryogenic energy storage system (PCAES) and analyzed bases on the simulation. This paper stores the air near the critical point that reduces the energy input. Result in the round-trip efficiency of PCAES is higher than LAES but PCAES requires a lot of pressurized tanks to keep the liquid air.

You *et al.* (2019) developed the LNG-LAES process by applying additional Organic Rankine cycle (ORC) to the LNG regasification process after the heat exchanger with air which the temperature is still low at approximately -65 °C. This supplementary could reduce the wasted cold and generate more energy.

Peng *et al*. (2019) presented the LAES coupled with LNG regasification and cold storage (LAES-LNG-CS). It was designed to recover cold energy from LNG and store it in pressurized Propane to supplement cold energy for air liquefaction. The result showed that the use of cold energy from LNG is efficient which power consumption per unit mass of liquid air could reduce by about 32% compared with the standalone LAES system.

Park *et al.* (2020) designed a novel power management system, liquid air energy storage with LNG. The proposed of this process uses LNG cold energy to produce liquid air and operates two mechanisms. During on-peak times, LNG cold energy is recovered and stored via liquid propane and the liquid air is expanded in a turbine to produce electricity. During off-peak times, the process uses both cold energy from LNG and propane to produce liquid air. Result in an electrical round-trip efficiency of 187.4%.

Qi *et al.* (2020) introduced the advanced integration of LNG regasification and LAES, enhancement in flexibility and safety. Due to the electricity market scenario, this process was designed to maximize the operating profit by varying the amount of LNG cold energy utilized in LAES. They reported that the liquid air storage pressure should not exceed 1.8 MPa to satisfy the industrial maximum storage pressure. In addition, the utilized of only high-grade portion of LNG in LAES during off-peak times could improve the electrical round-trip efficiency.

Wang *et al.* (2021) presented the standalone LAES by using packed bed cold and heat storage. Although packed bed cold and heat storage are non-flammable, but this process shows a lower round trip efficiency compare with the standalone liquid air energy storage

CHAPTER 3

CONCEPTUAL DESIGN

The integration of liquid air energy storage and cold energy utilization from LNG regasification is being chosen to improve the performance of power generation. This study has been evaluated the options that this process should be operated as peak-off peak hours or 24 hours and the optimal flow rate of air. As a result, from appendix A, this process will be operated as a peak-off peak period, stored liquid air at ambient pressure by using cold energy from LNG, liquid Propane, and cryogenic turbine to liquefy air.

This process is developed from (Park *et al.,* 2020). The proposed LNG-LAES-RC process operates as two conditions in on-peak and off-peak times. Therefore, air will be liquefied by using low-cost electricity while generating and selling electricity at a high price. Moreover, cold energy from both LNG and liquid air has been fully utilized with Rankine cycle, which the heat source is from the combustion of a small portion of NG.

During off-peak times, 22.00 - 09.00 in Thailand, are the hours in which electricity demand is relatively low that the cost will be decreased by 2.2092 baht per unit (ERC, 2012). During this period, electricity and cold energy are used to compress and liquefy air with low power expenses. This part of the process is called energy storage process.

During on peak times, 09.00 - 22.00 in Thailand, are the hours which electricity is commonly used that the cost will be increased by 3.8254 baht per unit (ERC, 2012). During this period, using the cold energy storage as liquid air to generate electricity and it will be sold back to the electricity authority at high price. This part of process is called energy release process.

This LNG-LAES-RC process is divided into 6 sections as shown in figure 3.1. Section 1 and 2 are operated only during off-peak period (energy storage process), section 4 operates only on-peak times (energy release process), while the others operate 24 hours.

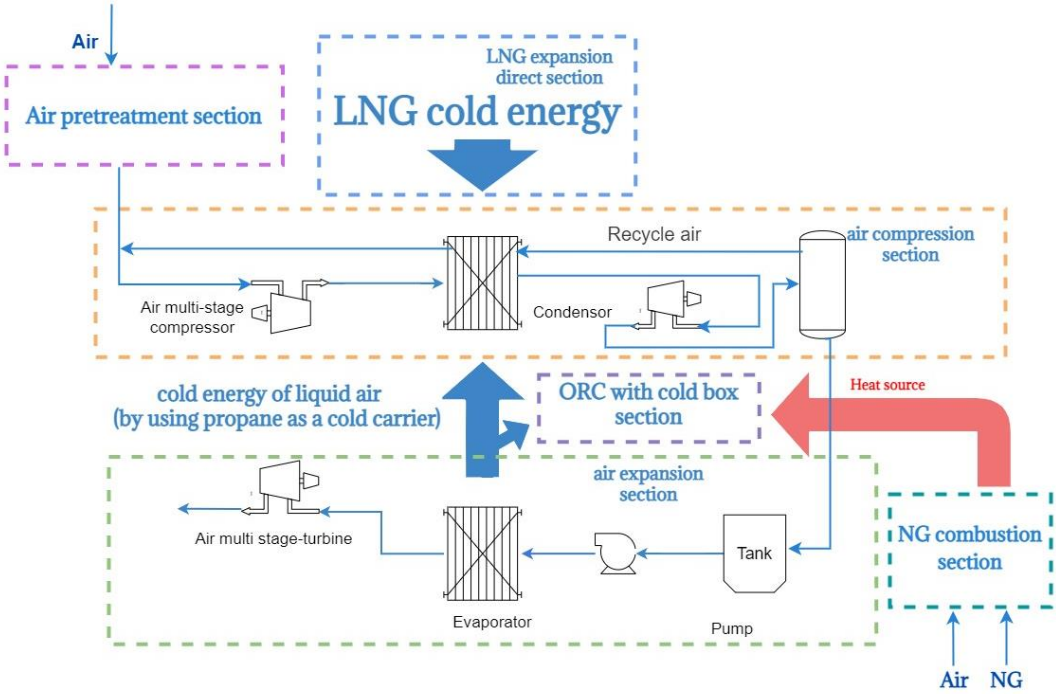


Figure 3.1. Simplification of the LNG-LAES-RC process

1) Air pretreatment section

Air from ambient is pretreated to remove the moisture and carbon dioxide to prevent its from freezing during air liquefaction. The flash drum and DCA (Direct Contact Aftercooler) are used to eliminate the major portion of water, while the remaining moisture and carbon dioxide are disposed by temperature swing adsorption (TSA). Furthermore, cold energy from LNG is used in this section as a heat sink to reduce the temperature of air and water.

2) Air compression section

The purified air is compressed and liquefied in this section. Treated air is passed through the multi-stage compressors and condensers, which cold energy from LNG and liquid Propane is used as a cooling source. Then air with low temperature and high pressure is sent to cryo-turbine, where the pressure decreases dramatically which makes the temperature significantly drops and finally air becomes liquid.

3) LNG direct expansion section

After LNG exchanges heat with air, its temperature is still low. So, LNG is sent to the Rankine cycle and direct expansion to utilize the wasted cold and generate more power. A multi-stage turbine is applied for LNG direct expansion. Heat exchangers are placed between turbines and all of the cold energy waste lines are recovered in RC with a cold box section.

4) Air expansion section

This section is where air expands and generates electricity. A multi-stage turbine is applied in this section and a heat exchanger is also placed between turbines to increase the temperature. Normally, cold energy from liquid air is transferred to the seawater. So, in this proposed process, liquid Propane is being used as a cold carrier to store cold energy from air discharging period to further use in energy storage period. Furthermore, the rest of the cold energy is recovered in RC with cold box section.

5) Rankine cycle with cold box section

The Rankine cycle with cold box section is added to recover a low-grade portion of cold energy. The cold energy waste lines from LNG direct expansion section and Air expansion section are applied with cold box to use as a heat sink in this additional RC instate of wasting them with seawater. The heat source for this RC is from NG combustion section.

6) NG combustion section

After LNG becomes NG, a small portion of natural gas is combusted to use as a heat source in the RC. Moreover, the hot oil is used as a working fluid in this section.

3.1 Block Flow Diagram

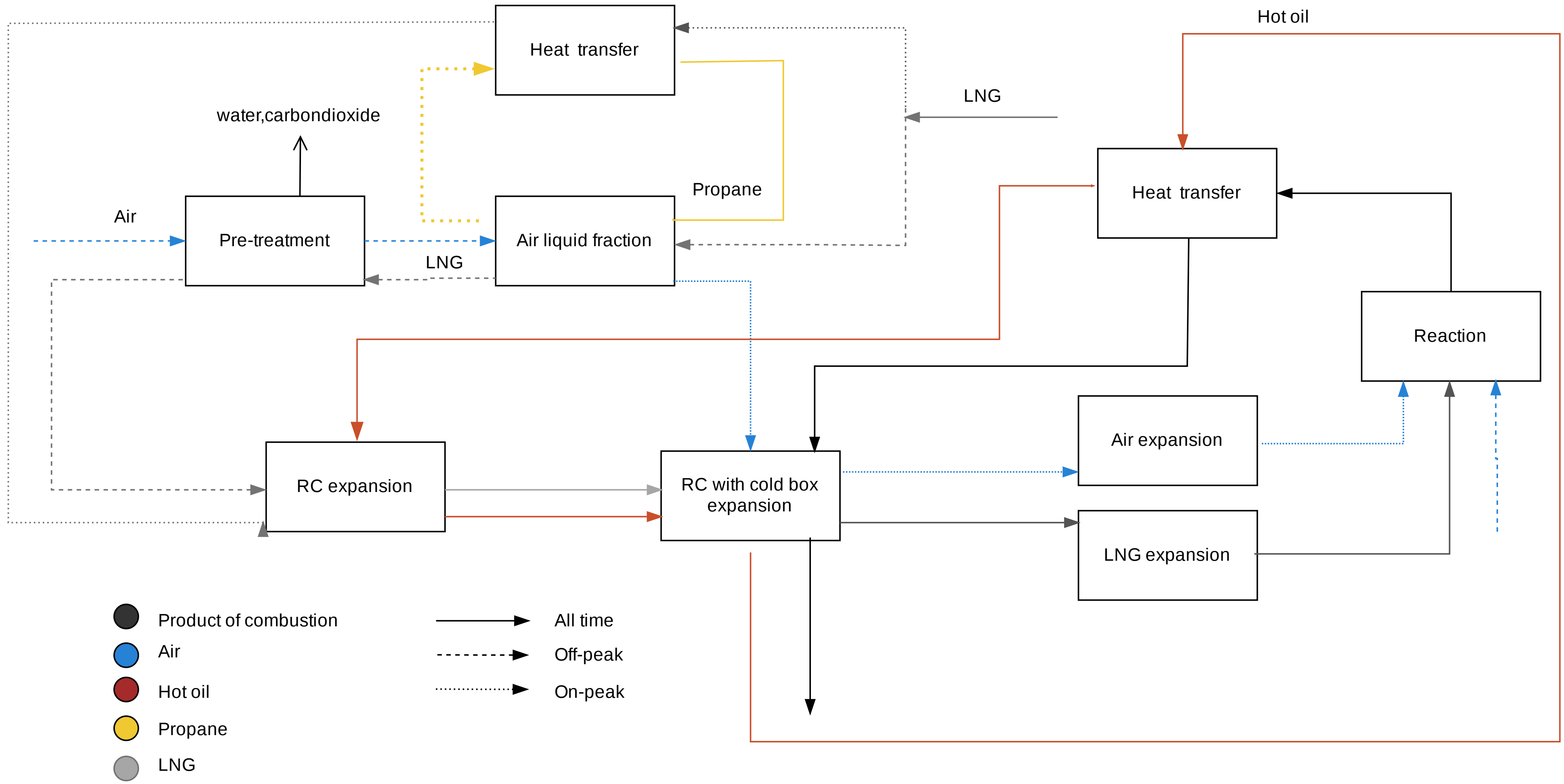


Figure 3.2. Block Flow Diagram of the LNG-LAES-RC process

3.2 Design Basis

Table 3.1: Design basis

Criterion	Value
LNG mass flow	100,000 kg/h
LNG inlet pressure	95.50 bar
LNG inlet temperature	-129.3 °C
LNG molar composition	
Methane	0.9984
Ethane	0.0001
Nitrogen	0.0015
RC working fluid composition	
Water	1.0000
Maximum pressure drop between inlet and out let of LNG	10 bar
Air mass flow	80,555 kg/h
Air molar composition	
Water	0.0177
Oxygen	0.2057
Nitrogen	0.7672
Carbon dioxide	0.0003
Argon	0.0091
Air inlet temperature	33 °C
Isentropic efficiency of air compressors (Kim & Chang, 2019)	0.85
Isentropic efficiency of air turbine (Kim & Chang, 2019)	0.85
Isentropic efficiency of air pumps (Kim & Chang, 2019)	0.75

Table 3.2: Equipment code and Pipe code definition

No.	Equipment code	Equipment name
1	AD	Adsorption
2	CB	Cold box (Plate fin heat exchanger)
3	D	Flash drum
4	DCA	Direct Contact Aftercooler
5	HE	Heat exchanger
6	K	Compressor
7	M	Mixer
8	PU	Pump
9	R	Reactor
10	S	Separator
11	SL	Splitter
12	TANK	Tank
13	TSA	Temperature Swing Adsorption
14	T	Turbine
No.	**Pipe code**	**Component**
1	A	Air
2	P	Propane
3	L	LNG
4	W	Water
5	C	Combustion product
6	H	Hot oil

Table 3.3: Section code definition

Section No.	Name
100	Air pretreatment section
200	Air compression section
300	LNG direct expansion section
400	Air expansion section
500	Rankine cycle with cold box section
600	NG combustion section

3.3 Design Philosophy

The design philosophy of this process is to fully utilize the cold energy of LNG and liquid air and minimize the power consumption in air compression section while maximizing the power generation in air expansion section and LNG direct expansion section.

To fully utilize the cold energy of LNG and liquid air, the cold energy of LNG is used to liquefy air and air pretreatment. While the high-grade portion of cold energy of liquid air is used to reduce the power consumption in the air compression section. The remaining cold energy of LNG and liquid air is applied with RC with cold box, where hot oil from NG combustion is used as a heat source to increase the amount of power generation. In other words, this additional NG combustion could provide a significant heat source to use in the supplementary RC with cold box, which could further improve the efficiency of this process and generate more electricity.

To minimize the power consumption in the air compression section, the optimization concept of each compressor is the lower temperature goes in the compressor, the less energy consumed. Therefore, the first compressor which receives the air with high temperature is used to increase the air's pressure only to make it able to pass through the pipe and the first heat exchanger. In the next compressor, when the air's temperature gets lower, more pressure is provided. Since air which is a hot stream flows as a counter-current with LNG and Propane (cold stream), the temperature of the air will be gradually decreased, so the differential pressure in the compressor will keep increasing according to the inlet temperature. Due to the same reason, the air is designed to be precooled by liquid Propane that stored cold energy from air expansion section to minimize power consumption.

To maximize the power generation in air expansion section and LNG direct expansion section, a multi-stage turbine is applied to avoid the consequence problems that might occur. Because if pressure drops dramatically, the temperature will significantly decrease which might be capable to produce liquid phase that could damage the engine. The idea to maximize power generation in the turbine is the higher temperature goes in, the more power is generated. Thus, a heat exchanger (cold box) is placed between turbines to increase the temperature. The heat source in this heat exchanger is from NG combustion, which is the major heat source in this process.

3.4 Control Philosophy

For the LNG-LAES-RC process, the flow rate of air is fixed to constant by controlling the flow rate of LNG. Since the temperature and pressure of LNG is unstable so the flow rate of LNG will be adjusted according to the required energy. In other words, the required energy is fixed, if the LNG inlet temperature is lower, the flow rate of LNG will be lesser.

In part of the Rankine cycle, the flow rate of the Rankine cycle is adjusted by a control valve because the cold energy of each period (off-peak period and on peak period) is unequal. The on peak period has the cold energy from both liquid air and LNG while off-peak hours have only from LNG. So, the flow rate of water in the Rankine cycle in the on peak period is more than the off-peak period.

The hot oil loop is controlled by adjusting the flow rate according to the required temperature. Because the cold energy during on peak period is more than in off-peak period, when the cold energy is higher, more heat is required resulting in more combustion and more flow rate of hot oil.

3.5 Process Control System (PCS) and Safety Instrumented System (SIS)

3.5.1 Process Control System (PCS)

For the LNG-LAES-RC process, the flow rate of the inlet line is controlled by the control valve. The flow and temperature transmitter transforms the signal into the electrical signal to transmit the signal to the flow indicating controller. The flow indicating controller receives the electrical signal and sends the signal to the flow converter. Then the flow converter transforms the signal into the wind signal to adjust the opening percentage of the valve.

The flow rate of air is fixed to constant by controlling the flow rate of the LNG. The signal is sensed by the temperature transmitter of air to the temperature indicator converter, then the temperature indicator converter sends the signal to the temperature converter to transfer the signal into the wind signal. The flow rate of LNG is controlled by the wind signal in the control valve.

The flow rate of Rankine cycle is controlled by the temperature of the water. The temperature indicator sends the signal to the temperature indicator controller, after that the temperature indicator controller sends the signal to the temperature convertor. The control valve is controlled by the wind signal from the temperature convertor. The Rankine cycle and the hot oil loop are similar.

The symbols of instrument and valve show in the table 3.4 and 3.5.

Table 3.4: Instrumentation symbols and its objective

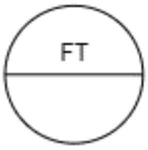
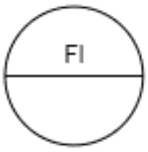
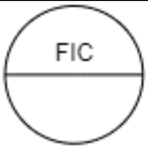
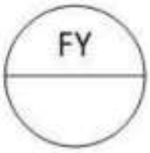
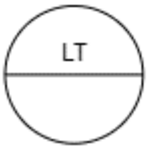
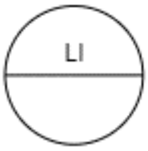
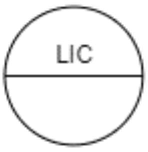
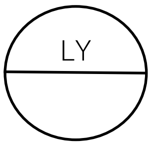
Instruments	Symbols	Objective
Flow Transmitter		To measure the flow rate of the fluid inside the pipe by transforming the signal into the electrical signal and transmit the signal to flow indicator.
Flow Indicator		To receive the signal from the flow transmitter and express the flowrate of the fluid.
Flow Indicator Controller		To receive the signal from the flow transmitter, express the flowrate of the fluid and send the signal to flow converter.
Flow Converter		To receive the signal from the flow indicator controller and transform the wind signal to adjust the opening percentage of the valve.
Level Transmitter		To measure fluid in equipment and send the signal to the level indicator controller
Level Indicator		To receive the signal from the level transmitter and express the level of liquid.
Level Indicator Controller		To receive the signal from the level transmitter and express the level of liquid.
Level Converter		To receive the signal from the level indicator controller and transform the wind signal to adjust the opening percentage of the valve.

Table 3.4: Instrumentation symbols and its objective (cont.)

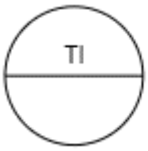
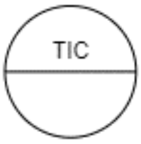
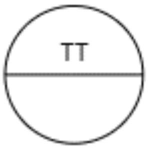
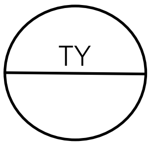
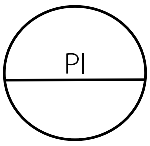
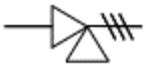
Instruments	**symbols**	**Objective**
Temperature Indicator		To receive the signal from the temperature transmitter and express the temperature of the fluid.
Temperature Indicator Controller		To receive the signal from the temperature transmitter, express the flowrate of the fluid and send the signal to the flow converter
Temperature Transmitter		To measure the temperature of the fluid inside the pipe by transforming the signal into the electrical signal to transmit the signal to temperature indicating.
Temperature Converter		To receive the signal from the temperature indicator controller and transform the wind signal to adjust the opening percentage of the valve.
Pressure Indicator		To measure and express the pressure

Table 3.5: Valve symbols and its objective

Type of valve	Symbol	Objective
Gate valve		To fully open or fully closed operation the flow of fluid.
Flanged valve		To drain the fluid.
Globe valve		To manual control the flow rate of the fluid.
Control valve		To control the flow rate of the fluid by adjusting the opening percentage according to the received signal.
Pressure relief valve		To protect a pressurized vessel during overload.
Check valve		To allow the flow of fluid in one direction.

3.5.2 Safety Instrumented System (SIS)

For the LNG-LAES-RC process, the pressure relief valve is installed at a pressurized instrument such as a reactor for safety. When the instrument is overpressure, the pressure relief valve will vent fluid from an over pressurized vessel to protect life and properties. Moreover, this process also has the additional pressure and temperature transmitters for the reactor to ensure that this process operates at safe state when pre-determined conditions are violated. This safety instrument system is the separate set of devices from the basic control system to reduce the risk.

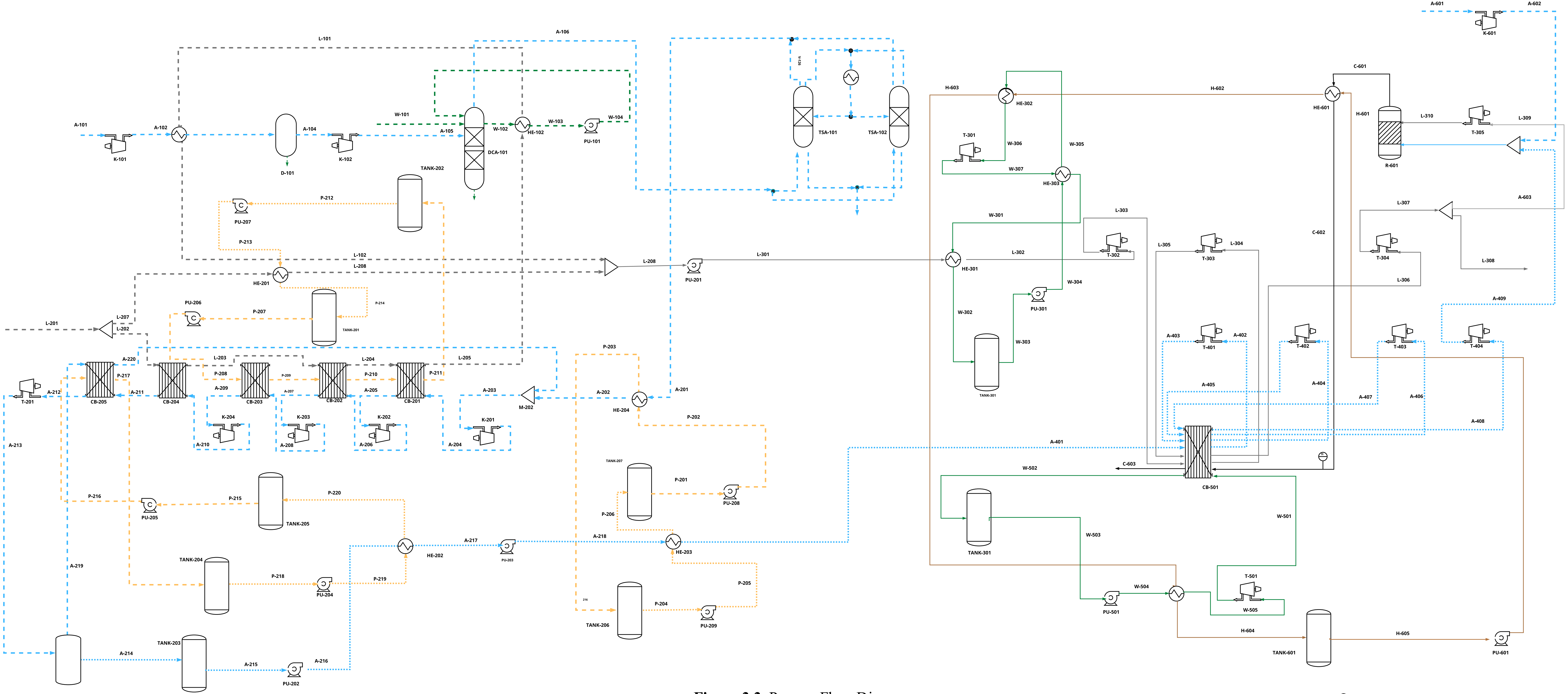


Figure 3.3. Process Flow Diagram

Product of combustion
Air
Hot oil
Propane
LNG

All time
Off-peak
On-peak

3.6 Process Description

Energy storage process

During the off-peak time, the power demand is low, this process is operated in order to produce liquid air to further use in the energy release period. The energy storage process is divided into 5 sections air pretreatment, air compression, LNG direct expansion, Rankine cycle with cold box and NG combustion section as shown in figure 3.4.

1. Air pretreatment section

Air from ambient is pretreated in this section to remove the moisture and carbon dioxide to prevent them from freezing. Air is compressed and passed through the heat exchanger to reduce its temperature (by using cold energy from LNG) before getting in the flash drum, where some moisture is eliminated. Then air is sent to the DCA (Direct Contact Aftercooler) to remove the major portion of water. In this DCA, chilled water is used to decrease the temperature of air by direct contact, making the moisture in the air condenses. In addition, there is a water loop for this DCA. The water that comes out from the middle will be reduce its temperature (by LNG cold energy) and recycle back at the top of this tower. After the air passed through this DCA, the remaining of moisture and carbon dioxide are disposed by temperature swing adsorption (TSA), which AA and 13X zeolite MS are used as adsorbents.

2. Air compression section

The pretreated air which consists of Nitrogen, Oxygen and Argon is compressed by compressor to passable in the heat exchanger and pipe. After that, the air is received the cold energy from LNG and liquid Propane. In the meanwhile, air is compressed until 80 bar, before sent to the cryo-turbine, where its temperature and pressure decrease and become liquid. After passing through the cryo-turbine, the major portion of air will be liquefied, while some will remain in a gas state which is called return air. This return air will be sent back to use as a heat sink in the cold box (CB-205), before being recycled back to the beginning of this section.

3. LNG direct expansion section

After the high-grade portion of cold energy is used to liquefy air, the remaining cold energy is used for RC to generate electricity. In this RC, hot oil from NG combustion is used as a heat source, moreover, there is a use of regenerator to reduce the heat and cold energy consumption, which is a significant method for energy saving. After that, LNG is passed through the multi-stage turbine. Between turbines, the temperature of air is increased to enlarge the power generation by exchanging heat with water in the RC with cold box section.

4. Rankine cycle with cold box section

Rankine cycle is applied with cold box. The cold energy waste line from LNG is used as a heat sink while the hot oil which receives heat from NG combustion is used as a heat source.

5. NG combustion section

After LNG direct expansion, most of NG will be sent out to the NG header at 41.45 °C, while the rest (1.01% of NG) is sent to the reactor, where the combustion reaction occurs. The combustion product is then exchanged heat with hot oil, which is the working medium to use as a heat source in RC.

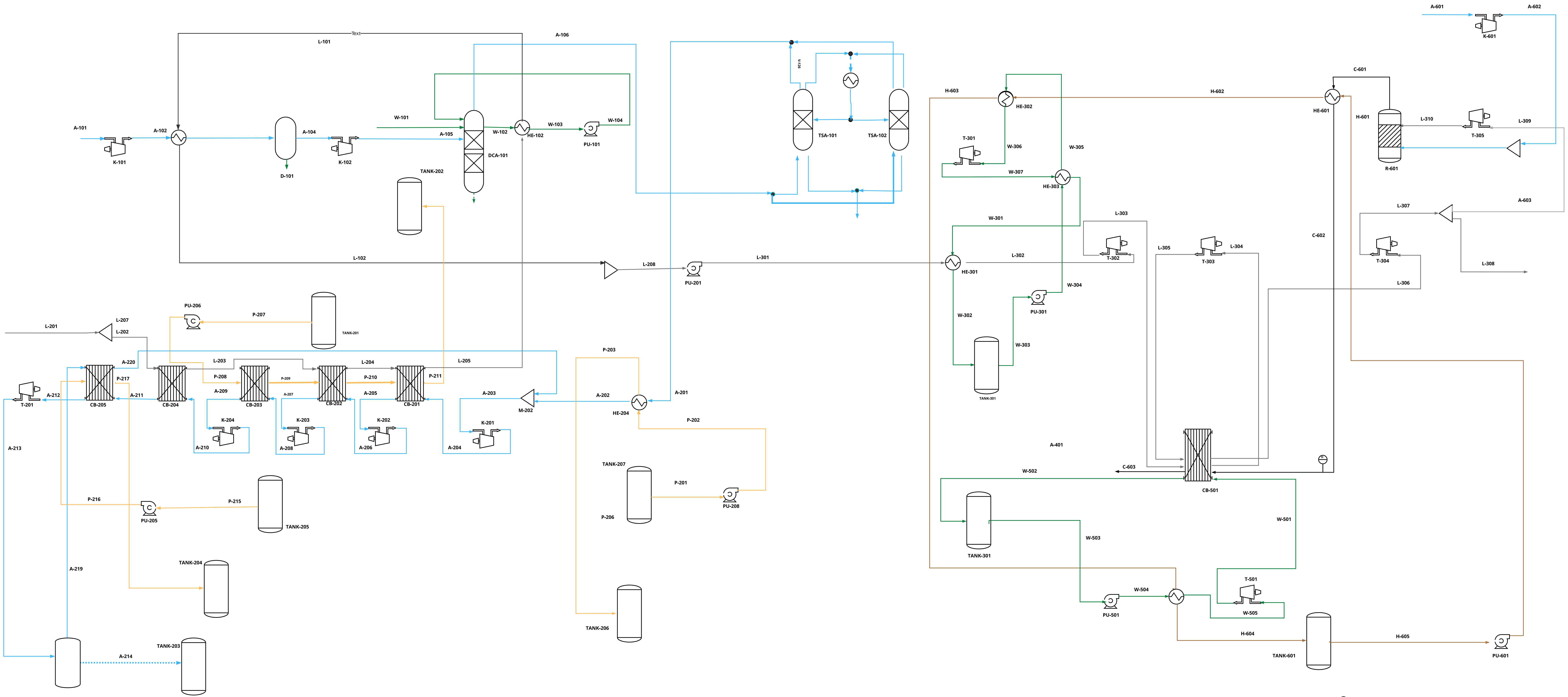


Figure 3.4. Process Flow Diagram during off-peak period

- Product of combustion
- Air
- Hot oil
- Propane
- LNG

Energy release process

During the on-peak time, power demand is high. This part of the process is operated in order to generate electricity by air expansion. The energy release process is divided into 4 parts, air expansion, LNG direct expansion, Rankine cycle with cold box and NG combustion section by following figure 3.5.

1. Air expansion section

Since liquid air contains a high-grade portion of cold energy which can be helpful to liquefy air in energy storage period, this first portion of cold energy is stored in liquid Propane to further cool liquid air. The second portion is also kept in liquid Propane but for precooling the inlet air. Then air is expanded by turbines to generate electricity. During air expansion, air has to be at a high temperature to improve the efficiency of power generation. Seawater is usually used to maintain the temperature of air by 15 °C (Park *et al.,* 2020) but this process applied the remaining cold energy with RC with cold box. Therefore, the waste cold energy is passed into the cold box in RC with cold box section, which the outlet temperature of air is up to approximately 110 °C, which means more electricity is produced.

2. LNG direct expansion section

In the energy release process, the high-grade portion of cold energy from LNG is stored in liquid Propane for later use in air compression section during the energy storage period. The remaining cold energy of LNG is then used for RC to generate electricity. The operation of the RC is the same as in energy storage period but the mass flow rate of the water in this RC will be adjusted according to the LNG temperature. After this, the LNG will be passed through the same lines conditions as in the energy storage process.

3. Organic Rankine cycle with cold box section

Organic Rankine cycle is applied with cold box. Using the cold energy waste line with Organic Rankine cycle. In the energy release process, cold energy from air, LNG and ORC that the condition is suitable with this section is used with Organic Rankine cycle and cold box.

4. Rankine cycle with cold box section

Rankine cycle is applied with cold box. The cold energy waste line from LNG and liquid air is used as a heat sink while the hot oil which receives heat from NG combustion is used as a heat source. The operation in this RC with cold box section is the same as in energy storage process but the flow rate of water is risen due to the increase of cold energy.

5. NG combustion section

The operation in this section is also the same as in energy storage process but there is an increase in the portion of NG to combustion, from 1.01% to 2.17% because in this energy release process, the cold energy waste lines are from both LNG and liquid air, which are more than energy storage process that has only LNG.

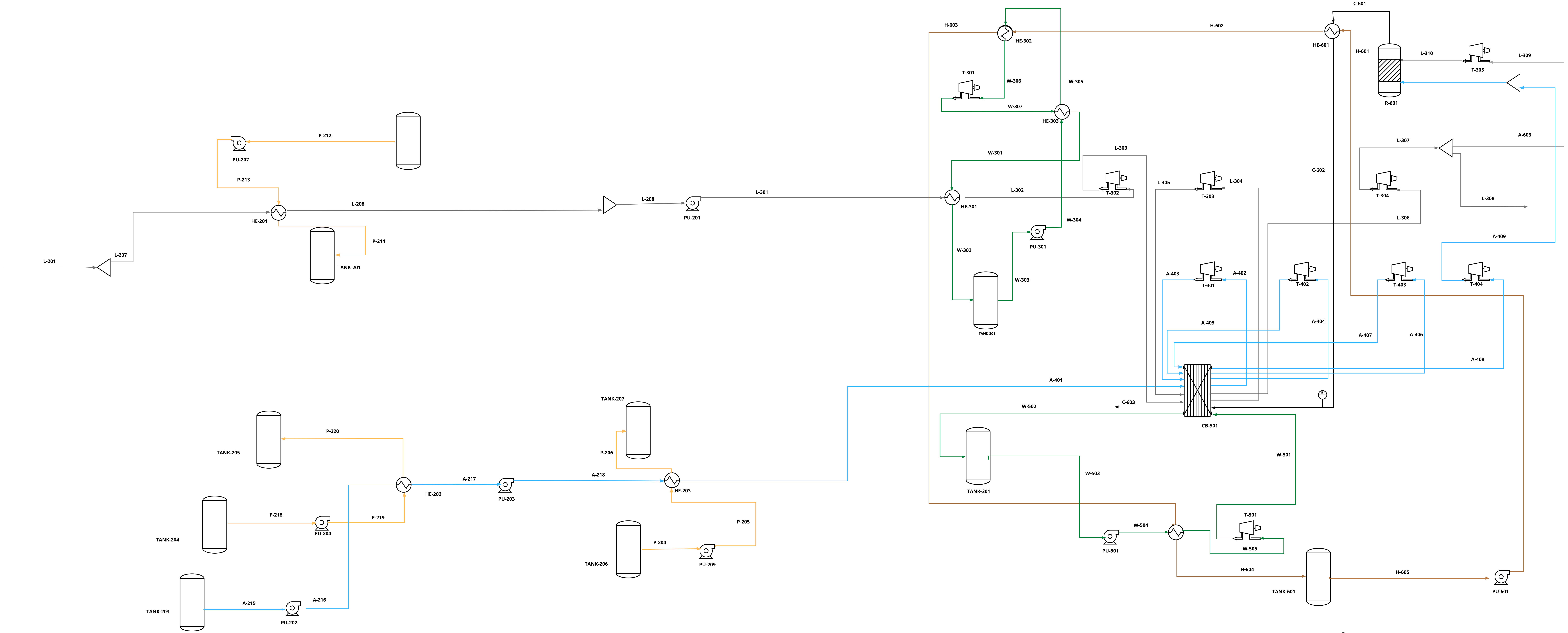


Figure 3.5. Process Flow Diagram during on peak period

CHAPTER 4

RESULTS AND DISCUSSION

4.1 HYSYS Simulation

The proposed LNG-LAES-RC process for off-peak and on-peak periods were simulated in Aspen HYSYS as shown in figure 4.1 and figure 4.2, respectively.

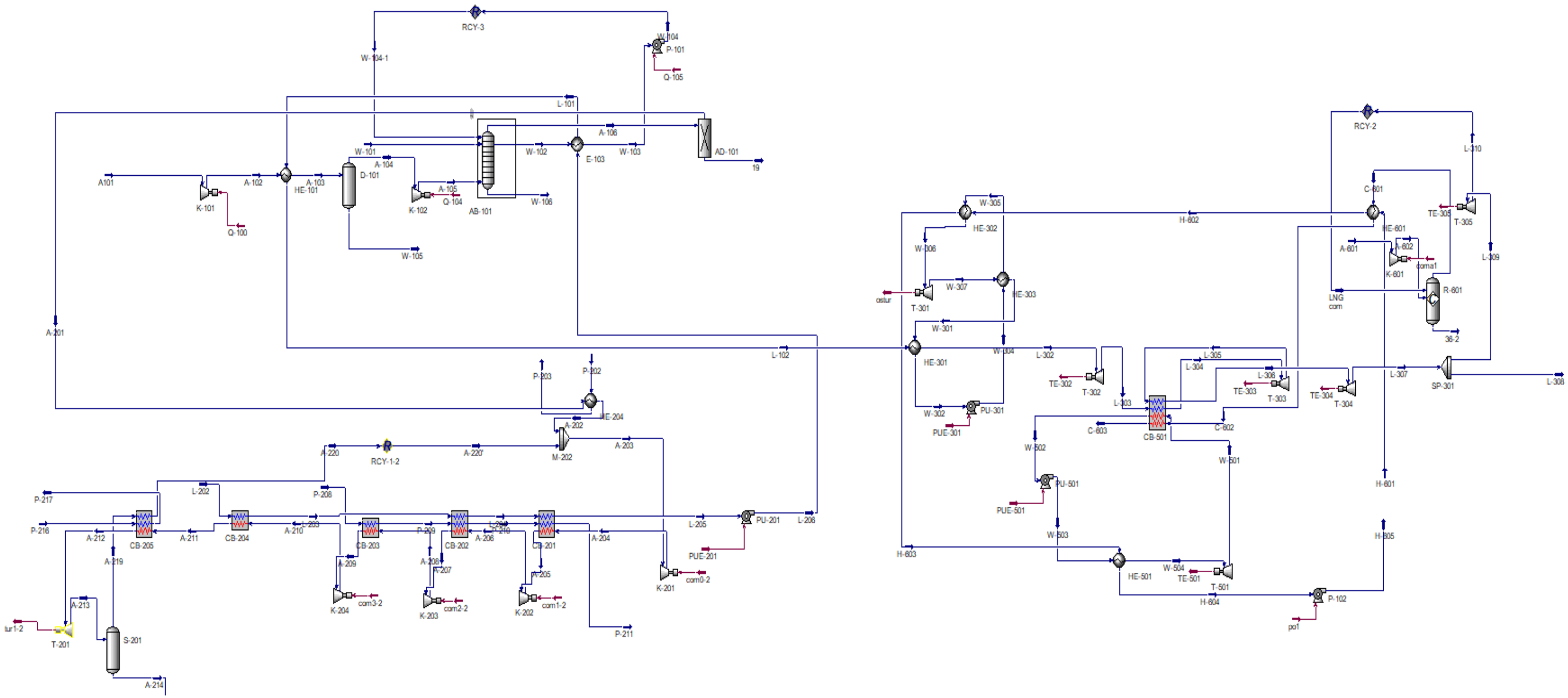


Figure 4.1. Simulation of the LNG-LAES-RC during off-peak period (energy storage process)

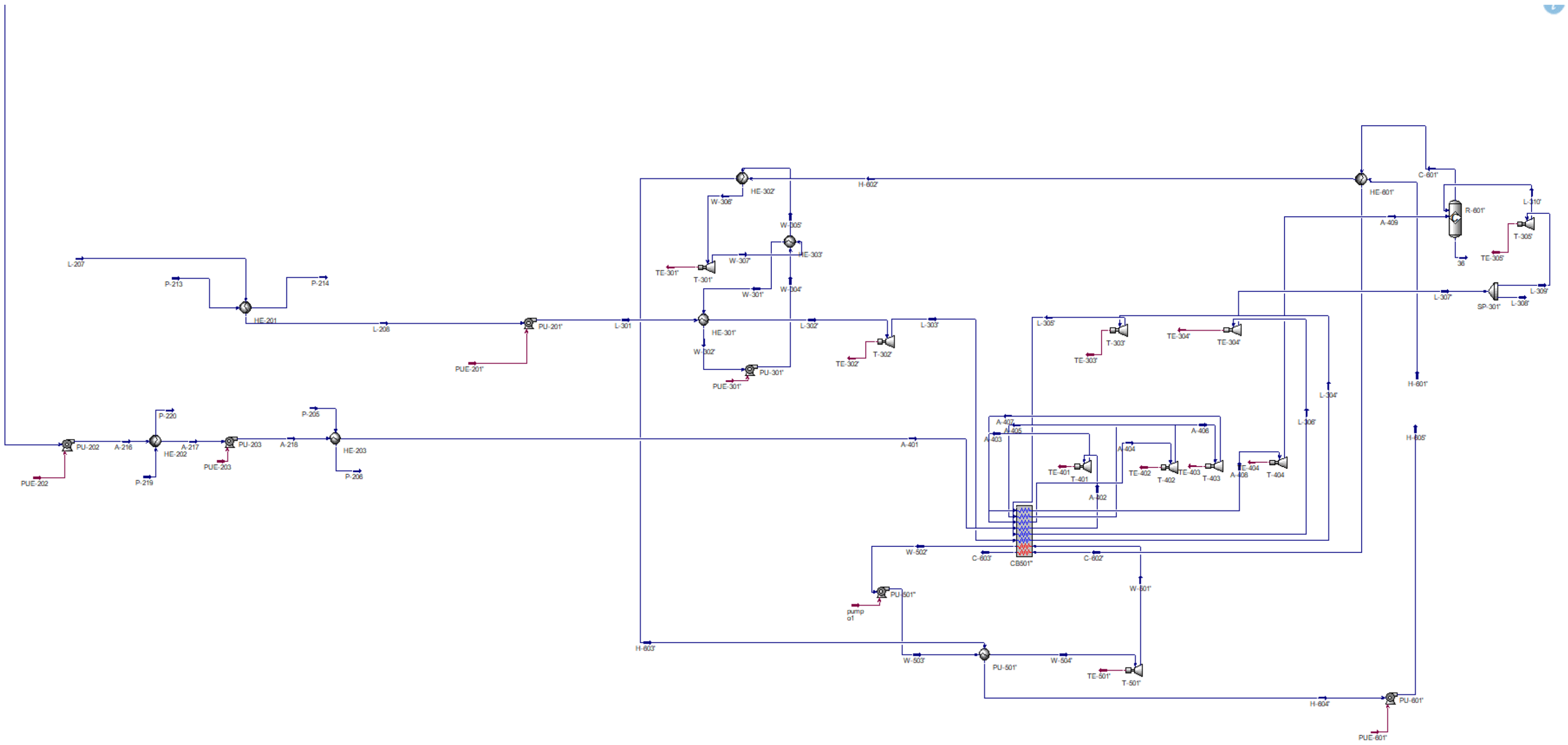


Figure 4.2. Simulation of the LNG-LAES-RC during on peak period (energy release process)

4.2 Power Consumption and Generation

Table 4.1 and table 4.2 present the net power consumption and net power generation of this process, respectively. The net power consumption is 8581.56 kW and the net power generation is 8779.768 kW. The net power generation is more than the net power consumption showing that the process gains the net power.

Table 4.1: Power performance of LNG-LAES-RC process with pressure drop and air pretreatment section in energy storage operation.

Energy storage operation			
Equipment	Power consumption (kW)	Equipment	Power generation (kW)
K-101	3400.0000	T-201	246.9000
K-102	241.3000	T-301	953.9000
K-201	1517.0000	T-302	876.6000
K-202	2353.0000	T-303	786.9000
K-203	2118.0000	T-304	537.4000
K-204	1114.0000	T-305	42.9400
PU-101	0.1616	T-501	529.1000
PU-201	1806.0000		
PU-301	1.6870		
PU-501	1.5040		
PU-601	2.6470		
Total	12555.3000	Total	3973.7400
Net power consumption = 8581.5600 kW			

Table 4.2: Power performance of LNG-LAES-RC process with pressure drop and air pretreatment section in energy release operation.

Energy release operation			
Equipment	Power consumption (kW)	Equipment	Power generation (kW)
PU-202	84.7300	T-301	1582.0000
PU-203	1052.0000	T-302	1251.0000
PU-301	1807.0000	T-303	873.4000
PU-501	4.9650	T-304	784.7000
PU-601	3.0880	T-305	92.1600
		T-401	1974.0000
		T-402	1940.0000
		T-403	1657.0000
		T-404	516.8000
		T-501	1066.0000
Total	2957.2920	Total	11737.0600
Net power generation = 8779.7680 kW			

Power performance of this process can be shown in terms of electrical round-trip efficiency that is calculated from the net power generation divided by net power consumption. This process is divided into 13 hours for on peak period and 11 hours for off-peak period so the electrical round-trip efficiency of this process is 120.91%.

4.3 Performance Comparison

Since there are several studies about LAES coupled with cold energy from LNG regasification, a comparison of the performance is occurred. In table 4.3, the electrical round-trip efficiency of this study is compared with other systems. The LNG-CES model (Lee *et al.,* 2017) is cryogenic energy storage that uses air as a medium, this is the earlier model that combined LAES with LNG regasification process. The LNG-ORC-LAES model (Lee *et al.,* 2019) was developed from LNG-CES by applying an additional indirect power generation cycle (ORC) for LNG before direct expansion. The LNG-LAES model (Qi *et al.,* 2020) was further improved by increasing Propane storage tank to recover cold energy from air discharging section. The LNG-TES-LAES model (Park *et al.,* 2020) was increasingly developed by adding liquid Propane to store cold energy from LNG during energy release period. Lastly, in this study, the LNG-LAES-RC model fully utilized cold energy from both LNG and liquid air in terms of liquid Propane and Rankine cycle, which means, this proposed process does not waste any cold energy with seawater. Furthermore, this study has applied the NG combustion to provide a heat source in Rankine cycle, which is the significant key to improving the efficiency.

However, the other models did not calculate pressure drop in the heat exchanger, moreover, the air pretreatment section was also not present. Therefore, the electrical round-trip efficiency that is used to compare with other research is based on the condition that the pressure drop in all heat exchangers is negligible and no air pretreatment section.

Another thing that needs to consider is that the LNG inlet temperature of this study is only -129.3 °C which is much higher than other research (-162 °C). However, even the cold energy of LNG in this study is noticeably less than others, the electrical round-trip efficiency is still higher. The results suggest that this proposed process has the highest electrical round-trip efficiency among other candidates. It proves that the recovery of a low-grade portion of cold energy by applied with cold box in the Rankine cycle along with the combustion of NG could generate more power and increase efficiency.

Table 4.3: Power performance comparison

	LNG inlet temperature (°C)	**Electrical round-trip efficiency (%)**
LNG-CES	-162	111.99
LNG-ORC-LAES	-162	113.84
LNG-LAES	-162	129.22
LNG-TES-LAES	-162	187.4
LNG-TES-RC-LAES (this study without pressure drop and air pretreatment)	-129.3	**196.69**

However, this study has made this process become more realistic by calculating pressure drop in all heat exchangers and presenting the air pretreatment section. By doing so, the electrical round-trip efficiency drops significantly to 120.91%. The effects of pressure drop and air pretreatment on electrical round-trip efficiency are illustrated in table 4.4. This process without pressure drop and air pretreatment has an electrical round-trip efficiency of 196.69%, then dropped to 170.07% when the pressure drop is calculated. Finally, when air pretreatment section is presented, the electrical round-trip efficiency fell again to only 120.91%, which is calculated to be 38.53% decrease. Furthermore, the details of power consumption and power generation of the process which negligible pressure drop and air pretreatment are shown in Appendix B.

The noticeable effect of the reduction of efficiency is in the additional air pretreatment section. With this section, air has to be compressed to 3 bar by the first heat exchanger, which receives a high-temperature air from ambient. Causing much more energy requirements that accounted to be 21.92% of the total power consumption. Moreover, this section also requires a considerable amount of cold energy from LNG, resulting in the reduction of this useful energy that could be applied with Rankine cycle to generate more electricity.

Table 4.4: Effects of pressure drop and air pretreatment

	Pressure drop in heat exchangers	**Air pretreatment**	**Electrical round-trip efficiency (%)**
LNG-TES-RC-LAES (no pressure drop and air pretreatment)	negligible	not presented	196.69
LNG-TES-RC-LAES (no air pretreatment)	calculated	not presented	170.07
LNG-TES-RC-LAES	calculated	presented	120.91

4.4 Material and Energy Balance

4.4.1 Material Balance

Table 4.5 and 4.6 show the overall material balance during off-peak and on peak period, respectively. Furthermore, the data for material balance in each section is illustrated in Appendix C.

Table 4.5: Overall material balance in off-peak period

Component	Inlet		Outlet	
Methane	Phase	Liquid	Phase	Gas
	Mass (kg/hr)	81826.0723	Mass (kg/hr)	80999.6290
	Mole (kmol/hr)	5100.4539	Mole (kmol/hr)	5048.9393
Propane	Phase	Liquid	Phase	Gas
	Mass (kg/hr)	5329.8496	Mass (kg/hr)	5276.0181
	Mole (kmol/hr)	120.8665	Mole (kmol/hr)	119.6457
i-Butane	Phase	Liquid	Phase	Gas
	Mass (kg/hr)	1658.7381	Mass (kg/hr)	1658.7382
	Mole (kmol/hr)	28.5379	Mole (kmol/hr)	28.5379
n-Butane	Phase	Liquid	Phase	Gas
	Mass (kg/hr)	1658.7381	Mass (kg/hr)	1658.7382
	Mole (kmol/hr)	28.5379	Mole (kmol/hr)	28.5379
Nitrogen	Phase	Mix	Phase	Mix
	Mass (kg/hr)	105706.1659	Mass (kg/hr)	45530.6472
	Mole (kmol/hr)	3775.2202	Mole (kmol/hr)	1625.3399
Ethane	Phase	Liquid	Phase	Gas
	Mass (kg/hr)	9338.5001	Mass (kg/hr)	9244.1813
	Mole (kmol/hr)	310.5597	Mole (kmol/hr)	307.4231
Argon	Phase	Gas	Phase	Mix
	Mass (kg/hr)	1779.3549	Mass (kg/hr)	761.4799
	Mole (kmol/hr)	44.5418	Mole (kmol/hr)	19.0618

Table 4.5: Overall material balance in off-peak period (cont.)

Component	Inlet		Outlet	
Oxygen	Phase	Gas	Phase	Gas
	Mass (kg/hr)	15737.5832	Mass (kg/hr)	10053.3749
	Mole (kmol/hr)	1010.2370	Mole (kmol/hr)	314.1680
Water	Phase	Mix	Phase	Liquid
	Mass (kg/hr)	18907.9289	Mass (kg/hr)	21021.2753
	Mole (kmol/hr)	1049.56	Mole (kmol/hr)	1166.8819
Carbon dioxide	Phase	Gas	Phase	Gas
	Mass (kg/hr)	36.9681	Mass (kg/hr)	2741.3700
	Mole (kmol/hr)	0.003	Mole (kmol/hr)	62.2900

Table 4.6: Overall material balance in on-peak period

Component	Inlet		Outlet	
Methane	Phase	Liquid	Phase	Gas
	Mass (kg/hr)	81826.0723	Mass (kg/hr)	80050.4466
	Mole (kmol/hr)	5100.4539	Mole (kmol/hr)	4989.7741
Propane	Phase	Liquid	Phase	Gas
	Mass (kg/hr)	5329.8496	Mass (kg/hr)	5214.1918
	Mole (kmol/hr)	120.8665	Mole (kmol/hr)	118.2437
i-Butane	Phase	Liquid	Phase	Gas
	Mass (kg/hr)	1658.7381	Mass (kg/hr)	1658.7381
	Mole (kmol/hr)	28.5379	Mole (kmol/hr)	28.5379
n-Butane	Phase	Liquid	Phase	Gas
	Mass (kg/hr)	1658.7381	Mass (kg/hr)	1658.7381
	Mole (kmol/hr)	28.5379	Mole (kmol/hr)	28.5379

Table 4.6: Overall material balance in on-peak period (cont.)

Component	Inlet		Outlet	
Nitrogen	Phase	Liquid	Phase	Gas
	Mass (kg/hr)	188.1018	Mass (kg/hr)	50809.4725
	Mole (kmol/hr)	6.7148	Mole (kmol/hr)	1813.7819
Ethane	Phase	Liquid	Phase	Gas
	Mass (kg/hr)	9338.5001	Mass (kg/hr)	9135.8547
	Mole (kmol/hr)	310.5597	Mole (kmol/hr)	303.8206
Argon	Phase	-	Phase	Gas
	Mass (kg/hr)	-	Mass (kg/hr)	860.4953
	Mole (kmol/hr)	-	Mole (kmol/hr)	21.5404
Oxygen	Phase	-	Phase	Gas
	Mass (kg/hr)	-	Mass (kg/hr)	7332.0947
	Mole (kmol/hr)	-	Mole (kmol/hr)	229.1280
Water	Phase	-	Phase	Gas
	Mass (kg/hr)	-	Mass (kg/hr)	4541.0366
	Mole (kmol/hr)	-	Mole (kmol/hr)	252.0683
Carbon dioxide	Phase	-	Phase	Gas
	Mass (kg/hr)	-	Mass (kg/hr)	810.4490
	Mole (kmol/hr)	-	Mole (kmol/hr)	132.0266

4.4.1 Energy Balance

The data are from aspen HYSYS. Table 4.7 shows energy balance in each equipment during off-peak period and table 4.8 shows energy balance during on peak period.

Table 4.7: Energy balance in equipment at off-peak period

Equipment	Code of equipment	Inlet		Outlet		Energy (kJ/hr)
		Code	Temperature (°C)	Code	Temperature (°C)	
Column	DCA-101	W-101	5.00	A-106	7.86	0
		W-104	25.00	W-102	27.75	
		A-105	30.79	W-106	27.75	
Adsorber	AD-101 AD-102	A-106	7.785	A-201	13.59	0
				A-107	-57.67	
Cold box	CB-201	A-204	-40.21	A-206	-40.21	0
		L-204	-91.89	L-205	-83.33	
		P-210	-52.40	P-211	-50.97	
Cold box	CB-202	A-206	-4.31	A-207	-89.23	0
		L-203	-98.35	L-204	-91.89	
		P-209	-74.04	P-210	-52.41	
Cold box	CB-203	P-208	-122.30	P-209	-74.04	0
		A-208	-10.04	A-209	-115.3	
Cold box	CB-204	L-202	-129.30	L-203	-98.35	0
		A-210	-65.21	A-211	-122.30	
Cold box	CB-205	A-211	81.93	A-212	-165.8	0
		A-219	-182.3	A-220	-152.6	
		P-216	-175	P-217	-127.3	

Table 4.7: Energy balance in equipment at off-peak period (cont.)

Equipment	Code of equipment	Inlet		Outlet		Energy (kJ/hr)
		Code	Temperature (°C)	Code	Temperature (°C)	
Cold box	CB-501	L-303	10.97	L-304	60.00	0
		L-305	39.33	L-306	60.00	
		C-602	247.50	C-603	147.50	
		W-501	132.10	W-502	90.00	
Compressor	K-101	A-101	33.00	A-102	180.40	3400.2600
Compressor	K-102	A-104	20.00	A-105	30.79	241.3340
Compressor	K-201	A-203	-82.54	A-204	-40.51	1067.6200
Compressor	K-202	A-205	-81.23	A-206	-4.31	1934.2740
Compressor	K-203	A-207	-89.23	A-208	-10.04	3151.0560
Compressor	K-204	A-209	-115.30	A-110	-65.21	1042.4430
Compressor	K-601	A-601	35.00	A-602	83.46	816.3015
Flash Drum	D-101	A-103	20.00	A-104	20.00	0
				W-105	20.00	
Heat exchanger	HE-101	A-102	180.4	L-101	-57.03	0
		A-103	20.00	L-102	-16.10	

Table 4.7: Energy balance in equipment at off-peak period (cont.)

Equipment	Code of equipment	Inlet		Inlet		Energy (kJ/hr)
		Code	Temperature (°C)	Code	Temperature (°C)	
Heat exchanger	HE-102	L-206	-63.46	L-101	-57.03	0
		W-102	27.75	W-103	5.00	
Heat exchanger	HE-201	L-207	-129.3	L-208	-78	0
		P-213	-35.25	P-214	-122.3	
Heat exchanger	HE-202	A-216	-180.5	A217	-140.7	0
		P-219	-127.30	P-220	-175.00	
Heat exchanger	HE-203	A-218	-83.70	A-401	-32.35	0
		P-205	-24.94	P-206	-77.56	
Heat exchanger	HE-204	A-201	13.59	A-202	-70.56	0
		P-202	-77.56	P-203	-24.88	
Heat exchanger	HE-301	L-102	-16.10	L-302	31.27	0
		W-301	110.30	W-302	90.00	
Heat exchanger	HE-302	H-602	683.5	H-603	351.7	0
		W-305	104.3	W-306	252.00	
Heat exchanger	HE-303	W-307	111.3	W-301	110.3	0
		W-304	90.07	W-305	104.30	
Heat exchanger	HE-501	W-503	90.70	W-504	278	0
		H-603	351.70	H-604	184.5	
Heat exchanger	HE-601	C-601	780.80	C-602	247.50	0
		H-601	184.20	H-602	683.50	
Pump	PU-101	W-103	5.00	W-104	5.00	1.6865
Pump	PU-201	L-205	-83.33	L-206	-63.46	1.50446
Pump	PU-202	-	-	-	-	-

Table 4.7: Energy balance in equipment at off-peak period (cont.)

Equipment	Code of equipment	Inlet		Outlet		Energy (kJ/hr)
		Code	Temperature (°C)	Code	Temperature (°C)	
Pump	PU-203	-	-	-	-	-
Pump	PU-301	W-302	90.00	W-304	90.07	1.5045
Pump	PU-501	W-502	90.00	W-503	90.07	1.5045
Pump	PU-601	H-604	184.50	H-605	184.30	2.6469
Reactor	R-601	L-301	-59.17	C-601	780.80	0
		A-602	83.46			
Separator	S-201	A-213	-182.30	A-214	-182.30	0
				A-219	-182.30	
Turbine	T-201	A-212	-165.80	A-213	-182.30	-214.5390
Turbine	T-301	W-306	252.00	W-307	111.30	-537.3707
Turbine	T-302	L-302	31.27	L-303	10.97	-919.2940
Turbine	T-303	L-304	60.00	L-305	39.33	-876.6050
Turbine	T-304	L-306	60.00	L-307	41.45	-786.9380
Turbine	T-305	L-309	41.45	L-310	-59.17	-42.9375
Turbine	T-401	-	-	-	-	-
Turbine	T-402	-	-	-	-	-

Table 4.7: Energy balance in equipment at off-peak period (cont.)

Equipment	Code of equipment	Inlet		Outlet		Energy (kJ/hr)
		Code	Temperature (°C)	Code	Temperature (°C)	
Turbine	T-403	-	-	-	-	-
Turbine	T-404	-	-	-	-	-
Turbine	T-501	W-504	278.00	W-501	132.10	529.1

Table 4.8: Energy balance in equipment at on peak period

Equipment	Code of equipment	Inlet		Outlet		Energy (kJ/hr)
		Code	Temperature (°C)	Code	Temperature (°C)	
Column	DCA-101	-	-	-	-	-
Adsorber	AD-101 AD-102	-	-	-	-	-
Cold box	CB-201	-	-	-	-	-
Cold box	CB-202	-	-	-	-	-
Cold box	CB-203	-	-	-	-	-
Cold box	CB-204	-	-	-	-	-
Cold box	CB-205	-	-	-	-	-

Table 4.8: Energy balance in equipment at on peak period (cont.)

Equipment	Code of equipment	Inlet		Outlet		Energy (kJ/hr)
		Code	Temperature (˚C)	Code	Temperature (˚C)	
Compressor	K-102	-	-	-	-	-
Cold box	CB-501	A-407	33.56	A-408	100.00	0
		A-405	11.06	A-406	105.00	
		A-403	2.13	A-404	110.00	
		A-401	-32.35	A-402	110.00	
		L-305	39.41	L-306	60.00	
		L-303	61.75	L-304	60.00	
		W-501	132.10	W-502	90.00	
		C-602	191.00	C-603	141.40	
Compressor	K-101	-	-	-	-	-
Compressor	K-102	-	-	-	-	-
Compressor	K-201	-	-	-	-	-
Compressor	K-202	-	-	-	-	-
Compressor	K-203	-	-	-	-	-
Compressor	K-204	-	-	-	-	-
Compressor	K-601	-	-	-	-	-
Flash Drum	D-101	-	-	-	-	-

Table 4.8: Energy balance in equipment at on peak period (cont.)

Equipment	Code of equipment	Inlet		Outlet		Energy (kJ/hr)
		Code	Temperature (°C)	Code	Temperature (°C)	
Heat exchanger	HE-101	-	-	-	-	-
Heat exchanger	HE-102	-	-	-	-	-
Heat exchanger	HE-201	L-207	-129.30	L-208	-78.01	0
		P-213	-35.25	P-214	-122.30	
Heat exchanger	HE-202	A-216	-180.50	A-217	-140.70	0
		P-219	-127.30	P-220	-175.00	
Heat exchanger	HE-203	A-218	-83.70	A-401	-32.35	0
		P-205	-24.94	P-206	-77.56	
Heat exchanger	HE-204	-	-	-	-	0
Heat exchanger	HE-301	W-301	110.30	W-302	90.00	0
		L-301	-56.22	L-302	87.36	
Heat exchanger	HE-302	H-602	683.5	H-603	351.7	0
		W-305	104.3	W-306	252.00	
Heat exchanger	HE-303	W-307	111.3	W-301	110.3	0
		W-304	90.07	W-305	104.30	
Heat exchanger	HE-501	W-503	90.70	W-504	278	0
		H-603	351.70	H-604	184.5	
Heat exchanger	HE-601	C-601	780.80	C-602	247.50	0
		H-601	184.20	H-602	683.50	
Pump	PU-101	-	-	-	-	-
Pump	PU-201	L-208	-78.01	L-301	-56.22	1806.7530
Pump	PU-202	A-215	-82.30	A-216	-180.50	89.0192

Table 4.8: Energy balance in equipment at on peak period (cont.)

Equipment	Code of equipment	Inlet		Outlet		Energy (kJ/hr)
		Code	Temperature (°C)	Code	Temperature (°C)	
Pump	PU-203	A-217	-140.70	A-218	-83.70	1148.5010
Pump	PU-301	W-302	90.00	W-304	90.07	4.9652
Pump	PU-501	W-502	90.00	W-503	90.07	3.0881
Pump	PU-601	H-604	184.50	H-605	184.30	5.5260
Reactor	R-601	L-301	-59.17	C-601	780.80	0
		A-602	83.46			
Separator	S-201	-	-	-	-	-
				-	-	
Turbine	T-201	-	-	-	-	-
Turbine	T-301	W-306	252.00	W-307	111.30	-537.3707
Turbine	T-302	L-302	31.27	L-303	10.97	-919.2940
Turbine	T-303	L-304	60.00	L-305	39.33	-876.6050
Turbine	T-304	L-306	60.00	L-307	41.45	-786.938
Turbine	T-305	L-309	41.45	L-310	-59.17	-42.9375

Table 4.8: Energy balance in equipment at on peak period (cont.)

Equipment	Code of equipment	Inlet		Outlet		Energy (kJ/hr)
		Code	Temperature (°C)	Code	Temperature (°C)	
Turbine	T-401	A-402	110.00	A-403	2.13	-1938.898
Turbine	T-402	A-404	110.00	A-405	11.06	-1817.154
Turbine	T-403	A-406	105.00	A-407	33.56	-1340.869
Turbine	T-404	A-408	100.00	A-409	82.88	-324.8887
Turbine	T-501	W-504	278.10	W-501	132.10	-1065.95

4.5 Preliminary Plot Plan and Top View

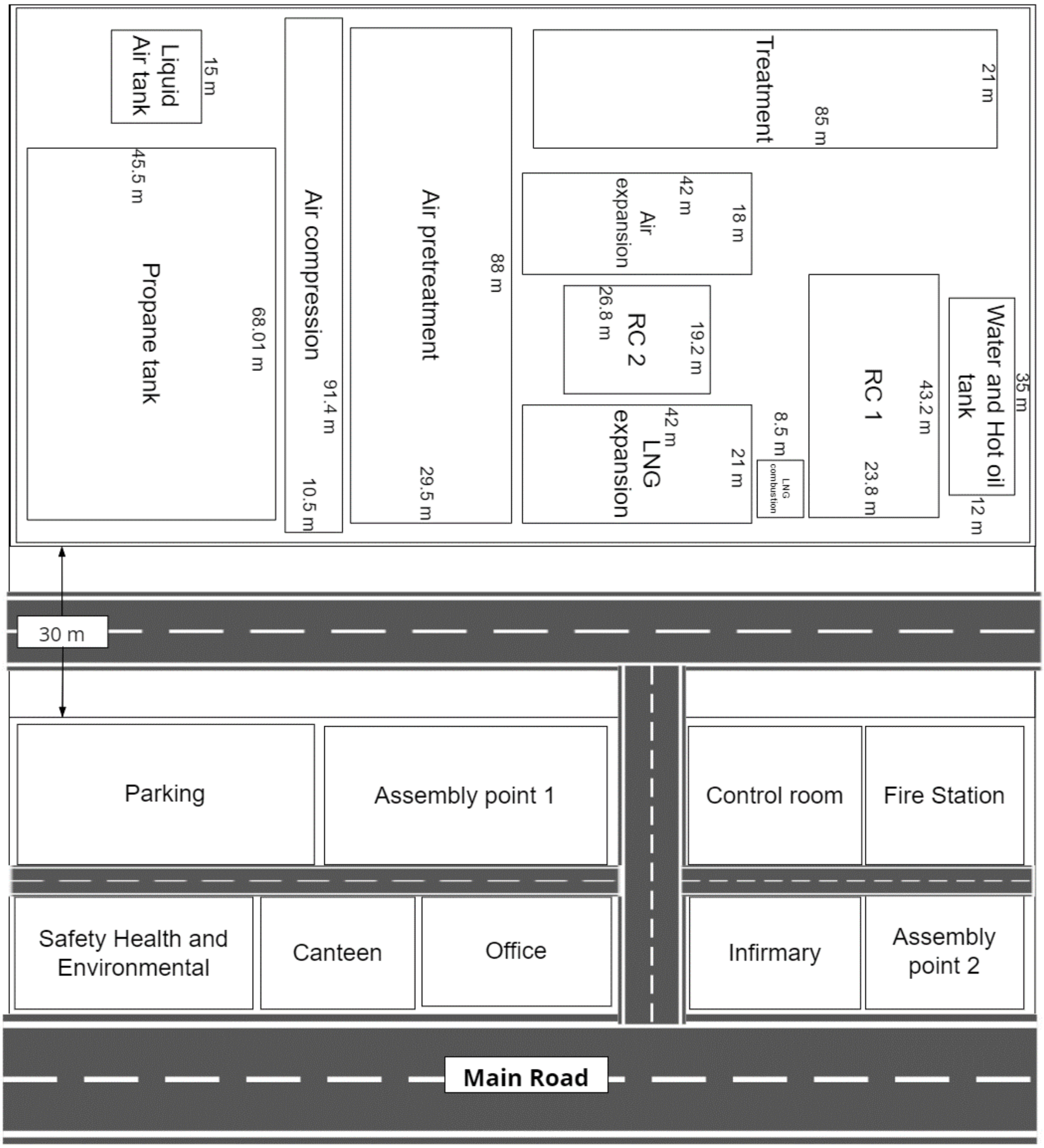


Figure 4.3. Preliminary Plot Plan

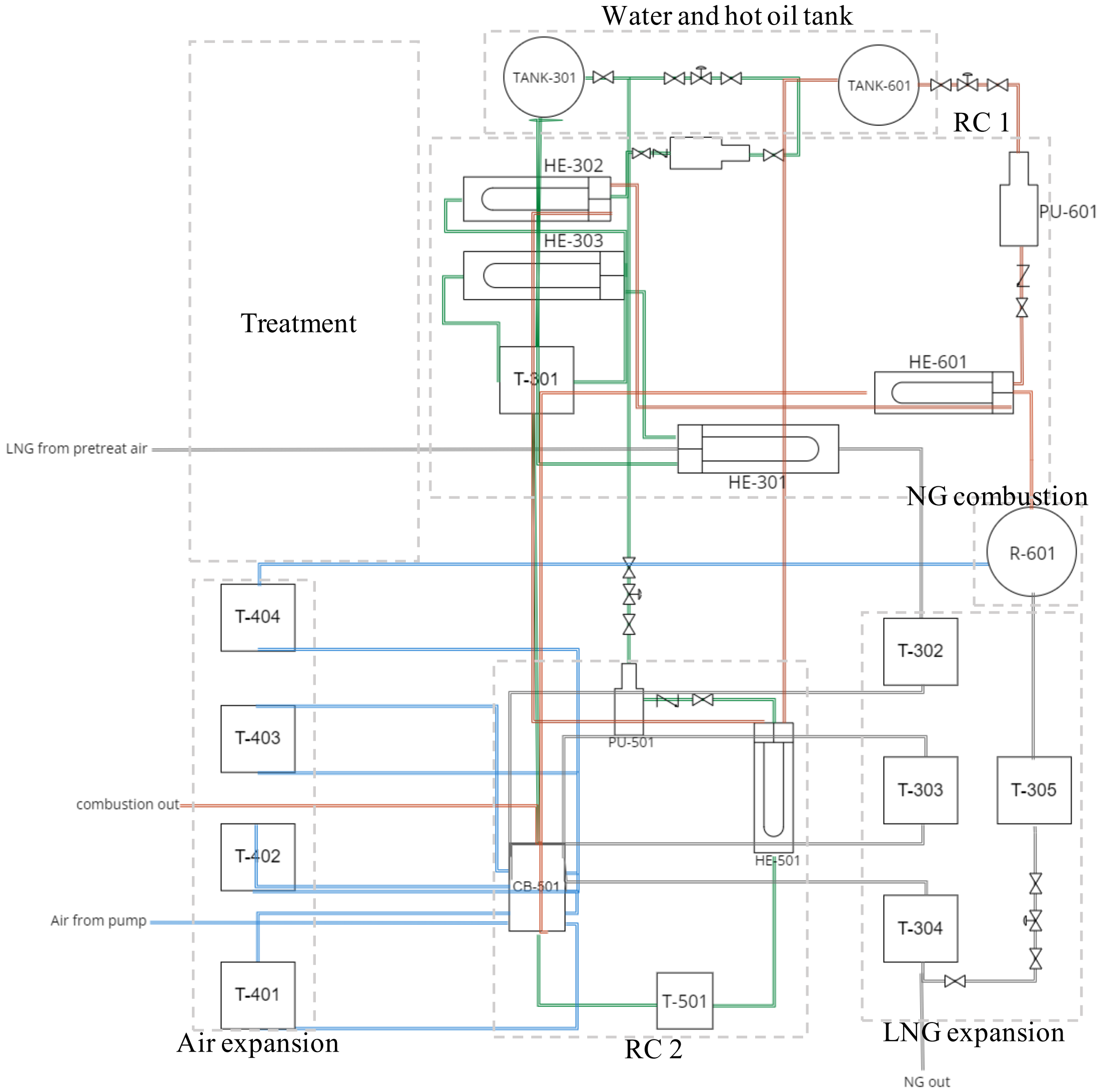


Figure 4.4. Top view A

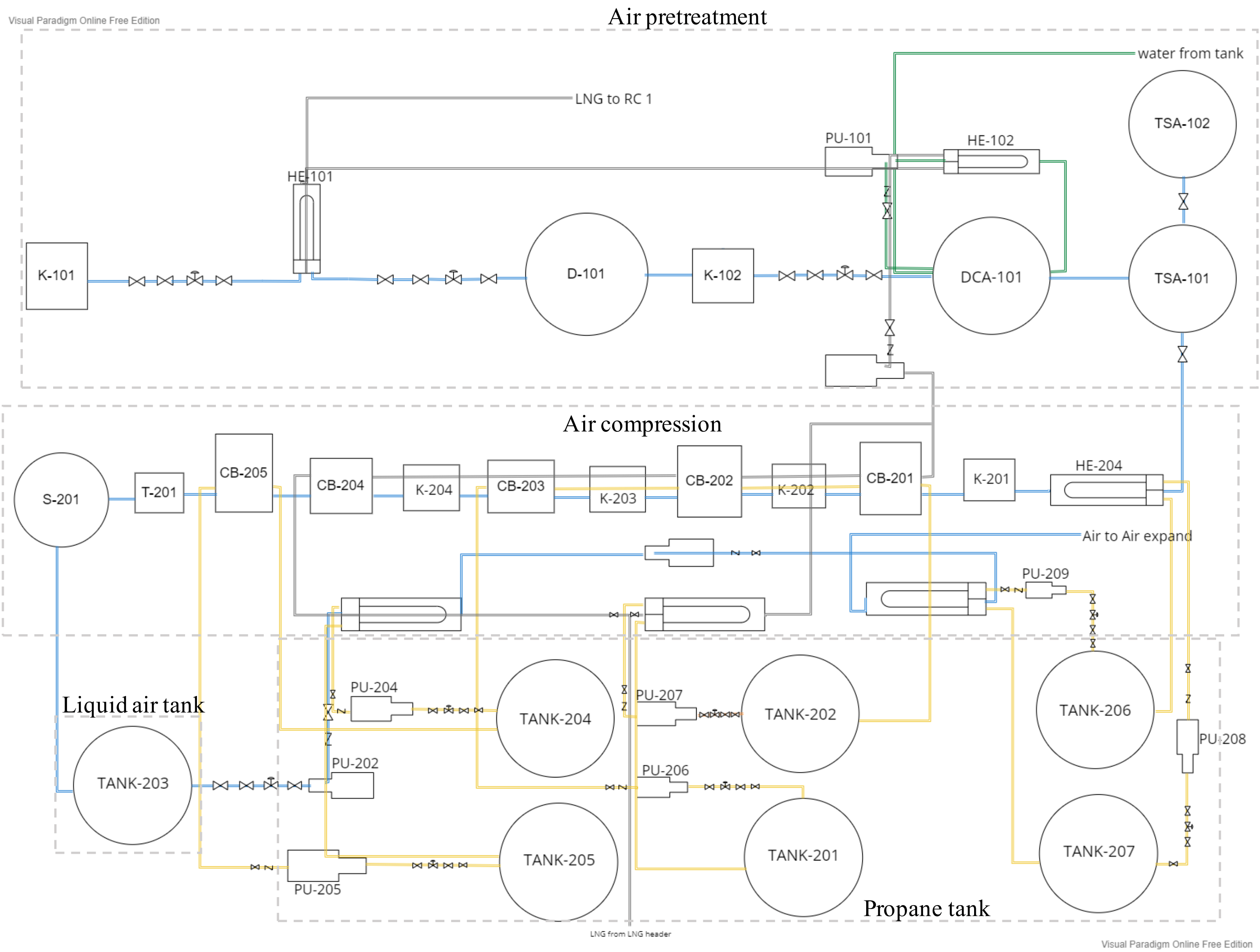


Figure 4.5. Top view B

4.6 Preliminary Piping and Instrument Diagram

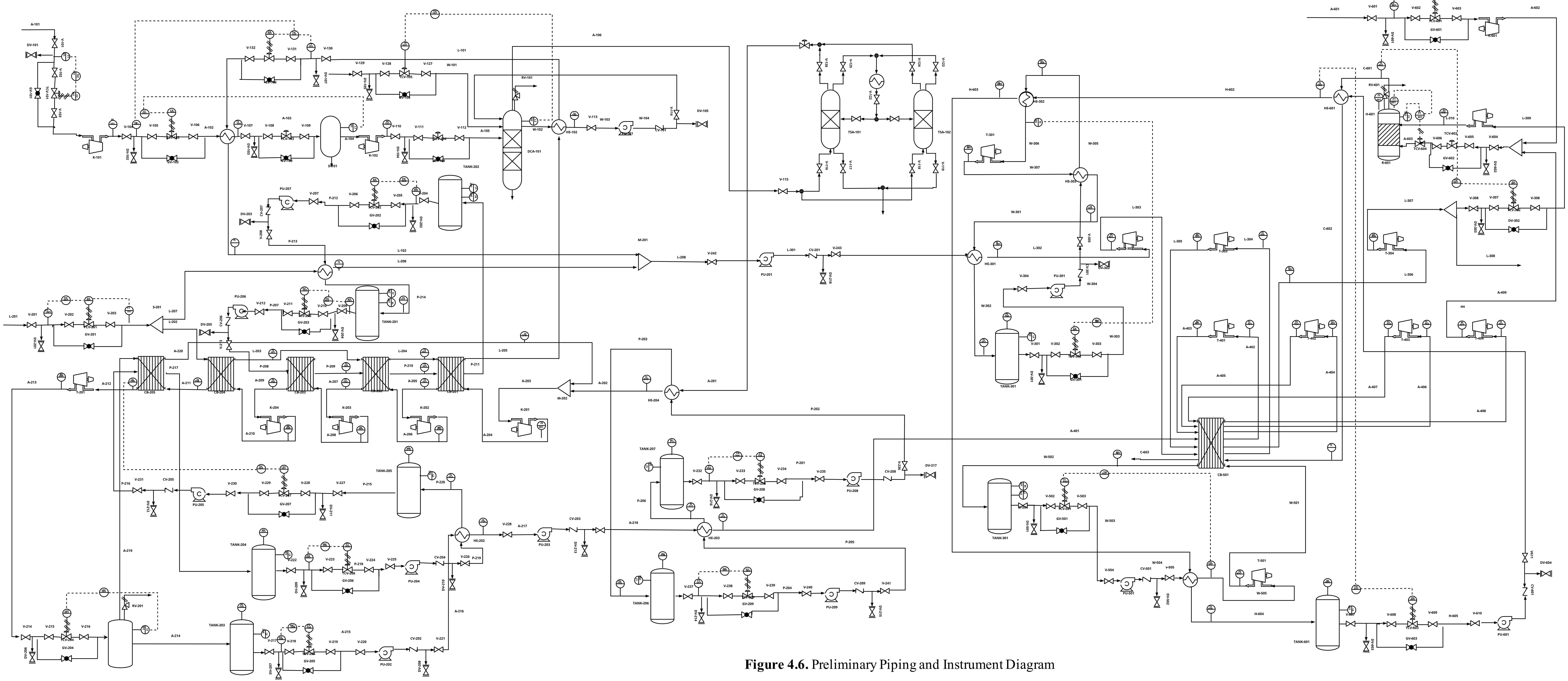


Figure 4.6. Preliminary Piping and Instrument Diagram

4.7 Preliminary Hydraulic Calculation

A hydraulic calculation is performed for the pump to provide criteria and minimum requirements for the selection of pumps. A method of hydraulic calculation are as follows: Firstly, the pressure drop in heat exchangers were calculated in Aspen EDR. Then estimating the distance and amount of valves by using preliminary plot plan and top view as shown in figure 4.3, 4.4 and 4.5, respectively. Finally, using excel to run the model. The results of a hydraulic calculation are shown in table 4.9 and the further information and assumptions are presented in the appendix D.

Table 4.9: The result of hydraulic calculation

Code of unit		**PU-101**	**PU-201**	**PU-202**	**PU-203**	**PU-204**
Psuction	[kPa]	143.5410	8,756.9970	10.4075	3,550.508	190.8001
Pdischarge	[kPa]	507.6954	32,222.100	183.4922	24,231.97	480.9482
Differential Pressure	[kPa]	364.1544	23,465.100	173.0847	20,681.46	290.1481
	[bar]	3.6415	234.6510	1.7308	206.8146	2.9015
Rated Flow	[m3/h]	24.2388	390.3478	88.8284	191.6559	180.0863
	[L/min]	403.9791	6,505.7960	1,480.474	3,194.265	3,001.439
Head	[m]	35.6315	8,326.8640	20.6915	5,334.398	43.1832
Vapor pressure	[kPa]	3.5600	110.0000	0.6133	0.613283	0.1953
NPSHa	[kPa]	139.9810	8,646.9970	9.7942	3,549.894	190.6048
Hydraulic Power	[kW]	2.4518	2,544.3190	4.2708	1,101.035	14.5144

Table 4.9: The result of hydraulic calculation (cont.)

Code of unit		PU-205	PU-206	PU-207	PU-208	PU-209
Psuction	[kPa]	185.9994	176.2695	189.1881	184.3294	288.8716
Pdischarge	[kPa]	455.6089	523.8685	385.6915	341.8637	440.2478
Differential Pressure	[kPa]	269.6095	347.5990	196.5034	157.5343	251.3762
	[bar]	2.6961	3.4760	1.9650	1.5753	2.5138
Rated Flow	[m3/h]	199.1643	214.3928	210.6179	106.1947	99.3542
	[L/min]	3,319.406	3,573.2130	3,510.299	1,769.912	1,655.903
Head	[m]	37.5501	52.1138	34.2042	25.3474	44.7209
Vapor pressure	[kPa]	0	0.3515	136.0000	15.7100	203.7000
NPSHa	[kPa]	185.9994	175.9180	53.1881	168.6194	85.1716
Hydraulic Power	[kW]	14.91572	20.7008	11.4964	4.6470	6.9376

Table 4.9: The result of hydraulic calculation (cont.)

Code of unit		PU-301	PU-501	PU-601
Psuction	[kPa]	90.8759	95.4174	170.6937
Pdischarge	[kPa]	543.5218	965.7124	691.6592
DifferentialPressure	[kPa]	452.6460	870.2950	520.9655
	[bar]	4.5265	8.7030	5.2097
Rated Flow	[m3/h]	25.0784	16.1021	88.6873
	[L/min]	417.9739	268.3675	1,478.122
Head	[m]	47.3380	90.9970	52.5035
Vapor pressure	[kPa]	70.1009	70.1009	0
NPSHa	[kPa]	20.7750	25.3165	170.6937
Hydraulic Power	[kW]	3.1532	3.8926	12.8342

4.8 Utility Requirements

This process requires electricity, Propane, hot oil and water as utilities. The quantity used and cost of each utility are shown in table 4.10.

Table 4.10: Utility Requirements

Utilities	Unit	Quantity	Cost/Unit
Electricity	kW	Shown in the table 4.1 and 4.2	Shown in the table 4.1 and 4.2
Propane	kg/hr	3,520,010	25 baht/kg
Hot oil	kg/hr	80,000	24.75 baht/liters
Water	m^3/hr	54	60 baht/ m^3

4.9 Equipment and Control Valve Data Sheets

The data and sizing of each equipment is demonstrated in table 4.11 to 4.18. The data for DCA column is shown in table 4.11, compressors in 4.12, flash drum in 4.13, heat exchangers in 4.14, pumps in 4.15, turbines in 4.16, reactor in 4.17, separator in 4.18 and storage tanks in 4.19 and 4.20.

Table 4.11: Data and sizing of DCA

Column	
Code of unit	**DCA-101**
Diameter Bottom section [m]	2.5908
Bottom tangent to tangent height [m]	9.7536
Design gauge pressure Bottom [kPag]	662.0794
Design temperature Bottom [C]	121.1111
Operating temperature Bottom [C]	31.89884
Number of trays Bottom section	10
Bottom Tray spacing [m]	0.6096

Table 4.12: Data and sizing of compressor

Compressor				
Code of unit	K-101	K-102	K-201	K-202
Actual gas flow rate Inlet [m3/h]	77,283.3428	24,549.9149	18,989.7965	11,594.2121
Design gauge pressure Inlet [kPag]	-0.0289	200.5711	191.2861	378.2981
Design gauge pressure Outlet [kPag]	202.5711	230.7611	427.3861	1,208.2981
Driver power [kW]	3,401.4230	241.4163	1,067.9848	1,934.9339
Molecular weight	28.7696	28.8768	28.8790	28.8790
Specific heat ratio	1.3970	1.3971	1.4052	1.3996
Compressibility factor Inlet	0.9993	0.9979	0.9899	0.9839
Compressibility factor Outlet	1.0005	0.9981	0.9911	0.9884
Driver type	MOTOR	MOTOR	MOTOR	MOTOR

Table 4.12: Data and sizing of compressors (cont.)

Compressor			
Code of unit	**K-203**	**K-204**	**K-601**
Actual gas flow rate Inlet [ACT_m3/h]	4,090.4379	997.4571	57,573.6594
Design gauge pressure Inlet [kPag]	1,158.9471	3,488.5301	-0.0289
Design gauge pressure Outlet [kPag]	3,538.2981	8,140.5301	48.6711
Driver power [kW]	1,922.7012	1,042.7986	816.5801
Molecular weight	28.8790	28.8790	28.9585
Specific heat ratio	1.3736	1.2409	1.3984
Compressibility factor Inlet	0.9517	0.7703	0.9995
Compressibility factor Outlet	0.9684	0.8419	0.9998
Driver type	MOTOR	MOTOR	MOTOR

Table 4.13: Data and sizing of flash drum

Flash drum	
Code of unit	**D-101**
Liquid volume [m3]	19.2822
Vessel diameter [m]	2.5908
Vessel tangent to tangent height [m]	3.6576
Design gauge pressure [kPag]	243.4211

Table 4.14: Data and sizing of heat exchangers

Heat exchanger				
Code of unit	**HE-101**	**HE-102**	**HE-201**	**HE-202**
Number of identical items	1	1	1	1
Heat transfer area [m2]	42.6607	11.1226	523.4927	369.2658
Front end TEMA symbol	B	B	B	B
Shell TEMA symbol	E	E	F	F
Rear end TEMA symbol	M	M	M	M
Tube design gauge pressure [kPag]	17,398.6207	17,398.6207	9,507.5361	2,679.8644
Tube design temperature [C]	208.2082	121.1111	-63.0278	-155.0778
Tube operating temperature [C]	180.4304	27.7535	-78.0064	-127.3000
Tube outside diameter [m]	0.0254	0.0254	0.0254	0.0254
Shell design gauge pressure [kPag]	26,148.5955	26,148.5955	6,304.5811	4,070.4611
Shell design temperature [C]	-43.8779	-84.8120	-63.0278	-168.4433
Shell operating temperature [C]	-16.1001	-57.0343	-35.2500	-140.67
Tube length extended [m]	6.0960	6.0960	6.0960	6.0960
Tube pitch [m]	0.0318	0.0318	0.0318	0.0318
Number of tube passes	1	1	2	2
Number of shell passes	1	1	2	2

Table 4.14: Data and sizing of heat exchangers (cont.)

Heat exchanger				
Code of unit	**HE-203**	**HE-204**	**HE-301**	**HE-302**
Number of identical items	1	1	1	1
Heat transfer area [m2]	751.9473	1005.4996	470.0129	82.0830
Front end TEMA symbol	B	B	B	B
Shell TEMA symbol	F	F	E	E
Rear end TEMA symbol	M	M	M	M
Tube design gauge pressure [kPag]	21027.6184	680.2544	26,150.0676	781.3401
Tube design temperature [C]	-52.7178	21.1111	138.0800	724.9455
Tube operating temperature [C]	-32.3489	13.5857	87.3579	252.0000
Tube outside diameter [m]	0.0254	0.0254	0.0254	0.0254
Shell design gauge pressure [kPag]	13984.6360	1,071.0461	17,399.6021	487.1171
Shell design temperature [C]	-52.7178	-52.6567	138.0800	724.9455
Shell operating temperature [C]	-24.9400	-24.8790	110.3022	697.1677
Tube length extended [m]	6.0960	6.0960	6.0960	6.0960
Tube pitch [m]	0.0318	0.0318	0.0318	0.0318
Number of tube passes	2	2	1	1
Number of shell passes	2	2	1	1

Table 4.14: Data and sizing of heat exchangers (cont.)

Heat exchanger			
Code of unit	**HE-303**	**HE-501**	**HE-601**
Number of identical items	1	1	1
Heat transfer area [m2]	47.1704	184.7027	1083.9918
Front end TEMA symbol	B	B	B
Shell TEMA symbol	F	F	F
Rear end TEMA symbol	M	M	M
Tube design gauge pressure [kPag]	492.7964	771.0001	532.9401
Tube design temperature [C]	139.0966	390.0384	1,328.9735
Tube operating temperature [C]	111.3189	278.1000	1,301.1957
Tube outside diameter [m]	0.0254	0.0254	0.0254
Shell design gauge pressure [kPag]	789.8591	480.2237	571.0461
Shell design temperature [C]	132.0966	390.0384	724.9455
Shell operating temperature [C]	104.3189	362.2606	697.1677
Tube length extended [m]	6.0960	6.0960	6.0960
Tube pitch [m]	0.0318	0.0318	0.0318
Number of tube passes	2	2	2
Number of shell passes	2	2	2

Table 4.15: Data and sizing of pumps

Pump				
Code of unit	**P-101**	**PU-201**	**PU-202**	**PU-301**
Liquid flow rate [m3/h]	24.2140	338.1290	90.5789	8.5119
Fluid head [m]	1.9786	4,981.6177	437.0658	62.7994
Fluid specific gravity	1.0222	0.3251	0.8177	0.9562
Design gauge pressure [kPag]	420.9521	26,150.0676	4,070.4611	789.8591
Design temperature [C]	21.1111	-	-	121.1111
Fluid viscosity [cP]	1.5010	0.0370	0.1240	0.3110
Pump efficiency [%]	75	75	75	75

Table 4.15: Data and sizing of pumps (cont.)

Pump			
Code of unit	**PU-203**	**PU-501**	**PU-601**
Liquid flow rate [m3/h]	209.1096	16.0926	57.6754
Fluid head [m]	4,699.0871	60.8183	18.2452
Fluid specific gravity	0.3542	0.9562	0.7623
Design gauge pressure [kPag]	21,027.6184	771.0001	571.0881
Design temperature [C]	-	121.1111	212.0765
Fluid viscosity [cP]	0.0330	0.3110	2.0020
Pump efficiency [%]	75	75	75

Table 4.16: Data and sizing of turbines

Turbine				
Code of unit	**T-201**	**T-301**	**T-302**	**T-303**
Actual gas flow rate Inlet [m3/h]		8,101.8419	668.8775	834.1355
Design gauge pressure Inlet [kPag]	8,085.7111	598.6711	24,771.9191	16,859.8381
Design temperature Inlet [C]		252.0000	87.3579	60.0000
Design gauge pressure Outlet [kPag]	225.7111	48.6711	16,900.0011	12,400.0011
Power output [kW]	214.6123	1,582.5362	1,251.3477	873.6744
Molecular weight	28.8790	18.0151	17.8710	17.8710
Specific heat ratio	1.1685	1.2948	1.1714	1.1715
Compressibility factor Inlet	0.3094	0.9765	0.9024	0.8304
Isentropic efficiency [%]	75	85	85	85

Table 4.16: Data and sizing of turbines (cont.)

Turbine				
Code of unit	**T-304**	**T-305**	**T-401**	**T-402**
Actual gas flow rate Inlet [m3/h]	1,149.0346	30.2050	426.9048	1,568.4814
Design gauge pressure Inlet [kPag]	12,362.5121	9,450.0011	19,987.3061	5,118.0141
Design temperature Inlet [C]	60.0000	41.5046	110.0000	110.0000
Design gauge pressure Outlet [kPag]	9,450.0011	1,400.0011	5,155.5631	1,405.9631
Power output [kW]	784.9933	92.1964	1,939.5597	1,817.7744
Molecular weight	17.8710	17.8710	28.9586	28.9586
Specific heat ratio	1.1839	1.1900	1.3225	1.3650
Compressibility factor Inlet	0.8406	0.8262	1.0525	1.0047
Isentropic efficiency [%]	85	85	85	85

Table 4.16: Data and sizing of turbines (cont.)

Turbine			
Code of unit	**T-403**	**T-404**	**T-501**
Actual gas flow rate Inlet [ACT_m3/h]	5,500.1191	14,121.7924	5,480.3442
Design gauge pressure Inlet [kPag]	1,361.1891	460.5651	598.6711
Design temperature Inlet [C]	105.0000	100.0000	278.1000
Design gauge pressure Outlet [kPag]	505.9631	360.5651	48.6711
Power output [kW]	1,341.3261	324.9996	1,066.3135
Molecular weight	28.9586	28.9586	18.0151
Specific heat ratio	1.3830	1.3884	1.2925
Compressibility factor Inlet	1.0002	0.9999	0.9799
Isentropic efficiency [%]	85	85	85

Table 4.17: Data and sizing of reactor

Reactor	
Code of unit	**R-601**
Liquid volume [m3]	0.03058
Vessel diameter [m]	0.1524
Vessel tangent to tangent height [m]	1.6764
Design temperature [C]	808.5979

Table 4.18: Data and sizing of separator

Separator	
Code of unit	**S-201**
Liquid volume [m3]	14.8119
Vessel diameter [m]	1.8288
Vessel tangent to tangent height [m]	5.6388
Design gauge pressure [kPag]	243.4211

Table 4.19: Data and sizing of cryogenic tank

Cryogenic tank				
Code of unit	**TANK-201**	**TANK-202**	**TANK-203**	**TANK-204**
Liquid volume [m3]	28.77315	28.77315	14.81192	28.14765
Vessel diameter [m]	2.286	2.286	1.8288	2.286
Vessel tangent to tangent height [m]	7.0104	7.0104	5.6388	6.858
Design gauge pressure [kPag]	1006.238	1006.238	243.4211	1023.429
Operating temperature [C]	-50.9738	-50.9738	-182.332	-127.3

Table 4.19: Data and sizing of cryogenic tank (cont.)

Cryogenic tank			
Code of unit	**TANK-205**	**TANK-206**	**TANK-207**
Liquid volume [m3]	28.14765	17.85326	17.85326
Vessel diameter [m]	2.286	1.9812	1.9812
Vessel tangent to tangent height [m]	6.858	5.7912	5.7912
Design gauge pressure [kPag]	1023.429	1066.204	1066.204
Operating temperature [C]	-127.3	-24.8484	-24.8484

Table 4.20: Data and sizing of **t**ank

Storage Tank	
Code of unit	**TANK-301**
Liquid volume [m3]	2.401933
Vessel diameter [m]	0.9144
Vessel tangent to tangent height [m]	3.6576
Design gauge pressure [kPag]	771.0461
Design temperature [C]	305.7778
Operating temperature [C]	278

Table 4.20: Data and sizing of tank (cont.)

Storage Tank	
Code of unit	**TANK-601**
Volume units	GALLONS
Vessel diameter [m]	15.5448
Vessel height [m]	7.0104
Design gauge pressure [kPag]	571.0881
Design temperature [C]	212.0765

4.9 Equipment List

Unit operation and the amount of each unit is listed in table 4.21.

Table 4.21: Equipment list

No.	Unit Operation	Code of unit	Amount
1	Column	DCA-101	1
2	Adsorber	TSA-101	1
3		TSA-102	1
4	Cold box	CB-201	1
5		CB-202	1
6		CB-203	1
7		CB-204	1
8		CB-205	1
9		CB-501	1
10	Compressor	K-101	1
11		K-102	1
12		K-201	1

Table 4.21: Equipment list (cont.)

No.	Unit Operation	Code of unit	Amount
13	Compressor	K-202	1
14		K-203	1
15		K-204	1
16		K-601	1
17	Flash drum	D-101	1
18	Heat exchanger	HE-101	1
19		HE-102	1
20		HE-201	1
21		HE-202	1
22		HE-203	1
23		HE-204	1
24		HE-301	1
25		HE-302	1
26		HE-303	1
27		HE-501	1
28		HE-601	1
29	Pump	PU-101	1
30		PU-201	1
31		PU-202	1
32		PU-203	1
33		PU-301	1
34		PU-501	1
35		PU-601	1
36	Reactor	R-601	1
37	Separator	S-201	1

Table 4.21: Equipment list (cont.)

No.	Unit Operation	Code of unit	Amount
38	Turbine	T-201	1
39		T-301	1
40		T-302	1
41		T-303	1
42		T-304	1
43		T-305	1
44		T-401	1
45		T-402	1
46		T-403	1
47		T-404	1
48		T-501	1
49	Storage tank	TANK-201	1
50		TANK-202	1
51		TANK-203	1
52		TANK-204	1
53		TANK-205	1
54		TANK-206	1
55		TANK-207	1
56		TANK-301	1
57		TANK-601	1

4.11 Equipment Specification Sheets

The specification sheet of each equipment is attached in Appendix E. Specification sheets for heat exchangers are from Aspen EDR, while the others from Aspen HYSYS.

4.12 Equipment Cost Summary

The price of each piece of equipment is demonstrated in table 4.22. All cost is based on the data from Aspen HYSYS, except for cold box which is assumed to be linear with capacity. Furthermore, the graph for the price of cold box is from (TIChE, 2021).

Table 4.22: Equipment cost summary

No.	Unit Operation	Code of unit	Amount	Price (Baht)
1	Column	DCA-101	1	4,847,700
2	Adsorber	TSA-101	1	1,036,200
3		TSA-102	1	1,036,200
4	Cold box	CB-201	1	54,416,546
5		CB-202	1	54,416,546
6		CB-203	1	42,041,546
7		CB-204	1	38,329,046
8		CB-205	1	43,702,395
9		CB-501	1	151,333,215
10	Compressor	K-101	1	183,414,000
11		K-102	1	48,849,900
12		K-201	1	52,380,900
13		K-202	1	45,021,900
14		K-203	1	42,916,500
15		K-204	1	43,758,000
16		K-601	1	99,986,700
17	Flash drum	D-101	1	1,184,700
18	Heat exchanger	HE-101	1	2,828,100
19		HE-102	1	1,046,100
20		HE-201	1	6,735,300

Table 4.22: Equipment cost summary (cont.)

No.	Unit Operation	Code of unit	Amount	Price (Baht)
21	Heat exchanger	HE-202	1	3,448,500
22		HE-203	1	21,753,600
23		HE-204	1	5,524,200
24		HE-301	1	18,955,200
25		HE-302	1	1,712,700
26		HE-303	1	554,400
27		HE-501	1	1,432,200
28		HE-601	1	28,495,500
29	Pump	PU-101	1	178,200
30		PU-201	1	160,647,300
31		PU-202	1	2,524,500
32		PU-203	1	137,817,900
33		PU-301	1	207,900
34		PU-501	1	188,100
35		PU-601	1	8,038,800
36	Reactor	R-601	1	501,600
37	Separator	S-201	1	1,023,000
38	Turbine	T-201	1	1,768,800
39		T-301	1	38,715,600
40		T-302	1	33,613,800
41		T-303	1	27,139,200
42		T-304	1	25,390,200
43		T-305	1	4,059,000
44		T-401	1	14,612,400
45		T-402	1	13,470,600

Table 4.22: Equipment cost summary (cont.)

No.	Unit Operation	Code of unit	Amount	Price (Baht)
46		T-403	1	20,733,900
47	Turbine	T-404	1	7,167,600
48		T-501	1	17,061,000
49	Storage tank	TANK-201	1	1,767,150
50		TANK-202	1	1,767,150
51		TANK-203	1	1,874,400
52		TANK-204	1	1,752,300
53		TANK-205	1	1,752,300
54		TANK-206	1	1,305,150
55		TANK-207	1	1,305,150
56		TANK-301	1	541,200
57		TANK-601	1	1,174,800
Total Equipment Cost				1,529,256,795

4.13 Economic Analysis (NPV, payback period, IRR)

From the performance data in table 4.1 and 4.2, the net power income per day is calculated and presented in table 4.24 by using the Time of Use Tariff in table 4.23. The net power income per day is calculated to be 155,410.39 baht and this number is then used to analyze the economics of this process as shown in table 4.25. Furthermore, the assumptions and details of this economic analysis are illustrated in Appendix F.

Table 4.23 Time of Use Tariff (ERC, 2012)

Time of use	Tariff (baht/unit)
Off peak	2.2092
On Peak	3.8254

Table 4.24: Income consumption of the LNG-LAES-RC process

Income consumption			
Energy storage operation			
Net power consumption	**Time** (ERC, 2012)	**NG used in combustion (baht/day)**	**Expenses (baht/day)**
8,581.56 kW	22.00 - 09.00 (11 h)	13,748.54229	208,542.1962
Energy release operation			
Net power generation	**Time** (ERC, 2012)	**NG used in combustion (baht/day)**	**Income (baht/day)**
8,779.77 kW	09.00 - 22.00 (13 h)	34,918.49264	436,619.6186
Cost of LNG cold energy = 24,000 baht/day			
Net Income = 155,410.39 baht/day			

Table 4.25: Economic analysis

S_j (total income)	56.72 million baht/year
d_j (Depreciation)	300.97 million baht/year
Φ (tax rate)	0.2
TPC (Total Product Cost)	1.61 billion baht/year
A_j (net cash flow)	-9.45 million baht/year
Discount rate	0.1
NPV	-17.43 billion baht
IRR	-
Payback period	-

The NPV of this process is -17.43 billion baht, while the IRR and payback period were not able to calculate due to the negative net cash flow. From the data, it could be inferred that this proposed process tends to suffer a loss in continuing operations, which the total economy could suffer around 17 billion baht in losses for a lifetime of 25 years.

This process might losses due to several possible reasons. Firstly, the electricity price is cheap, which may not be worth investing, compared with the process that has existing products. Air separation plants, for instance, could sell products in high-priced, which leads to an NPV of up to 2.24 billion baht (Kim et al., 2006). Even this process has adjusted the period of consuming and selling electricity to matched with the low-priced and high-priced time, the earnings are still low, which could be because there is too little difference between the tariff in the off-peak and on-peak period. Second, the price of equipment could be another reason, because there is too much purchased equipment in this process, resulting in high total capital investment that inverse with the proceeds from selling electricity. Besides, it could be because the cost of each piece of equipment that took from Aspen HYSYS is overpriced. Finding other references would decrease the discrepancy and may reduce the total capital investment. Lastly, it might be because the integration with LAES really requires a high-grade portion of cold energy, which this study lack. The existence of this cold energy is one of the reasons that other researches could achieve a positive NPV as shown in table 4.26.

Table 4.26: Economic evaluation results compared with other researches

	Pressure drop in heat exchangers	**Air pretreatment**	**NPV (billion baht)**
LNG-ORC-LAES (Lee *et al.,* 2019)	negligible	not presented	1.05
LNG-LAES (Qi *et al.,* 2020)	negligible	not presented	1.49
LNG-LAES-RC (this study)	calculated	presented	-17.43

Another reason that this study achieved negative NPV while the others are positive, is that this process is based on the realistic which pressure drop has been calculated and the air pretreatment section is concerned. The presenting of air pretreatment section caused a dramatic drop in both efficiency and economic terms as the equipment cost in this section is around 244 million baht, which accounted to be 15.98% of the total purchased equipment. Moreover, this section consumed a significant amount of power and cold energy which considerably reduce the overall power income.

4.14 Safety, Health, and Environmental Considerations

The factory is separated into 2 zones that are buildings and the industrial plant of LNG-LAES-RC process. The building zone is between the industrial plant and the main road as it is the first barrier for safety. The building zone consists of parking, office, control room, canteen including fire station and assembly point for accident emergency.

The Industrial plant LNG-LAES-RC process is legally designed for safety according to the plant layout spacing standards (Naseer, 2020), the distance between the control buildings and the industrial plant is 30 meters, which meets the safety spacing requirement. Similarly, in the Industrial part, the distance between equipment is also following plant layout spacing standards such as the spacing of turbine between other equipment is 7 meters. In addition, Emergency showers and sprinklers are located as near the hazard place. In part of the wastewater and the polluted air is treated at the treatment section before releasing to the environment.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The proposed LNG-LAES-RC process is designed to be an effective option for LNG cold energy utilization. The conceptual design of this process is to minimize the power consumption while maximizing the power generation and fully utilize the cold energy from both LNG and liquid air by using liquid Propane as intermediate thermal storage, Rankine cycle and NG combustion. LNG can be continuously regasified while LAES operates as peak-off peak hours to match with the electricity market scenario. The result of this process is shown in terms of electrical round-trip efficiency, 120.91% with the calculated pressure drop and presenting of air pretreatment section. However, even this process has less amount of cold energy, which the LNG inlet temperature is only -129.3 °C compared to -162 °C of others, this process still achieved the highest electrical round-trip efficiency in the same assumption that negligible pressure drop and no air pretreatment section, which was reaching 196.96%. In economic terms, the NPV of this process is –17.43 billion baht with no IRR and payback period so this process tends to suffer a loss due to the lack of high-grade portion of cold energy, the low price of electricity, the high price of purchased equipment and the existing of air pretreatment section.

Even this process obtains the lowest NPV and gets losses, the electrical round-trip efficiency is the highest. It proved that the concept which fully utilizes the cold energy along with the combustion of NG could be applied and helpful with the combination of LNG cold energy and LAES process or other integrations.

5.2 Recommendations

This process is not worth investing. The LNG cold energy utilization process might be worth it when combined with other existing processes, not constructing the new one. For example, integrating the LNG cold energy utilization with the neighboring Ethylene plant, which the efficiency of LNG cold energy utilization facilities is higher than Air Separation and displayed to be the highest (Fujiwara *et al.,* 2011). Therefore, finding and combining with the neighboring Chemical plant that normally has demand in cold energy might be a better idea.

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[redacted]

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APPENDIX A

Evaluation of options

A.1 24-hours plant and peak-off peak operation

The integration of liquid air energy storage and cold energy utilization from LNG regasification is being chosen to improve the performance of power generation. This combination is a new novel concept that uses electricity and cold energy to cool down air until it liquefies and stores liquid air in the tank. When power is required, liquid air releases stored energy by air expansion, then power is generated. Due to this, LAES normally operates as off-peak and on-peak hours. However, to ensure that operating as off-peak and on-peak times has higher efficiency than 24-hour plant, both options are evaluated by simulation in Aspen plus as shown in figure A.1, A.2 and A.3. Since the use of cold energy in the LNG direction expansion section in 24-hour and peak-off peak process are similar, it is assumed to be equal. So, only air storage and release sections are concerned.

Operating 24 hours

In 24-hour operation, power performance data is shown in table A.1. Net power consumption for energy storage section is 8,655.202 kW. Net power generation for energy release section is 10,862.19 kW, resulting in a net power generation of 2,206.988 kW.

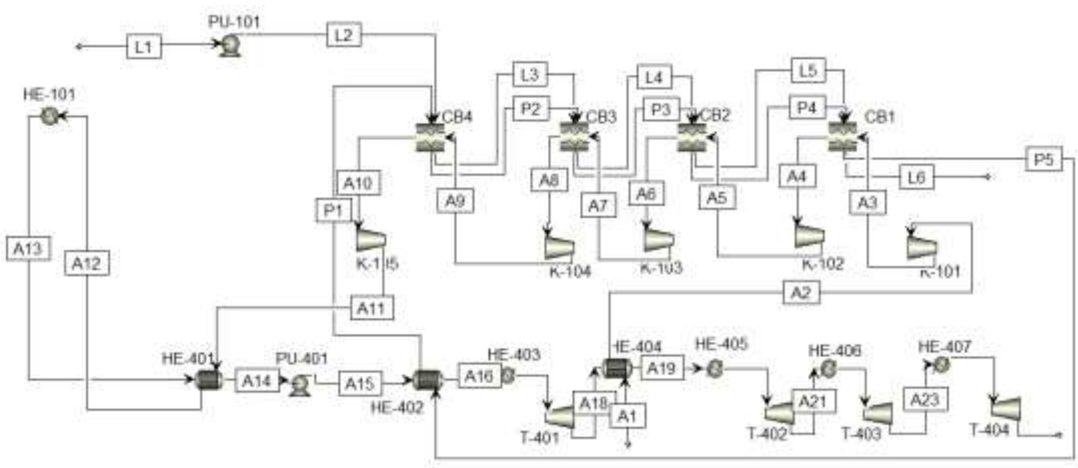


Figure A.1. 24-hour process

Table A.1: Power performance of the 24-hour process

Equipment	Power consumption (kW)	Equipment	Power generation (kW)
K-101	1,510.96	T-401	2,726.68
K-102	1187.21	T-402	2,796.76
K-103	2054.51	T-403	2,687.94
K-104	1279.14	T-404	2,650.81
K-105	344.222		
PU-101	1,185.04		
PU-401	1,094.12		
Total	8,655.202	Total	10,862.19
Net power generation = 2,206.988 kW			

Operating as off-peak and on-peak hours

In a simple process design, it is assumed to be 12 hours for both off-peak and on-peak periods. During off-peak times, cold energy is used to liquefy air for energy storage. During on-peak times, when the electricity demand is high, liquid air is released to generate power. Table A.2 presents the power performance data of a simple off-peak and on-peak operation. Net power consumption during energy storage operation is 6,185.171 kW. Net power generation during energy release operation is 9,728.16 kW.

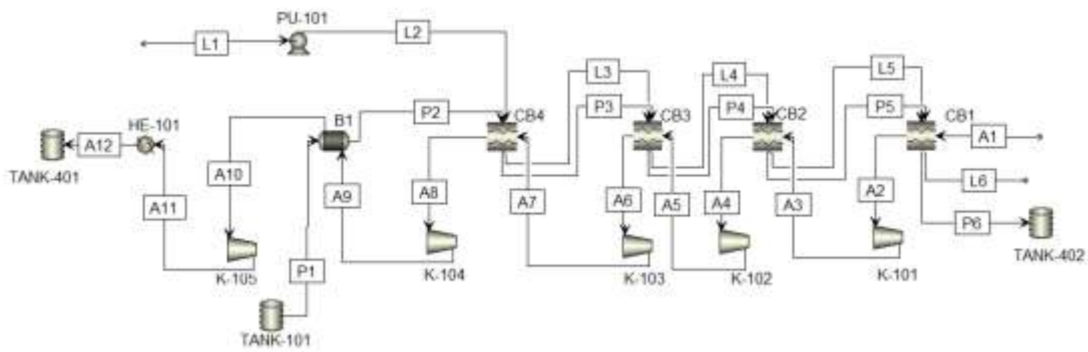


Figure A.2. Simple off-peak process

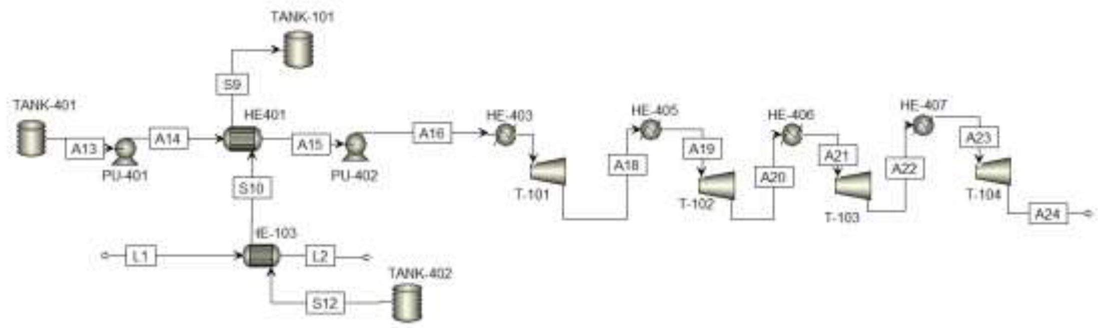


Figure A.3. Simple on-peak process

Table A.2: Power performance of the simple off-peak and on-peak process

Energy storage operation			
Equipment	**Power consumption (kW)**	**Equipment**	**Power generation (kW)**
K-101	1,267.42		
K-102	1,183.83		
K-103	936.482		
K-104	751.897		
K-105	860.502		
PU-101	1185.04		
Total	6,185.171	Total	0
Net power consumption = 6,185.171 kW			
Energy release operation			
Equipment	**Power consumption (kW)**	**Equipment**	**Power generation (kW)**
PU-401	96.867	T-401	2,840.29
PU-402	1,428.89	T-402	2,913.3
		T-403	2,739.07
		T-404	2,761.26
Total	1,525.757	Total	11,253.92
Net power generation = 9,728.163 kW			

From power performance data above, economic is calculated and shown in Table A.4 by using time of use tariff in Table 4.7 and assumed to be 12 hours for on-peak period. In full-time operation, net power income for off-peak and on-peak period are 57,130.97 and 95,294.21 baht/day, respectively. Resulting in 152,425.18 baht/day for total power income. In peak-off peak operation, net power expenses during off-peak hours is 160,111.82 baht/day and net power income during on-peak hours is 420,046.557 baht. Resulting in a total power income of 259,934.746 baht/day.

According to the data, it can be concluded that in a simple process design, peak-off peak operation tends to achieve greater efficiency in both energy and economic terms. Moreover, operating as peak-off peak times has a surplus cold energy during air discharging period that could be useful to improve its efficiency. Therefore, operating as peak-off peak hours has been selected.

Table A.4: 24-hour and peak-off peak comparison

	24-hour operation	**Peak – off peak operation**
Net power consumption (kW)	8,655.202	6,185.171
Net power generation (kW)	10,862.19	9,728.163
Net power expenses during off peak hours (baht/day)	0	160,111.82
Net power income during off peak hours (baht/day)	57,130.97	0
Net power income during on peak hours (baht/day)	95,294.21	420,046.557
Total power income (baht/day)	152,425.18	259,934.746

A.2 Optimal flow rate of air

After the operation is selected, the optimal flow rate of air must be considered. Firstly, the flow rate of 125,000 kg/h and 100,000 kg/h were roughly calculated, and the results showed that 100,000 kg/h of air tends to obtain higher efficiency than 125,000 kg/h, meaning that the flow rate of air shall be equal or less than 100,000 kg/h. Therefore, the flow rate of 100,000 kg/h and 70,000 kg/h were simulated in Aspen HYSYS and the results are demonstrated in table A.5 and A.6 for 100,000 kg/h, A.7 and A.8 for 70,000 kg/h.

Table A.5 Power performance of the airflow rate 100,000 kg/h during energy storage process

Energy storage operation			
Equipment	Power consumption (kW)	Equipment	Power generation (kW)
K-201	1634	T-201	293.5
K-202	2203	T-301	1,161
K-203	2254	T-302	879.7
K-204	2156	T-303	793
K-205	1123	T-304	1024
PU-201	1805	T-305	61.88
PU-301	3.408	T-501	539
PU-501	1.508		
Total	11,179.92	Total	4,752.08
Net power consumption = 6,427.836 kW			

Table A.6: Power performance of the airflow rate 100,000 kg/h during energy release process

Energy release operation			
Equipment	Power consumption (kW)	Equipment	Power generation (kW)
PU-201	84.45	T-301	1,161
PU-202	951.3	T-302	1,024
PU-203	1805	T-303	879.7
PU-301	3.408	T-304	793.1
PU-501	4.473	T-305	91.67
		T-401	1,510
		T-402	2,166
		T-403	2,340
		T-404	1,982
		T-501	1,599
Total	2,957.292	Total	13,546.47
Net power generation = 10,697.84 kW			

Table A.7: Power performance of the airflow rate 70,000 kg/h during energy storage process

Energy storage operation			
Equipment	Power consumption (kW)	Equipment	Power generation (kW)
K-201	1,149	T-201	236.5
K-202	1,452	T-301	1,161
K-203	2,106	T-302	965.4
K-204	1,658	T-303	660.9
K-205	891.4	T-304	731
PU-201	1,708	T-305	52.57
PU-301	3.408	T-501	533.1
PU-501	1.539		
Total	8,969.347	Total	4,340.47
Net power generation = 4628.877 kW			

Table A.8: Power performance of the airflow rate 70,000 kg/h during energy release operation

Energy release operation			
Equipment	Power consumption (kW)	Equipment	Power generation (kW)
PU-201	67.35	T-301	1,161
PU-202	742.1	T-302	965.4
PU-203	1,709	T-303	749
PU-301	3.408	T-304	828.5
PU-501	3.941	T-305	80.24
		T-401	1,866
		T-402	1,204
		T-403	1,750
		T-404	1,865
		T-501	1,304
Total	2,525.799	Total	11,773.14
Net power generation = 9,247.341 kW			

From the data in the table above, economics was calculated by using the Time of Use Tariff and presented in table A.9 that indicates both the electrical round-trip efficiency and total power income of the air 100,000 and 70,000 kg/h. For 100,000 kg/h of air, the electrical round-trip efficiency is 196.69% which is lower than the airflow rate of 70,000 kg/h, which accounted to be 236.01%. Although the efficiency of 100,000 kg/h is lower, the economic is higher, which are 321,191.24 and 294,623.25 baht/day for 100,000 and 70,000 kg/h, respectively. Thus, 100,000 kg/h of air has been chosen due to the higher power income.

Table A.9: Efficiency and economics of air 100,000 and 70,000 kg/h comparison

	Air 100,000 kg/h	**Air 70,000 kg/h**
Net power consumption (kW)	6,427.84	4,628.88
Net power generation (kW)	10,697.84	9,247.34
Net power expenses during off peak hours (baht/day)	156,204.13	112,487.27
Net power income during on peak hours (baht/day)	532,005.67	459,872.12
Total NG used in combustion (baht/day)	54,610.30	52,761.60
Total power income (baht/day)	321,191.24	294,623.25
Electrical round-trip efficiency (%)	196.69	236.01

APPENDIX B

Appendix B shows the details of power generation and power consumption of the proposed process with the condition that negligible pressure drop and air pretreatment section, and calculated pressure drop with no air pretreatment section.

Table B.1: Power performance of the LNG-LAES-RC process during energy storage operation without pressure drop and air pretreatment section

Energy storage operation			
Equipment	Power consumption (kW)	Equipment	Power generation (kW)
K-201	1634	T-201	293.5
K-202	2203	T-301	1,161
K-203	2254	T-302	879.7
K-204	2156	T-303	793
K-205	1123	T-304	1024
PU-201	1805	T-305	61.88
PU-301	3.408	T-501	539
PU-501	1.508		
Total	11,179.92	Total	4,752.08
Net power consumption = 6,427.836 kW			

Table B.2: Power performance of the LNG-LAES-RC process during energy release operation without pressure drop and air pretreatment section

Energy release operation			
Equipment	Power consumption (kW)	Equipment	Power generation (kW)
PU-201	84.45	T-301	1,161
PU-202	951.3	T-302	1,024
PU-203	1805	T-303	879.7
PU-301	3.408	T-304	793.1
PU-501	4.473	T-305	91.67
		T-401	1,510
		T-402	2,166
		T-403	2,340
		T-404	1,982
		T-501	1,599
Total	2,957.292	Total	13,546.47
Net power generation = 10,697.84 kW			

Table B.3: Power performance of the LNG-LAES-RC process during energy storage operation with calculated pressure drop but no air pretreatment section

Energy storage operation			
Equipment	Power consumption (kW)	Equipment	Power generation (kW)
K-201	1,634	T-201	262.8
K-202	1,783	T-301	1161
K-203	2,522	T-302	876.5
K-204	2,206	T-303	786.8
K-205	1,141	T-304	1,014
PU-201	1,819	T-305	61.95
PU-301	3.644	T-501	539
PU-501	1.532		
Total	11,110.18	Total	4,702.05
Net power consumption = 6,408.126 kW			

Table B.4: Power performance of the LNG-LAES-RC process during energy release operation with calculated pressure drop but no air pretreatment section

Energy release operation			
Equipment	Power consumption (kW)	Equipment	Power generation (kW)
PU-201	1,807	T-301	1,161
PU-202	82.04	T-302	1,011
PU-203	947.1	T-303	873.4
PU-301	3.644	T-304	784.7
PU-501	4.301	T-305	91.74
		T-401	1,975
		T-402	1,985
		T-403	1,839
		T-404	860
		T-501	1,485
Total	2,844.085	Total	12,065.84
Net power generation = 9,221.755 kW			

APPENDIX C

Material balance

Table C.1; Material balance in section 100

Component	A-101 (Gas phase), Off-peak period				A-102 (Gas phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	2148.1600	0.7672	60176.4071	0.7470	2148.1600	0.7672	60176.4071	0.7470
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	25.4800	0.0091	1017.8751	0.0126	25.4800	0.0091	1017.8751	0.0126
Oxygen	575.9600	0.2057	1843.7200	0.2288	575.9600	0.2057	1843.7200	0.2288
Water	49.5600	0.0177	892.8284	0.0111	49.5600	0.0177	892.8284	0.0111
Carbon dioxide	0.8400	0.0003	36.9681	0.0005	0.8400	0.0003	36.9681	0.0005

Table C.1: Material balance in section 100 (cont.)

Component	A-103 (Gas phase), Off-peak period				A-104 (Gas phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.7470	2148.1600	0.7672	60176.4071	2148.1591	0.7749	60176.3826	0.7517
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0126	25.4800	0.0091	1017.8751	25.4800	0.0092	1017.8751	0.0127
Oxygen	0.2288	575.9600	0.2057	1843.7200	575.9600	0.2078	18430.7185	0.2302
Water	0.0111	49.5600	0.0177	892.8284	21.9106	0.0079	934.7225	0.0049
Carbon dioxide	0.0005	0.8400	0.0003	36.9681	0.8400	0.0003	36.9676	0.0005

Table C.1: Material balance in section 100 (cont.)

Component	A-105 (Gas phase), Off-peak period				A-106 (Gas phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	2148.1591	0.7749	60176.3826	0.7517	2148.1283	0.7784	60175.5185	0.7538
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	25.4800	0.0092	1017.8751	0.0127	25.4800	0.0092	1017.8750	0.0128
Oxygen	575.9600	0.2078	18430.7185	0.2302	575.9578	0.2087	18430.6481	0.2308
Water	21.9106	0.0079	934.7225	0.0049	9.0998	0.0033	163.9341	0.0021
Carbon dioxide	0.8400	0.0003	36.9676	0.0005	0.8395	0.0003	36.9478	0.0005

Table C.1: Material balance in section 100 (cont.)

Component	W-101 (Liquid phase), Off-peak period				W-102 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0381	0.0000	1.0659	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0027	0.0000	0.0870	0.0000
Water	1000	1	18015.1005	1	1249.9587	1	22518.1310	0.9999
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.1: Material balance in section 100 (cont.)

Component	W-103 (Liquid phase), Off-peak period				W-104 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0381	0.0000	1.0659	0.0000	0.0381	0.0000	1.0659	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000
Oxygen	0.0027	0.0000	0.0870	0.0000	0.0027	0.0000	0.0870	0.0000
Water	1249.9587	1.000	22518.1310	0.9999	1249.9587	1.0000	22518.1310	0.9999
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.1: Material balance in section 100 (cont.)

Component	W-105 (Liquid phase), Off-peak period				W-106 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0009	0.0000	0.0246	0.0000	0.0308	0.0000	0.8637	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0022	0.0000	0.0705	0.0000
Water	27.6494	1.0000	498.1059	0.9999	1012.810	1.0000	18245.8854	0.9999
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000

Table C.1: Material balance in section 100 (cont.)

Component	L-101 (Liquid phase), Off-peak period				L-102 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	5100.4539	0.9115	81826.0723	0.8183	5100.4539	0.9115	81826.0723	0.8183
Propane	120.8665	0.0216	5329.8496	0.0533	120.8665	0.0216	5329.8496	0.0533
i-Butane	28.5379	0.0051	1658.7381	0.0166	28.5379	0.0051	1658.7381	0.0166
n-Butane	28.5379	0.0051	1658.7381	0.0166	28.5379	0.0051	1658.7381	0.0166
Nitrogen	6.7148	0.0012	188.1018	0.0019	6.7148	0.0012	188.1018	0.0019
Ethane	310.5597	0.0555	5338.1011	0.0934	310.5597	0.0555	5338.1011	0.0934
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200

Component	A-201 (Gas phase), Off-peak period				A-202 (Gas phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	248.1283	0.7813	60175.5185	0.7557	248.1283	0.7813	60175.5185	0.7557
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	25.4800	0.0093	1017.8750	0.0128	25.4800	0.0093	1017.8750	0.0128
Oxygen	575.9578	0.2095	18430.6481	0.2315	575.9578	0.2095	18430.6481	0.2315
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	A-203 (Gas phase), Off-peak period				A-204 (Gas phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	248.1283	0.7813	60175.5185	0.7557	248.1283	0.7813	60175.5185	0.7557
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	25.4800	0.0093	1017.8750	0.0128	25.4800	0.0093	1017.8750	0.0128
Oxygen	575.9578	0.2095	18430.6481	0.2315	575.9578	0.2095	18430.6481	0.2315
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	A-205 (Gas phase), Off-peak period				A-206 (Gas phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	248.1283	0.7813	60175.5185	0.7557	248.1283	0.7813	60175.5185	0.7557
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	25.4800	0.0093	1017.8750	0.0128	25.4800	0.0093	1017.8750	0.0128
Oxygen	575.9578	0.2095	18430.6481	0.2315	575.9578	0.2095	18430.6481	0.2315
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	A-207 (Gas phase), Off-peak period				A-208 (Gas phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	248.1283	0.7813	60175.5185	0.7557	248.1283	0.7813	60175.5185	0.7557
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	25.4800	0.0093	1017.8750	0.0128	25.4800	0.0093	1017.8750	0.0128
Oxygen	575.9578	0.2095	18430.6481	0.2315	575.9578	0.2095	18430.6481	0.2315
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	A-209 (Gas phase), Off-peak period				A-210 (Gas phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	248.1283	0.7813	60175.5185	0.7557	248.1283	0.7813	60175.5185	0.7557
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	25.4800	0.0093	1017.8750	0.0128	25.4800	0.0093	1017.8750	0.0128
Oxygen	575.9578	0.2095	18430.6481	0.2315	575.9578	0.2095	18430.6481	0.2315
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	A-211 (Gas phase), Off-peak period				A-212 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	248.1283	0.7813	60175.5185	0.7557	248.1283	0.7813	60175.5185	0.7557
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	25.4800	0.0093	1017.8750	0.0128	25.4800	0.0093	1017.8750	0.0128
Oxygen	575.9578	0.2095	18430.6481	0.2315	575.9578	0.2095	18430.6481	0.2315
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	A-213 (Mix phase), Off-peak period				A-214 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	248.1283	0.7813	60175.5185	0.7557	2135.6247	0.7803	59825.2563	0.7547
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	25.4800	0.0093	1017.8750	0.0128	25.4568	0.0093	1016.9490	0.0128
Oxygen	575.9578	0.2095	18430.6481	0.2315	575.6784	0.2104	18424.5903	0.2324
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	A-215 (Liquid phase), Off-peak period				A-216 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	1807.0671	0.7803	50621.3707	0.7547	1807.0671	0.7803	50621.3707	0.7547
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	21.5404	0.0093	860.4953	0.0128	21.5404	0.0093	860.4953	0.0128
Oxygen	487.1887	0.2104	15590.379	0.2324	487.1887	0.2104	15590.379	0.2324
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	A-217 (Liquid phase), Off-peak period				A-218 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	1807.0671	0.7803	50621.3707	0.7547	1807.0671	0.7803	50621.3707	0.7547
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	21.5404	0.0093	860.4953	0.0128	21.5404	0.0093	860.4953	0.0128
Oxygen	487.1887	0.2104	15590.379	0.2324	487.1887	0.2104	15590.379	0.2324
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	A-219 (Gas phase), Off-peak period				A220 (Gas phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	476.5038	0.9119	13348.3002	0.8993	476.5038	0.9119	13348.3002	0.8993
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	2.6647	0.0051	106.4489	0.0072	2.6647	0.0051	106.4489	0.0072
Oxygen	43.3901	0.0830	1388.4824	0.0935	43.3901	0.0830	1388.4824	0.0935
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	L-201 (Liquid phase), Off-peak period				L-202 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	5100.4539	0.9115	81826.0723	0.8183	5100.4539	0.9115	81826.0723	0.8183
Propane	120.8665	0.0216	5329.8496	0.0533	120.8665	0.0216	5329.8496	0.0533
i-Butane	18.5379	0.0051	1658.7381	0.0166	18.5379	0.0051	1658.7381	0.0166
n-Butane	28.5379	0.0051	1658.7381	0.0166	28.5379	0.0051	1658.7381	0.0166
Nitrogen	6.7148	0.0012	188.1018	0.0019	6.7148	0.0012	188.1018	0.0019
Ethane	310.5597	0.0555	9338.5001	0.0934	310.5597	0.0555	9338.5001	0.0934
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	L-203 (Liquid phase), Off-peak period				L-204 (Liquid phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	5100.4539	0.9115	81826.0723	0.8183	5100.4539	0.9115	81826.0723	0.8183
Propane	120.8665	0.0216	5329.8496	0.0533	120.8665	0.0216	5329.8496	0.0533
i-Butane	18.5379	0.0051	1658.7381	0.0166	18.5379	0.0051	1658.7381	0.0166
n-Butane	28.5379	0.0051	1658.7381	0.0166	28.5379	0.0051	1658.7381	0.0166
Nitrogen	6.7148	0.0012	188.1018	0.0019	6.7148	0.0012	188.1018	0.0019
Ethane	310.5597	0.0555	9338.5001	0.0934	310.5597	0.0555	9338.5001	0.0934
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	L-205 (Liquid phase), On peak period				L-206 (Liquid phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	5100.4539	0.9115	81826.0723	0.8183	5100.4539	0.9115	81826.0723	0.8183
Propane	120.8665	0.0216	5329.8496	0.0533	120.8665	0.0216	5329.8496	0.0533
i-Butane	18.5379	0.0051	1658.7381	0.0166	18.5379	0.0051	1658.7381	0.0166
n-Butane	28.5379	0.0051	1658.7381	0.0166	28.5379	0.0051	1658.7381	0.0166
Nitrogen	6.7148	0.0012	188.1018	0.0019	6.7148	0.0012	188.1018	0.0019
Ethane	310.5597	0.0555	9338.5001	0.0934	310.5597	0.0555	9338.5001	0.0934
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	L-207 (Liquid phase), Off-peak period				L-208 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	5100.4539	0.9115	81826.0723	0.8183	5100.4539	0.9115	81826.0723	0.8183
Propane	120.8665	0.0216	5329.8496	0.0533	120.8665	0.0216	5329.8496	0.0533
i-Butane	18.5379	0.0051	1658.7381	0.0166	18.5379	0.0051	1658.7381	0.0166
n-Butane	28.5379	0.0051	1658.7381	0.0166	28.5379	0.0051	1658.7381	0.0166
Nitrogen	6.7148	0.0012	188.1018	0.0019	6.7148	0.0012	188.1018	0.0019
Ethane	310.5597	0.0555	9338.5001	0.0934	310.5597	0.0555	9338.5001	0.0934
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2; Material balance in section 200 (cont.)

Component	P-201 (Liquid phase), Off-peak period				P-202 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	1360.6368	1	60000.0001	1	1360.6368	1	60000.0001	1
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	P-203 (Liquid phase), Off-peak period				P-204 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	1360.6368	1	60000.0001	1	1151.3080	1	50469.2308	1
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	P-205 (Liquid phase), Off-peak period				P-206 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	1151.3080	1	50469.2308	1	1151.3080	1	50469.2308	1
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	P-207 (Liquid phase), Off-peak period				P-208 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	2948.0663	1	130000.0000	1	2948.0663	1	130000.0000	1
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	P-209 (Liquid phase), Off-peak period				P-210 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	2948.0663	1	130000.0000	1	2948.0663	1	130000.0000	1
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	P-211 (Liquid phase), Off-peak period				P-212 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	2948.0663	1	130000.0000	1	2494.5008	1	110000.0000	1
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	P-213 (Liquid phase), On peak period				P-214 (Liquid phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	2494.5008	1	110000.0000	1	2494.5008	1	110000.0000	1
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	P-215 (Liquid phase), On peak period				P-216 (Liquid phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	2948.0463	1	130000	1	2948.0463	1	130000	1
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	P-217 (Liquid phase), Off-peak period				P-218 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	2948.0463	1	130000	1	2494.5008	1	110000	1
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.2: Material balance in section 200 (cont.)

Component	P-219 (Liquid phase), On peak period				P-220 (Liquid phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	2494.5008	1	110000	1	2494.5008	1	110000	1
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.3: Material balance in section 300

Component	L-301 (Liquid phase), Off-peak period				L-302 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	5100.4539	0.9115	81826.0723	0.8183	5100.4539	0.9115	81826.0723	0.8183
Propane	120.8665	0.0216	5329.8496	0.0533	120.8665	0.0216	5329.8496	0.0533
i-Butane	18.5379	0.0051	1658.7381	0.0166	18.5379	0.0051	1658.7381	0.0166
n-Butane	28.5379	0.0051	1658.7381	0.0166	28.5379	0.0051	1658.7381	0.0166
Nitrogen	6.7148	0.0012	188.1018	0.0019	6.7148	0.0012	188.1018	0.0019
Ethane	310.5597	0.0555	9338.5001	0.0934	310.5597	0.0555	9338.5001	0.0934
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.3: Material balance in section 300 (cont.)

Component	L-303 (Liquid phase)				L-304 (Liquid phase)			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	5100.4539	0.9115	81826.0723	0.8183	5100.4539	0.9115	81826.0723	0.8183
Propane	120.8665	0.0216	5329.8496	0.0533	120.8665	0.0216	5329.8496	0.0533
i-Butane	18.5379	0.0051	1658.7381	0.0166	18.5379	0.0051	1658.7381	0.0166
n-Butane	28.5379	0.0051	1658.7381	0.0166	28.5379	0.0051	1658.7381	0.0166
Nitrogen	6.7148	0.0012	188.1018	0.0019	6.7148	0.0012	188.1018	0.0019
Ethane	310.5597	0.0555	9338.5001	0.0934	310.5597	0.0555	9338.5001	0.0934
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.3: Material balance in section 300 (cont.)

Component	L-305 (Liquid phase)				L-306 (Liquid phase)			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	5100.4539	0.9115	81826.0723	0.8183	5100.4539	0.9115	81826.0723	0.8183
Propane	120.8665	0.0216	5329.8496	0.0533	120.8665	0.0216	5329.8496	0.0533
i-Butane	18.5379	0.0051	1658.7381	0.0166	18.5379	0.0051	1658.7381	0.0166
n-Butane	28.5379	0.0051	1658.7381	0.0166	28.5379	0.0051	1658.7381	0.0166
Nitrogen	6.7148	0.0012	188.1018	0.0019	6.7148	0.0012	188.1018	0.0019
Ethane	310.5597	0.0555	9338.5001	0.0934	310.5597	0.0555	9338.5001	0.0934
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.3: Material balance in section 300 (cont.)

Component	L-307 (Liquid phase)				L-308 (Liquid phase)			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	5100.4539	0.9115	81826.0723	0.8183	5048.9393	0.9115	80999.6290	0.8183
Propane	120.8665	0.0216	5329.8496	0.0533	119.6457	0.0216	5276.0181	0.0533
i-Butane	18.5379	0.0051	1658.7381	0.0166	28.2497	0.0051	1641.9849	0.0166
n-Butane	28.5379	0.0051	1658.7381	0.0166	28.2497	0.0051	1641.9849	0.0166
Nitrogen	6.7148	0.0012	188.1018	0.0019	6.6470	0.0012	186.2020	0.0019
Ethane	310.5597	0.0555	9338.5001	0.0934	307.4231	0.0555	9244.1813	0.0934
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.3: Material balance in section 300 (cont.)

Component	L-309 (Liquid phase)				L-310 (Liquid phase)			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	51.5146	0.9115	826.4433	0.8183	51.5146	0.9115	826.4433	0.8183
Propane	1.2208	0.0216	53.8315	0.0533	1.2208	0.0216	53.8315	0.0533
i-Butane	0.2882	0.0051	16.7533	0.0166	0.2882	0.0051	16.7533	0.0166
n-Butane	0.2882	0.0051	16.7533	0.0166	0.2882	0.0051	16.7533	0.0166
Nitrogen	0.0678	0.0012	1.8998	0.0019	0.0678	0.0012	1.8998	0.0019
Ethane	3.1367	0.9115	94.3189	0.0934	3.1367	0.9115	94.3189	0.0934
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.3: Material balance in section 300 (cont.)

Component	L-308 (Liquid phase), On peak period				L-309 (Liquid phase) , On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	4984.7741	0.9115	80050.4466	0.8183	110.6798	0.9115	1775.6258	0.8183
Propane	118.2437	0.0216	5214.1918	0.0533	2.6228	0.0216	115.6577	0.0533
i-Butane	27.9186	0.0051	1622.7435	0.0166	0.6193	0.0051	35.9946	0.0166
n-Butane	27.9186	0.0051	1622.7435	0.0166	0.6193	0.0051	35.946	0.0166
Nitrogen	6.5691	0.0012	184.0200	0.0019	0.1457	0.0012	4.0818	0.0019
Ethane	303.8206	0.9115	9135.8547	0.0934	6.7391	0.9115	202.6455	0.0934
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.3: Material balance in section 300 (cont.)

Component	L-310 (Liquid phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	110.6798	0.9115	1775.6258	0.8183
Propane	2.6228	0.0216	115.6577	0.0533
i-Butane	0.6193	0.0051	35.9946	0.0166
n-Butane	0.6193	0.0051	35.946	0.0166
Nitrogen	0.1457	0.0012	4.0818	0.0019
Ethane	6.7391	0.9115	202.6455	0.0934
Argon	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000

Table C.3: Material balance in section 300 (cont.)

Component	W-301 (Liquid phase), Off-peak period				W-302 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	411.0441	1	7405.0000	1	411.0441	1	7405.0000	1
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.3: Material balance in section 300 (cont.)

Component	W-303 (Liquid phase), Off-peak period				W-304 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	411.0441	1	7405.0000	1	411.0441	1	7405.0000	1
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.3: Material balance in section 300 (cont.)

Component	W-305 (Liquid phase), Off-peak period				W-306 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	411.0441	1	7405.0000	1	411.0441	1	7405.0000	1
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.3: Material balance in section 300 (cont.)

Component	W-307 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000
Water	411.0441	1	7405.0000	1
Carbon dioxide	0.0000	0.0000	0.0000	0.0000

Table C.3: Material balance in section 300 (cont.)

Component	W-301 (Liquid phase), On peak period				W-302 (Liquid phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	1210.0959	1	21800.0000	1	1210.0959	1	21800.0000	1
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.3: Material balance in section 300 (cont.)

Component	W-303 (Liquid phase), On peak period				W-304 (Liquid phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	1210.0959	1	21800.0000	1	1210.0959	1	21800.0000	1
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.3: Material balance in section 300 (cont.)

Component	W-305 (Liquid phase), On peak period				W-306 (Liquid phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	1210.0959	1	21800.0000	1	1210.0959	1	21800.0000	1
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.3: Material balance in section 300 (cont.)

Component	W-307 (Liquid phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000
Water	1210.0959	1	21800.0000	1
Carbon dioxide	0.0000	0.0000	0.0000	0.0000

Table C.4: Material balance in section 400

Component	A-401 (Gas phase), On peak period				A-402 (Gas phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	1807.0671	0.7803	50621.3707	0.7547	1807.0671	0.7803	50621.3707	0.7547
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	21.5404	0.0093	860.4953	0.0128	21.5404	0.0093	860.4953	0.0128
Oxygen	487.1887	0.2104	15590.379	0.2324	487.1887	0.2104	15590.379	0.2324
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.4: Material balance in section 400 (cont.)

Component	A-403 (Gas phase), On peak period				A-404 (Gas phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	1807.0671	0.7803	50621.3707	0.7547	1807.0671	0.7803	50621.3707	0.7547
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	21.5404	0.0093	860.4953	0.0128	21.5404	0.0093	860.4953	0.0128
Oxygen	487.1887	0.2104	15590.379	0.2324	487.1887	0.2104	15590.379	0.2324
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.4: Material balance in section 400 (cont.)

Component	A-405 (Gas phase), On peak period				A-406 (Gas phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	1807.0671	0.7803	50621.3707	0.7547	1807.0671	0.7803	50621.3707	0.7547
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	21.5404	0.0093	860.4953	0.0128	21.5404	0.0093	860.4953	0.0128
Oxygen	487.1887	0.2104	15590.379	0.2324	487.1887	0.2104	15590.379	0.2324
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.4: Material balance in section 400 (cont.)

Component	A-407 (Gas phase), On peak period				A-408 (Gas phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	1807.0671	0.7803	50621.3707	0.7547	1807.0671	0.7803	50621.3707	0.7547
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	21.5404	0.0093	860.4953	0.0128	21.5404	0.0093	860.4953	0.0128
Oxygen	487.1887	0.2104	15590.379	0.2324	487.1887	0.2104	15590.379	0.2324
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.4: Material balance in section 400 (cont.)

Component	A-409 (Gas phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000
Nitrogen	1807.0671	0.7803	50621.3707	0.7547
Ethane	0.0000	0.0000	0.0000	0.0000
Argon	21.5404	0.0093	860.4953	0.0128
Oxygen	487.1887	0.2104	15590.379	0.2324
Water	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000

Table C.5: Material balance in section 500

Component	W-501 (Liquid phase), Off-peak period				W-502 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	385.7875	1	6950.0000	1	385.7875	1	6950.0000	1
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.5: Material balance in section 500 (cont.)

Component	W-503 (Liquid phase), Off-peak period				W-504 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	385.7875	1	6950.0000	1	385.7875	1	6950.0000	1
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.5: Material balance in section 500 (cont.)

Component	W-501 (Liquid phase), On peak				W-502 (Liquid phase), On peak			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	777.1258	1	14000.0000	1	777.1258	1	14000.0000	1
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.5: Material balance in section 500 (cont.)

Component	W-503 (Liquid phase), On peak				W-504 (Liquid phase), On peak			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	777.1258	1	14000.0000	1	777.1258	1	14000.0000	1
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.6: Material balance in section 600

Component	A-601 (Liquid phase)				A-602 (Liquid phase)			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	1618.5934	0.7812	45341.6571	0.7557	1618.5934	0.7812	45341.6571	0.7557
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	19.0618	0.0092	76.4798	0.0127	19.0618	0.0092	76.4798	0.0127
Oxygen	434.2770	0.2096	13896.8632	0.2316	434.2770	0.2096	13896.8632	0.2316
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table C.6: Material balance in section 600 (cont.)

Component	A-603 (Gas phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000
Nitrogen	1807.0671	0.7803	50621.3707	0.7547
Ethane	0.0000	0.0000	0.0000	0.0000
Argon	21.5404	0.0093	860.4953	0.0128
Oxygen	487.1887	0.2104	15590.379	0.2324
Water	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000

Table C.6: Material balance in section 600 (cont.)

Component	A-603 (Gas phase), On peak			
	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000
Nitrogen	1618.5934	0.7812	45341.6571	0.7557
Ethane	0.0000	0.0000	0.0000	0.0000
Argon	19.0618	0.0092	76.4798	0.0127
Oxygen	434.2770	0.2096	13896.8632	0.2316
Water	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000

Table C.6: Material balance in section 600 (cont.)

Component	C-601 (Liquid phase), Off-peak period				C-602 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.2882	0.0001	16.7533	0.0003	0.2882	0.0001	16.7533	0.0003
n-Butane	0.2882	0.0001	16.7533	0.0003	0.2882	0.0001	16.7533	0.0003
Nitrogen	1618.6612	0.7595	45343.5569	0.7432	1618.6612	0.7595	45343.5569	0.7432
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	19.0618	0.0089	761.4798	0.0125	19.0618	0.0089	761.4798	0.0125
Oxygen	314.1658	0.1471	10053.3044	0.1648	314.1658	0.1471	10053.3044	0.1648
Water	117.3221	0.0550	2113.5700	0.0346	117.3221	0.0550	2113.5700	0.0346
Carbon dioxide	61.4501	0.0288	2104.4025	0.0443	61.4501	0.0288	2104.4025	0.0443

Table C.6: Material balance in section 600 (cont.)

Component	C-603 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000
i-Butane	0.2882	0.0001	16.7533	0.0003
n-Butane	0.2882	0.0001	16.7533	0.0003
Nitrogen	1618.6612	0.7595	45343.5569	0.7432
Ethane	0.0000	0.0000	0.0000	0.0000
Argon	19.0618	0.0089	761.4798	0.0125
Oxygen	314.1658	0.1471	10053.3044	0.1648
Water	117.3221	0.0550	2113.5700	0.0346
Carbon dioxide	61.4501	0.0288	2104.4025	0.0443

Table C.6: Material balance in section 600 (cont.)

Component	C-601 (Liquid phase), On peak period				C-602 (Liquid phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.6193	0.0003	35.9946	0.0005	0.6193	0.0003	35.9946	0.0005
n-Butane	0.6193	0.0003	35.9946	0.0005	0.6193	0.0003	35.9946	0.0005
Nitrogen	1807.2128	0.7397	50625.4525	0.7311	1807.2128	0.7397	50625.4525	0.7311
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	21.5404	0.0088	860.4953	0.0124	21.5404	0.0088	860.4953	0.0124
Oxygen	229.1280	0.0938	7332.0947	0.1059	229.1280	0.0938	7332.0947	0.1059
Water	252.0683	0.1032	4541.0366	0.0156	252.0683	0.1032	4541.0366	0.0156
Carbon dioxide	132.0266	0.0540	5810.4490	0.0839	132.0266	0.0540	5810.4490	0.0839

Table C.6: Material balance in section 600 (cont.)

Component	C-603 (Liquid phase), On peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000
i-Butane	0.6193	0.0003	35.9946	0.0005
n-Butane	0.6193	0.0003	35.9946	0.0005
Nitrogen	1807.2128	0.7397	50625.4525	0.7311
Ethane	0.0000	0.0000	0.0000	0.0000
Argon	21.5404	0.0088	860.4953	0.0124
Oxygen	229.1280	0.0938	7332.0947	0.1059
Water	252.0683	0.1032	4541.0366	0.0156
Carbon dioxide	132.0266	0.0540	5810.4490	0.0839

Table C.6; Material balance in section 600 (cont.)

Component	H-601 (Liquid phase), Off-peak period				H-602 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hot oil	40.1059	1	40000	1	40.1059	1	40000	1

Table C.6: Material balance in section 600 (cont.)

Component	H-603 (Liquid phase), Off-peak period				H-604 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hot oil	40.1059	1	40000	1	40.1059	1	40000	1

Table C.6: Material balance in section 600 (cont.)

Component	H-605 (Liquid phase), Off-peak period			
	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000
Hot oil	40.1059	1	40000	1

Table C.6: Material balance in section 600 (cont.)

Component	H-601 (Liquid phase), On peak				H-602 (Liquid phase), On peak			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hot oil	80.2118	1	80000	1	80.2118	1	80000	1

Table C.6: Material balance in section 600 (cont.)

Component	H-603 (Liquid phase), On peak				H-604 (Liquid phase), On peak			
	kmol/hr	Mole fraction	kg/hr	Mass fraction	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hot oil	80.2118	1	80000	1	80.2118	1	80000	1

Table C.6: Material balance in section 600 (cont.)

Component	H-605 (Liquid phase), On peak			
	kmol/hr	Mole fraction	kg/hr	Mass fraction
Methane	0.0000	0.0000	0.0000	0.0000
Propane	0.0000	0.0000	0.0000	0.0000
i-Butane	0.0000	0.0000	0.0000	0.0000
n-Butane	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0000	0.0000	0.0000	0.0000
Ethane	0.0000	0.0000	0.0000	0.0000
Argon	0.0000	0.0000	0.0000	0.0000
Oxygen	0.0000	0.0000	0.0000	0.0000
Water	0.0000	0.0000	0.0000	0.0000
Carbon dioxide	0.0000	0.0000	0.0000	0.0000
Hot oil	80.2118	1	80000	1

APPENDIX D

Hydraulic Calculation

Assumptions

- Flow rate is including 10% design margin
- System has no heat loss and gain
- The average velocity for liquid in pipe is 4.5 m/s
- The average velocity for gas in pipe is 17.5 m/s

Table D.1: Hydraulic calculation

Section	Unit	P-201		P-202	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		106.1947		179.4454
Pipe ID (Theory)	[mm]		91.34012		118.7343
Velocity (real)	[m/s]		4.63501		4.060178
Mass flow rate	[kg/h]		66000		66000
Density	[kg/m3]		621.5		367.8
Viscosity	[cP]		0.3091		0.05079
Pipe ID (real)	[mm]		90		125
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		8.805		23.2341
Outlet Pipe ID	[mm]		101.6		141.3
Calculation					
Volumetric flow rate	[m3/h]		106.1947		179.4454
Pipe cross sectional area	[m2]		0.006362		0.012272
ε/D			0.000278		0.0002
Velocity	[m/s]		4.636875		4.061812
Erosional Velocity	[m/s]		4.011247		5.214277
N_{RE}	[-]		839092.9		3676743
fm	[-]		0.015598		0.014018
Velocity head	[kPa]		6.681315		3.03404
ΔP/100m	[kPa/100m]		115.7961		34.02555
ρv2	[kg/m-s2]		13362.63		6068.08
Pipe fitting		**unit**	**K/unit**	**unit**	K/unit
Elbow		1	0.257398	2	0.240858
Tee elbow		0	0.513842	0	0.481498
Tee through		3	0.06429	1	0.060201
Block valve		5	0.12858	1	0.120402
Check Valve		0	1.925121	1	1.805208
Pipe size change		0	0	0	0
Piping length K-factor			1.526024		2.605611
Pipe fitting K-factor			1.093166		2.467526
Total K-total			2.61919		5.073137
Difference of Elavation	[m]		-0.3		3.2893
ΔPf	[kPa]		17.49964		15.3921
ΔP Elavation	[kPa]		-1.82907		11.86818
ΔP Specified	[kPa]	heat ex	0		4.842
ΔPtotal	[kPa]		15.67056		32.10228
P inlet	[kPa]		200		1000
P outlet	[kPa]		184.3294		967.8977
P inlet (bar)	[bar]		200		
delta P	[kPa]	15.67056	0.156706	32.10228	0.321023
Differential Pressure	[kPa]	168.6627	1.686627		

Table D.1: Hydraulic calculation (cont.)

Section	Unit	P-203		P-204	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		117.4377		99.35421
Pipe ID (Theory)	[mm]		96.05367		88.34934
Velocity (real)	[m/s]		5.125727		4.336448
Mass flow rate	[kg/h]		66000		55847
Density	[kg/m3]		562		562.1
Viscosity	[cP]		0.1639		0.164
Pipe ID (real)	[mm]		90		90
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		31.6555		7.8
Outlet Pipe ID	[mm]		101.6		101.6
Calculation					
Volumetric flow rate	[m3/h]		117.4377		99.35421
Pipe cross sectional area	[m2]		0.006362		0.006362
ε/D			0.000278		0.000278
Velocity	[m/s]		5.12779		4.338193
Erosional Velocity	[m/s]		4.218245		4.21787
N_{RE}	[-]		1582450		1338200
fm	[-]		0.0152		0.015285
Velocity head	[kPa]		7.388678		5.289338
ΔP/100m	[kPa/100m]		124.7879		89.83345
ρv2	[kg/m-s2]		14777.36		10578.68
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		3	0.25695	1	0.257042
Tee elbow		0	0.513394	0	0.513487
Tee through		0	0.064206	3	0.064223
Block valve		0	0.128412	5	0.128446
Check Valve		0	1.924281	0	1.924454
Pipe size change		0	0	0	0
Piping length K-factor			5.346318		1.324742
Pipe fitting K-factor			0.77085		1.091944
Total K-total			6.117168		2.416686
Difference of Elavation	[m]		11.7107		-0.3
ΔPf	[kPa]		45.19778		12.78267
ΔP Elavation	[kPa]		64.56367		-1.65426
ΔP Specified	[kPa]	exchanger	0		0
ΔPtotal	[kPa]		109.7614		11.12841
P inlet	[kPa]		967.89772		300
P outlet	[kPa]		858.1363		288.8716
P inlet (bar)	[bar]				
delta P	[kPa]	109.7614	1.097614	11.12841	0.111284

Table D.1: Hydraulic calculation (cont.)

Section	Unit	P-205		P-206	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		56.28319		89.85841
Pipe ID (Theory)	[mm]		66.49662		84.02132
Velocity (real)	[m/s]		4.709609		4.963769
Mass flow rate	[kg/h]		55847		55847
Density	[kg/m3]		992.25		621.5
Viscosity	[cP]		0.656		0.3091
Pipe ID (real)	[mm]		65		80
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		5.0447		47.9553
Outlet Pipe ID	[mm]		73.03		88.9
Calculation					
Volumetric flow rate	[m3/h]		56.28319		89.85841
Pipe cross sectional area	[m2]		0.003318		0.005027
ε/D			0.000385		0.000313
Velocity	[m/s]		4.711505		4.965767
Erosional Velocity	[m/s]		3.174603		4.011247
N_{RE}	[-]		463223.2		798764
fm	[-]		0.016989		0.015938
Velocity head	[kPa]		11.01312		7.662736
ΔP/100m	[kPa/100m]		287.8572		152.6649
ρv2	[kg/m-s2]		22026.24		15325.47
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		1	0.279881	2	0.264502
Tee elbow		0	0.558035	0	0.528002
Tee through		1	0.069862	0	0.066063
Block valve		1	0.139725	0	0.132126
Check Valve		1	2.089392	0	1.978128
Pipe size change		0	0	0	0
Piping length K-factor			1.318566		9.55415
Pipe fitting K-factor			2.57886		0.529003
Total K-total			3.897426		10.08315
Difference of Elavation	[m]		2.0447		12.9553
ΔPf	[kPa]		42.92283		77.26454
ΔP Elevation	[kPa]		19.90305		78.98736
ΔP Specified	[kPa]		21.17		0
ΔPtotal	[kPa]		83.99588		156.2519
P inlet	[kPa]		1000		916.00412
P outlet	[kPa]		916.0041		759.7522
P inlet (bar)	[bar]				
delta P	[kPa]	83.99588	0.839959	156.2519	1.562519

Table D.1: Hydraulic calculation (cont.)

Section	Unit	P-207		P-208	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		214.3928		144.1169
Pipe ID (Theory)	[mm]		129.7822		106.4064
Velocity (real)	[m/s]		4.850908		5.095042
Mass flow rate	[kg/h]		143000		143000
Density	[kg/m3]		667		992.25
Viscosity	[cP]		0.6768		0.656
Pipe ID (real)	[mm]		125		100
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		14.325		39.7
Outlet Pipe ID	[mm]		141.3		114.3
Calculation					
Volumetric flow rate	[m3/h]		214.3928		144.1169
Pipe cross sectional area	[m2]		0.012272		0.007854
ε/D			0.0002		0.00025
Velocity	[m/s]		4.85286		5.097093
Erosional Velocity	[m/s]		3.872015		3.174603
N_{RE}	[-]		597823.9		770974.1
fm	[-]		0.01522		0.015418
Velocity head	[kPa]		7.85401		12.8895
ΔP/100m	[kPa/100m]		95.62954		198.7317
ρv2	[kg/m-s2]		15708.02		25779.01
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		1	0.241978	3	0.251838
Tee elbow		0	0.482618	0	0.502638
Tee through		3	0.060411	1	0.062895
Block valve		5	0.120822	1	0.125789
Check Valve		0	1.807309	1	1.882946
Pipe size change		0	0	0	0
Piping length K-factor			1.744196		6.120987
Pipe fitting K-factor			1.02732		2.827142
Total K-total			2.771516		8.948129
Difference of Elevation	[m]		0.3		0.7
ΔPf	[kPa]		21.76751		115.337
ΔP Elavation	[kPa]		1.962981		6.813781
ΔP Specified	[kPa]		0		39.77
ΔPtotal	[kPa]		23.73049		161.9207
P inlet	[kPa]		200		1000
P outlet	[kPa]		176.2695		838.0793
P inlet (bar)	[bar]				
delta P	[kPa]	23.73049	0.237305	161.9207	1.619207
Differential Pressure	[kPa]				

Table D.1: Hydraulic calculation (cont.)

Section	Unit	P-209		P-210	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		232.8232		244.0273
Pipe ID (Theory)	[mm]		135.2456		138.4616
Velocity (real)	[m/s]		5.267919		3.834324
Mass flow rate	[kg/h]		143000		143000
Density	[kg/m3]		614.2		586
Viscosity	[cP]		0.2813		0.205
Pipe ID (real)	[mm]		125		150
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		3.9		3.6
Outlet Pipe ID	[mm]		141.3		168.28
Calculation					
Volumetric flow rate	[m3/h]		232.8232		244.0273
Pipe cross sectional area	[m2]		0.012272		0.017671
ε/D			0.0002		0.000167
Velocity	[m/s]		5.270039		3.835867
Erosional Velocity	[m/s]		4.035014		4.130962
N_{RE}	[-]		1438348		1644745
fm	[-]		0.014425		0.013932
Velocity head	[kPa]		8.529183		4.311165
ΔP/100m	[kPa/100m]		98.42365		40.04308
ρv2	[kg/m-s2]		17058.37		8622.33
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.241196	0	0.234353
Tee elbow		0	0.481836	0	0.46822
Tee through		0	0.060264	0	0.058558
Block valve		0	0.120529	0	0.117116
Check Valve		0	1.805843	0	1.754912
Pipe size change		0	0	0	0
Piping length K-factor			0.450046		0.334376
Pipe fitting K-factor			0.482392		0
Total K-total			0.932438		0.334376
Difference of Elavation	[m]		2.3		0
ΔPf	[kPa]		7.952936		1.441551
ΔP Elavation	[kPa]		13.85819		0
ΔP Specified	[kPa]		0.1836		6.67
ΔPtotal	[kPa]		21.99473		8.111551
P inlet	[kPa]		838.07927		816.08454
P outlet	[kPa]		816.0845		807.973
P inlet (bar)	[bar]				
delta P	[kPa]	21.99473	0.219947	8.111551	0.081116
Differential Pressure	[kPa]				

Table D.1: Hydraulic calculation (cont.)

Section	Unit	P-211		P-212	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		246.1697		210.6179
Pipe ID (Theory)	[mm]		139.0681		128.6346
Velocity (real)	[m/s]		3.867987		4.765497
Mass flow rate	[kg/h]		143000		121000
Density	[kg/m3]		580.9		574.5
Viscosity	[cP]		0.195		0.1832
Pipe ID (real)	[mm]		150		125
Pipe roughness (ε)	[mm]		0.05		0.025
Pipe length	[m]		40.7348		7.8
Outlet Pipe ID	[mm]		168.28		141.3
Calculation					
Volumetric flow rate	[m3/h]		246.1697		210.6179
Pipe cross sectional area	[m2]		0.017671		0.012272
ε/D			0.000333		0.0002
Velocity	[m/s]		3.869544		4.767415
Erosional Velocity	[m/s]		4.149056		4.172103
N_{RE}	[-]		1729091		1868777
fm	[-]		0.015683		0.014276
Velocity head	[kPa]		4.349015		6.528688
ΔP/100m	[kPa/100m]		45.47071		74.56415
ρv2	[kg/m-s2]		8698.03		13057.38
Pipe fitting		unit	K/unit	unit	K/unit
Elbow		4	0.234329	1	0.241068
Tee elbow		0	0.468196	0	0.481708
Tee through		0	0.058553	3	0.06024
Block valve		0	0.117107	5	0.120481
Check Valve		0	1.754868	0	1.805603
Pipe size change		0	0	0	0
Piping length K-factor			4.258988		0.890838
Pipe fitting K-factor			0.937317		1.024192
Total K-total			5.196305		1.91503
Difference of Elavation	[m]		19.17		-0.3
ΔPf	[kPa]		22.59881		12.50263
ΔP Elavation	[kPa]		109.2427		-1.69075
ΔP Specified	[kPa]		0	heat ex	0
ΔPtotal	[kPa]		131.8415		10.81188
P inlet	[kPa]		807.97299		200
P outlet	[kPa]		676.1315		189.1881
P inlet (bar)	[bar]				90.5
delta P	[kPa]	131.8415	1.318415	10.81188	0.108119
Differential Pressure	[kPa]				

Table D.1: Hydraulic calculation (cont.)

Section	Unit	P-213		P-214	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		328.9831		181.4093
Pipe ID (Theori)	[mm]		160.767		119.3823
Velocity (real)	[m/s]		5.169208		4.104614
Mass flow rate	[kg/h]		121000		121000
Density	[kg/m3]		367.8		667
Viscosity	[cP]		0.05079		0.6768
Pipe ID (real)	[mm]		150		125
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		17.5587		53.4413
Outlet Pipe ID	[mm]		168.28		141.3
Calculation					
Volumetric flow rate	[m3/h]		328.9831		181.4093
Pipe cross sectional area	[m2]		0.017671		0.012272
ε/D			0.000167		0.0002
Velocity	[m/s]		5.171288		4.106266
Erosional Velocity	[m/s]		5.214277		3.872015
N_{RE}	[-]		5617247		505851
fm	[-]		0.013454		0.015437
Velocity head	[kPa]		4.917895		5.623285
ΔP/100m	[kPa/100m]		44.1111		69.44615
ρv2	[kg/m-s2]		9835.789		11246.57
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		3	0.234009	4	0.242221
Tee elbow		0	0.467876	0	0.482861
Tee through		1	0.058493	0	0.060457
Block valve		1	0.116987	0	0.120913
Check Valve		1	1.754267	0	1.807765
Pipe size change		0	0	0	0
Piping length K-factor			1.574929		6.599866
Pipe fitting K-factor			2.631774		0.968886
Total K-total			4.206703		7.568752
Difference of Elavation	[m]		2.9337		17.0663
ΔPf	[kPa]		20.68812		42.56125
ΔP Elavation	[kPa]		10.58514		111.6694
ΔP Specified	[kPa]		0.1876	exchanger	0
ΔPtotal	[kPa]		31.46086		154.2307
P inlet	[kPa]		1000		968.53914
P outlet	[kPa]		968.5391		814.3085
P inlet (bar)	[bar]				
delta P	[kPa]	31.46086	0.314609	154.2307	1.542307

Table D.1: Hydraulic calculation (cont.)

Section	Unit	P-215		P-216	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		199.1643		199.1643
Pipe ID (Theory)	[mm]		125.0881		125.0881
Velocity (real)	[m/s]		4.506345		4.506345
Mass flow rate	[kg/h]		143000		143000
Density	[kg/m3]		718		718
Viscosity	[cP]		3.501		3.501
Pipe ID (real)	[mm]		125		125
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		7.8		51.9473
Outlet Pipe ID	[mm]		141.3		141.3
Calculation					
Volumetric flow rate	[m3/h]		199.1643		199.1643
Pipe cross sectional area	[m2]		0.012272		0.012272
ε/D			0.0002		0.0002
Velocity	[m/s]		4.508159		4.508159
Erosional Velocity	[m/s]		3.731967		3.731967
N_{RE}	[-]		115569		115569
fm	[-]		0.018622		0.018622
Velocity head	[kPa]		7.296134		7.296134
ΔP/100m	[kPa/100m]		108.6949		108.6949
ρv2	[kg/m-s2]		14592.27		14592.27
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		1	0.247562	3	0.247562
Tee elbow		0	0.488202	0	0.488202
Tee through		3	0.061458	1	0.061458
Block valve		5	0.122916	1	0.122916
Check Valve		0	1.817779	1	1.817779
Pipe size change		0	0	0	0
Piping length K-factor			1.162013		7.738904
Pipe fitting K-factor			1.046515		2.74484
Total K-total			2.208529		10.48374
Difference of Elavation	[m]		-0.3		1.1325
ΔPf	[kPa]		16.11372		76.49081
ΔP Elavation	[kPa]		-2.11307		7.976854
ΔP Specified	[kPa]		0		0.4762
ΔPtotal	[kPa]		14.00065		84.94386
P inlet	[kPa]		**200**		**1000**
P outlet	[kPa]		185.9994		915.0561
P inlet (bar)	[bar]				
delta P	[kPa]	14.00065	0.140006	84.94386	0.849439

Table D.1: Hydraulic calculation (cont.)

Section	Unit	P-217		P-218	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		212.8293		180.0863
Pipe ID (Theory)	[mm]		129.3081		118.9462
Velocity (real)	[m/s]		4.815531		4.07468
Mass flow rate	[kg/h]		143000		121000
Density	[kg/m3]		671.9		671.9
Viscosity	[cP]		0.7587		0.7588
Pipe ID (real)	[mm]		125		125
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		40.4323		7.8
Outlet Pipe ID	[mm]		141.3		141.3
Calculation					
Volumetric flow rate	[m3/h]		212.8293		180.0863
Pipe cross sectional area	[m2]		0.012272		0.012272
ε/D			0.0002		0.0002
Velocity	[m/s]		4.81747		4.07632
Erosional Velocity	[m/s]		3.857871		3.857871
N_{RE}	[-]		533290.1		451186
fm	[-]		0.015366		0.0156
Velocity head	[kPa]		7.796732		5.582276
ΔP/100m	[kPa/100m]		95.84252		69.66863
ρv2	[kg/m-s2]		15593.46		11164.55
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		4	0.24214	1	0.242413
Tee elbow		0	0.48278	0	0.483053
Tee through		0	0.060441	3	0.060492
Block valve		0	0.120883	5	0.120985
Check Valve		0	1.807613	0	1.808125
Pipe size change		0	0	0	0
Piping length K-factor			4.970202		0.973466
Pipe fitting K-factor			0.96856		1.028815
Total K-total			5.938763		2.002281
Difference of Elavation	[m]		18.8675		-0.3
ΔPf	[kPa]		46.30294		11.17728
ΔP Elavation	[kPa]		124.3621		-1.9774
ΔP Specified	[kPa]		0		0
ΔPtotal	[kPa]		170.665		9.199881
P inlet	[kPa]		915.05614		200
P outlet	[kPa]		744.3911		190.8001
P inlet (bar)	[bar]				
delta P	[kPa]	170.665	1.70665	9.199881	0.091999

Table D.1: Hydraulic calculation (cont.)

Section	Unit	P-219		P-220	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		121.9451		168.5237
Pipe ID (Theory)	[mm]		97.87963		115.0643
Velocity (real)	[m/s]		4.311189		4.505034
Mass flow rate	[kg/h]		121000		121000
Density	[kg/m3]		992.25		718
Viscosity	[cP]		0.656		3.501
Pipe ID (real)	[mm]		100		115
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		21.3814		49.6186
Outlet Pipe ID	[mm]		114.3		127
Calculation					
Volumetric flow rate	[m3/h]		121.9451		168.5237
Pipe cross sectional area	[m2]		0.007854		0.010387
ε/D			0.00025		0.000217
Velocity	[m/s]		4.312925		4.506848
N_{RE}	[m/s]		3.174603		3.731967
fm	[-]		652362.7		106292.6
fm	[-]		0.015581		0.018963
Velocity head	[kPa]		9.22858		7.291891
ΔP/100m	[kPa/100m]		143.7902		120.243
ρv2	[kg/m-s2]		18457.16		14583.78
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		1	0.252026	4	0.2517
Tee elbow		0	0.502826	0	0.495874
Tee through		0	0.06293	0	0.062455
Block valve		1	0.12586	0	0.124909
Check Valve		1	1.883299	0	1.845416
Pipe size change		0	0	0	0
Piping length K-factor			3.331428		8.182088
Pipe fitting K-factor			2.261186		1.006801
Total K-total			5.592613		9.188889
Difference of Elevation	[m]		6.7564		13.2436
ΔPf	[kPa]		51.61188		67.00438
ΔP Elavation	[kPa]		65.76661		93.28236
ΔP Specified	[kPa]		3.283		0
ΔPtotal	[kPa]		120.6615		160.2867
P inlet	[kPa]		1000		879.33851
P outlet	[kPa]		879.3385		719.0518
P inlet (bar)	[bar]				
delta P	[kPa]	120.6615	1.206615	160.2867	1.602867

Table D.1: Hydraulic calculation (cont.)

Section	Unit	L-201/202		L-203	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		261.2206		299.0756
Pipe ID (Theory)	[mm]		143.2564		153.2853
Velocity (real)	[m/s]		4.104477		4.69928
Mass flow rate	[kg/h]		110000		110000
Density	[kg/m3]		421.1		367.8
Viscosity	[cP]		0.08331		0.05079
Pipe ID (real)	[mm]		150		150
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		503.5		8.3035
Outlet Pipe ID	[mm]		141.3		141.3
Calculation					
Volumetric flow rate	[m3/h]		261.2206		299.0756
Pipe cross sectional area	[m2]		0.017671		0.017671
ε/D			0.000167		0.000167
Velocity	[m/s]		4.106129		4.701171
Erosional Velocity	[m/s]		4.873123		5.214277
N_{RE}	[-]		3113235		5106588
fm	[-]		0.013621		0.013475
Velocity head	[kPa]		3.549934		4.064376
ΔP/100m	[kPa/100m]		32.23626		36.51296
ρv2	[kg/m-s2]		7099.869		8128.751
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		4	0.234124	1	0.234023
Tee elbow		0	0.46799	0	0.46789
Tee through		0	0.058515	0	0.058496
Block valve		4	0.11703	0	0.116992
Check Valve		0	1.754482	0	1.754294
Pipe size change		0	0	0	0
Piping length K-factor			45.72184		0.745958
Pipe fitting K-factor			1.404613		0.234023
Total K-total			47.12646		0.979981
Difference of Elavation	[m]		0		-0.5
ΔPf	[kPa]		167.2958		3.983013
ΔP Elevation	[kPa]		0		-1.80406
ΔP Specified	[kPa]	heat ex	47.09		18.83
ΔPtotal	[kPa]		214.3858		21.00895
P inlet	[kPa]		9050		8835.6142
P outlet	[kPa]		8835.614		8814.605
P inlet (bar)	[bar]		90.5		
delta P	[kPa]	214.3858	2.143858	21.00895	0.21009

Table D.1: Hydraulic calculation (cont.)

Section	Unit	L-204		L-205	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		311.5265		336.9066
Pipe ID (Theory)	[mm]		156.4435		162.6915
Velocity (real)	[m/s]		4.894917		5.293706
Mass flow rate	[kg/h]		110000		110000
Density	[kg/m3]		353.1		326.5
Viscosity	[cP]		0.04534		0.03774
Pipe ID (real)	[mm]		150		150
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		4.1		16.9868
Outlet Pipe ID	[mm]		141.3		141.3
Calculation					
Volumetric flow rate	[m3/h]		311.5265		336.9066
Pipe cross sectional area	[m2]		0.017671		0.017671
ε/D			0.000167		0.000167
Velocity	[m/s]		4.896887		5.295837
Erosional Velocity	[m/s]		5.321709		5.534245
N_{RE}	[-]		5720415		6872380
fm	[-]		0.01345		0.013415
Velocity head	[kPa]		4.233581		4.578491
ΔP/100m	[kPa/100m]		37.96229		40.94739
ρv2	[kg/m-s2]		8467.162		9156.983
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		1	0.234007	3	0.233983
Tee elbow		0	0.467873	0	0.46785
Tee through		0	0.058493	0	0.058488
Block valve		0	0.116986	0	0.116977
Check Valve		0	1.754262	0	1.754218
Pipe size change		0	0	0	0
Piping length K-factor			0.367645		1.519202
Pipe fitting K-factor			0.234007		0.701949
Total K-total			0.601651		2.221151
Difference of Elavation	[m]		-0.5		1.5
ΔPf	[kPa]		2.547139		10.16952
ΔP Elavation	[kPa]		-1.73196		4.804448
ΔP Specified	[kPa]	exchanger	6.14		0
ΔPtotal	[kPa]		6.955184		14.97397
P inlet	[kPa]		8814.6052		8807.65
P outlet	[kPa]		8807.65		8792.676
P inlet (bar)	[bar]				
delta P	[kPa]	6.955184	0.069552	14.97397	0.14974

Table D.1: Hydraulic calculation (cont.)

Section	Unit	L-206		L-207	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		261.2206		299.0756
Pipe ID (Theori)	[mm]		143.2564		153.2853
Velocity (real)	[m/s]		4.104477		4.69928
Mass flow rate	[kg/h]		110000		110000
Density	[kg/m3]		421.1		367.8
Viscosity	[cP]		0.08331		0.02868
Pipe ID (real)	[mm]		150		150
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		498.9337		111.1091
Outlet Pipe ID	[mm]		141.3		141.3
Calculation					
Volumetric flow rate	[m3/h]		261.2206		299.0756
Pipe cross sectional area	[m2]		0.017671		0.017671
ε/D			0.000167		0.000167
Velocity	[m/s]		4.106129		4.701171
Erosional Velocity	[m/s]		4.873123		5.214277
N_{RE}	[-]		3113235		9043362
fm	[-]		0.013621		0.013373
Velocity head	[kPa]		3.549934		4.064376
ΔP/100m	[kPa/100m]		32.23626		36.23409
ρv2	[kg/m-s2]		7099.869		8128.751
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		4	0.234124	4	0.233955
Tee elbow		0	0.46799	0	0.467822
Tee through		0	0.058515	0	0.058483
Block valve		0	0.11703	0	0.116967
Check Valve		0	1.754482	0	1.754166
Pipe size change		0	0	0	0
Piping length K-factor			45.30719		9.905426
Pipe fitting K-factor			0.936495		0.935821
Total K-total			46.24368		10.84125
Difference of Elavation	[m]		2.9337		1.698
ΔPf	[kPa]		164.162		44.0629
ΔP Elavation	[kPa]		12.11909		6.126584
ΔP Specified	[kPa]	heat ex	0.07905		128.1
ΔPtotal	[kPa]		176.3602		178.2895
P inlet	[kPa]		8792.6761		8835.6142
P outlet	[kPa]		8616.316		8657.325
P inlet (bar)	[bar]		90.5		
delta P	[kPa]	176.3602	1.763602	178.2895	1.782895

Table D.1: Hydraulic calculation (cont.)

Section	Unit	L-101		L-102	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		307.0053		390.3478
Pipe ID (Theory)	[mm]		155.3042		175.1201
Velocity (real)	[m/s]		4.823877		3.450043
Mass flow rate	[kg/h]		110000		110000
Density	[kg/m3]		358.3		281.8
Viscosity	[cP]		0.02859		0.02693
Pipe ID (real)	[mm]		150		200
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		13.8645		40.5
Outlet Pipe ID	[mm]		141.3		219.08
Calculation					
Volumetric flow rate	[m3/h]		307.0053		390.3478
Pipe cross sectional area	[m2]		0.017671		0.031416
ε/D			0.000167		0.000125
Velocity	[m/s]		4.825818		3.451432
Erosional Velocity	[m/s]		5.282951		5.957026
N_{RE}	[-]		9071830		7223272
fm	[-]		0.013372		0.01272
Velocity head	[kPa]		4.172139		1.678455
ΔP/100m	[kPa/100m]		37.19362		10.67503
ρv2	[kg/m-s2]		8344.278		3356.91
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.233955	0	0.225511
Tee elbow		0	0.467822	0	0.450911
Tee through		3	0.058483	0	0.056371
Block valve		4	0.116966	0	0.112742
Check Valve		0	1.754165	0	1.690708
Pipe size change		0	0	0	0
Piping length K-factor			1.235987		2.575813
Pipe fitting K-factor			1.111225		0
Total K-total			2.347212		2.575813
Difference of Elavation	[m]		0.4445		0
ΔPf	[kPa]		9.792894		4.323385
ΔP Elavation	[kPa]		1.562383		0
ΔP Specified	[kPa]	heat ex	20		0
ΔPtotal	[kPa]		31.35528		4.323385
P inlet	[kPa]		8792.6761		8761.3208
P outlet	[kPa]		8761.321		8756.997
P inlet (bar)	[bar]				
delta P	[kPa]	31.35528	0.313553	4.323385	0.043234

Table D.1: Hydraulic calculation (cont.)

Section	**Unit**	**L-303**		**L-304**	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		840.9786		834.5979
Pipe ID (Theori)	[mm]		257.0411		256.0642
Velocity (real)	[m/s]		4.757051		4.720958
Mass flow rate	[kg/h]		**110000**		**110000**
Density	[kg/m3]		**130.8**		**131.8**
Viscosity	[cP]		**0.01842**		**0.01842**
Pipe ID (real)	[mm]		**250**		**250**
Pipe roughness (ε)	[mm]		**0.025**		**0.025**
Pipe length	[m]		**24.8042**		**25.8042**
Outlet Pipe ID	[mm]		**273.05**		**273.05**
Calculation					
Volumetric flow rate	[m3/h]		840.9786		834.5979
Pipe cross sectional area	[m2]		0.049087		0.049087
ε/D			0.0001		0.0001
Velocity	[m/s]		4.758965		4.722858
Erosional Velocity	[m/s]		8.743718		8.710484
N_{RE}	[-]		8448326		8448326
fm	[-]		0.0122		0.0122
Velocity head	[kPa]		1.481163		1.469925
ΔP/100m	[kPa/100m]		7.227811		7.172972
ρv2	[kg/m-s2]		2962.326		2939.85
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		**2**	0.220415	**2**	0.220415
Tee elbow		**0**	0.440735	**0**	0.440735
Tee through		**0**	0.055098	**0**	0.055098
Block valve		**0**	0.110196	**0**	0.110196
Check Valve		**0**	1.652578	**0**	1.652578
Pipe size change		**0**	0	**0**	0
Piping length K-factor			1.210401		1.259199
Pipe fitting K-factor			0.440829		0.440829
Total K-total			1.65123		1.700028
Difference of Elavation	[m]		-2.3041		2.3042
ΔPf	[kPa]		2.445741		2.498914
ΔP Elevation	[kPa]		-2.9565		2.979234
ΔP Specified	[kPa]	exchanger	40.16		4462
ΔPtotal	[kPa]		39.64924		4467.478
P inlet	[kPa]		17067.745		17028.095
P outlet	[kPa]		17028.1		12560.62
P inlet (bar)	[bar]				
delta P	[kPa]	39.64924	0.396492	4467.478	44.67478

Table D.1: Hydraulic calculation (cont.)

Section	Unit	L-305		L-306	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		1017.576		1149.906
Pipe ID (Theori)	[mm]		282.7442		300.567
Velocity (real)	[m/s]		5.755987		4.517027
Mass flow rate	[kg/h]		110000		110000
Density	[kg/m3]		108.1		95.66
Viscosity	[cP]		0.01616		0.01614
Pipe ID (real)	[mm]		250		300
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		25.8042		25.8042
Outlet Pipe ID	[mm]		273.05		323.85
Calculation					
Volumetric flow rate	[m3/h]		1017.576		1149.906
Pipe cross sectional area	[m2]		0.049087		0.070686
ε/D			0.0001		8.33E-05
Velocity	[m/s]		5.758304		4.518845
Erosional Velocity	[m/s]		9.618053		10.22433
N_{RE}	[-]		9629837		8034808
fm	[-]		0.012174		0.01184
Velocity head	[kPa]		1.792193		0.976687
ΔP/100m	[kPa/100m]		8.726915		3.85468
ρv2	[kg/m-s2]		3584.387		1953.373
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.220403	2	0.217033
Tee elbow		0	0.440723	0	0.433966
Tee through		0	0.055096	0	0.054252
Block valve		0	0.110191	0	0.108504
Check Valve		0	1.652556	0	1.627187
Pipe size change		0	0	0	0
Piping length K-factor			1.256511		1.018412
Pipe fitting K-factor			0.440806		0.434066
Total K-total			1.697317		1.452478
Difference of Elavation	[m]		-2.3042		2.3042
ΔPf	[kPa]		3.04192		1.418616
ΔP Elavation	[kPa]		-2.44351		2.162318
ΔP Specified	[kPa]		0		2950.49
ΔPtotal	[kPa]		0.598406		2954.071
P inlet	[kPa]		12560.617		12560.019
P outlet	[kPa]		12560.02		9605.948
P inlet (bar)	[bar]				
delta P	[kPa]	0.598406	0.005984	2954.071	29.54071

Table D.1: Hydraulic calculation (cont.)

Section	Unit	L-307		L-308	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		1392.934		1392.934
Pipe ID (Theori)	[mm]		330.8076		330.8076
Velocity (real)	[m/s]		5.471682		5.471682
Mass flow rate	[kg/h]		110000		110000
Density	[kg/m3]		78.97		78.97
Viscosity	[cP]		0.01463		0.01463
Pipe ID (real)	[mm]		300		300
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		15		2.5
Outlet Pipe ID	[mm]		323.85		323.85
Calculation					
Volumetric flow rate	[m3/h]		1392.934		1392.934
Pipe cross sectional area	[m2]		0.070686		0.070686
ε/D			8.33E-05		8.33E-05
Velocity	[m/s]		5.473885		5.473885
Erosional Velocity	[m/s]		11.25302		11.25302
N_{RE}	[-]		8864102		8864102
fm	[-]		0.011816		0.011816
Velocity head	[kPa]		1.183105		1.183105
ΔP/100m	[kPa/100 m]		4.660006		4.660006
ρv2	[kg/m-s2]		2366.211		2366.211
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.217024	2	0.217024
Tee elbow		0	0.433957	0	0.433957
Tee through		3	0.05425	0	0.05425
Block valve		4	0.108501	1	0.108501
Check Valve		0	1.627169	0	1.627169
Pipe size change		0	0	0	0
Piping length K-factor			0.590819		0.09847
Pipe fitting K-factor			1.0308		0.542548
Total K-total			1.621619		0.641017
Difference of Elavation	[m]		0		1.5
ΔPf	[kPa]		1.918546		0.758391
ΔP Elavation	[kPa]		0		1.162044
ΔP Specified	[kPa]	exchanger	0		0
ΔPtotal	[kPa]		1.918546		1.920435
P inlet	[kPa]		**9605.948**		**9604.0294**
P outlet	[kPa]		9604.029		9602.109
P inlet (bar)	[bar]				
delta P	[kPa]	1.918546	0.019185	1.920435	0.019204

Table D.1: Hydraulic calculation (cont.)

Section	Unit	L-309=304		L-310	
Velocity	[m/s]		4.5		17.5
Volume	[m3/h]		834.5979		6376.812
Pipe ID (Theori)	[mm]		256.0642		358.9213
Velocity (real)	[m/s]		4.720958		18.4035
Mass flow rate	[kg/h]		110000		110000
Density	[kg/m3]		131.8		17.25
Viscosity	[cP]		0.01842		28.263238
Pipe ID (real)	[mm]		250		350
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		25.8242		17
Outlet Pipe ID	[mm]		273.05		377.6
Calculation					
Volumetric flow rate	[m3/h]		834.5979		6376.812
Pipe cross sectional area	[m2]		0.049087		0.096211
ε/D			0.0001		7.14E-05
Velocity	[m/s]		4.722858		18.4109
Erosional Velocity	[m/s]		8.710484		24.07717
N_{RE}	[-]		8448326		3932.877
fm	[-]		0.0122		0.039824
Velocity head	[kPa]		1.469925		2.923542
ΔP/100m	[kPa/100m]		7.172972		33.26498
ρv2	[kg/m-s2]		2939.85		5847.084
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.220415	2	0.417928
Tee elbow		0	0.440735	0	0.632442
Tee through		3	0.055098	0	0.091769
Block valve		4	0.110196	0	0.183537
Check Valve		0	1.652578	0	1.990257
Pipe size change		0	0	0	0
Piping length K-factor			1.260175		1.934314
Pipe fitting K-factor			1.046905		0.835855
Total K-total			2.30708		2.770169
Difference of Elavation	[m]		2.3042		2
ΔPf	[kPa]		3.391234		8.098706
ΔP Elavation	[kPa]		2.979234		0.338445
ΔP Specified	[kPa]		8050		0
ΔPtotal	[kPa]		8056.37		8.437151
P inlet	[kPa]		9602.109		1545.7385
P outlet	[kPa]		1545.739		1537.301
P inlet (bar)	[bar]				
delta P	[kPa]	8056.37	80.5637	8.437151	0.084372

Table D.1: Hydraulic calculation (cont.)

Section	Unit	W-101		W-102	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		11.66		16.51467
Pipe ID (Theori)	[mm]		30.26631		36.02011
Velocity (real)	[m/s]		4.025608		5.701678
Mass flow rate	[kg/h]		19822		24772
Density	[kg/m3]		1700		1500
Viscosity	[cP]		0.8904		0.8371
Pipe ID (real)	[mm]		32		32
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		86.7355		6.4192
Outlet Pipe ID	[mm]		42.16		42.16
Calculation					
Volumetric flow rate	[m3/h]		11.66		16.51467
Pipe cross sectional area	[m2]		0.000804		0.000804
ε/D			0.000781		0.000781
Velocity	[m/s]		4.027228		5.703973
Erosional Velocity	[m/s]		2.425356		2.581989
N_{RE}	[-]		246048.1		327070.5
fm	[-]		0.019874		0.019565
Velocity head	[kPa]		13.78578		24.40148
ΔP/100m	[kPa/100m]		856.1703		1491.902
ρv2	[kg/m-s2]		27571.56		48802.96
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.362001	3	0.361196
Tee elbow		0	0.720751	0	0.719946
Tee through		3	0.090297	0	0.090146
Block valve		4	0.180594	0	0.180292
Check Valve		0	2.696721	0	2.695211
Pipe size change		0	0	0	0
Piping length K-factor			53.86736		3.924687
Pipe fitting K-factor			1.717271		1.083588
Total K-total			55.58463		5.008275
Difference of Elavation	[m]		5		0.9192
ΔPf	[kPa]		766.2775		122.2093
ΔP Elavation	[kPa]		83.385		13.52603
ΔP Specified	[kPa]	heat ex	0		20
ΔPtotal	[kPa]		849.6625		155.7354
P inlet	[kPa]		1000		331
P outlet	[kPa]		150.3375		175.2646
P inlet (bar)	[bar]		10		
delta P	[kPa]	849.6625	8.496625	155.7354	1.557354

Table D.1: Hydraulic calculation (cont.)

Section	Unit	W-103		W-104	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		24.23875		24.23875
Pipe ID (Theori)	[mm]		43.63804		43.63804
Velocity (real)	[m/s]		5.355784		5.355784
Mass flow rate	[kg/h]		24772		24772
Density	[kg/m3]		1022		1022
Viscosity	[cP]		1.501		1.501
Pipe ID (real)	[mm]		40		40
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		3.9192		10.5
Outlet Pipe ID	[mm]		48.26		48.26
Calculation					
Volumetric flow rate	[m3/h]		24.23875		24.23875
Pipe cross sectional area	[m2]		0.001257		0.001257
ε/D			0.000625		0.000625
Velocity	[m/s]		5.35794		5.35794
Erosional Velocity	[m/s]		3.128056		3.128056
N_{RE}	[-]		145924.4		145924.4
fm	[-]		0.020007		0.020007
Velocity head	[kPa]		14.66954		14.66954
ΔP/100m	[kPa/100m]		733.7217		733.7217
ρv2	[kg/m-s2]		29339.08		29339.08
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.332482	2	0.332482
Tee elbow		0	0.659482	0	0.659482
Tee through		0	0.082778	1	0.082778
Block valve		1	0.165556	1	0.165556
Check Valve		0	2.462779	1	2.462779
Pipe size change		0	0	0	0
Piping length K-factor			1.960254		5.251751
Pipe fitting K-factor			0.83052		3.376078
Total K-total			2.790774		8.627829
Difference of Elavation	[m]		-0.9192		5
ΔPf	[kPa]		40.93937		126.5663
ΔP Elavation	[kPa]		-9.21573		50.1291
ΔP Specified	[kPa]	exchanger	0		0
ΔPtotal	[kPa]		31.72364		176.6954
P inlet	[kPa]		175.26465		143.54101
P outlet	[kPa]		143.541		-33.1544
P inlet (bar)	[bar]				
delta P	[kPa]	31.72364	0.317236	176.6954	1.766954

Table D.1: Hydraulic calculation (cont.)

Section	Unit	W-301		W-302	
Velocity	[m/s]		17.5		4.5
Volume	[m3/h]		916.5889		25.07844
Pipe ID (Theori)	[mm]		136.077		44.38747
Velocity (real)	[m/s]		14.40207		5.541321
Mass flow rate	[kg/h]		23980		23980
Density	[kg/m3]		26.16222		956.2
Viscosity	[cP]		1.6760441		0.3113
Pipe ID (real)	[mm]		150		40
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		4.7888		23.7779
Outlet Pipe ID	[mm]		168.28		48.26
Calculation					
Volumetric flow rate	[m3/h]		916.5889		25.07844
Pipe cross sectional area	[m2]		0.017671		0.001257
ε/D			0.000167		0.000625
Velocity	[m/s]		14.40787		5.543551
Erosional Velocity	[m/s]		19.55072		3.233893
N_{RE}	[-]		33734.95		681110.7
fm	[-]		0.02341		0.018193
Velocity head	[kPa]		2.715464		14.69247
ΔP/100m	[kPa/100m]		42.3786		668.2407
ρv2	[kg/m-s2]		5430.927		29384.95
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		3	0.257581	4	0.328175
Tee elbow		0	0.491448	0	0.655175
Tee through		0	0.062913	3	0.08197
Block valve		0	0.125826	5	0.16394
Check Valve		0	1.798464	1	2.454702
Pipe size change		0	0	0	0
Piping length K-factor			0.747359		10.81463
Pipe fitting K-factor			0.772743		4.833013
Total K-total			1.520102		15.64764
Difference of Elavation	[m]		-2.2888		0.6779
ΔPf	[kPa]		4.127781		229.9025
ΔP Elavation	[kPa]		-0.58742		6.35892
ΔP Specified	[kPa]	heat ex	14.24		0
ΔPtotal	[kPa]		17.78036		236.2614
P inlet	[kPa]		344.91766		327.13731
P outlet	[kPa]		327.1373		90.87586
P inlet (bar)	[bar]		1.45		
delta P	[kPa]	17.78036	0.177804	236.2614	2.362614

Table D.1: Hydraulic calculation (cont.)

Section	Unit	W-304		W-305	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		25.07319		25.38909
Pipe ID (Theori)	[mm]		44.38283		44.66155
Velocity (real)	[m/s]		5.540162		5.609964
Mass flow rate	[kg/h]		23980		23980
Density	[kg/m3]		956.4		944.5
Viscosity	[cP]		0.3111		0.2668
Pipe ID (real)	[mm]		40		40
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		9.7888		8.0865
Outlet Pipe ID	[mm]		48.26		48.26
Calculation					
Volumetric flow rate	[m3/h]		25.07319		25.38909
Pipe cross sectional area	[m2]		0.001257		0.001257
ε/D			0.000625		0.000625
Velocity	[m/s]		5.542392		5.612222
Erosional Velocity	[m/s]		3.233555		3.253861
N_{RE}	[-]		681548.5		794714.2
fm	[-]		0.018192		0.018108
Velocity head	[kPa]		14.6894		14.87448
ΔP/100m	[kPa/100m]		668.0871		673.3691
ρv2	[kg/m-s2]		29378.8		29748.95
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		3	0.328174	5	0.328007
Tee elbow		0	0.655174	0	0.655007
Tee through		1	0.08197	0	0.081939
Block valve		1	0.16394	0	0.163877
Check Valve		1	2.454701	0	2.454387
Pipe size change		0	0	0	0
Piping length K-factor			4.452034		3.660767
Pipe fitting K-factor			3.685133		1.640033
Total K-total			8.137167		5.3008
Difference of Elavation	[m]		-2.2888		0.8001
ΔPf	[kPa]		119.5301		78.84663
ΔP Elevation	[kPa]		-21.4742		7.413363
ΔP Specified	[kPa]		8.519		0.1029
ΔPtotal	[kPa]		106.5749		86.36289
P inlet	[kPa]		1200		1093.4251
P outlet	[kPa]		1093.425		1007.062
P inlet (bar)	[bar]				
delta P	[kPa]	106.5749	1.065749	86.36289	0.863629

Table D.1: Hydraulic calculation (cont.)

Section	Unit	W-306		W-307	
Velocity	[m/s]		17.5		17.5
Volume	[m3/h]		8106.829		28030.39
Pipe ID (Theori)	[mm]		404.6904		752.5095
Velocity (real)	[m/s]		17.91282		17.61731
Mass flow rate	[kg/h]		23980		23980
Density	[kg/m3]		2.958		0.8555
Viscosity	[cP]		0.01819		0.01247
Pipe ID (real)	[mm]		400		750
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		8.9887		9.7888
Outlet Pipe ID	[mm]		406.4		762
Calculation					
Volumetric flow rate	[m3/h]		8106.829		28030.39
Pipe cross sectional area	[m2]		0.125664		0.441786
ε/D			6.25E-05		3.33E-05
Velocity	[m/s]		17.92003		17.6244
Erosional Velocity	[m/s]		58.14347		108.116
N_{RE}	[-]		1165639		906836.7
fm	[-]		0.012689		0.012555
Velocity head	[kPa]		0.474947		0.132867
ΔP/100m	[kPa/100m]		1.506622		0.222416
ρv2	[kg/m-s2]		949.8947		265.7349
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		4	0.213386	3	0.207656
Tee elbow		0	0.426086	0	0.414429
Tee through		0	0.053304	0	0.051859
Block valve		0	0.106607	0	0.103717
Check Valve		0	1.596537	0	1.552454
Pipe size change		0	0	0	0
Piping length K-factor			0.285138		0.163861
Pipe fitting K-factor			0.853545		0.622967
Total K-total			1.138684		0.786828
Difference of Elavation	[m]		1.4887		-2.2888
ΔPf	[kPa]		0.540815		0.104544
ΔP Elavation	[kPa]		0.043199		-0.01921
ΔP Specified	[kPa]	exchanger	0		4.997
ΔPtotal	[kPa]		0.584014		5.082335
P inlet	[kPa]		1007.0622		350
P outlet	[kPa]		1006.478		344.9177
P inlet (bar)	[bar]				
delta P	[kPa]	0.584014	0.00584	5.082335	0.050823

Table D.1: Hydraulic calculation (cont.)

Section	Unit	W-501		W-502	
Velocity	[m/s]		17.5		4.5
Volume	[m3/h]		19005.31		16.10542
Pipe ID (Theori)	[mm]		619.6334		35.57101
Velocity (real)	[m/s]		18.66402		5.560385
Mass flow rate	[kg/h]		15400		15400
Density	[kg/m3]		0.8103		956.2
Viscosity	[cP]		0.01333		0.3113
Pipe ID (real)	[mm]		600		32
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		16.6084		71.6459
Outlet Pipe ID	[mm]		609.6		42.16
Calculation					
Volumetric flow rate	[m3/h]		19005.31		16.10542
Pipe cross sectional area	[m2]		0.282743		0.000804
ε/D			4.17E-05		0.000781
Velocity	[m/s]		18.67153		5.562623
Erosional Velocity	[m/s]		111.0905		3.233893
N_{RE}	[-]		680999.7		546763.2
fm	[-]		0.013192		0.019164
Velocity head	[kPa]		0.141246		14.79374
ΔP/100m	[kPa/100m]		0.310561		885.9441
ρv2	[kg/m-s2]		282.4918		29587.48
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		4	0.209641	2	0.360213
Tee elbow		0	0.418108	0	0.718963
Tee through		0	0.052337	0	0.089962
Block valve		0	0.104674	0	0.179924
Check Valve		0	1.565703	0	2.693368
Pipe size change		0	0	0	0
Piping length K-factor			0.365173		42.90616
Pipe fitting K-factor			0.838566		0.720426
Total K-total			1.203739		43.62658
Difference of Elavation	[m]		1.6084		8.6054
ΔPf	[kPa]		0.170023		645.4004
ΔP Elavation	[kPa]		0.012785		80.72142
ΔP Specified	[kPa]	heat ex	0.1955		0
ΔPtotal	[kPa]		0.378308		726.1218
P inlet	[kPa]		950		949.62169
P outlet	[kPa]		949.6217		223.4999
P inlet (bar)	[bar]		90.5		
delta P	[kPa]	0.378308	0.003783	726.1218	7.261218

Table D.1: Hydraulic calculation (cont.)

Section	Unit	W-503		W-504	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		16.10205		15.52028
Pipe ID (Theori)	[mm]		35.56729		34.91885
Velocity (real)	[m/s]		5.559222		0.201786
Mass flow rate	[kg/h]		15400		15400
Density	[kg/m3]		956.4		992.25
Viscosity	[cP]		0.3111		0.656
Pipe ID (real)	[mm]		32		164.9
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		7.8		2.5
Outlet Pipe ID	[mm]		42.16		168.3
Calculation					
Volumetric flow rate	[m3/h]		16.10205		15.52028
Pipe cross sectional area	[m2]		0.000804		0.021357
ε/D			0.000781		0.000152
Velocity	[m/s]		5.56146		0.201867
Erosional Velocity	[m/s]		3.233555		3.174603
N_{RE}	[-]		547114.7		50350.51
fm	[-]		0.019163		0.021488
Velocity head	[kPa]		14.79065		0.020217
ΔP/100m	[kPa/100m]		885.7404		0.26345
ρv2	[kg/m-s2]		29581.3		40.43458
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		1	0.360212	2	0.246695
Tee elbow		0	0.718962	0	0.477502
Tee through		3	0.089962	1	0.060681
Block valve		5	0.179923	1	0.121362
Check Valve		0	2.693367	1	1.76084
Pipe size change		0	0	0	0
Piping length K-factor			4.671043		0.325774
Pipe fitting K-factor			1.529714		2.436273
Total K-total			6.200757		2.762046
Difference of Elavation	[m]		1.7447		1.5
ΔPf	[kPa]		91.71321		0.055841
ΔP Elavation	[kPa]		16.36927		14.60096
ΔP Specified	[kPa]	exchanger	20		0
ΔPtotal	[kPa]		128.0825		14.6568
P inlet	[kPa]		223.49988		1700
P outlet	[kPa]		95.41739		1685.343
P inlet (bar)	[bar]				
delta P	[kPa]	128.0825	1.280825	14.6568	0.146568

Table D.1: Hydraulic calculation (cont.)

Section	Unit	W-505	
Velocity	[m/s]		17.5
Volume	[m3/h]		5484.33
Pipe ID (Theori)	[mm]		332.8582
Velocity (real)	[m/s]		21.54339
Mass flow rate	[kg/h]		15400
Density	[kg/m3]		2.808
Viscosity	[cP]		0.0193
Pipe ID (real)	[mm]		300
Pipe roughness (ε)	[mm]		0.025
Pipe length	[m]		15.9553
Outlet Pipe ID	[mm]		323.85
Calculation			
Volumetric flow rate	[m3/h]		5484.33
Pipe cross sectional area	[m2]		0.070686
ε/D			8.33E-05
Velocity	[m/s]		21.55206
Erosional Velocity	[m/s]		59.67624
N_{RE}	[-]		940697
fm	[-]		0.013296
Velocity head	[kPa]		0.652146
ΔP/100m	[kPa/100m]		2.890365
ρv2	[kg/m-s2]		1304.291
Pipe fitting		**unit**	**K/unit**
Elbow		4	0.217784
Tee elbow		0	0.434717
Tee through		0	0.054393
Block valve		0	0.108786
Check Valve		0	1.628595
Pipe size change		0	0
Piping length K-factor			0.707152
Pipe fitting K-factor			0.871135
Total K-total			1.578288
Difference of Elavation	[m]		0.9553
ΔPf	[kPa]		1.029273
ΔP Elavation	[kPa]		0.026315
ΔP Specified	[kPa]		0
ΔPtotal	[kPa]		1.055588
P inlet	[kPa]		1685.3432
P outlet	[kPa]		1684.288
P inlet (bar)	[bar]		
delta P	[kPa]	1.055588	0.010556

Table D.1: Hydraulic calculation (cont.)

Section	Unit	H-601		H-602	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		115.3947		112.1591
Pipe ID (Theori)	[mm]		95.2145		93.87012
Velocity (real)	[m/s]		5.036556		4.895333
Mass flow rate	[kg/h]		88000		88000
Density	[kg/m3]		762.6		784.6
Viscosity	[cP]		2.018		0.06754
Pipe ID (real)	[mm]		90		90
Pipe roughness (ε)	[mm]		0.025	0.025	0.025
Pipe length	[m]		16.5932		24.0227
Outlet Pipe ID	[mm]		101.6		101.6
Calculation					
Volumetric flow rate	[m3/h]		115.3947		112.1591
Pipe cross sectional area	[m2]		0.006362		0.006362
ε/D			0.000278		0.000278
Velocity	[m/s]		5.038584		4.897303
Erosional Velocity	[m/s]		3.621192		3.570063
N_{RE}	[-]		171366.8		5120198
fm	[-]		0.017971		0.014859
Velocity head	[kPa]		9.680187		9.408757
ΔP/100m	[kPa/100m]		193.2907		155.3386
ρv2	[kg/m-s2]		19360.37		18817.51
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.261113	4	0.256601
Tee elbow		0	0.517557	0	0.513045
Tee through		1	0.064986	0	0.06414
Block valve		1	0.129973	0	0.128281
Check Valve		1	1.932086	0	1.923626
Pipe size change		0	0	0	0
Piping length K-factor			3.313274		3.966149
Pipe fitting K-factor			2.649271		1.026403
Total K-total			5.962545		4.992551
Difference of Elavation	[m]		8.89		-7.3787
ΔPf	[kPa]		57.71855		46.9737
ΔP Elevation	[kPa]		66.50703		-56.7933
ΔP Specified	[kPa]	heat ex	118.9		2
ΔPtotal	[kPa]		243.1256		-7.81961
P inlet	[kPa]		500		256.87441
P outlet	[kPa]		256.8744		264.694
P inlet (bar)	[bar]		550		
delta P	[kPa]	243.1256	2.431256	-7.81961	-0.0782

Table D.1: Hydraulic calculation (cont.)

Section	Unit	H-603		H-604	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		135.4471		116.4329
Pipe ID (Theori)	[mm]		103.1561		95.64187
Velocity (real)	[m/s]		5.911771		5.081871
Mass flow rate	[kg/h]		88000		88000
Density	[kg/m3]		649.7		755.8
Viscosity	[cP]		0.2848		1.697
Pipe ID (real)	[mm]		90		90
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		20.9684		79.089
Outlet Pipe ID	[mm]		101.6		101.6
Calculation					
Volumetric flow rate	[m3/h]		135.4471		116.4329
Pipe cross sectional area	[m2]		0.006362		0.006362
ε/D			0.000278		0.000278
Velocity	[m/s]		5.914151		5.083916
Erosional Velocity	[m/s]		3.923228		3.637446
N_{RE}	[-]		1214249		203782.1
fm	[-]		0.015341		0.017583
Velocity head	[kPa]		11.36234		9.76728
ΔP/100m	[kPa/100m]		193.6764		190.8202
ρv2	[kg/m-s2]		22724.67		19534.56
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		3	0.257103	4	0.26037
Tee elbow		0	0.513548	0	0.516815
Tee through		0	0.064235	3	0.064847
Block valve		0	0.128469	5	0.129694
Check Valve		0	1.924569	0	1.930694
Pipe size change		0	0	0	0
Piping length K-factor			3.574162		15.45137
Pipe fitting K-factor			0.77131		1.884494
Total K-total			4.345472		17.33586
Difference of Elavation	[m]		0.5334		1.9347
ΔPf	[kPa]		49.37472		169.3242
ΔP Elavation	[kPa]		3.399655		14.34464
ΔP Specified	[kPa]	exchanger	19.91		0
ΔPtotal	[kPa]		72.68438		183.6688
P inlet	[kPa]		264.69402		192.00964
P outlet	[kPa]		192.0096		8.340798
P inlet (bar)	[bar]				
delta P	[kPa]	72.68438	0.726844	183.6688	1.836688

Table D.1: Hydraulic calculation (cont.)

cc	Unit	H-605	
Velocity	[m/s]		4.5
Volume	[m3/h]		88.68733
Pipe ID (Theori)	[mm]		83.47203
Velocity (real)	[m/s]		4.899079
Mass flow rate	[kg/h]		88000
Density	[kg/m3]		992.25
Viscosity	[cP]		0.656
Pipe ID (real)	[mm]		80
Pipe roughness (ε)	[mm]		0.025
Pipe length	[m]		7.8
Outlet Pipe ID	[mm]		88.9
Calculation			
Volumetric flow rate	[m3/h]		88.68733
Pipe cross sectional area	[m2]		0.005027
ε/D			0.000313
Velocity	[m/s]		4.901051
Erosional Velocity	[m/s]		3.174603
N_{RE}	[-]		593057
fm	[-]		0.016202
Velocity head	[kPa]		11.91707
ΔP/100m	[kPa/100m]		241.3537
ρv2	[kg/m-s2]		23834.14
Pipe fitting		**unit**	**K/unit**
Elbow		1	0.264849
Tee elbow		0	0.528349
Tee through		3	0.066128
Block valve		5	0.132256
Check Valve		0	1.978779
Pipe size change		0	0
Piping length K-factor			1.579716
Pipe fitting K-factor			1.124512
Total K-total			2.704228
Difference of Elavation	[m]		-0.3
ΔPf	[kPa]		32.22648
ΔP Elavation	[kPa]		-2.92019
ΔP Specified	[kPa]		0
ΔPtotal	[kPa]		29.30628
P inlet	[kPa]		200
P outlet	[kPa]		170.6937
P inlet (bar)	[bar]		
delta P	[kPa]	29.30628	0.293063

Table D.1: Hydraulic calculation (cont.)

Section	Unit	C-601		C-602	
Velocity	[m/s]		17.5		17.5
Volume	[m3/h]		83825.88		25258.19
Pipe ID (Theori)	[mm]		1301.327		714.3293
Velocity (real)	[m/s]		17.53575		18.2238
Mass flow rate	[kg/h]		67111		67111
Density	[kg/m3]		0.8006		2.657
Viscosity	[cP]		0.06439		0.02413
Pipe ID (real)	[mm]		1300		700
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		16.6434		46.5994
Outlet Pipe ID	[mm]		1320.8		711.2
Calculation					
Volumetric flow rate	[m3/h]		83825.88		25258.19
Pipe cross sectional area	[m2]		1.327323		0.384845
ε/D			1.92E-05		3.57E-05
Velocity	[m/s]		17.54281		18.23113
Erosional Velocity	[m/s]		111.7615		61.34854
N_{RE}	[-]		283556.5		1405225
fm	[-]		0.014911		0.01193
Velocity head	[kPa]		0.123192		0.441559
ΔP/100m	[kPa/100m]		0.141304		0.752546
ρv2	[kg/m-s2]		246.3847		883.1184
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		3	0.206729	3	0.207826
Tee elbow		0	0.410637	0	0.415084
Tee through		0	0.051506	0	0.051921
Block valve		0	0.103012	0	0.103842
Check Valve		0	1.534598	0	1.555496
Pipe size change		0	0	0	0
Piping length K-factor			0.190903		0.79419
Pipe fitting K-factor			0.620187		0.623479
Total K-total			0.81109		1.417669
Difference of Elavation	[m]		-1.11		0.0154
ΔPf	[kPa]		0.09992		0.625985
ΔP Elavation	[kPa]		-0.00872		0.000401
ΔP Specified	[kPa]	heat ex	7.16		0.285
ΔPtotal	[kPa]		7.251202		0.911386
P inlet	[kPa]		9050		9042.7488
P outlet	[kPa]		9042.749		9041.837
P inlet (bar)	[bar]		90.5		
delta P	[kPa]	7.251202	0.072512	0.911386	0.009114

Table D.1: Hydraulic calculation (cont.)

Section	Unit	C-603	
Velocity	[m/s]		17.5
Volume	[m3/h]		23133.75
Pipe ID (Theori)	[mm]		683.6289
Velocity (real)	[m/s]		19.35763
Mass flow rate	[kg/h]		67111
Density	[kg/m3]		2.901
Viscosity	[cP]		0.02137
Pipe ID (real)	[mm]		650
Pipe roughness (ε)	[mm]		0.025
Pipe length	[m]		18.75
Outlet Pipe ID	[mm]		660.4
Calculation			
Volumetric flow rate	[m3/h]		23133.75
Pipe cross sectional area	[m2]		0.331831
ε/D			3.85E-05
Velocity	[m/s]		19.36542
Erosional Velocity	[m/s]		58.7119
N_{RE}	[-]		1708769
fm	[-]		0.011739
Velocity head	[kPa]		0.543966
ΔP/100m	[kPa/100m]		0.982377
ρv2	[kg/m-s2]		1087.931
Pipe fitting		unit	K/unit
Elbow		**1**	**0.208284**
Tee elbow		0	0.416099
Tee through		0	0.052042
Block valve		0	0.104083
Check Valve		0	1.559493
Pipe size change		0	0
Piping length K-factor			0.338616
Pipe fitting K-factor			0.208284
Total K-total			0.5469
Difference of Elevation	[m]		0
ΔPf	[kPa]		0.297495
ΔP Elevation	[kPa]		0
ΔP Specified	[kPa]	exchanger	0
ΔPtotal	[kPa]		0.297495
P inlet	[kPa]		9041.8374
P outlet	[kPa]		9041.54
P inlet (bar)	[bar]		
delta P	[kPa]	0.297495	0.002975

Table D.1: Hydraulic calculation (cont.)

Section	Unit	A-102		A-103	
Velocity	[m/s]		17.5		17.5
Volume	[m3/h]		38241.26		5446.835
Pipe ID (Theori)	[mm]		878.9486		331.7184
Velocity (real)			16.69091		15.71958
facphase L			1		0.0099
facphase V			0		0.9901
Viscosity L			0.02525		1.002
Viscosity V			0		0.01855
Density L			2.317		0.9901
Density V			0		16.42
Mass flow rate	[kg/h]		88605		88605
Density	[kg/m3]		2.317		16.267244
Viscosity	[cP]		0.02525		0.0282862
Pipe ID (real)	[mm]		900		350
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		3.0065		3.909
Outlet Pipe ID	[mm]		914.4		355.6
Calculation					
Volumetric flow rate	[m3/h]		38241.26		5446.835
Pipe cross sectional area	[m2]		0.636173		0.096211
ε/D			2.78E-05		7.14E-05
Velocity	[m/s]		16.69763		15.72591
Erosional Velocity	[m/s]		65.69571		24.7938
N_{RE}	[-]		1378993		3165366
fm	[-]		0.011784		0.011947
Velocity head	[kPa]		0.323002		2.011479
ΔP/100m	[kPa/100m]		0.422929		6.865797
ρv2	[kg/m-s2]		646.0046		4022.958
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		0	0.206225	2	0.214767
Tee elbow		0	0.411869	0	0.429281
Tee through		3	0.05152	3	0.053676
Block valve		4	0.10304	4	0.107352
Check Valve		0	1.543421	0	1.609331
Pipe size change		0	0	0	0
Piping length K-factor			0.039366		0.133426
Pipe fitting K-factor			0.566719		1.01997
Total K-total			0.606085		1.153396
Difference of Elavation	[m]		1.265		2.109
ΔPf	[kPa]		0.195767		2.320032
ΔP Elavation	[kPa]		0.028753		0.336558
ΔP Specified	[kPa]	Strainer	0	Strainer	0
ΔPtotal	[kPa]		0.22452		2.656589
P inlet	[kPa]		100		100
P outlet	[kPa]		99.77548		97.34341
P inlet (bar)	[bar]		1		1
delta P	[kPa]	0.22452	0.002245	2.656589	0.026566

Table D.1: Hydraulic calculation (cont.)

Section	Unit	A-104		A-105	
Velocity	[m/s]		17.5		17.5
Volume	[m3/h]		38241.26		23304.84
Pipe ID (Theori)	[mm]		878.9486		686.1522
Velocity (real)			16.69091		16.81446
facphase L			1		0
facphase V			0		1
Viscosity L			0.02525		0
Viscosity V			0		0.01907
Density L			2.317		0
Density V			0		3.802
Mass flow rate	[kg/h]		88605		88605
Density	[kg/m3]		2.317		3.802
Viscosity	[cP]		0.02525		0.01907
Pipe ID (real)	[mm]		900		700
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		4.155		5
Outlet Pipe ID	[mm]		914.4		711.2
Calculation					
Volumetric flow rate	[m3/h]		38241.26		23304.84
Pipe cross sectional area	[m2]		0.636173		0.384845
ε/D			2.78E-05		3.57E-05
Velocity	[m/s]		16.69763		16.82123
Erosional Velocity	[m/s]		65.69571		51.28542
N_{RE}	[-]		1378993		2347562
fm	[-]		0.011784		0.011314
Velocity head	[kPa]		0.323002		0.537895
ΔP/100m	[kPa/100m]		0.422929		0.869369
ρv2	[kg/m-s2]		646.0046		1075.79
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		1	0.206225	1	0.207598
Tee elbow		0	0.411869	0	0.414855
Tee through		3	0.05152	3	0.051878
Block valve		0	0.10304	4	0.103756
Check Valve		0	1.543421	0	1.555068
Pipe size change		0	0	0	0
Piping length K-factor			0.054404		0.080812
Pipe fitting K-factor			0.360784		0.778258
Total K-total			0.415189		0.85907
Difference of Elavation	[m]		3.3155		3.5
ΔPf	[kPa]		0.134107		0.462089
ΔP Elavation	[kPa]		0.075361		0.130542
ΔP Specified	[kPa]	Strainer	0	Strainer	0
ΔPtotal	[kPa]		0.209467		0.592631
P inlet	[kPa]		100		100
P outlet	[kPa]		99.79053		99.40737
P inlet (bar)	[bar]		1		1
delta P	[kPa]	0.209467	0.002095	0.592631	0.005926

Table D.1: Hydraulic calculation (cont.)

Section	Unit	A-106	
Velocity	[m/s]		17.5
Volume	[m3/h]		21754.24
Pipe ID (Theori)	[mm]		662.9325
Velocity (real)			18.20329
facphase L			0
facphase V			1
Viscosity L			0
Viscosity V			0.01802
Density L			0
Density V			4.073
Mass flow rate	[kg/h]		88605
Density	[kg/m3]		4.073
Viscosity	[cP]		0.01802
Pipe ID (real)	[mm]		650
Pipe roughness (ε)	[mm]		0.025
Pipe length	[m]		6.5
Outlet Pipe ID	[mm]		660.4
Calculation			
Volumetric flow rate	[m3/h]		21754.24
Pipe cross sectional area	[m2]		0.331831
ε/D			3.85E-05
Velocity	[m/s]		18.21062
Erosional Velocity	[m/s]		49.5499
N_{RE}	[-]		2675455
fm	[-]		0.011259
Velocity head	[kPa]		0.675358
ΔP/100m	[kPa/100m]		1.169839
ρv2	[kg/m-s2]		1350.715
Pipe fitting		**unit**	**K/unit**
Elbow		3	0.208114
Tee elbow		0	0.41593
Tee through		0	0.05201
Block valve		2	0.10402
Check Valve		0	1.559176
Pipe size change		0	0
Piping length K-factor			0.112592
Pipe fitting K-factor			0.832383
Total K-total			0.944974
Difference of Elavation	[m]		-3.5
ΔPf	[kPa]		0.638196
ΔP Elavation	[kPa]		-0.13985
ΔP Specified	[kPa]	Strainer	0
ΔPtotal	[kPa]		0.498349
P inlet	[kPa]		100
P outlet	[kPa]		99.50165
P inlet (bar)	[bar]		1
delta P	[kPa]	0.498349	0.004983

Table D.1: Hydraulic calculation (cont.)

Section	**Unit**	**A-201**		**A-202**	
Velocity	[m/s]		17.5		17.5
Volume	[m3/h]		23477.74		17466
Pipe ID (Theori)	[mm]		688.6928		594.0104
Velocity (real)			16.93921		17.15235
facphase L			0		0
facphase V			1		1
Viscosity L			0		0
Viscosity V			0.01835		0.01372
Density L			0		0
Density V			3.774		5.073
Mass flow rate	[kg/h]		88605		88605
Density	[kg/m3]		3.774		5.073
Viscosity	[cP]		0.01835		0.01372
Pipe ID (real)	[mm]		700		600
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		11.9207		4.0893
Outlet Pipe ID	[mm]		711.2		609.6
Calculation					
Volumetric flow rate	[m3/h]		23477.74		17466
Pipe cross sectional area	[m2]		0.384845		0.282743
ε/D			3.57E-05		4.17E-05
Velocity	[m/s]		16.94603		17.15926
Erosional Velocity	[m/s]		51.47532		44.39843
N_{RE}	[-]		2439674		3806804
fm	[-]		0.011274		0.011062
Velocity head	[kPa]		0.541886		0.746847
ΔP/100m	[kPa/100m]		0.872757		1.376901
ρv2	[kg/m-s2]		1083.771		1493.695
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.207585	2	0.208677
Tee elbow		0	0.414842	0	0.417143
Tee through		0	0.051876	0	0.052156
Block valve		2	0.103752	0	0.104312
Check Valve		0	1.555043	0	1.563894
Pipe size change		0	0	0	0
Piping length K-factor			0.191994		0.075391
Pipe fitting K-factor			0.622673		0.417354
Total K-total			0.814667		0.492745
Difference of Elavation	[m]		-3.7107		-3.2893
ΔPf	[kPa]		0.441456		0.368005
ΔP Elavation	[kPa]		-0.13738		-0.1637
ΔP Specified	[kPa]		17.39	Strainer	0
ΔPtotal	[kPa]		17.69408		0.204309
P inlet	[kPa]		100		100
P outlet	[kPa]		82.30592		99.79569
P inlet (bar)	[bar]		1		1
delta P	[kPa]	17.69408	0.176941	0.204309	0.002043

Table D.1: Hydraulic calculation (cont.)

Section	Unit	A-203		A-204	
Velocity	[m/s]		17.5		17.5
Volume	[m3/h]		29153.47		17391.04
Pipe ID (Theori)	[mm]		767.4366		592.7345
Velocity (real)			18.32317		17.07874
facphase L			0		0
facphase V			1		1
Viscosity L			0		0
Viscosity V			0.01295		0.01636
Density L			0		0
Density V			3.649		6.117
Mass flow rate	[kg/h]		106381		106381
Density	[kg/m3]		3.649		6.117
Viscosity	[cP]		0.01295		0.01636
Pipe ID (real)	[mm]		750		600
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		1.8		2.711
Outlet Pipe ID	[mm]		762		609.6
Calculation					
Volumetric flow rate	[m3/h]		29153.47		17391.04
Pipe cross sectional area	[m2]		0.441786		0.282743
ε/D			3.33E-05		4.17E-05
Velocity	[m/s]		18.33054		17.08562
Erosional Velocity	[m/s]		52.34956		40.43252
N_{RE}	[-]		3873831		3832985
fm	[-]		0.010788		0.011057
Velocity head	[kPa]		0.613048		0.892832
ΔP/100m	[kPa/100m]		0.881838		1.645316
ρv2	[kg/m-s2]		1226.096		1785.665
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		0	0.20698	2	0.208675
Tee elbow		0	0.413753	0	0.417142
Tee through		0	0.051732	0	0.052156
Block valve		0	0.103464	0	0.104312
Check Valve		0	1.551187	0	1.563891
Pipe size change		0	0	0	0
Piping length K-factor			0.025892		0.049958
Pipe fitting K-factor			0		0.417351
Total K-total			0.025892		0.467309
Difference of Elavation	[m]		0		0.911
ΔPf	[kPa]		0.015873		0.417229
ΔP Elavation	[kPa]		0		0.054667
ΔP Specified	[kPa]	Strainer	0	Strainer	49.09
ΔPtotal	[kPa]		0.015873		49.5619
P inlet	[kPa]		100		100
P outlet	[kPa]		99.98413		50.4381
P inlet (bar)	[bar]		1		1
delta P	[kPa]	0.015873	0.000159	49.5619	0.495619

Table D.1: Hydraulic calculation (cont.)

Section	**Unit**	**A-205**		**A-206**	
Velocity	[m/s]		17.5		17.5
Volume	[m3/h]		15019.2		7031.13
Pipe ID (Theori)	[mm]		550.8341		376.886
Velocity (real)			17.55312		15.53596
facphase L			0		0
facphase V			1		1
Viscosity L			0		0
Viscosity V			0.01305		0.0182
Density L			0		0
Density V			7.083		15.13
Mass flow rate	[kg/h]		106381		106381
Density	[kg/m3]		7.083		15.13
Viscosity	[cP]		0.01305		0.0182
Pipe ID (real)	[mm]		550		400
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		2.711		2.0987
Outlet Pipe ID	[mm]		558.8		405.4
Calculation					
Volumetric flow rate	[m3/h]		15019.2		7031.13
Pipe cross sectional area	[m2]		0.237583		0.125664
ε/D			4.55E-05		6.25E-05
Velocity	[m/s]		17.56018		15.54221
Erosional Velocity	[m/s]		37.57434		25.70872
N_{RE}	[-]		5242018		5168212
fm	[-]		0.010978		0.011471
Velocity head	[kPa]		1.092057		1.827404
ΔP/100m	[kPa/100m]		2.179798		5.24075
ρv2	[kg/m-s2]		2184.114		3654.807
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.209389	2	0.212855
Tee elbow		0	0.418625	0	0.425555
Tee through		0	0.052338	0	0.053204
Block valve		0	0.104675	0	0.106408
Check Valve		0	1.569559	0	1.59554
Pipe size change		0	0	0	0
Piping length K-factor			0.054113		0.060188
Pipe fitting K-factor			0.418778		0.42571
Total K-total			0.472891		0.485898
Difference of Elavation	[m]		-0.911		1.04935
ΔPf	[kPa]		0.516424		0.887931
ΔP Elavation	[kPa]		-0.0633		0.15575
ΔP Specified	[kPa]	Strainer	0	Strainer	49.35
ΔPtotal	[kPa]		0.453124		50.39368
P inlet	[kPa]		100		100
P outlet	[kPa]		99.54688		49.60632
P inlet (bar)	[bar]		1		1
delta P	[kPa]	0.453124	0.004531	50.39368	0.503937

Table D.1: Hydraulic calculation (cont.)

Section	Unit	A-207		A-208	
Velocity	[m/s]		17.5		17.5
Volume	[m3/h]		4613.226		2245.746
Pipe ID (Theori)	[mm]		305.281		212.9991
Velocity (real)			18.12154		19.84877
facphase L			0		0
facphase V			1		1
Viscosity L			0		0
Viscosity V			0.0128		0.01807
Density L			0		0
Density V			23.06		47.37
Mass flow rate	[kg/h]		106381		106381
Density	[kg/m3]		23.06		47.37
Viscosity	[cP]		0.0128		0.01807
Pipe ID (real)	[mm]		300		200
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		2.0987		2.4846
Outlet Pipe ID	[mm]		323.85		219.08
Calculation					
Volumetric flow rate	[m3/h]		4613.226		2245.746
Pipe cross sectional area	[m2]		0.070686		0.031416
ε/D			8.33E-05		0.000125
Velocity	[m/s]		18.12883		19.85676
Erosional Velocity	[m/s]		20.8243		14.52942
N_{RE}	[-]		9798068		10410786
fm	[-]		0.011794		0.012656
Velocity head	[kPa]		3.789388		9.338777
ΔP/100m	[kPa/100m]		14.89773		59.09477
ρv2	[kg/m-s2]		7578.776		18677.55
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.217015	2	0.225477
Tee elbow		0	0.433948	0	0.450877
Tee through		0	0.054249	0	0.056364
Block valve		0	0.108497	0	0.112729
Check Valve		0	1.627153	0	1.690644
Pipe size change		0	0	0	0
Piping length K-factor			0.082509		0.157223
Pipe fitting K-factor			0.43403		0.450954
Total K-total			0.516539		0.608176
Difference of Elavation	[m]		-1.0493		0.6846
ΔPf	[kPa]		1.957366		5.679625
ΔP Elavation	[kPa]		-0.23737		0.318133
ΔP Specified	[kPa]	Strainer	0	Strainer	49.77
ΔPtotal	[kPa]		1.719995		55.76776
P inlet	[kPa]		100		100
P outlet	[kPa]		98.28		44.23224
P inlet (bar)	[bar]		1		1
delta P	[kPa]	1.719995	0.0172	55.76776	0.557678

Table D.1: Hydraulic calculation (cont.)

Section	Unit	A-209		A-210	
Velocity	[m/s]		17.5		17.5
Volume	[m3/h]		1074.773		666.1302
Pipe ID (Theori)	[mm]		147.3519		116.0051
Velocity (real)			16.88756		17.80723
facphase L			0		0
facphase V			1		1
Viscosity L			0		0
Viscosity V			0.01261		0.01757
Density L			0		0
Density V			98.98		159.7
Mass flow rate	[kg/h]		106381		106381
Density	[kg/m3]		98.98		159.7
Viscosity	[cP]		0.01261		0.01757
Pipe ID (real)	[mm]		150		115
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		2.4846		3.11925
Outlet Pipe ID	[mm]		168.2		127
Calculation					
Volumetric flow rate	[m3/h]		1074.773		666.1302
Pipe cross sectional area	[m2]		0.017671		0.010387
ε/D			0.000167		0.000217
Velocity	[m/s]		16.89436		17.8144
Erosional Velocity	[m/s]		10.05139		7.913116
N_{RE}	[-]		19891400		18620961
fm	[-]		0.013298		0.014021
Velocity head	[kPa]		14.1254		25.34061
ΔP/100m	[kPa/100m]		125.2238		308.955
ρv2	[kg/m-s2]		28250.81		50681.22
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.233907	2	0.244217
Tee elbow		0	0.467774	0	0.488391
Tee through		0	0.058474	0	0.061052
Block valve		0	0.116948	0	0.122103
Check Valve		0	1.754075	0	1.831385
Pipe size change		0	0	0	0
Piping length K-factor			0.220264		0.380302
Pipe fitting K-factor			0.467814		0.488434
Total K-total			0.688077		0.868735
Difference of Elavation	[m]		-0.6846		1.31925
ΔPf	[kPa]		9.71937		22.01429
ΔP Elavation	[kPa]		-0.66474		2.066812
ΔP Specified	[kPa]	Strainer	0	Strainer	46.07
ΔPtotal	[kPa]		9.054628		70.1511
P inlet	[kPa]		100		100
P outlet	[kPa]		90.94537		29.8489
P inlet (bar)	[bar]		1		1
delta P	[kPa]	9.054628	0.090546	70.1511	0.701511

Table D.1: Hydraulic calculation (cont.)

Section	Unit	A-211		A-212	
Velocity	[m/s]		17.5		4.5
Volume	[m3/h]		269.5237		140.4555
Pipe ID (Theori)	[mm]		73.78972		105.046
Velocity (real)			14.88846		4.965599
facphase L			0		1
facphase V			1		0
Viscosity L			0		0.08492
Viscosity V			0.02404		0
Density L			0		757.4
Density V			394.7		0
Mass flow rate	[kg/h]		106381		106381
Density	[kg/m3]		394.7		757.4
Viscosity	[cP]		0.02404		0.08492
Pipe ID (real)	[mm]		80		100
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		3.736		9.66755
Outlet Pipe ID	[mm]		88.9		114.3
Calculation					
Volumetric flow rate	[m3/h]		269.5237		140.4555
Pipe cross sectional area	[m2]		0.005027		0.007854
ε/D			0.000313		0.00025
Velocity	[m/s]		14.89445		4.967597
Erosional Velocity	[m/s]		5.033458		3.633602
N_{RE}	[-]		19563531		4430591
fm	[-]		0.015107		0.014579
Velocity head	[kPa]		43.78106		9.345189
ΔP/100m	[kPa/100m]		826.7443		136.2411
ρv2	[kg/m-s2]		87562.13		18690.38
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.263541	2	0.250981
Tee elbow		0	0.527041	0	0.501781
Tee through		0	0.065883	0	0.062734
Block valve		0	0.131765	0	0.125468
Check Valve		0	1.976327	0	1.881339
Pipe size change		0	0	0	0
Piping length K-factor			0.705492		1.409407
Pipe fitting K-factor			0.527082		0.501961
Total K-total			1.232573		1.911368
Difference of Elavation	[m]		-1.868		1.86755
ΔPf	[kPa]		53.96337		17.86209
ΔP Elavation	[kPa]		-7.23291		13.87607
ΔP Specified	[kPa]	Strainer	0.0575	Strainer	0
ΔPtotal	[kPa]		46.78796		31.73817
P inlet	[kPa]		100		100
P outlet	[kPa]		53.21204		68.26183
P inlet (bar)	[bar]		1		1
delta P	[kPa]	46.78796	0.46788	31.73817	0.317382

Table D.1: Hydraulic calculation (cont.)

Section	**Unit**	**A-213 (mix)**		**A-214**	
Velocity	[m/s]		6.8075		4.5
Volume	[m3/h]		154.2247		104.9767
Pipe ID (Theori)	[mm]		89.49516		90.81479
Velocity (real)			6.731342		4.581848
facphase L			0.8225		1
facphase V			0.1775		0
Viscosity L			0.1374		0.1374
Viscosity V			0.006146		0
Density L			836.5		836.5
Density V			9.905		0
Mass flow rate	[kg/h]		106381		87813
Density	[kg/m3]		689.77939		836.5
Viscosity	[cP]		0.3162263		0.1374
Pipe ID (real)	[mm]		90		90
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		8		17.725
Outlet Pipe ID	[mm]		101.6		101.6
Calculation					
Volumetric flow rate	[m3/h]		154.2247		104.9767
Pipe cross sectional area	[m2]		0.006362		0.006362
ε/D			0.000278		0.000278
Velocity	[m/s]		6.734052		4.583692
Erosional Velocity	[m/s]		3.807544		3.457539
N_{RE}	[-]		1321999		2511523
fm	[-]		0.015292		0.015021
Velocity head	[kPa]		15.63987		8.787531
ΔP/100m	[kPa/100m]		265.7419		146.6666
ρv2	[kg/m-s2]		31279.74		17575.06
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.25705	2	0.256763
Tee elbow		0	0.513494	0	0.513207
Tee through		3	0.064225	0	0.064171
Block valve		4	0.128449	0	0.128342
Check Valve		0	1.924468	0	1.923931
Pipe size change		0	0	0	0
Piping length K-factor			1.359305		2.958357
Pipe fitting K-factor			1.22057		0.513526
Total K-total			2.579875		3.471883
Difference of Elavation	[m]		0.5		7
ΔPf	[kPa]		40.3489		30.50928
ΔP Elavation	[kPa]		3.383368		57.44246
ΔP Specified	[kPa]	Strainer	0	Strainer	0
ΔPtotal	[kPa]		43.73227		87.95173
P inlet	[kPa]		100		100
P outlet	[kPa]		56.26773		12.04827
P inlet (bar)	[bar]		1		1
delta P	[kPa]	43.73227	0.437323	87.95173	0.879517

Table D.1: Hydraulic calculation (cont.)

Section	Unit	A-215 (T-PU)		A-216	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		88.82845		88.53211
Pipe ID (Theori)	[mm]		83.53841		83.39895
Velocity (real)			4.906875		4.890505
facphase L			1		1
facphase V			0		0
Viscosity L			0.1893		0.1329
Viscosity V			0		0
Density L			836.5		839.3
Density V			0		0
Mass flow rate	[kg/h]		74305		74305
Density	[kg/m3]		836.5		839.3
Viscosity	[cP]		0.1893		0.1329
Pipe ID (real)	[mm]		80		80
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		10		8.5564
Outlet Pipe ID	[mm]		88.9		88.9
Calculation					
Volumetric flow rate	[m3/h]		88.82845		88.53211
Pipe cross sectional area	[m2]		0.005027		0.005027
ε/D			0.000313		0.000313
Velocity	[m/s]		4.90885		4.892473
Erosional Velocity	[m/s]		3.457539		3.451766
N_{RE}	[-]		1735342		2471785
fm	[-]		0.015492		0.01537
Velocity head	[kPa]		10.07849		10.04487
ΔP/100m	[kPa/100m]		195.1667		192.9868
ρv2	[kg/m-s2]		20156.98		20089.73
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.263961	2	0.263824
Tee elbow		0	0.527461	0	0.527324
Tee through		3	0.065961	1	0.065936
Block valve		4	0.131923	1	0.131871
Check Valve		0	1.977114	1	1.976857
Pipe size change		0	0	0	0
Piping length K-factor			1.936468		1.643896
Pipe fitting K-factor			1.253498		2.702311
Total K-total			3.189966		4.346208
Difference of Elavation	[m]		7		6.7564
ΔPf	[kPa]		32.15004		43.65707
ΔP Elavation	[kPa]		57.44246		55.62904
ΔP Specified	[kPa]	Strainer	0	Strainer	4.233
ΔPtotal	[kPa]		89.59249		103.5191
P inlet	[kPa]		100		3634
P outlet	[kPa]		10.40751		3530.481
P inlet (bar)	[bar]		1		1
delta P	[kPa]	89.59249	0.895925	103.5191	1.035191

Table D.1: Hydraulic calculation (cont.)

Section	Unit	A-217		A-218	
Velocity	[m/s]		4.5		4.5
Volume	[m3/h]		191.6559		191.6559
Pipe ID (Theori)	[mm]		122.7076		122.7076
Velocity (real)			4.336457		16.03719
facphase L			1		1
facphase V			0		0
Viscosity L			0.03541		0.03541
Viscosity V			0		0
Density L			387.7		387.7
Density V			0		0
Mass flow rate	[kg/h]		74305		74305
Density	[kg/m3]		387.7		387.7
Viscosity	[cP]		0.03541		0.03541
Pipe ID (real)	[mm]		125		65
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		8.5564		3.8447
Outlet Pipe ID	[mm]		141.3		73.03
Calculation					
Volumetric flow rate	[m3/h]		191.6559		191.6559
Pipe cross sectional area	[m2]		0.012272		0.003318
ε/D			0.0002		0.000385
Velocity	[m/s]		4.338203		16.04365
Erosional Velocity	[m/s]		5.078695		5.078695
N_{RE}	[-]		5937310		11417904
fm	[-]		0.013911		0.015815
Velocity head	[kPa]		3.648257		49.89673
ΔP/100m	[kPa/100m]		40.60139		1214.008
ρv2	[kg/m-s2]		7296.515		99793.46
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.240775	2	0.278224
Tee elbow		0	0.481415	0	0.556378
Tee through		0	0.060185	1	0.069552
Block valve		1	0.120371	1	0.139103
Check Valve		0	1.805053	1	2.086285
Pipe size change		0	0	0	0
Piping length K-factor			0.95224		0.935431
Pipe fitting K-factor			0.60192		2.851388
Total K-total			1.55416		3.786819
Difference of Elavation	[m]		-6.7564		2.0447
ΔPf	[kPa]		5.669976		188.9499
ΔP Elavation	[kPa]		-25.6969		7.776683
ΔP Specified	[kPa]	Strainer	0	Strainer	15.91
ΔPtotal	[kPa]		-20.0269		212.6366
P inlet	[kPa]		3530.4809		20120
P outlet	[kPa]		3550.508		19907.36
P inlet (bar)	[bar]		1		1
delta P	[kPa]	-20.0269	-0.20027	212.6366	2.126366

Table D.1: Hydraulic calculation (cont.)

Section	**Unit**	**A-219**		**A-220**	
Velocity	[m/s]		17.5		17.5
Volume	[m3/h]		1874.609		3668.84
Pipe ID (Theori)	[mm]		194.6044		272.2462
Velocity (real)			16.56851		20.75304
facphase L			0		0
facphase V			1		1
Viscosity L			0		0
Viscosity V			0.006146		0.009604
Density L			0		0
Density V			9.905		5.061
Mass flow rate	[kg/h]		18568		18568
Density	[kg/m3]		9.905		5.061
Viscosity	[cP]		0.006146		0.009604
Pipe ID (real)	[mm]		200		250
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		7.66755		22.50305
Outlet Pipe ID	[mm]		219.08		273.05
Calculation					
Volumetric flow rate	[m3/h]		1874.609		3668.84
Pipe cross sectional area	[m2]		0.031416		0.049087
ε/D			0.000125		0.0001
Velocity	[m/s]		16.57518		20.76139
Erosional Velocity	[m/s]		31.77406		44.45103
N_{RE}	[-]		5342570		2735146
fm	[-]		0.012792		0.01261
Velocity head	[kPa]		1.360633		1.090735
ΔP/100m	[kPa/100m]		8.702813		5.501605
ρv2	[kg/m-s2]		2721.266		2181.469
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		2	0.22555	2	0.220612
Tee elbow		0	0.45095	0	0.440932
Tee through		0	0.056378	0	0.055135
Block valve		0	0.112756	0	0.11027
Check Valve		0	1.690781	0	1.652948
Pipe size change		0	0	0	0
Piping length K-factor			0.490428		1.135041
Pipe fitting K-factor			0.451099		0.441225
Total K-total			0.941527		1.576266
Difference of Elavation	[m]		5.86755		1.13245
ΔPf	[kPa]		1.281073		1.719288
ΔP Elavation	[kPa]		0.570138		0.056224
ΔP Specified	[kPa]	Strainer	0	Strainer	0
ΔPtotal	[kPa]		1.851212		1.775513
P inlet	[kPa]		19907.363		100
P outlet	[kPa]		19905.51		98.22449
P inlet (bar)	[bar]		1		1
delta P	[kPa]	1.851212	0.018512	1.775513	0.017755

Table D.1: Hydraulic calculation (cont.)

Section	Unit	A-401		A-402	
Velocity	[m/s]		17.5		17.5
Volume	[m3/h]		225.3715		430.0058
Pipe ID (Theori)	[mm]		67.47563		93.204
Velocity (real)			18.85842		18.76818
facphase L			0		0
facphase V			1		1
Viscosity L			0		0
Viscosity V			0.0587		0.02665
Density L			0		0
Density V			329.7		172.8
Mass flow rate	[kg/h]		74305		74305
Density	[kg/m3]		329.7		172.8
Viscosity	[cP]		0.0587		0.02665
Pipe ID (real)	[mm]		65		90
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		54.7887		10.088
Outlet Pipe ID	[mm]		73.03		101.6
Calculation					
Volumetric flow rate	[m3/h]		225.3715		430.0058
Pipe cross sectional area	[m2]		0.003318		0.006362
ε/D			0.000385		0.000278
Velocity	[m/s]		18.86601		18.77573
Erosional Velocity	[m/s]		5.507323		7.607258
N_{RE}	[-]		6887700		10956855
fm	[-]		0.015852		0.014773
Velocity head	[kPa]		58.67444		30.45843
ΔP/100m	[kPa/100m]		1430.947		499.9585
ρv2	[kg/m-s2]		117348.9		60916.86
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		3	0.27827	2	0.256517
Tee elbow		0	0.556424	0	0.512962
Tee through		0	0.06956	0	0.064125
Block valve		0	0.13912	0	0.12825
Check Valve		0	2.086372	0	1.92347
Pipe size change		0	0	0	0
Piping length K-factor			13.36182		1.65589
Pipe fitting K-factor			0.83481		0.513035
Total K-total			14.19663		2.168925
Difference of Elavation	[m]		-1.43789		2.3042
ΔPf	[kPa]		832.9795		66.06205
ΔP Elavation	[kPa]		-4.65063		3.906006
ΔP Specified	[kPa]	Strainer	18.26	Strainer	14830
ΔPtotal	[kPa]		846.5889		14899.97
P inlet	[kPa]		19907.363		19060.775
P outlet	[kPa]		19060.77		4160.806
P inlet (bar)	[bar]		1		1
delta P	[kPa]	846.5889	8.465889	14899.97	148.9997

Table D.1: Hydraulic calculation (cont.)

Section	**Unit**	**A-403**		**A-404**	
Velocity	[m/s]		17.5		17.5
Volume	[m3/h]		1095.782		1601.746
Pipe ID (Theori)	[mm]		148.7851		179.8847
Velocity (real)			17.21768		14.15685
facphase L			0		0
facphase V			1		1
Viscosity L			0		0
Viscosity V			0.01889		0.02341
Density L			0		0
Density V			67.81		46.39
Mass flow rate	[kg/h]		74305		74305
Density	[kg/m3]		67.81		46.39
Viscosity	[cP]		0.01889		0.02341
Pipe ID (real)	[mm]		150		200
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		9.3042		11.148
Outlet Pipe ID	[mm]		168.28		219.08
Calculation					
Volumetric flow rate	[m3/h]		1095.782		1601.746
Pipe cross sectional area	[m2]		0.017671		0.031416
ε/D			0.000167		0.000125
Velocity	[m/s]		17.22461		14.16254
Erosional Velocity	[m/s]		12.14376		14.68209
N_{RE}	[-]		9274755		5612990
fm	[-]		0.013369		0.012779
Velocity head	[kPa]		10.05918		4.652399
ΔP/100m	[kPa/100m]		89.65532		29.72665
ρv2	[kg/m-s2]		20118.36		9304.798
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		4	0.233953	4	0.225543
Tee elbow		0	0.46782	0	0.450943
Tee through		0	0.058483	0	0.056377
Block valve		0	0.116966	0	0.112753
Check Valve		0	1.754162	0	1.690767
Pipe size change		0	0	0	0
Piping length K-factor			0.829264		0.712305
Pipe fitting K-factor			0.935812		0.90217
Total K-total			1.765075		1.614475
Difference of Elavation	[m]		-2.3042		2.3042
ΔPf	[kPa]		17.75521		7.511183
ΔP Elavation	[kPa]		-1.53279		1.048609
ΔP Specified	[kPa]	Strainer	37.55	Strainer	3712
ΔPtotal	[kPa]		53.77242		3720.56
P inlet	[kPa]		4160.81		5257
P outlet	[kPa]		4107.038		1536.44
P inlet (bar)	[bar]		1		1
delta P	[kPa]	53.77242	0.537724	3720.56	37.2056

Table D.1: Hydraulic calculation (cont.)

Section	Unit	A-405		A-406	
Velocity	[m/s]		17.5		17.5
Volume	[m3/h]		4200.396		5892.546
Pipe ID (Theori)	[mm]		291.3014		345.0237
Velocity (real)			16.49987		17.0059
facphase L			0		0
facphase V			1		1
Viscosity L			0		0
Viscosity V			0.01829		0.02261
Density L			0		0
Density V			17.69		12.61
Mass flow rate	[kg/h]		74305		74305
Density	[kg/m3]		17.69		12.61
Viscosity	[cP]		0.01829		0.02261
Pipe ID (real)	[mm]		300		350
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		10.3042		18.10235
Outlet Pipe ID	[mm]		323.85		355.6
Calculation					
Volumetric flow rate	[m3/h]		4200.396		5892.546
Pipe cross sectional area	[m2]		0.070686		0.096211
ε/D			8.33E-05		7.14E-05
Velocity	[m/s]		16.50651		17.01275
Erosional Velocity	[m/s]		23.77585		28.16064
N_{RE}	[-]		4789506		3320910
fm	[-]		0.012006		0.011918
Velocity head	[kPa]		2.409952		1.824879
ΔP/100m	[kPa/100m]		9.644424		6.213823
ρv2	[kg/m-s2]		4819.905		3649.758
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		4	0.2171	4	0.214755
Tee elbow		0	0.434034	0	0.429269
Tee through		0	0.054265	0	0.053674
Block valve		0	0.108529	0	0.107347
Check Valve		0	1.627313	0	1.609309
Pipe size change		0	0	0	0
Piping length K-factor			0.412365		0.616396
Pipe fitting K-factor			0.868401		0.859021
Total K-total			1.280767		1.475417
Difference of Elavation	[m]		-2.3042		2.3042
ΔPf	[kPa]		3.086587		2.692457
ΔP Elavation	[kPa]		-0.39987		0.285039
ΔP Specified	[kPa]	Strainer	0.4477	Strainer	855.2
ΔPtotal	[kPa]		3.134419		858.1775
P inlet	[kPa]		1536.4402		1533.3058
P outlet	[kPa]		1533.306		675.1283
P inlet (bar)	[bar]		1		1
delta P	[kPa]	3.134419	0.031344	858.1775	8.581775

Table D.1: Hydraulic calculation (cont.)

Section	Unit	A-407		A-408	
Velocity	[m/s]		17.5		17.5
Volume	[m3/h]		12396.56		16980.12
Pipe ID (Theori)	[mm]		500.4354		585.6899
Velocity (real)			17.53049		19.84487
facphase L			0		0
facphase V			1		1
Viscosity L			0		0
Viscosity V			0.01901		0.02228
Density L			0		0
Density V			5.994		4.376
Mass flow rate	[kg/h]		74305		74305
Density	[kg/m3]		5.994		4.376
Viscosity	[cP]		0.01901		0.02228
Pipe ID (real)	[mm]		500		550
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		17.8042		26.10235
Outlet Pipe ID	[mm]		508		558.8
Calculation					
Volumetric flow rate	[m3/h]		12396.56		16980.12
Pipe cross sectional area	[m2]		0.19635		0.237583
ε/D			0.00005		4.55E-05
Velocity	[m/s]		17.53755		19.85285
Erosional Velocity	[m/s]		40.84526		47.80368
N_{RE}	[-]		2764862		2144607
fm	[-]		0.011534		0.011652
Velocity head	[kPa]		0.921774		0.862369
ΔP/100m	[kPa/100m]		2.126308		1.826968
ρv2	[kg/m-s2]		1843.548		1724.738
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		4	0.210449	4	0.209609
Tee elbow		0	0.420609	0	0.418846
Tee through		0	0.052594	0	0.052379
Block valve		0	0.105189	0	0.104758
Check Valve		0	1.576743	0	1.569972
Pipe size change		0	0	0	0
Piping length K-factor			0.410699		0.55299
Pipe fitting K-factor			0.841797		0.838438
Total K-total			1.252497		1.391427
Difference of Elavation	[m]		-2.3042		2.3042
ΔPf	[kPa]		1.154519		1.199924
ΔP Elavation	[kPa]		-0.13549		0.098916
ΔP Specified	[kPa]	Strainer	0.454	Strainer	100
ΔPtotal	[kPa]		1.47303		101.2988
P inlet	[kPa]		675.12829		675.12829
P outlet	[kPa]		673.6553		573.8295
P inlet (bar)	[bar]		1		1
delta P	[kPa]	1.47303	0.01473	101.2988	1.012988

Table D.1: Hydraulic calculation (cont.)

Section	Unit	A-409		A-601	
Velocity	[m/s]		17.5		17.5
Volume	[m3/h]		20368.7		45051.19
Pipe ID (Theori)	[mm]		641.4739		954.0048
Velocity (real)			17.04391		15.92719
facphase L			0		0
facphase V			1		1
Viscosity L			0		0
Viscosity V			0.0137		0.02153
Density L			0		0
Density V			3.648		1.465
Mass flow rate	[kg/h]		74305		66000
Density	[kg/m3]		3.648		1.465
Viscosity	[cP]		0.0137		0.02153
Pipe ID (real)	[mm]		650		1000
Pipe roughness (ε)	[mm]		0.025		0.025
Pipe length	[m]		39.458		15.2159
Outlet Pipe ID	[mm]		660.4		1016
Calculation					
Volumetric flow rate	[m3/h]		20368.7		45051.19
Pipe cross sectional area	[m2]		0.331831		0.785398
ε/D			3.85E-05		0.000025
Velocity	[m/s]		17.05077		15.9336
Erosional Velocity	[m/s]		52.35674		82.61924
	[-]		2951153		1084195
fm	[-]		0.01117		0.012102
Velocity head	[kPa]		0.53029		0.185967
ΔP/100m	[kPa/100m]		0.91131		0.22505
ρv2	[kg/m-s2]		1060.579		371.9337
Pipe fitting		**unit**	**K/unit**	**unit**	**K/unit**
Elbow		0	0.208086	2	0.205818
Tee elbow		0	0.415902	0	0.410898
Tee through		0	0.052005	6	0.051408
Block valve		0	0.104009	8	0.102817
Check Valve		0	1.559124	0	1.539484
Pipe size change		0	0	0	0
Piping length K-factor			0.678091		0.184137
Pipe fitting K-factor			0		1.542619
Total K-total			0.678091		1.726757
Difference of Elavation	[m]		-3		5
ΔPf	[kPa]		0.359585		0.32112
ΔP Elavation	[kPa]		-0.10736		0.071858
ΔP Specified	[kPa]	Strainer	0	Strainer	0
ΔPtotal	[kPa]		0.252224		0.392978
P inlet	[kPa]		573.82945		100
P outlet	[kPa]		573.5772		99.60702
P inlet (bar)	[bar]		1		1
delta P	[kPa]	0.252224	0.002522	0.392978	0.00393

APPENDIX E

Equipment Specification Sheets

ALPEMA Sheet

PLATE-FIN Heat Exchanger Specification Sheet

2	Company:												
3	Location:												
4	Service of Unit: Our Reference:												
5	Item No.: Your Reference:												
6	Date: Rev No.: Job No.:												
7	Stream i.d./fluid name				1/ A-204->A205			2/ P-206->P-207			3/ L-204>L-205		
8	Flow rate	Total		kg/s	27.7778			36.1111			27.7778		
9		Vap./liq.	In	kg/s	27.7778	/	0	0	/	36.1111	0	/	27.7778
10		Vap./liq.	Out		27.7778	/	0	0	/	36.1111	0	/	27.7778
11	Molecular weight	Vap.	In/Out		28.8309	/	28.8309		/			/	
12		Liq.	In/Out			/		44.097	/	44.097	17.87096	/	17.87096
13	Density	Vap.	In/Out	kg/m³	5.24	/	7.33		/			/	
14		Liq.	In/Out			/		587.05	/	574.46	351.26	/	325.17
15	Viscosity	Vap.	In/Out	mPa-s	0.0172	/	0.013		/			/	
16		Liq.	In/Out			/		0.2071	/	0.1833	0.0447	/	0.037
17	Specific heat	Vap.	In/Out	kJ/(kg-K)	1.011	/	1.006		/			/	
18		Liq.	In/Out			/		2.148	/	2.223	3.975	/	4.364
19	Thermal cond.	Vap.	In/Out	W/(m-K)	0.0236	/	0.0179		/			/	
20		Liq.	In/Out			/		0.136	/	0.1298	0.087	/	0.0762
21	Temperature	In/Out		°C	-7.54	/	-81.23	-46.12	/	-35.25	-88.48	/	-78.04
22	Operating pressure	In		bar	4			10			91.50998		
23	Maximum allowable pressure drop			bar	0.5			0.5			0.5		
24	Heat load			kW	-2063			857.3			1205		
25	Calculated MTD			°C	17.58								
26	Fouling resistance			m²-K/W	0			0			0		
27	Core size			mm	Width		591.81	Height		699.6	Length		1822.02
28	Number of layers				52			26			26		
29	Fin code: Heat transfer fin				1			2			3		
30	Fin code: Distributor fin				4			5			5		
31	Heat transfer surface/core			m²	1321			185			161		
32	Core opening size	In/Out		mm	312.86	/	333.12	296.07	/	236.48	213.79	/	224.55
33	Nozzle size	In/Out		mm	254.46	/	254.46	154.08	/	102.26	154.08	/	128.2
34	Calculated frictional pressure drop			bar	0.49088			0.06667			0.06144		
35	Notes												
36													
37													

ALPEMA Sheet

PLATE-FIN Heat Exchanger Specification Sheet

2	Company:													
3	Location:													
4	Service of Unit:			Our Reference:										
5	Item No.:			Your Reference:										
6	Date:	Rev No.:		Job No.:										
7	Stream i.d./fluid name				1/	A-206->A-207		2/	P-206->P-207		3/	L-203->L-204		
8	Flow rate	Total		kg/s	27.7778			36.1111			27.7778			
9		Vap./liq.	In	kg/s	27.7778	/	0	0	/	36.1111	0	/	27.7778	
10		Vap./liq.	Out		27.7778	/	0	0	/	36.1111	0	/	27.7778	
11	Molecular weight	Vap.	In/Out		28.8309	/	28.8309		/			/		
12		Liq.	In/Out			/		44.097	/	44.097	17.87096	/	17.87096	
13	Density	Vap.	In/Out	kg/m³	14.9	/	23.09		/			/		
14		Liq.	In/Out			/		612.98	/	587.05	367.19	/	351.26	
15	Viscosity	Vap.	In/Out	mPa-s	0.0179	/	0.0128		/			/		
16		Liq.	In/Out			/		0.277	/	0.2071	0.0505	/	0.0447	
17	Specific heat	Vap.	In/Out	kJ/(kg-K)	1.03	/	1.054		/			/		
18		Liq.	In/Out			/		2.006	/	2.148	3.757	/	3.975	
19	Thermal cond.	Vap.	In/Out	W/(m-K)	0.0247	/	0.018		/			/		
20		Liq.	In/Out			/		0.1493	/	0.136	0.1006	/	0.087	
21	Temperature	In/Out		°C	1.69	/	-89.23	-69.57	/	-46.12	-96.51	/	-88.48	
22	Operating pressure	In		bar	11.7			10			91.50998			
23	Maximum allowable pressure drop			bar	0.5			0.5			0.5			
24	Heat load			kW	-2618.8			1757.9			861.3			
25	Calculated MTD			°C	20.37									
26	Fouling resistance			m²-K/W	0			0			0			
27	Core size			mm	Width		596.5	Height		566.6	Length		2098.74	
28	Number of layers				42			21			21			
29	Fin code: Heat transfer fin				1			2			3			
30	Fin code: Distributor fin				4			5			5			
31	Heat transfer surface/core			m²	857.1			162			89.1			
32	Core opening size		In/Out	mm	322.96	/	337.5	295.86	/	231.21	214.07	/	224.55	
33	Nozzle size		In/Out	mm	254.46	/	254.46	154.08	/	128.2	128.2	/	128.2	
34	Calculated frictional pressure drop			bar	0.49351			0.18364			0.18833			
35	Notes													
36														
37														

ALPEMA Sheet

PLATE-FIN Heat Exchanger Specification Sheet

2	Company:			
3	Location:			
4	Service of Unit: Our Reference:			
5	Item No.: Your Reference:			
6	Date: Rev No.: Job No.:			
7	Stream i.d./fluid name	1/ A208->A-209	2/ P-205->P-206	3/
8	Flow rate Total kg/s	27.7778	36.1111	
9	Vap./liq. In kg/s	27.7778 / 0	0 / 36.1111	/
10	Vap./liq. Out	27.7778 / 0	0 / 36.1111	/
11	Molecular weight Vap. In/Out	28.8309 / 28.8309	/	/
12	Liq. In/Out	/	44.097 / 44.097	/
13	Density Vap. In/Out kg/m³	46.96 / 98.95	/	/
14	Liq. In/Out	/	667.03 / 612.98	/
15	Viscosity Vap. In/Out mPa-s	0.018 / 0.0126	/	/
16	Liq. In/Out	/	0.6768 / 0.277	/
17	Specific heat Vap. In/Out kJ/(kg-K)	1.088 / 1.462	/	/
18	Liq. In/Out	/	1.748 / 2.006	/
19	Thermal cond. Vap. In/Out W/(m-K)	0.0255 / 0.0192	/	/
20	Liq. In/Out	/	0.179 / 0.1493	/
21	Temperature In/Out °C	-7.05 / -115.3	-122.3 / -69.57	/
22	Operating pressure In bar	35	10	
23	Maximum allowable pressure drop bar	0.5	0.5	
24	Heat load kW	-3560.8	3560.5	
25	Calculated MTD °C	22.24		
26	Fouling resistance m²-K/W	0	0	
27	Core size mm	Width 603.54	Height 667.6	Length 1369.18
28	Number of layers	59	30	
29	Fin code: Heat transfer fin	1	2	
30	Fin code: Distributor fin	3	4	
31	Heat transfer surface/core m²	357.7	187.2	
32	Core opening size In/Out mm	344.1 / 253.22	198.2 / 170.71	/
33	Nozzle size In/Out mm	304.76 / 202.74	154.08 / 128.2	/
34	Calculated frictional pressure drop bar	0.49768	0.39774	
35	Notes			
36				
37				

ALPEMA Sheet

PLATE-FIN Heat Exchanger Specification Sheet

2	Company:											
3	Location:											
4	Service of Unit: Our Reference:											
5	Item No.: Your Reference:											
6	Date: Rev No.: Job No.:											
7	Stream i.d./fluid name				1/	A-210->A-211		2/	L-202->L-203		3/		
8	Flow rate	Total		kg/s	27.7778			27.7778					
9		Vap./liq.	In	kg/s	27.7778	/	0	0	/	27.7778		/	
10		Vap./liq.	Out		27.7778	/	0	0	/	27.7778		/	
11	Molecular weight	Vap.	In/Out		28.8309	/	28.8309		/			/	
12		Liq.	In/Out			/		17.87096	/	17.87096		/	
13	Density	Vap.	In/Out	kg/m³	157.95	/	387.49		/			/	
14		Liq.	In/Out			/		421.06	/	367.19		/	
15	Viscosity	Vap.	In/Out	mPa-s	0.0174	/	0.0234		/			/	
16		Liq.	In/Out			/		0.0833	/	0.0505		/	
17	Specific heat	Vap.	In/Out	kJ/(kg-K)	1.413	/	3.279		/			/	
18		Liq.	In/Out			/		3.246	/	3.757		/	
19	Thermal cond.	Vap.	In/Out	W/(m-K)	0.0265	/	0.0412		/			/	
20		Liq.	In/Out			/		0.1519	/	0.1006		/	
21	Temperature	In/Out		°C	-65.35	/	-122.3	-129.3	/	-96.51		/	
22	Operating pressure	In		bar	80			91.50998					
23	Maximum allowable pressure drop			bar	0.5			0.5					
24	Heat load			kW	-3155.3			3155.8					
25	Calculated MTD			°C	11.51								
26	Fouling resistance			m²-K/W	0			0					
27	Core size			mm	Width		531.02	Height		580.4	Length		2638.45
28	Number of layers				32			29					
29	Fin code: Heat transfer fin				1			1					
30	Fin code: Distributor fin				2			2					
31	Heat transfer surface/core			m²	298			270.1					
32	Core opening size	In/Out		mm	256.88	/	236.73	224.55	/	224.55		/	
33	Nozzle size	In/Out		mm	202.74	/	154.08	154.08	/	154.08		/	
34	Calculated frictional pressure drop			bar	0.49071			0.47095					
35	Notes												
36													
37													

ALPEMA Sheet

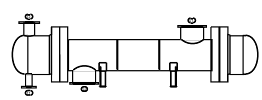
PLATE-FIN Heat Exchanger Specification Sheet

2	Company:				
3	Location:				
4	Service of Unit: Our Reference:				
5	Item No.: Your Reference:				
6	Date: Rev No.: Job No.:				
7	Stream i.d./fluid name		1/ A-211->A-212	2/ P-211->P-212	3/ A-219->A-220
8	Flow rate Total	kg/s	27.7778	36.1111	5.7443
9	Vap./liq. In	kg/s	27.7778 / 0	0 / 36.1111	5.7443 / 0
10	Vap./liq. Out		0 / 27.7778	0 / 36.1111	5.7443 / 0
11	Molecular weight Vap. In/Out		28.8309 /	/	28.35176 / 28.35176
12	Liq. In/Out		/ 28.8309	44.097 / 44.097	/
13	Density Vap. In/Out	kg/m³	383.48 /	/	6.55 / 3.46
14	Liq. In/Out		/ 754.96	717.99 / 671.95	/
15	Viscosity Vap. In/Out	mPa-s	0.0234 /	/	0.0058 / 0.0102
16	Liq. In/Out		/ 0.0846	3.5008 / 0.7588	/
17	Specific heat Vap. In/Out	kJ/(kg-K)	3.279 /	/	1.037 / 1.01
18	Liq. In/Out		/ 2.009	1.575 / 1.727	/
19	Thermal cond. Vap. In/Out	W/(m-K)	0.0412 /	/	0.008 / 0.0142
20	Liq. In/Out		/ 0.1382	0.2081 / 0.1818	/
21	Temperature In/Out	°C	-122.3 / -165.8	-175 / -127.3	-190.65 / -123.6
22	Operating pressure In	bar	80	10	1.5
23	Maximum allowable pressure drop	bar	0.5	0.5	0.3
24	Heat load	kW	-3223.1	2831.5	391.6
25	Calculated MTD	°C	8.9		
26	Fouling resistance	m²-K/W	0	0	0
27	Core size	mm	Width 600	Height 856.4	Length 2264.92
28	Number of layers		33	29	36
29	Fin code: Heat transfer fin		1	2	3
30	Fin code: Distributor fin		4	4	5
31	Heat transfer surface/core	m²	851.7	925	1362.7
32	Core opening size In/Out	mm	171.21 / 113.63	225.28 / 142.46	282.76 / 282.76
33	Nozzle size In/Out	mm	154.08 / 102.26	202.74 / 128.2	254.46 / 254.46
34	Calculated frictional pressure drop	bar	0.05748	0.47617	0.29446
35	Notes				
36					
37					

TEMA Sheet

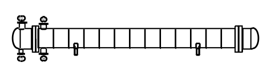
Heat Exchanger Specification Sheet

1	Company:					
2	Location:					
3	Service of Unit:	Our Reference:				
4	Item No.:	Your Reference:				
5	Date:	Rev No.:	Job No.:			
6	Size: 19 - 96	in	Type: BEM	Horizontal	Connected in: 3 parallel	1 series
7	Surf/unit(eff.) 914.7	ft^2	Shells/unit 3		Surf/shell(eff.) 304.9	ft^2
8	**PERFORMANCE OF ONE UNIT**					
9	Fluid allocation		Shell Side		Tube Side	
10	Fluid name		A-102->A-103		L-101->L-102	
11	Fluid quantity, Total	lb/h	177592.9		220462.3	
12	Vapor (In/Out)	lb/h	177592.9	176574.1	0	0
13	Liquid	lb/h	0	1018.8	220462.3	220462.3
14	Noncondensable	lb/h	0	0	0	0
15						
16	Temperature (In/Out)	°F	356.77	66.83	-70.66	3.01
17	Bubble / Dew point	°F	-396.98 / 92.86	-397.4 / 90.1	/	/
18	Density Vapor/Liquid	lb/ft^3	0.145 /	0.208 / 63.153	/ 23.059	/ 18.21
19	Viscosity	cp	0.0253 /	0.0185 / 1.0169	/ 0.0287	/ 0.0272
20	Molecular wt, Vap		28.77	28.87		
21	Molecular wt, NC					
22	Specific heat	BTU/(lb-F)	0.2506 /	0.2419 / 1.0304	/ 0.827	/ 0.8642
23	Thermal conductivity	BTU/(ft-h-F)	0.021 /	0.015 / 0.348	/ 0.044	/ 0.043
24	Latent heat	BTU/lb	1047	1054.6		
25	Pressure (abs)	psi	44.08	40.52	3625.93	3624.89
26	Velocity (Mean/Max)	ft/s	48.22 / 180.88		4.91 / 5.74	
27	Pressure drop, allow./calc.	psi	3.75	3.56	7.25	1.04
28	Fouling resistance (min)	ft^2-h-F/BTU	0		0	0 Ao based
29	Heat exchanged 13825440	BTU/h			MTD (corrected) 197.94	°F
30	Transfer rate, Service 76.36		Dirty 93.21		Clean 93.21	BTU/(h-ft^2-F)
31	**CONSTRUCTION OF ONE SHELL**				**Sketch**	
32			Shell Side	Tube Side		
33	Design/Vacuum/test pressure	psi	50 / /	3990 / /		
34	Design temperature / MDMT	°F	420 /	100 /		
35	Number passes per shell		1	2		
36	Corrosion allowance	in	0.125	0.125		
37	Connections In	in	1 14 / -	1 3.5 / -		
38	Size/Rating Out		1 14 / -	1 6 / -		
39	Nominal Intermediate		/ -	/ -		
40	Tube #: 217	OD: 0.75	Tks. Average 0.083 in	Length: 96 in	Pitch: 0.9375 in	Tube pattern:30
41	Tube type: Plain		Insert:None	Fin#:	#/in	Material:Carbon Steel
42	Shell Carbon Steel	ID 19.25	OD 20	in	Shell cover	-
43	Channel or bonnet	Carbon Steel			Channel cover	-
44	Tubesheet-stationary	Carbon Steel	-		Tubesheet-floating	-
45	Floating head cover	-			Impingement protection	None
46	Baffle-cross Carbon Steel	Type	Single segmental	Cut(%d) 41.56	Verti Spacing: c/c 25.5	in
47	Baffle-long -		Seal Type		Inlet 30.1875	in
48	Supports-tube	U-bend	0		Type	
49	Bypass seal			Tube-tubesheet joint	Expanded only (2 grooves)(App.A 'i')	
50	Expansion joint	-		Type	None	
51	RhoV2-Inlet nozzle	2039	Bundle entrance	1224	Bundle exit 1492	lb/(ft-s^2)
52	Gaskets - Shell side	-		Tube side	Flat Metal Jacket Fibe	
53	Floating head	-				
54	Code requirements	ASME Code Sec VIII Div 1		TEMA class	R - refinery service	
55	Weight/Shell	10939.4	Filled with water 11791.9	Bundle	3470.7	lb
56	Remarks					
57						
58						



TEMA Sheet

Heat Exchanger Specification Sheet

1	Company:					
2	Location:					
3	Service of Unit: Our Reference:					
4	Item No.: Your Reference:					
5	Date: Rev No.: Job No.:					
6	Size: 584 - 6096 mm Type: BFM Horizontal		Connected in: 2 parallel 1 series			
7	Surf/unit(eff.) 317.6 m² Shells/unit 2		Surf/shell(eff.) 158.8 m²			
8	**PERFORMANCE OF ONE UNIT**					
9	Fluid allocation		Shell Side		Tube Side	
10	Fluid name		P-213->L-214		L-207->L-208	
11	Fluid quantity, Total	kg/s	30.5556		27.7778	
12	Vapor (In/Out)	kg/s	0	0	0	0
13	Liquid	kg/s	30.5556	30.5556	27.7778	27.7778
14	Noncondensable	kg/s	0	0	0	0
15						
16	Temperature (In/Out)	°C	-35.25	-122.3	-129.3	-77.95
17	Bubble / Dew point	°C	/	/	/	/
18	Density Vapor/Liquid	kg/m³	/ 574.46	/ 667.02	/ 421.06	/ 324.91
19	Viscosity	mPa-s	/ 0.1832	/ 0.6769	/ 0.0833	/ 0.037
20	Molecular wt, Vap					
21	Molecular wt, NC					
22	Specific heat	kJ/(kg-K)	/ 2.223	/ 1.748	/ 3.246	/ 4.37
23	Thermal conductivity	W/(m-K)	/ 0.1298	/ 0.179	/ 0.1519	/ 0.0762
24	Latent heat	kJ/kg				
25	Pressure (abs)	bar	10	9.81239	91.51301	91.43396
26	Velocity (Mean/Max)	m/s	0.6 / 0.82		0.96 / 1.11	
27	Pressure drop, allow./calc.	bar	0.25855	0.18761	1.01513	0.07905
28	Fouling resistance (min)	m²-K/W	0		0	0 Ao based
29	Heat exchanged 5230.2 kW		MTD (corrected) 20.27 °C			
30	Transfer rate, Service 812.6		Dirty 814.8		Clean 814.8 W/(m²-K)	
31	**CONSTRUCTION OF ONE SHELL**				**Sketch**	
32			Shell Side	Tube Side		
33	Design/Vacuum/test pressure	bar	11.03162/ /	101.353 / /		
34	Design temperature / MDMT	°C	37.78 /	37.78 /		
35	Number passes per shell		2	2		
36	Corrosion allowance	mm	3.18	3.18		
37	Connections	In mm	1 152.4 / -	1 101.6 / -		
38	Size/Rating	Out	1 152.4 / -	1 152.4 / -		
39	Nominal	Intermediate	/ -	/ -		
40	Tube #: 450 OD: 19.05 Tks. Average 2.11 mm Length: 6096 mm Pitch: 23.81 mm Tube pattern:30					
41	Tube type: Plain Insert:None Fin#: #/m Material:Carbon Steel					
42	Shell Carbon Steel ID 590.55 OD 609.6 mm			Shell cover -		
43	Channel or bonnet Carbon Steel			Channel cover -		
44	Tubesheet-stationary Carbon Steel -			Tubesheet-floating -		
45	Floating head cover -			Impingement protection None		
46	Baffle-cross Carbon Steel Type Single segmental Cut(%d) 39.52 Verti				Spacing: c/c 457.2 mm	
47	Baffle-long Carbon Steel Seal Type				Inlet 433.39 mm	
48	Supports-tube U-bend 0 Type					
49	Bypass seal Tube-tubesheet joint Expanded only (2 grooves)(App.A 'i')					
50	Expansion joint - Type None					
51	RhoV2-Inlet nozzle 1170 Bundle entrance 183 Bundle exit 455 kg/(m-s²)					
52	Gaskets - Shell side - Tube side Flat Metal Jacket Fibe					
53	Floating head -					
54	Code requirements ASME Code Sec VIII Div 1 TEMA class R - refinery service					
55	Weight/Shell 5862 Filled with water 7330.1 Bundle 3343.4 kg					
56	Remarks					
57						
58						

Aspen Exchanger Design and Rating   Shell & Tube V12

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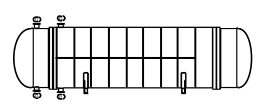
TEMA Sheet

Heat Exchanger Specification Sheet

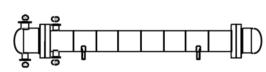
1	Company:					
2	Location:					
3	Service of Unit:	Our Reference:				
4	Item No.:	Your Reference:				
5	Date:	Rev No.:	Job No.:			
6	Size: 2311 - 6096 mm	Type: BFM Horizontal		Connected in: 1 parallel 1 series		
7	Surf/unit(eff.) 2835.8 m²	Shells/unit 1		Surf/shell(eff.) 2835.8 m²		
8	**PERFORMANCE OF ONE UNIT**					
9	Fluid allocation		Shell Side		Tube Side	
10	Fluid name		A-216->A-217		P-219->P-220	
11	Fluid quantity, Total	kg/s	18.644		30.5556	
12	Vapor (In/Out)	kg/s	0	0	0	0
13	Liquid	kg/s	18.644	18.644	30.5556	30.5556
14	Noncondensable	kg/s	0	0	0	0
15						
16	Temperature (In/Out)	°C	-189.17	-141.9	-127.3	-175.01
17	Bubble / Dew point	°C	-141.74 / -141.41	-141.77 / -141.43	/	/
18	Density Vapor/Liquid	kg/m³	/ 860.94	/ 412.57	/ 671.95	/ 718
19	Viscosity	mPa-s	/ 0.1504	/ 0.037	/ 0.7588	/ 3.5023
20	Molecular wt, Vap					
21	Molecular wt, NC					
22	Specific heat	kJ/(kg-K)	/ 1.804	/ 20.211	/ 1.727	/ 1.575
23	Thermal conductivity	W/(m-K)	/ 0.196	/ 0.0584	/ 0.1818	/ 0.2081
24	Latent heat	kJ/kg				
25	Pressure (abs)	bar	36.5	36.45767	10	9.96716
26	Velocity (Mean/Max)	m/s	0.16 / 0.32		0.06 / 0.06	
27	Pressure drop, allow./calc.	bar	0.49987	0.04233	0.25855	0.03283
28	Fouling resistance (min)	m²-K/W	0		0	0 Ao based
29	Heat exchanged 2418.7	kW		MTD (corrected) 8.84		°C
30	Transfer rate, Service 96.5		Dirty 97.4	Clean 97.4		W/(m²-K)
31	**CONSTRUCTION OF ONE SHELL**				**Sketch**	
32			Shell Side	Tube Side		
33	Design/Vacuum/test pressure	bar	40.67909/ /	11.03162/ /		
34	Design temperature / MDMT	°C	37.78 /	37.78 /		
35	Number passes per shell		2	2		
36	Corrosion allowance	mm	3.18	3.18		
37	Connections	In mm	1 152.4 / -	1 152.4 / -		
38	Size/Rating	Out	1 152.4 / -	1 152.4 / -		
39	Nominal	Intermediate	/ -	/ -		
40	Tube #: 8111 OD: 19.05 Tks. Average 2.11 mm	Length: 6096 mm		Pitch: 23.81 mm	Tube pattern:30	
41	Tube type: Plain	Insert:None		Fin#: #/m	Material:Carbon Steel	
42	Shell Carbon Steel	ID 2311.4 OD 2400.3 mm		Shell cover	-	
43	Channel or bonnet	Carbon Steel		Channel cover	-	
44	Tubesheet-stationary	Carbon Steel -		Tubesheet-floating	-	
45	Floating head cover	-		Impingement protection	None	
46	Baffle-cross Carbon Steel	Type Single segmental	Cut(%d) 25.02	Verti Spacing: c/c 647.7		mm
47	Baffle-long Carbon Steel	Seal Type		Inlet 654.05		mm
48	Supports-tube	U-bend 0		Type		
49	Bypass seal		Tube-tubesheet joint	Expanded only (2 grooves)(App.A 'i')		
50	Expansion joint	-	Type None			
51	RhoV2-Inlet nozzle 1162	Bundle entrance 59		Bundle exit 159		kg/(m-s²)
52	Gaskets - Shell side	-	Tube side	Flat Metal Jacket Fibe		
53	Floating head	-				
54	Code requirements	ASME Code Sec VIII Div 1		TEMA class R - refinery service		
55	Weight/Shell	77560	Filled with water 104399.4	Bundle 52273.8		kg
56	Remarks					
57						
58						



TEMA Sheet

Heat Exchanger Specification Sheet

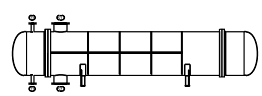
#						
1	Company:					
2	Location:					
3	Service of Unit: Our Reference:					
4	Item No.: Your Reference:					
5	Date: Rev No.: Job No.:					
6	Size: 610 - 5486.4 mm Type: BFM Horizontal				Connected in: 1 parallel 2 series	
7	Surf/unit(eff.) 304.2 m² Shells/unit 2				Surf/shell(eff.) 152.1 m²	
8	**PERFORMANCE OF ONE UNIT**					
9	Fluid allocation		Shell Side		Tube Side	
10	Fluid name		P-205->P-206		A-218->A-219	
11	Fluid quantity, Total	kg/s	14.1026		18.644	
12	Vapor (In/Out)	kg/s	0	0	18.644	18.644
13	Liquid	kg/s	14.1026	14.1026	0	0
14	Noncondensable	kg/s	0	0	0	0
15						
16	Temperature (In/Out)	°C	23.9	-77.56	-97.55	16.95
17	Bubble / Dew point	°C	26.92 / 26.92	26.09 / 26.09	/	-94 / -85.55
18	Density Vapor/Liquid	kg/m³	/ 494.45	/ 621.48	526.71 /	240.3 /
19	Viscosity	mPa-s	/ 0.1009	/ 0.3092	0.0363 /	0.0247 /
20	Molecular wt, Vap				28.96	28.96
21	Molecular wt, NC					
22	Specific heat	kJ/(kg-K)	/ 2.825	/ 1.961	1.926 /	1.301 /
23	Thermal conductivity	W/(m-K)	/ 0.0956	/ 0.1539	0.06 /	0.0385 /
24	Latent heat	kJ/kg				
25	Pressure (abs)	bar	10	9.78831	200	199.8409
26	Velocity (Mean/Max)	m/s	0.46 / 0.75		1.15 / 1.87	
27	Pressure drop, allow./calc.	bar	0.25855	0.21168	2.1	0.15915
28	Fouling resistance (min)	m²-K/W	0		0	0 Ao based
29	Heat exchanged 3334.9 kW				MTD (corrected) 18.95	°C
30	Transfer rate, Service 578.5		Dirty 593.5		Clean 593.5	W/(m²-K)
31	**CONSTRUCTION OF ONE SHELL**				**Sketch**	
32			Shell Side		Tube Side	
33	Design/Vacuum/test pressure	bar	11.03162/ /		220.6323/ /	
34	Design temperature / MDMT	°C	60 /		54.44 /	
35	Number passes per shell		2		2	
36	Corrosion allowance	mm	3.18		3.18	
37	Connections In	mm	1 152.4 / -		1 152.4 / -	
38	Size/Rating Out		1 152.4 / -		1 203.2 / -	
39	Nominal Intermediate		1 152.4 / -		1 152.4 / -	
40	Tube #: 489 OD: 19.05 Tks. Average 2.11 mm Length: 5486.4 mm Pitch: 23.81 mm Tube pattern:30					
41	Tube type: Plain Insert:None Fin#: #/m Material:Carbon Steel					
42	Shell Carbon Steel ID 609.6 OD 628.65 mm				Shell cover -	
43	Channel or bonnet Carbon Steel				Channel cover -	
44	Tubesheet-stationary Carbon Steel -				Tubesheet-floating -	
45	Floating head cover -				Impingement protection None	
46	Baffle-cross Carbon Steel Type Single segmental Cut(%d) 39.85 Verti				Spacing: c/c 641.35 mm	
47	Baffle-long Carbon Steel Seal Type				Inlet 674.69 mm	
48	Supports-tube U-bend 0 Type					
49	Bypass seal Tube-tubesheet joint Expanded only (2 grooves)(App.A 'i')					
50	Expansion joint - Type None					
51	RhoV2-Inlet nozzle 1158 Bundle entrance 82 Bundle exit 89 kg/(m-s²)					
52	Gaskets - Shell side - Tube side Flat Metal Jacket Fibe					
53	Floating head -					
54	Code requirements ASME Code Sec VIII Div 1 TEMA class R - refinery service					
55	Weight/Shell 9310.1 Filled with water 10659 Bundle 4102.9 kg					
56	Remarks					
57						
58						



TEMA Sheet

Heat Exchanger Specification Sheet

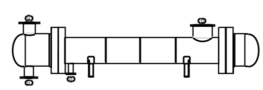
1	Company:					
2	Location:					
3	Service of Unit: Our Reference:					
4	Item No.: Your Reference:					
5	Date: Rev No.: Job No.:					
6	Size: 940 - 3657.6 mm Type: BFM Horizontal			Connected in: 5 parallel 1 series		
7	Surf/unit(eff.) 1276.7 m² Shells/unit 5			Surf/shell(eff.) 255.3 m²		
8	**PERFORMANCE OF ONE UNIT**					
9	Fluid allocation		Shell Side		Tube Side	
10	Fluid name		A-201->A-202		P-201->P-202	
11	Fluid quantity, Total	kg/s	22.118		16.6667	
12	Vapor (In/Out)	kg/s	22.118	22.1178	0	0
13	Liquid	kg/s	0	0.0002	16.6667	16.6667
14	Noncondensable	kg/s	0	0	0	0
15						
16	Temperature (In/Out)	°C	13.56	-70.6	-77.56	-24.88
17	Bubble / Dew point	°C	-247.32 / -52.84	-247.54 / -53.49	/	/
18	Density Vapor/Liquid	kg/m³	3.77 /	4.95 /	/ 621.48	/ 562.01
19	Viscosity	mPa-s	0.0183 /	0.0137 /	/ 0.3091	/ 0.1639
20	Molecular wt, Vap		28.96	28.96		
21	Molecular wt, NC					
22	Specific heat	kJ/(kg-K)	1.008 /	0.996 /	/ 1.961	/ 2.3
23	Thermal conductivity	W/(m-K)	0.0251 /	0.0187 /	/ 0.1539	/ 0.1238
24	Latent heat	kJ/kg				
25	Pressure (abs)	bar	3.1	2.85378	10	9.9688
26	Velocity (Mean/Max)	m/s	10.42 / 13.61		0.05 / 0.06	
27	Pressure drop, allow./calc.	bar	0.25855	0.24622	0.49987	0.0312
28	Fouling resistance (min)	m²-K/W	0		0 0	Ao based
29	Heat exchanged 1861.7 kW			MTD (corrected) 17.84 °C		
30	Transfer rate, Service 81.8		Dirty 83.7	Clean 83.7 W/(m²-K)		

31	**CONSTRUCTION OF ONE SHELL**					**Sketch**
32				Shell Side	Tube Side	
33	Design/Vacuum/test pressure		bar	3.44738 / /	11.03162/ /	
34	Design temperature / MDMT		°C	48.89 /	37.78 /	
35	Number passes per shell			2	2	
36	Corrosion allowance		mm	3.18	3.18	
37	Connections	In	mm	1 254 / -	1 50.8 / -	
38	Size/Rating	Out		1 254 / -	1 50.8 / -	
39	Nominal	Intermediate		/ -	/ -	
40	Tube #: 1203 OD: 19.05 Tks. Average 2.11 mm Length: 3657.6 mm Pitch: 23.81 mm Tube pattern:30					
41	Tube type: Plain Insert:None Fin#: #/m Material:Carbon Steel					
42	Shell Carbon Steel ID 939.8 OD 962.02 mm				Shell cover -	
43	Channel or bonnet Carbon Steel				Channel cover -	
44	Tubesheet-stationary Carbon Steel -				Tubesheet-floating -	
45	Floating head cover -				Impingement protection None	
46	Baffle-cross Carbon Steel Type Single segmental Cut(%d) 39.03 Verti					Spacing: c/c 660.4 mm
47	Baffle-long Carbon Steel Seal Type					Inlet 782.64 mm
48	Supports-tube U-bend 0 Type					
49	Bypass seal Tube-tubesheet joint Expanded only (2 grooves)(App.A 'i')					
50	Expansion joint - Type None					
51	RhoV2-Inlet nozzle 2003 Bundle entrance 554 Bundle exit 523 kg/(m-s²)					
52	Gaskets - Shell side - Tube side Flat Metal Jacket Fibe					
53	Floating head -					
54	Code requirements ASME Code Sec VIII Div 1 TEMA class R - refinery service					
55	Weight/Shell 6426.5 Filled with water 8911.1 Bundle 4584.1 kg					
56	Remarks					
57						
58						

TEMA Sheet

Heat Exchanger Specification Sheet

1	Company:						
2	Location:						
3	Service of Unit:	Our Reference:					
4	Item No.:	Your Reference:					
5	Date:	Rev No.:	Job No.:				
6	Size : 483 - 3048 mm	Type : BEM Horizontal		Connected in : 2 parallel 1 series			
7	Surf/unit(eff.) 78.1 m²	Shells/unit 2		Surf/shell(eff.) 39 m²			
8	**PERFORMANCE OF ONE UNIT**						
9	Fluid allocation		Shell Side		Tube Side		
10	Fluid name		W-301->W-302		L-301->L-302		
11	Fluid quantity, Total	kg/h	21800		100000		
12	Vapor (In/Out)	kg/h	21211	0	0	100000	
13	Liquid	kg/h	589	21800	100000	0	
14	Noncondensable	kg/s	0	0	0	0	
15							
16	Temperature (In/Out)	°C	110.31	90	-56.22	87.4	
17	Bubble / Dew point	°C	110.3 / 110.31	108.2 / 108.2	-5.76 / 6.8	-5.79 / 6.77	
18	Density Vapor/Liquid	kg/m³	0.83 / 939.14	/ 956.24	/ 367.81	124.12 /	
19	Viscosity	mPa-s	0.0124 / 0.2515	/ 0.3113	/ 0.0287	0.0219 /	
20	Molecular wt, Vap		18.02			17.87	
21	Molecular wt, NC						
22	Specific heat	kJ/(kg-K)	1.917 / 4.424	/ 4.375	/ 3.468	3.18 /	
23	Thermal conductivity	W/(m-K)	0.0253 / 0.6844	/ 0.6759	/ 0.0754	0.0692 /	
24	Latent heat	kJ/kg	2248.9	2254.6	20.9	20.9	
25	Pressure (abs)	bar	1.45003	1.35041	250.0133	249.0942	
26	Velocity (Mean/Max)	m/s	12.5 / 71.58		5.59 / 10.79		
27	Pressure drop, allow./calc.	bar	0.14241	0.09962	1.28082	0.9191	
28	Fouling resistance (min)	m²-K/W	0		0	0	Ao based
29	Heat exchanged 13791.1	kW		MTD (corrected) 71.5		°C	
30	Transfer rate, Service 2470.3		Dirty 2878	Clean 2878		W/(m²-K)	

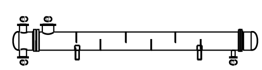
31	**CONSTRUCTION OF ONE SHELL**					**Sketch**
32				Shell Side	Tube Side	
33	Design/Vacuum/test pressure		bar	3.44738 / /	275.1009/ /	
34	Design temperature / MDMT		°C	148.89 /	126.67 /	
35	Number passes per shell			1	4	
36	Corrosion allowance		mm	3.18	3.18	
37	Connections	In	mm	1 355.6 / -	1 152.4 / -	
38	Size/Rating	Out		1 76.2 / -	1 203.2 / -	
39	Nominal	Intermediate		/ -	/ -	

40	Tube #: 234 OD: 19.05 Tks. Average 2.11 mm Length: 3048 mm Pitch: 23.81 mm Tube pattern:30		
41	Tube type: Plain Insert:None Fin#: #/m Material:Carbon Steel		
42	Shell Carbon Steel ID 488.95 OD 508 mm	Shell cover -	
43	Channel or bonnet Carbon Steel	Channel cover -	
44	Tubesheet-stationary Carbon Steel -	Tubesheet-floating -	
45	Floating head cover -	Impingement protection None	
46	Baffle-cross Carbon Steel Type Single segmental Cut(%d) 37.99 Verti	Spacing: c/c 647.7 mm	
47	Baffle-long - Seal Type	Inlet 746.12 mm	
48	Supports-tube U-bend 0 Type		
49	Bypass seal Tube-tubesheet joint Expanded only (2 grooves)(App.A 'i')		
50	Expansion joint - Type None		
51	RhoV2-Inlet nozzle 1360 Bundle entrance 1519 Bundle exit 4 kg/(m-s²)		
52	Gaskets - Shell side - Tube side Flat Metal Jacket Fibe		
53	Floating head -		
54	Code requirements ASME Code Sec VIII Div 1 TEMA class R - refinery service		
55	Weight/Shell 5379 Filled with water 5885.2 Bundle 1749.3 kg		
56	Remarks		
57			
58			

TEMA Sheet

Heat Exchanger Specification Sheet

1	Company:					
2	Location:					
3	Service of Unit: Our Reference:					
4	Item No.: Your Reference:					
5	Date: Rev No.: Job No.:					
6	Size: 432 - 4876.8 mm Type: BEM Horizontal			Connected in: 1 parallel 1 series		
7	Surf/unit(eff.) 66.1 m²		Shells/unit 1	Surf/shell(eff.) 66.1 m²		
8	PERFORMANCE OF ONE UNIT					
9	Fluid allocation		Shell Side		Tube Side	
10	Fluid name		W-305->W-306		H-602->H-603	
11	Fluid quantity, Total	kg/h	16000		70000	
12	Vapor (In/Out)	kg/h	0	16000	0	0
13	Liquid	kg/h	16000	0	70000	70000
14	Noncondensable	kg/s	0	0	0	0
15						
16	Temperature (In/Out)	°C	104.32	251.98	480.94	282.14
17	Bubble / Dew point	°C	165.02 / 165.02	163.92 / 163.92	/	/
18	Density Vapor/Liquid	kg/m³	/ 944.51	2.88 /	/ 572.68	/ 699.96
19	Viscosity	mPa-s	/ 0.2668	0.0182 /	/ 0.1315	/ 0.5649
20	Molecular wt, Vap			18.02		
21	Molecular wt, NC					
22	Specific heat	kJ/(kg-K)	/ 4.407	2.025 /	/ 2.6	/ 2.821
23	Thermal conductivity	W/(m-K)	/ 0.6824	0.039 /	/ 0.0997	/ 0.1274
24	Latent heat	kJ/kg	2088.9	2092.6		
25	Pressure (abs)	bar	7	6.81016	5	4.84709
26	Velocity (Mean/Max)	m/s	10.4 / 37.54		1.53 / 1.64	
27	Pressure drop, allow./calc.	bar	0.49987	0.18983	0.25855	0.15291
28	Fouling resistance (min)	m²-K/W	0		0	0 Ao based
29	Heat exchanged 11281.2 kW			MTD (corrected) 199.84 °C		
30	Transfer rate, Service 853.7		Dirty 928.5	Clean 928.5 W/(m²-K)		

31	CONSTRUCTION OF ONE SHELL				Sketch
32			Shell Side	Tube Side	
33	Design/Vacuum/test pressure	bar	8.27371 / /	5.51581 / /	
34	Design temperature / MDMT	°C	287.78 /	521.11 /	
35	Number passes per shell		1	2	
36	Corrosion allowance	mm	3.18	3.18	
37	Connections In	mm	1 76.2 / -	1 152.4 / -	
38	Size/Rating Out		1 254 / -	1 152.4 / -	
39	Nominal Intermediate		/ -	/ -	
40	Tube #: 232 OD: 19.05 Tks. Average 2.11 mm Length: 4876.8 mm Pitch: 23.81 mm Tube pattern:30				
41	Tube type: Plain Insert:None Fin#: #/m Material:Carbon Steel				
42	Shell Carbon Steel ID 438.15 OD 457.2 mm			Shell cover -	
43	Channel or bonnet Carbon Steel			Channel cover -	
44	Tubesheet-stationary Carbon Steel -			Tubesheet-floating -	
45	Floating head cover -			Impingement protection None	
46	Baffle-cross Carbon Steel Type Single segmental Cut(%d) 41.31 Horiz Spacing: c/c 596.9 mm				
47	Baffle-long - Seal Type			Inlet 889 mm	
48	Supports-tube U-bend 0 Type				
49	Bypass seal Tube-tubesheet joint Expanded only (2 grooves)(App.A 'i')				
50	Expansion joint - Type None				
51	RhoV2-Inlet nozzle 919 Bundle entrance 5 Bundle exit 1541 kg/(m-s²)				
52	Gaskets - Shell side - Tube side Flat Metal Jacket Fibe				
53	Floating head -				
54	Code requirements ASME Code Sec VIII Div 1 TEMA class R - refinery service				
55	Weight/Shell 1984.7 Filled with water 2665 Bundle 1178.5 kg				
56	Remarks				
57					
58					

Aspen Exchanger Design and Rating Shell & Tube V12

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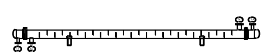
TEMA Sheet

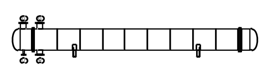
Heat Exchanger Specification Sheet

1	Company:						
2	Location:						
3	Service of Unit:	Our Reference:					
4	Item No.:	Your Reference:					
5	Date:	Rev No.:	Job No.:				
6	Size: 203 - 5486.4 mm	Type: BEM Horizontal		Connected in: 1 parallel 1 series			
7	Surf/unit(eff.) 15.2 m²	Shells/unit 1		Surf/shell(eff.) 15.2 m²			
8	**PERFORMANCE OF ONE UNIT**						
9	Fluid allocation		Shell Side		Tube Side		
10	Fluid name		W-307->W-301		W-304->W-305		
11	Fluid quantity, Total	kg/h	16000		16000		
12	Vapor (In/Out)	kg/h	0	0	0	0	
13	Liquid	kg/h	16000	16000	16000	16000	
14	Noncondensable	kg/h	0	0	0	0	
15							
16	Temperature (In/Out)	°C	111.31	97.76	90.7	104.3	
17	Bubble / Dew point	°C	111.31 / 111.32	109.58 / 109.58	/	/	
18	Density Vapor/Liquid	kg/m³	/ 938.28	/ 949.79	/ 955.9	/ 944.53	
19	Viscosity	mPa-s	/ 0.2491	/ 0.2857	/ 0.3088	/ 0.2669	
20	Molecular wt, Vap						
21	Molecular wt, NC						
22	Specific heat	kJ/(kg-K)	/ 4.427	/ 4.392	/ 4.376	/ 4.407	
23	Thermal conductivity	W/(m-K)	/ 0.6846	/ 0.6797	/ 0.6763	/ 0.6824	
24	Latent heat	kJ/kg					
25	Pressure (abs)	bar	1.5	1.41481	7	6.95002	
26	Velocity (Mean/Max)	m/s	0.37 / 0.48		0.58 / 0.58		
27	Pressure drop, allow./calc.	bar	0.15513	0.08519	0.49987	0.04997	
28	Fouling resistance (min)	m²-K/W	0		0	0 Ao based	
29	Heat exchanged 266.1 kW				MTD (corrected) 7.81 °C		
30	Transfer rate, Service 2237.7	Dirty 2266			Clean 2266 W/(m²-K)		
31	**CONSTRUCTION OF ONE SHELL**				**Sketch**		
32			Shell Side	Tube Side			
33	Design/Vacuum/test pressure	bar	3.44738 / /	8.27371 / /			
34	Design temperature / MDMT	°C	148.89 /	143.33 /			
35	Number passes per shell		1	1			
36	Corrosion allowance	mm	3.18	3.18			
37	Connections	In mm	1 88.9 / -	1 50.8 / -			
38	Size/Rating	Out	1 76.2 / -	1 50.8 / -			
39	Nominal	Intermediate	/ -	/ -			
40	Tube #: 47	OD: 19.05	Tks. Average 2.11 mm	Length: 5486.4 mm	Pitch: 23.81 mm	Tube pattern:30	
41	Tube type: Plain	Insert:None		Fin#: #/m	Material:Carbon Steel		
42	Shell Carbon Steel	ID 205	OD 219.08 mm	Shell cover -			
43	Channel or bonnet	Carbon Steel		Channel cover -			
44	Tubesheet-stationary	Carbon Steel	-	Tubesheet-floating -			
45	Floating head cover	-		Impingement protection None			
46	Baffle-cross Carbon Steel	Type Single segmental	Cut(%d) 39.94	Horiz	Spacing: c/c 190.5 mm		
47	Baffle-long -	Seal Type			Inlet 323.85 mm		
48	Supports-tube	U-bend 0		Type			
49	Bypass seal		Tube-tubesheet joint	Expanded only (2 grooves)(App.A 'i')			
50	Expansion joint	-	Type None				
51	RhoV2-Inlet nozzle 517	Bundle entrance 134		Bundle exit 132	kg/(m-s²)		
52	Gaskets - Shell side	-	Tube side	Flat Metal Jacket Fibe			
53	Floating head	-					
54	Code requirements	ASME Code Sec VIII Div 1		TEMA class R - refinery service			
55	Weight/Shell	664.6	Filled with water 821.3	Bundle 272.6	kg		
56	Remarks						
57							
58							

TEMA Sheet

Heat Exchanger Specification Sheet

1	Company:						
2	Location:						
3	Service of Unit:	Our Reference:					
4	Item No.:	Your Reference:					
5	Date:	Rev No.:	Job No.:				
6	Size: 635 - 6096 mm	Type: BFM Horizontal		Connected in: 1 parallel 1 series			
7	Surf/unit(eff.) 191.3 m²	Shells/unit 1		Surf/shell(eff.) 191.3 m²			
8	**PERFORMANCE OF ONE UNIT**						
9	Fluid allocation		Shell Side		Tube Side		
10	Fluid name		H-603->H-604		W-504->W-505		
11	Fluid quantity, Total	kg/s	19.4444		1.9667		
12	Vapor (In/Out)	kg/s	0	0	0	1.9667	
13	Liquid	kg/s	19.4444	19.4444	1.9667	0	
14	Noncondensable	kg/s	0	0	0	0	
15							
16	Temperature (In/Out)	°C	282.14	180.01	89.83	278.1	
17	Bubble / Dew point	°C	/	/	165.02 / 165.02	164.56 / 164.56	
18	Density Vapor/Liquid	kg/m³	/ 699.96	/ 765.18	/ 956.61	2.78 /	
19	Viscosity	mPa-s	/ 0.5649	/ 2.1401	/ 0.3119	0.0193 /	
20	Molecular wt, Vap					18.02	
21	Molecular wt, NC						
22	Specific heat	kJ/(kg-K)	/ 2.821	/ 2.429	/ 4.374	2.039 /	
23	Thermal conductivity	W/(m-K)	/ 0.1274	/ 0.1403	/ 0.6758	0.0417 /	
24	Latent heat	kJ/kg			2088.9	2090.5	
25	Pressure (abs)	bar	5	4.80085	7	6.92065	
26	Velocity (Mean/Max)	m/s	0.47 / 0.71		7.88 / 15.71		
27	Pressure drop, allow./calc.	bar	0.25855	0.19915	0.49987	0.07935	
28	Fouling resistance (min)	m²-K/W	0		0	0	Ao based
29	Heat exchanged 5220.8 kW				MTD (corrected) 55.73 °C		
30	Transfer rate, Service 489.8		Dirty 508.7		Clean 508.7	W/(m²-K)	

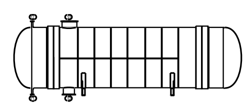
31	**CONSTRUCTION OF ONE SHELL**				**Sketch**
32			Shell Side	Tube Side	
33	Design/Vacuum/test pressure	bar	5.51581 / /	8.27371 / /	
34	Design temperature / MDMT	°C	321.11 /	315.56 /	
35	Number passes per shell		2	2	
36	Corrosion allowance	mm	3.18	3.18	
37	Connections	In mm	1 152.4 / -	1 31.75 / -	
38	Size/Rating	Out	1 152.4 / -	1 152.4 / -	
39	Nominal	Intermediate	/ -	/ -	

40	Tube #: 532 OD: 19.05 Tks. Average 2.11 mm Length: 6096 mm Pitch: 23.81 mm Tube pattern:30
41	Tube type: Plain Insert:None Fin#: #/m Material:Carbon Steel
42	Shell Carbon Steel ID 635 OD 654.05 mm / Shell cover -
43	Channel or bonnet Carbon Steel / Channel cover -
44	Tubesheet-stationary Carbon Steel - / Tubesheet-floating -
45	Floating head cover - / Impingement protection None
46	Baffle-cross Carbon Steel Type Single segmental Cut(%d) 40.26 Verti / Spacing: c/c 666.75 mm
47	Baffle-long Carbon Steel Seal Type / Inlet 669.92 mm
48	Supports-tube U-bend 0 Type
49	Bypass seal Tube-tubesheet joint Expanded only (2 grooves)(App.A 'i')
50	Expansion joint - Type None
51	RhoV2-Inlet nozzle 1555 Bundle entrance 207 Bundle exit 133 kg/(m-s²)
52	Gaskets - Shell side - Tube side Flat Metal Jacket Fibe
53	Floating head -
54	Code requirements ASME Code Sec VIII Div 1 TEMA class R - refinery service
55	Weight/Shell 4672 Filled with water 6426.2 Bundle 3318.3 kg
56	Remarks
57	
58	

TEMA Sheet

Heat Exchanger Specification Sheet

1	Company:					
2	Location:					
3	Service of Unit:	Our Reference:				
4	Item No.:	Your Reference:				
5	Date:	Rev No.:	Job No.:			
6	Size: 2540 - 6096 mm	Type: BFM Horizontal		Connected in: 10 parallel 6 series		
7	Surf/unit(eff.) 88152.3 m^2	Shells/unit 60		Surf/shell(eff.) 3135.9 m^2		
8	**PERFORMANCE OF ONE UNIT**					
9	Fluid allocation		Shell Side		Tube Side	
10	Fluid name		C-601>C-602		H-601->H-602	
11	Fluid quantity, Total	kg/h	81481		80000	
12	Vapor (In/Out)	kg/h	81481	81481	0	0
13	Liquid	kg/h	0	0	80000	80000
14	Noncondensable	kg/h	0	0	0	0
15						
16	Temperature (In/Out)	°C	1103.62	106.99	100	566.9
17	Bubble / Dew point	°C	/	/	/	/
18	Density Vapor/Liquid	kg/m^3	0.37 /	1.21 /	/ 816.73	/ 515.3
19	Viscosity	mPa-s	0.0583 /	0.0211 /	/ 6.8385	/ 0.0837
20	Molecular wt, Vap		28.43	28.43		
21	Molecular wt, NC					
22	Specific heat	kJ/(kg-K)	1.279 /	1.075 /	/ 2.133	/ 1.227
23	Thermal conductivity	W/(m-K)	0.0854 /	0.0305 /	/ 0.1498	/ 0.086
24	Latent heat	kJ/kg				
25	Pressure (abs)	bar	1.5	1.34487	5	4.92894
26	Velocity (Mean/Max)	m/s	14.73 / 30.45		0.01 / 0.02	
27	Pressure drop, allow./calc.	bar	0.15513	1.18867	0.49987	0.07106
28	Fouling resistance (min)	m^2-K/W	0		0	0 Ao based
29	Heat exchanged 26757	kW			MTD (corrected) 121.71	°C
30	Transfer rate, Service 1.2		Dirty 45.2		Clean 45.2	W/(m^2-K)

31	**CONSTRUCTION OF ONE SHELL**				**Sketch**	
32			Shell Side	Tube Side		
33	Design/Vacuum/test pressure	bar	3.44738 / /	5.51581 / /		
34	Design temperature / MDMT	°C	1143.33 /	604.44 /		
35	Number passes per shell		2	6		
36	Corrosion allowance	mm	3.18	3.18		
37	Connections	In mm	1 609.6 / -	1 76.2 / -		
38	Size/Rating	Out	1 457.2 / -	1 50.8 / -		
39	Nominal	Intermediate	1 457.2 / -	1 50.8 / -		

40	Tube #: 9345 OD: 19.05 Tks. Average 2.11 mm Length: 6096 mm Pitch: 23.81 mm Tube pattern:30		
41	Tube type: Plain Insert:None Fin#: #/m Material:Carbon Steel		
42	Shell Carbon Steel ID 2540 OD 2609.85 mm	Shell cover -	
43	Channel or bonnet Carbon Steel	Channel cover -	
44	Tubesheet-stationary Carbon Steel -	Tubesheet-floating -	
45	Floating head cover -	Impingement protection None	
46	Baffle-cross Carbon Steel Type Single segmental Cut(%d) 24.83 Verti	Spacing: c/c 685.8 mm	
47	Baffle-long Carbon Steel Seal Type	Inlet 746.12 mm	
48	Supports-tube U-bend 0 Type		
49	Bypass seal Tube-tubesheet joint Expanded only (2 grooves)(App.A 'i')		
50	Expansion joint - Type None		
51	RhoV2-Inlet nozzle 183 Bundle entrance 208 Bundle exit 118 kg/(m-s^2)		
52	Gaskets - Shell side - Tube side Flat Metal Jacket Fibe		
53	Floating head -		
54	Code requirements ASME Code Sec VIII Div 1 TEMA class R - refinery service		
55	Weight/Shell 88070.8 Filled with water 120003.9 Bundle 65112.9 kg		
56	Remarks		
57			
58			

aspentech

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 19:43:41 2022

Compressor: K-101

DESIGN

Connections

Inlet Stream

STREAM NAME	FROM UNIT OPERATION
A101	

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
A-102	Heat Exchanger	HE-101

Energy Stream

STREAM NAME	FROM UNIT OPERATION
Q-100	

Parameters

Speed:	---	Duty:	3.4003e+03 kW
Adiabatic Eff.:	75.00	PolyTropic Eff.:	78.40
Adiabatic Head:	1.162e+004 m	Polytropic Head:	1.215e+004 m
Adiabatic Fluid Head:	114.0 kJ/kg	Polytropic Fluid Head:	119.1 kJ/kg

Polytropic Exp.	1.560	Isentropic Exp.	1.394	Poly Head Factor	1.001

User Variables

Conditions

Name		A101	A-102	Q-100	
Vapour		1.0000	1.0000	---	
Temperature	(C)	33.0000 *	180.4304	---	
Pressure	(bar)	1.0130 *	3.0390	---	
Molar Flow	(kgmole/h)	2800.0000 *	2800.0000	---	
Mass Flow	(kg/h)	80554.7987	80554.7987	---	
Std Ideal Liq Vol Flow	(m3/h)	92.5085	92.5085	---	
Molar Enthalpy	(kcal/kgmole)	-997.6	47.29	---	
Molar Entropy	(kJ/kgmole-C)	153.8	156.3	---	
Heat Flow	(kW)	-3.2464e+03	1.5391e+02	3.4003e+03	

Results

Adiabatic Head	(m)	1.162e+004	Power Consumed	(kW)	3400
Polytropic Head	(m)	1.215e+004	Polytropic Head Factor		1.001
Adiabatic Fluid Head	(kJ/kg)	114.0	Polytropic Exponent		1.560
Polytropic Fluid Head	(kJ/kg)	119.1	Isentropic Exponent		1.394
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		78			---

DYNAMICS

Dynamic Specifications

Duty	(kW)	3400	Active	Head	(m)	1.215e+004	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	119.1	Not Active
Polytropic Efficiency		78	Active	Capacity	(ACT_m3/h)	7.031e+004	Not Active
Pressure Increase	(bar)	2.026	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

* Specified by user.

aspentech

	Case Name:	LAES new model 23 real process v12.hsc
	Unit Set:	NewUser2c
	Date/Time:	Mon Jan 31 19:43:59 2022

Compressor: K-102

DESIGN

Connections

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
A-104	Separator	D-101

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
A-105	Absorber	AB-101

Energy Stream

STREAM NAME	FROM UNIT OPERATION
Q-104	

Parameters

Speed:	---	Duty:	2.4133e+02 kW
Adiabatic Eff.:	75.00	PolyTropic Eff.:	75.34
Adiabatic Head:	830.0 m	Polytropic Head:	833.7 m
Adiabatic Fluid Head:	8.139 kJ/kg	Polytropic Fluid Head:	8.176 kJ/kg

Polytropic Exp.	1.617	Isentropic Exp.	1.404	Poly Head Factor	1.000

User Variables

Conditions

Name		A-104	A-105	Q-104	
Vapour		1.0000	1.0000	---	
Temperature	(C)	20.0000	30.7869	---	
Pressure	(bar)	3.0190	3.3209	---	
Molar Flow	(kgmole/h)	2772.3497	2772.3497	---	
Mass Flow	(kg/h)	80056.6662	80056.6662	---	
Std Ideal Liq Vol Flow	(m3/h)	92.0093	92.0093	---	
Molar Enthalpy	(kcal/kgmole)	-526.5	-451.6	---	
Molar Entropy	(kJ/kgmole-C)	142.8	143.1	---	
Heat Flow	(kW)	-1.6965e+03	-1.4551e+03	2.4133e+02	

Results

Adiabatic Head	(m)	830.0	Power Consumed	(kW)	241.3
Polytropic Head	(m)	833.7	Polytropic Head Factor		1.000
Adiabatic Fluid Head	(kJ/kg)	8.139	Polytropic Exponent		1.617
Polytropic Fluid Head	(kJ/kg)	8.176	Isentropic Exponent		1.404
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		75			---

DYNAMICS

Dynamic Specifications

Duty	(kW)	241.3	Active	Head	(m)	833.7	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	8.176	Not Active
Polytropic Efficiency		75	Active	Capacity	(ACT_m3/h)	2.233e+004	Not Active
Pressure Increase	(bar)	0.3019	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Licensed to: * Specified by user.

aspentech		
	Case Name:	LAES new model 23 real process v12.hsc
	Unit Set:	NewUser2c
	Date/Time:	Mon Jan 31 19:44:13 2022

Compressor: K-201

DESIGN

Connections

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
A-203	Mixer	M-202

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
A-204	LNG	CB-201

Energy Stream

STREAM NAME	FROM UNIT OPERATION
com0-2	

Parameters

Speed:	---	Duty:	1.0676e+03 kW
Adiabatic Eff.:	85.00 *	PolyTropic Eff.:	86.22
Adiabatic Head:	3580 m	Polytropic Head:	3631 m
Adiabatic Fluid Head:	35.10 kJ/kg	Polytropic Fluid Head:	35.61 kJ/kg

Polytropic Exp.	1.518	Isentropic Exp.	1.417	Poly Head Factor	1.000

User Variables

Conditions

Name		A-203	A-204	com0-2	
Vapour		1.0000	1.0000	---	
Temperature	(C)	-82.5448	-40.2082	---	
Pressure	(bar)	2.9262	5.2872	---	
Molar Flow	(kgmole/h)	3222.5194	3222.5194	---	
Mass Flow	(kg/h)	93063.1385	93063.1385	---	
Std Ideal Liq Vol Flow	(m3/h)	107.7173	107.7173	---	
Molar Enthalpy	(kcal/kgmole)	-751.0	-466.0	---	
Molar Entropy	(kJ/kgmole-C)	129.9	130.6	---	
Heat Flow	(kW)	-2.8128e+03	-1.7452e+03	1.0676e+03	

Results

Adiabatic Head	(m)	3580		Power Consumed	(kW)	1068
Polytropic Head	(m)	3631		Polytropic Head Factor		1.000
Adiabatic Fluid Head	(kJ/kg)	35.10		Polytropic Exponent		1.518
Polytropic Fluid Head	(kJ/kg)	35.61		Isentropic Exponent		1.417
Adiabatic Efficiency		85	*	Speed	(rpm)	---
Polytropic Efficiency		86				---

DYNAMICS

Dynamic Specifications

Duty	(kW)	1068		Active	Head	(m)	3631	Not Active
Adiabatic Efficiency		85	*	Not Active	Fluid Head	(kJ/kg)	35.61	Not Active
Polytropic Efficiency		86		Active	Capacity	(ACT_m3/h)	1.728e+004	Not Active
Pressure Increase	(bar)	2.361	*	Not Active	Speed	(rpm)	---	Not Active
		---			Use Characteristic Curves			No

* Specified by user.

aspentech

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 19:44:23 2022

Compressor: K-202

DESIGN

Connections

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
A-205	LNG	CB-201

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
A-206	LNG	CB-202

Energy Stream

STREAM NAME	FROM UNIT OPERATION
com1-2	

Parameters

Speed:	---	Duty:	1.9343e+03 kW
Adiabatic Eff.:	85.00 *	PolyTropic Eff.:	86.98
Adiabatic Head:	6485 m	Polytropic Head:	6637 m
Adiabatic Fluid Head:	63.60 kJ/kg	Polytropic Fluid Head:	65.08 kJ/kg

Polytropic Exp.	1.516	Isentropic Exp.	1.422	Poly Head Factor	0.9998

User Variables

Conditions

Name		A-205	A-206	com1-2	
Vapour		1.0000	1.0000	---	
Temperature	(C)	-81.2300	-4.3087	---	
Pressure	(bar)	4.7963	13.0963	---	
Molar Flow	(kgmole/h)	3222.5194	3222.5194	---	
Mass Flow	(kg/h)	93063.1385	93063.1385	---	
Std Ideal Liq Vol Flow	(m3/h)	107.7173	107.7173	---	
Molar Enthalpy	(kcal/kgmole)	-749.9	-233.4	---	
Molar Entropy	(kJ/kgmole-C)	125.8	127.1	---	
Heat Flow	(kW)	-2.8084e+03	-8.7417e+02	1.9343e+03	

Results

Adiabatic Head	(m)	6485	Power Consumed	(kW)	1934
Polytropic Head	(m)	6637	Polytropic Head Factor		0.9998
Adiabatic Fluid Head	(kJ/kg)	63.60	Polytropic Exponent		1.516
Polytropic Fluid Head	(kJ/kg)	65.08	Isentropic Exponent		1.422
Adiabatic Efficiency		85 *	Speed	(rpm)	---
Polytropic Efficiency		87			---

DYNAMICS

Dynamic Specifications

Duty	(kW)	1934	Active	Head	(m)	6637	Not Active
Adiabatic Efficiency		85 *	Not Active	Fluid Head	(kJ/kg)	65.08	Not Active
Polytropic Efficiency		87	Active	Capacity	(ACT_m3/h)	1.055e+004	Not Active
Pressure Increase	(bar)	8.300 *	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Licensed to: * Specified by user.

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 19:44:40 2022

Compressor: K-203

DESIGN

Connections

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
A-207	LNG	CB-202

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
A-208	LNG	CB-203

Energy Stream

STREAM NAME	FROM UNIT OPERATION
com2-2	

Parameters

Speed:	---	Duty:	1.9220e+03 kW
Adiabatic Eff.:	85.00 *	PolyTropic Eff.:	87.11
Adiabatic Head:	6444 m	Polytropic Head:	6604 m
Adiabatic Fluid Head:	63.20 kJ/kg	Polytropic Fluid Head:	64.76 kJ/kg

Polytropic Exp.	1.548	Isentropic Exp.	1.450	Poly Head Factor	0.9985

User Variables

Conditions

Name		A-207	A-208	com2-2	
Vapour		1.0000	1.0000	---	
Temperature	(C)	-89.2300	-10.0383	---	
Pressure	(bar)	12.6028	36.3963	---	
Molar Flow	(kgmole/h)	3222.5194	3222.5194	---	
Mass Flow	(kg/h)	93063.1385	93063.1385	---	
Std Ideal Liq Vol Flow	(m3/h)	107.7173	107.7173	---	
Molar Enthalpy	(kcal/kgmole)	-841.3	-328.1	---	
Molar Entropy	(kJ/kgmole-C)	116.0	117.2	---	
Heat Flow	(kW)	-3.1511e+03	-1.2290e+03	1.9220e+03	

Results

Adiabatic Head	(m)	6444		Power Consumed	(kW)	1922
Polytropic Head	(m)	6604		Polytropic Head Factor		0.9985
Adiabatic Fluid Head	(kJ/kg)	63.20		Polytropic Exponent		1.548
Polytropic Fluid Head	(kJ/kg)	64.76		Isentropic Exponent		1.450
Adiabatic Efficiency		85	*	Speed	(rpm)	---
Polytropic Efficiency		87				---

DYNAMICS

Dynamic Specifications

Duty	(kW)	1922		Active	Head	(m)	6604	Not Active
Adiabatic Efficiency		85	*	Not Active	Fluid Head	(kJ/kg)	64.76	Not Active
Polytropic Efficiency		87		Active	Capacity	(ACT_m3/h)	3721	Not Active
Pressure Increase	(bar)	23.79	*	Not Active	Speed	(rpm)	---	Not Active
		---			Use Characteristic Curves			No

Licensed to: * Specified by user.

aspentech	Case Name:	LAES new model 23 real process v12.hsc
	Unit Set:	NewUser2c
	Date/Time:	Mon Jan 31 19:44:49 2022

Compressor: K-204

DESIGN

Connections

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
A-209	LNG	CB-203

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
A-210	LNG	CB-204

Energy Stream

STREAM NAME	FROM UNIT OPERATION
com3-2	

Parameters

Speed:	---	Duty:	1.0424e+03 kW
Adiabatic Eff.:	85.00 *	PolyTropic Eff.:	86.65
Adiabatic Head:	3495 m	Polytropic Head:	3563 m
Adiabatic Fluid Head:	34.28 kJ/kg	Polytropic Fluid Head:	34.94 kJ/kg

Polytropic Exp.	1.781	Isentropic Exp.	1.652	Poly Head Factor	0.9954

User Variables

Conditions

Name		A-209	A-210	com3-2	
Vapour		1.0000	1.0000	---	
Temperature	(C)	-115.3000	-65.2140	---	
Pressure	(bar)	35.8986	82.4186	---	
Molar Flow	(kgmole/h)	3222.5194	3222.5194	---	
Mass Flow	(kg/h)	93063.1385	93063.1385	---	
Std Ideal Liq Vol Flow	(m3/h)	107.7173	107.7173	---	
Molar Enthalpy	(kcal/kgmole)	-1193	-914.4	---	
Molar Entropy	(kJ/kgmole-C)	99.58	100.4	---	
Heat Flow	(kW)	-4.4670e+03	-3.4245e+03	1.0424e+03	

Results

Adiabatic Head	(m)	3495		Power Consumed	(kW)	1042
Polytropic Head	(m)	3563		Polytropic Head Factor		0.9954
Adiabatic Fluid Head	(kJ/kg)	34.28		Polytropic Exponent		1.781
Polytropic Fluid Head	(kJ/kg)	34.94		Isentropic Exponent		1.652
Adiabatic Efficiency		85	*	Speed	(rpm)	---
Polytropic Efficiency		87				---

DYNAMICS

Dynamic Specifications

Duty	(kW)	1042		Active	Head	(m)	3563	Not Active
Adiabatic Efficiency		85	*	Not Active	Fluid Head	(kJ/kg)	34.94	Not Active
Polytropic Efficiency		87		Active	Capacity	(ACT_m3/h)	907.5	Not Active
Pressure Increase	(bar)	46.52	*	Not Active	Speed	(rpm)	---	Not Active
		---			Use Characteristic Curves			No

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 23:18:14 2022

Pump: P-101

CONNECTIONS

Inlet Stream

Stream Name	From Unit Operation	
W-103	Heat Exchanger	E-103

Outlet Stream

Stream Name	To Unit Operation	
W-104	Recycle	RCY-3

Energy Stream

Stream Name	From Unit Operation
Q-105	

PARAMETERS

Adiabatic Efficiency (%):	75.00	Delta P:	0.1981 bar	Pressure Ratio:	1.060 *	Duty:	0.1616 kW
Multiphase Pump							Not Active

CURVES

Delta P:	0.1981 bar	Duty:	0.1616 kW		
Coefficient A:	0.0000 *	Coefficient B:	0.0000 *	Coefficient C:	0.0000 *

Parameter Preferences	Units for Head:	m	Flow Basis	ActVolFlow	Units for Flow:	m3/h

User Variables

NPSH

NPSH Required	---	NPSH Required based on	Turton Method
NPSH Available	7.358 m	Enable NPSH Curves:	No

NPSH Required Parameters

Suction Specific Speed	---	Units Type	---

NPSH Curves

Inertia

Rotational inertia (kg-m2)	---	Radius of gyration (m)	0.1000	Mass (kg)	---	Friction loss factor (kg-m2/s)	-3277

Start Up

Design Flow Typical Operating Capacity	10.00 m3/h

CONDITIONS

Name		W-103	W-104	Q-105	
Vapour		0.0000	0.0000	---	
Temperature	(C)	5.0000	5.0016	---	
Pressure	(bar)	3.3010	3.4991	---	
Molar Flow	(kgmole/h)	1250.0000	1250.0000	---	
Mass Flow	(kg/h)	22519.3084	22519.3084	---	
Std Ideal Liq Vol Flow	(m3/h)	22.5650	22.5650	---	
Molar Enthalpy	(kcal/kgmole)	-6.878e+004	-6.878e+004	---	
Molar Entropy	(kJ/kgmole-C)	48.31	48.31	---	
Heat Flow	(kW)	-9.9917e+04	-9.9917e+04	1.6160e-01	

PERFORMANCE

Results

* Specified by user.

Pump: P-101 (continued)

Results

Total Head	---	Velocity Head	-4.950e-006 m
Total Fluid Head	---		
Pressure Head	1.976 m	Delta P excluding Static Head Results	---

DYNAMICS

Dynamic Specifications

Head	(m)	---	Not Active	Power	(kW)	0.1616	Not Active
Fluid Head	(kJ/kg)	---	Not Active	Capacity	(m3/h)	22.57	
Speed	(rpm)	---	Not Active	Use Characteristic Curves			Not Active
Efficiency	(%)	75.00	Active	Pump is Acting as a Turbine			Not Active
Pressure Increase	(bar)	0.1981	Active				

Malfunction Details

Total Pump Failure	Not Active	Pump Overheating	Not Active	Pump Performance Deterioration	Not Active
Delay Time	---	Delay Time	---	Delay Time	---
Ramp Time	---	Ramp Time	---	Ramp Time	---
		Additional Heat	---	Decrease in Head	---
				Decrease in Efficiency	---

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

* Specified by user.

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 23:18:40 2022

Pump: PU-201

CONNECTIONS

Inlet Stream

Stream Name	From Unit Operation	
L-205	LNG	CB-201

Outlet Stream

Stream Name	To Unit Operation	
L-206	Heat Exchanger	E-103

Energy Stream

Stream Name	From Unit Operation
PUE-201	

PARAMETERS

Adiabatic Efficiency (%):	75.00	Delta P:	159.2 bar *	Pressure Ratio:	2.754	Duty:	1740 kW
Multiphase Pump							Not Active

CURVES

Delta P:	159.2 bar *	Duty:	1740 kW				
Coefficient A:	0.0000 *	Coefficient B:	0.0000 *	Coefficient C:	0.0000 *		
Parameter Preferences	Units for Head:	m	Flow Basis	ActVolFlow	Units for Flow:	m3/h	

User Variables

NPSH

NPSH Required	---	NPSH Required based on	Turton Method
NPSH Available	1648 m	Enable NPSH Curves:	No

NPSH Required Parameters

Suction Specific Speed	---	Units Type	---

NPSH Curves

Inertia

Rotational inertia (kg-m2)	---	Radius of gyration (m)	0.1000	Mass (kg)	---	Friction loss factor (kg-m2/s)	-3277

Start Up

Design Flow Typical Operating Capacity	10.00 m3/h

CONDITIONS

Name		L-205	L-206	PUE-201	
Vapour		0.0000	0.0000	---	
Temperature	(C)	-83.3303	-63.4604	---	
Pressure	(bar)	90.7893	249.9993	---	
Molar Flow	(kgmole/h)	5595.6708	5595.6708	---	
Mass Flow	(kg/h)	100000.0001	100000.0001	---	
Std Ideal Liq Vol Flow	(m3/h)	316.1090	316.1090	---	
Molar Enthalpy	(kcal/kgmole)	-2.089e+004	-2.062e+004	---	
Molar Entropy	(kJ/kgmole-C)	106.7	108.5	---	
Heat Flow	(kW)	-1.3586e+05	-1.3412e+05	1.7402e+03	

PERFORMANCE

Results

Licensed to:

* Specified by user.

aspentech	Case Name:	LAES new model 23 real process v12.hsc
	Unit Set:	NewUser2c
	Date/Time:	Mon Jan 31 23:18:40 2022

Pump: PU-201 (continued)

Results

Total Head	---	Velocity Head	-18.77 m
Total Fluid Head	---		
Pressure Head	4791 m	Delta P excluding Static Head Results	---

DYNAMICS

Dynamic Specifications

Head	(m)	---	Not Active	Power	(kW)	1740	Not Active
Fluid Head	(kJ/kg)	---	Not Active	Capacity	(m3/h)	316.1	
Speed	(rpm)	---	Not Active				
Efficiency	(%)	75.00	Active	Use Characteristic Curves			Not Active
Pressure Increase	(bar)	159.2 *	Active	Pump is Acting as a Turbine			Not Active

Malfunction Details

Total Pump Failure	Not Active	Pump Overheating	Not Active	Pump Performance Deterioration	Not Active
Delay Time	---	Delay Time	---	Delay Time	---
Ramp Time	---	Ramp Time	---	Ramp Time	---
		Additional Heat	---	Decrease in Head	---
				Decrease in Efficiency	---

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

aspentech	
Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 23:18:55 2022

Pump: PU-202

CONNECTIONS

Inlet Stream

Stream Name	From Unit Operation	
A-215	Tee	TEE-101

Outlet Stream

Stream Name	To Unit Operation	
A-216	Heat Exchanger	HE-202

Energy Stream

Stream Name	From Unit Operation
PUE-202	

PARAMETERS

Adiabatic Efficiency (%):	90.00 *	Delta P:	35.00 bar *	Pressure Ratio:	11.70	Duty:	89.02 kW
Multiphase Pump							Not Active

CURVES

Delta P:	35.00 bar *	Duty:	89.02 kW		
Coefficient A:	0.0000 *	Coefficient B:	0.0000 *	Coefficient C:	0.0000 *

Parameter Preferences						
Units for Head:	m	Flow Basis	ActVolFlow	Units for Flow:	m3/h	

User Variables

NPSH

NPSH Required	---	NPSH Required based on	Turton Method
NPSH Available	6.929 m	Enable NPSH Curves:	No

NPSH Required Parameters

Suction Specific Speed	---	Units Type	---

NPSH Curves

Inertia

Rotational inertia (kg-m2)	---	Radius of gyration (m)	0.1000	Mass (kg)	---	Friction loss factor (kg-m2/s)	-3277

Start Up

Design Flow Typical Operating Capacity	10.00 m3/h

CONDITIONS

Name		A-215	A-216	PUE-202	
Vapour		0.0000	0.0000	---	
Temperature	(C)	-182.3321	-180.5343	---	
Pressure	(bar)	3.2704	38.2704	---	
Molar Flow	(kgmole/h)	2327.0846	2327.0846	---	
Mass Flow	(kg/h)	67389.0729	67389.0729	---	
Std Ideal Liq Vol Flow	(m3/h)	77.4988	77.4988	---	
Molar Enthalpy	(kcal/kgmole)	-2738	-2706	---	
Molar Entropy	(kJ/kgmole-C)	48.58	48.88	---	
Heat Flow	(kW)	-7.4063e+03	-7.3173e+03	8.9019e+01	

PERFORMANCE

Results

Licensed to: * Specified by user.

Pump: PU-202 (continued)

Results

Total Head	---	Velocity Head	-5.410e-002 m
Total Fluid Head	---		
Pressure Head	436.4 m	Delta P excluding Static Head Results	---

DYNAMICS

Dynamic Specifications

Head	(m)	---	Not Active	Power	(kW)	89.02	Not Active
Fluid Head	(kJ/kg)	---	Not Active	Capacity	(m3/h)	77.50	
Speed	(rpm)	---	Not Active				
Efficiency	(%)	90.00 *	Active	Use Characteristic Curves			Not Active
Pressure Increase	(bar)	35.00 *	Active	Pump is Acting as a Turbine			Not Active

Malfunction Details

Total Pump Failure	Not Active	Pump Overheating	Not Active	Pump Performance Deterioration	Not Active
Delay Time	---	Delay Time	---	Delay Time	---
Ramp Time	---	Ramp Time	---	Ramp Time	---
		Additional Heat	---	Decrease in Head	---
				Decrease in Efficiency	---

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Licensed to: * Specified by user.

aspentech	Case Name:	LAES new model 23 real process v12.hsc
	Unit Set:	NewUser2c
	Date/Time:	Mon Jan 31 23:19:06 2022

Pump: PU-203

CONNECTIONS

Inlet Stream

Stream Name	From Unit Operation	
A-217	Heat Exchanger	HE-202

Outlet Stream

Stream Name	To Unit Operation	
A-218	Heat Exchanger	HE-203

Energy Stream

Stream Name	From Unit Operation
PUE-203	

PARAMETERS

Adiabatic Efficiency (%):	75.00	Delta P:	163.0 bar *	Pressure Ratio:	5.264	Duty:	1149 kW
Multiphase Pump							Not Active

CURVES

Delta P:	163.0 bar *	Duty:			1149 kW
Coefficient A:	0.0000 *	Coefficient B:	0.0000 *	Coefficient C:	0.0000 *

Parameter Preferences	Units for Head:	m	Flow Basis	ActVolFlow	Units for Flow:	m3/h

User Variables

NPSH

NPSH Required	---	NPSH Required based on	Turton Method
NPSH Available	-82.18 m	Enable NPSH Curves:	No

NPSH Required Parameters

Suction Specific Speed	---	Units Type	---

NPSH Curves

Inertia

Rotational inertia (kg-m2)	---	Radius of gyration (m)	0.1000	Mass (kg)	---	Friction loss factor (kg-m2/s)	-3277

Start Up

Design Flow Typical Operating Capacity	10.00 m3/h

CONDITIONS

Name		A-217	A-218	PUE-203	
Vapour		0.0000	1.0000	---	
Temperature	(C)	-140.6656	-83.7012	---	
Pressure	(bar)	38.2281	201.2281	---	
Molar Flow	(kgmole/h)	2327.0846	2327.0846	---	
Mass Flow	(kg/h)	67389.0729	67389.0729	---	
Std Ideal Liq Vol Flow	(m3/h)	77.4988	77.4988	---	
Molar Enthalpy	(kcal/kgmole)	-1820	-1395	---	
Molar Entropy	(kJ/kgmole-C)	80.59	84.59	---	
Heat Flow	(kW)	-4.9213e+03	-3.7728e+03	1.1485e+03	

PERFORMANCE

Results

Pump: PU-203 (continued)

Results

Total Head	---	Velocity Head	-15.39 m
Total Fluid Head	---		
Pressure Head	4692 m	Delta P excluding Static Head Results	---

DYNAMICS

Dynamic Specifications

Head	(m)	---	Not Active	Power	(kW)	1149	Not Active
Fluid Head	(kJ/kg)	---	Not Active	Capacity	(m3/h)	77.50	
Speed	(rpm)	---	Not Active				
Efficiency	(%)	75.00	Active	Use Characteristic Curves			Not Active
Pressure Increase	(bar)	163.0 *	Active	Pump is Acting as a Turbine			Not Active

Malfunction Details

Total Pump Failure	Not Active	Pump Overheating	Not Active	Pump Performance Deterioration	Not Active
Delay Time	---	Delay Time	---	Delay Time	---
Ramp Time	---	Ramp Time	---	Ramp Time	---
		Additional Heat	---	Decrease in Head	---
				Decrease in Efficiency	---

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Licensed to:

* Specified by user.

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 23:19:47 2022

Pump: PU-301

CONNECTIONS

Inlet Stream

Stream Name	From Unit Operation	
W-302'	Heat Exchanger	HE-301'

Outlet Stream

Stream Name	To Unit Operation	
W-304'	Heat Exchanger	HE-303'

Energy Stream

Stream Name	From Unit Operation
PUE-301'	

PARAMETERS

Adiabatic Efficiency (%):	75.00	Delta P:	5.881 bar *	Pressure Ratio:	5.497	Duty:	4.965 kW
Multiphase Pump							Not Active

CURVES

Delta P:	5.881 bar *	Duty:	4.965 kW		
Coefficient A:	0.0000 *	Coefficient B:	0.0000 *	Coefficient C:	0.0000 *

Parameter Preferences	Units for Head:	m	Flow Basis	ActVolFlow	Units for Flow:	m3/h

User Variables

NPSH

NPSH Required	---	NPSH Required based on	Turton Method
NPSH Available	6.993 m	Enable NPSH Curves:	No
NPSH Required Parameters			
Suction Specific Speed	---	Units Type	---
NPSH Curves			

Inertia

Rotational inertia (kg-m2)	---	Radius of gyration (m)	0.1000	Mass (kg)	---	Friction loss factor (kg-m2/s)	-3277

Start Up

Design Flow Typical Operating Capacity	10.00 m3/h

CONDITIONS

Name		W-302'	W-304'	PUE-301'
Vapour		0.0000	0.0000	---
Temperature	(C)	90.0000	90.0741	---
Pressure	(bar)	1.3076	7.1881	---
Molar Flow	(kgmole/h)	1210.0959	1210.0959	---
Mass Flow	(kg/h)	21800.0000	21800.0000	---
Std Ideal Liq Vol Flow	(m3/h)	21.8440	21.8440	---
Molar Enthalpy	(kcal/kgmole)	-6.720e+004	-6.719e+004	---
Molar Entropy	(kJ/kgmole-C)	69.09	69.10	---
Heat Flow	(kW)	-9.4504e+04	-9.4499e+04	4.9652e+00

PERFORMANCE

Results

Pump: PU-301 (continued)

Results

Total Head	---	Velocity Head	-2.058e-004 m
Total Fluid Head	---	Delta P excluding Static Head Results	---
Pressure Head	62.71 m		

DYNAMICS

Dynamic Specifications

Head	(m)	---	Not Active	Power	(kW)	4.965	Not Active
Fluid Head	(kJ/kg)	---	Not Active	Capacity	(m3/h)	21.84	
Speed	(rpm)	---	Not Active	Use Characteristic Curves			Not Active
Efficiency	(%)	75.00	Active	Pump is Acting as a Turbine			Not Active
Pressure Increase	(bar)	5.881 *	Active				

Malfunction Details

Total Pump Failure	Not Active	Pump Overheating	Not Active	Pump Performance Deterioration	Not Active
Delay Time	---	Delay Time	---	Delay Time	---
Ramp Time	---	Ramp Time	---	Ramp Time	---
		Additional Heat	---	Decrease in Head	---
				Decrease in Efficiency	---

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

* Specified by user.

Pump: PU-501

CONNECTIONS

Inlet Stream

Stream Name	From Unit Operation	
W-502'	LNG	CB501"

Outlet Stream

Stream Name	To Unit Operation	
W-503'	Heat Exchanger	PU-501'

Energy Stream

Stream Name	From Unit Operation
pump o1	

PARAMETERS

Adiabatic Efficiency (%):	75.00	Delta P:	5.695 bar *	Pressure Ratio:	5.366	Duty:	3.088 kW
Multiphase Pump							Not Active

CURVES

Delta P:	5.695 bar *	Duty:	3.088 kW		
Coefficient A:	0.0000 *	Coefficient B:	0.0000 *	Coefficient C:	0.0000 *

Parameter Preferences	Units for Head:	m	Flow Basis	ActVolFlow	Units for Flow:	m3/h

User Variables

NPSH

NPSH Required	---	NPSH Required based on	Turton Method
NPSH Available	6.649 m	Enable NPSH Curves:	No

NPSH Required Parameters

Suction Specific Speed	---	Units Type	---

NPSH Curves

Inertia

Rotational inertia (kg-m2)	---	Radius of gyration (m)	0.1000	Mass (kg)	---	Friction loss factor (kg-m2/s)	-3277

Start Up

Design Flow Typical Operating Capacity	10.00 m3/h

CONDITIONS

Name		W-502'	W-503'	pump o1	
Vapour		0.0000	0.0000	---	
Temperature	(C)	90.0000	90.0718	---	
Pressure	(bar)	1.3045	6.9995	---	
Molar Flow	(kgmole/h)	777.1258	777.1258	---	
Mass Flow	(kg/h)	14000.0000	14000.0000	---	
Std Ideal Liq Vol Flow	(m3/h)	14.0283	14.0283	---	
Molar Enthalpy	(kcal/kgmole)	-6.720e+004	-6.719e+004	---	
Molar Entropy	(kJ/kgmole-C)	69.09	69.10	---	
Heat Flow	(kW)	-6.0691e+04	-6.0687e+04	3.0881e+00	

PERFORMANCE

Results

* Specified by user.

Pump: PU-501 (continued)

Results

Total Head	---	Velocity Head	-8.221e-005 m
Total Fluid Head	---	Delta P excluding Static Head Results	---
Pressure Head	60.73 m		

DYNAMICS

Dynamic Specifications

Head	(m)	---	Not Active	Power	(kW)	3.088	Not Active
Fluid Head	(kJ/kg)	---	Not Active	Capacity	(m3/h)	14.03	
Speed	(rpm)	---	Not Active	Use Characteristic Curves			Not Active
Efficiency	(%)	75.00	Active	Pump is Acting as a Turbine			Not Active
Pressure Increase	(bar)	5.695 *	Active				

Malfunction Details

Total Pump Failure	Not Active	Pump Overheating	Not Active	Pump Performance Deterioration	Not Active
Delay Time	---	Delay Time	---	Delay Time	---
Ramp Time	---	Ramp Time	---	Ramp Time	---
		Additional Heat	---	Decrease in Head	---
				Decrease in Efficiency	---

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Licensed to: * Specified by user.

Pump: PU-601

CONNECTIONS

Inlet Stream

Stream Name	From Unit Operation	
H-604'	Heat Exchanger	PU-501'

Outlet Stream

Stream Name	To Unit Operation
H-605'	

Energy Stream

Stream Name	From Unit Operation
PUE-601'	

PARAMETERS

Adiabatic Efficiency (%):	75.00	Delta P:	1.408 bar *	Pressure Ratio:	1.392	Duty:	5.526 kW
Multiphase Pump							Not Active

CURVES

Delta P:	1.408 bar *	Duty:	5.526 kW		
Coefficient A:	0.0000 *	Coefficient B:	0.0000 *	Coefficient C:	0.0000 *

Parameter Preferences	Units for Head:	m	Flow Basis	ActVolFlow	Units for Flow:	m3/h

User Variables

NPSH

NPSH Required	---	NPSH Required based on	Turton Method
NPSH Available	59.98 m	Enable NPSH Curves:	No

NPSH Required Parameters

Suction Specific Speed	---	Units Type	---

NPSH Curves

Inertia

Rotational inertia (kg-m2)	0.5000	Radius of gyration (m)	0.1000	Mass (kg)	50.00	Friction loss factor (kg-m2/s)	5.000e-002

Start Up

Design Flow Typical Operating Capacity	10.00 m3/h

CONDITIONS

Name		H-604'	H-605'	PUE-601'
Vapour		0.0000	0.0000	---
Temperature	(C)	195.9789	195.8072	---
Pressure	(bar)	3.5922	5.0002	---
Molar Flow	(kgmole/h)	80.2118	80.2118	---
Mass Flow	(kg/h)	80000.0000	80000.0000	---
Std Ideal Liq Vol Flow	(m3/h)	91.7750	91.7750	---
Molar Enthalpy	(kcal/kgmole)	2.678e+004	2.684e+004	---
Molar Entropy	(kJ/kgmole-C)	-7186	-7187	---
Heat Flow	(kW)	2.4964e+03	2.5019e+03	5.5260e+00

PERFORMANCE

Results

Pump: PU-601 (continued)

Results

Total Head	---	Velocity Head	-3.336e-003 m
Total Fluid Head	---		
Pressure Head	19.02 m	Delta P excluding Static Head Results	---

DYNAMICS

Dynamic Specifications

Head	(m)	---	Not Active	Power	(kW)	5.526	Not Active
Fluid Head	(kJ/kg)	---	Not Active	Capacity	(m3/h)	91.78	
Speed	(rpm)	---	Not Active				
Efficiency	(%)	75.00	Active	Use Characteristic Curves			Not Active
Pressure Increase	(bar)	1.408 *	Active	Pump is Acting as a Turbine			Not Active

Malfunction Details

Total Pump Failure	Not Active	Pump Overheating	Not Active	Pump Performance Deterioration	Not Active
Delay Time	---	Delay Time	---	Delay Time	---
Ramp Time	---	Ramp Time	---	Ramp Time	---
		Additional Heat	---	Decrease in Head	---
				Decrease in Efficiency	---

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Licensed to: * Specified by user.

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 19:46:01 2022

Expander: T-201

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
A-212	LNG	CB-205

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
A-213	Separator	S-201

Energy Stream

STREAM NAME	TO UNIT OPERATION
tur1-2	

PARAMETERS

Duty:	2.1454e+02 kW	Speed:	---
Adiabatic Eff.:	75.00	PolyTropic Eff.:	72.06
Adiabatic Head:	1128 m	Polytropic Head:	1174 m
Adiabatic Fluid Head:	11.07 kJ/kg	Polytropic Fluid Head:	11.52 kJ/kg

Polytropic Exp.	1.476	Isentropic Exp.	1.545	Poly Head Factor	0.5334

User Variables

CONDITIONS

Name		A-212	A-213	tur1-2	
Vapour		0.0000	0.1466	---	
Temperature	(C)	-165.8000	-182.3321	---	
Pressure	(bar)	81.8704	3.2704	---	
Molar Flow	(kgmole/h)	3222.5194	3222.5194	---	
Mass Flow	(kg/h)	93063.1385	93063.1385	---	
Std Ideal Liq Vol Flow	(m3/h)	107.7173	107.7173	---	
Molar Enthalpy	(kcal/kgmole)	-2493	-2550	---	
Molar Entropy	(kJ/kgmole-C)	56.07	56.95	---	
Heat Flow	(kW)	-9.3371e+03	-9.5516e+03	2.1454e+02	

DYNAMICS

Dynamic Specifications

Duty	(kW)	214.5		Active
Adiabatic Efficiency		75		Not Active
Polytropic Efficiency		72		Active
Pressure Increase	(bar)	78.60	*	Not Active

Head	(m)	1174	Not Active
Fluid Head	(kJ/kg)	11.52	Not Active
Capacity	(ACT_m3/h)	122.5	Not Active
Speed	(rpm)	---	Not Active
Use Characteristic Curves			Not Active

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Licensed to: * Specified by user.

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 19:50:15 2022

Expander: T-301

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
W-306'	Heat Exchanger	HE-302'

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
W-307'	Heat Exchanger	HE-303'

Energy Stream

STREAM NAME	TO UNIT OPERATION
TE-301'	

PARAMETERS

Duty:	1.5820e+03 kW	Speed:	---
Adiabatic Eff.:	85.00 *	PolyTropic Eff.:	84.17
Adiabatic Head:	3.134e+004 m	Polytropic Head:	3.165e+004 m
Adiabatic Fluid Head:	307.3 kJ/kg	Polytropic Fluid Head:	310.4 kJ/kg

Polytropic Exp.	1.242	Isentropic Exp.	1.263	Poly Head Factor	0.9854

User Variables

CONDITIONS

Name		W-306'	W-307'	TE-301'	
Vapour		1.0000	1.0000	---	
Temperature	(C)	252.0000 *	111.3189	---	
Pressure	(bar)	7.0000 *	1.5000	---	
Molar Flow	(kgmole/h)	1210.0959	1210.0959	---	
Mass Flow	(kg/h)	21800.0000 *	21800.0000	---	
Std Ideal Liq Vol Flow	(m3/h)	21.8440	21.8440	---	
Molar Enthalpy	(kcal/kgmole)	-5.600e+004	-5.712e+004	---	
Molar Entropy	(kJ/kgmole-C)	176.7	178.9	---	
Heat Flow	(kW)	-7.8752e+04	-8.0334e+04	1.5820e+03	

DYNAMICS

Dynamic Specifications

Duty	(kW)	1582	Active	Head	(m)	3.165e+004	Not Active
Adiabatic Efficiency		85 *	Not Active	Fluid Head	(kJ/kg)	310.4	Not Active
Polytropic Efficiency		84	Active	Capacity	(ACT_m3/h)	7371	Not Active
Pressure Increase	(bar)	5.500 *	Not Active	Speed	(rpm)	---	Not Active
				Use Characteristic Curves			Not Active

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Licensed to: * Specified by user.

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 19:50:29 2022

Expander: T-302

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
L-302'	Heat Exchanger	HE-301'

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
L-303'	LNG	CB501"

Energy Stream

STREAM NAME	TO UNIT OPERATION
TE-302'	

PARAMETERS

Duty:	1.2509e+03 kW	Speed:	---
Adiabatic Eff.:	85.00 *	PolyTropic Eff.:	84.44
Adiabatic Head:	5402 m	Polytropic Head:	5438 m
Adiabatic Fluid Head:	52.98 kJ/kg	Polytropic Fluid Head:	53.33 kJ/kg

Polytropic Exp.	1.669	Isentropic Exp.	1.775	Poly Head Factor	0.9985

User Variables

CONDITIONS

Name		L-302'	L-303'	TE-302'	
Vapour		1.0000	1.0000	---	
Temperature	(C)	87.3579	61.7499	---	
Pressure	(bar)	248.7325	170.0133	---	
Molar Flow	(kgmole/h)	5595.6708	5595.6708	---	
Mass Flow	(kg/h)	100000.0001	100000.0001	---	
Std Ideal Liq Vol Flow	(m3/h)	316.1090	316.1090	---	
Molar Enthalpy	(kcal/kgmole)	-1.840e+004	-1.859e+004	---	
Molar Entropy	(kJ/kgmole-C)	142.2	142.6	---	
Heat Flow	(kW)	-1.1963e+05	-1.2088e+05	1.2509e+03	

DYNAMICS

Dynamic Specifications

Duty	(kW)	1251		Active
Adiabatic Efficiency		85	*	Not Active
Polytropic Efficiency		84		Active
Pressure Increase	(bar)	78.72	*	Not Active

Head	(m)	5438	Not Active
Fluid Head	(kJ/kg)	53.33	Not Active
Capacity	(ACT_m3/h)	608.5	Not Active
Speed	(rpm)	---	Not Active
Use Characteristic Curves			Not Active

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

* Specified by user.

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 19:50:43 2022

Expander: T-303

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
L-304'	LNG	CB501"

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
L-305'	LNG	CB501"

Energy Stream

STREAM NAME	TO UNIT OPERATION
TE-303'	

PARAMETERS

Duty:	8.7338e+02 kW	Speed:	---
Adiabatic Eff.:	85.00 *	PolyTropic Eff.:	84.53
Adiabatic Head:	3772 m	Polytropic Head:	3793 m
Adiabatic Fluid Head:	36.99 kJ/kg	Polytropic Fluid Head:	37.20 kJ/kg

Polytropic Exp.	1.544	Isentropic Exp.	1.637	Poly Head Factor	0.9990

User Variables

CONDITIONS

Name		L-304'	L-305'	TE-303'	
Vapour		1.0000	1.0000	---	
Temperature	(C)	60.0000	39.4121	---	
Pressure	(bar)	169.6117	125.0133	---	
Molar Flow	(kgmole/h)	5595.6708	5595.6708	---	
Mass Flow	(kg/h)	100000.0001	100000.0001	---	
Std Ideal Liq Vol Flow	(m3/h)	316.1090	316.1090	---	
Molar Enthalpy	(kcal/kgmole)	-1.861e+004	-1.874e+004	---	
Molar Entropy	(kJ/kgmole-C)	142.3	142.6	---	
Heat Flow	(kW)	-1.2103e+05	-1.2190e+05	8.7338e+02	

DYNAMICS

Dynamic Specifications

Duty	(kW)	873.4		Active
Adiabatic Efficiency		85	*	Not Active
Polytropic Efficiency		85		Active
Pressure Increase	(bar)	44.60	*	Not Active

Head	(m)	3793	Not Active
Fluid Head	(kJ/kg)	37.20	Not Active
Capacity	(ACT_m3/h)	758.9	Not Active
Speed	(rpm)	---	Not Active
Use Characteristic Curves			Not Active

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Licensed to: * Specified by user.

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 19:50:56 2022

Expander: TE-304

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
L-306'	LNG	CB501"

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
L-307'	Tee	SP-301'

Energy Stream

STREAM NAME	TO UNIT OPERATION
TE-304'	

PARAMETERS

Duty:	7.8473e+02 kW	Speed:	---
Adiabatic Eff.:	85.00 *	PolyTropic Eff.:	84.59
Adiabatic Head:	3389 m	Polytropic Head:	3406 m
Adiabatic Fluid Head:	33.24 kJ/kg	Polytropic Fluid Head:	33.40 kJ/kg

Polytropic Exp.	1.388	Isentropic Exp.	1.463	Poly Head Factor	0.9994

User Variables

CONDITIONS

Name		L-306'	L-307'	TE-304'	
Vapour		1.0000	1.0000	---	
Temperature	(C)	60.0000	41.5046	---	
Pressure	(bar)	124.6384	95.5133	---	
Molar Flow	(kgmole/h)	5595.6708	5595.6708	---	
Mass Flow	(kg/h)	100000.0001	100000.0001	---	
Std Ideal Liq Vol Flow	(m3/h)	316.1090	316.1090	---	
Molar Enthalpy	(kcal/kgmole)	-1.847e+004	-1.859e+004	---	
Molar Entropy	(kJ/kgmole-C)	146.2	146.5	---	
Heat Flow	(kW)	-1.2014e+05	-1.2093e+05	7.8473e+02	

DYNAMICS

Dynamic Specifications

Duty	(kW)	784.7		Active
Adiabatic Efficiency		85	*	Not Active
Polytropic Efficiency		85		Active
Pressure Increase	(bar)	29.13	*	Not Active

Head	(m)	3406	Not Active
Fluid Head	(kJ/kg)	33.40	Not Active
Capacity	(ACT_m3/h)	1045	Not Active
Speed	(rpm)	---	Not Active
Use Characteristic Curves			Not Active

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Licensed to: * Specified by user.

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 19:53:00 2022

Expander: T-305

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
L-309'	Tee	SP-301'

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
L-310'	Conversion Reactor	R-601'

Energy Stream

STREAM NAME	TO UNIT OPERATION
TE-305'	

PARAMETERS

Duty:	9.2165e+01 kW	Speed:	---
Adiabatic Eff.:	85.00 *	PolyTropic Eff.:	82.64
Adiabatic Head:	1.834e+004 m	Polytropic Head:	1.887e+004 m
Adiabatic Fluid Head:	179.9 kJ/kg	Polytropic Fluid Head:	185.0 kJ/kg

Polytropic Exp.	1.216	Isentropic Exp.	1.266	Poly Head Factor	0.9702

User Variables

CONDITIONS

Name		L-309'	L-310'	TE-305'	
Vapour		1.0000	0.9784	---	
Temperature	(C)	41.5046	-59.0503	---	
Pressure	(bar)	95.5133	15.0133	---	
Molar Flow	(kgmole/h)	121.4261	121.4261	---	
Mass Flow	(kg/h)	2170.0000	2170.0000	---	
Std Ideal Liq Vol Flow	(m3/h)	6.8596	6.8596	---	
Molar Enthalpy	(kcal/kgmole)	-1.859e+004	-1.925e+004	---	
Molar Entropy	(kJ/kgmole-C)	146.5	148.7	---	
Heat Flow	(kW)	-2.6241e+03	-2.7163e+03	9.2165e+01	

DYNAMICS

Dynamic Specifications

Duty	(kW)	92.16		Active
Adiabatic Efficiency		85	*	Not Active
Polytropic Efficiency		83		Active
Pressure Increase	(bar)	80.50	*	Not Active

Head	(m)	1.887e+004	Not Active
Fluid Head	(kJ/kg)	185.0	Not Active
Capacity	(ACT_m3/h)	27.48	Not Active
Speed	(rpm)	---	Not Active
Use Characteristic Curves			Not Active

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Licensed to:

* Specified by user.

aspentech

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 19:51:54 2022

Expander: T-401

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
A-402	LNG	CB501"

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
A-403	LNG	CB501"

Energy Stream

STREAM NAME	TO UNIT OPERATION
TE-401	

PARAMETERS

Duty:	1.9389e+03 kW	Speed:	---
Adiabatic Eff.:	85.00 *	PolyTropic Eff.:	82.15
Adiabatic Head:	1.243e+004 m	Polytropic Head:	1.286e+004 m
Adiabatic Fluid Head:	121.9 kJ/kg	Polytropic Fluid Head:	126.1 kJ/kg

Polytropic Exp.	1.449	Isentropic Exp.	1.575	Poly Head Factor	0.9928

User Variables

CONDITIONS

Name		A-402	A-403	TE-401	
Vapour		1.0000	1.0000	---	
Temperature	(C)	110.0000	2.1252	---	
Pressure	(bar)	200.8863	52.5689	---	
Molar Flow	(kgmole/h)	2327.0846	2327.0846	---	
Mass Flow	(kg/h)	67389.0729	67389.0729	---	
Std Ideal Liq Vol Flow	(m3/h)	77.4988	77.4988	---	
Molar Enthalpy	(kcal/kgmole)	447.4	-269.5	---	
Molar Entropy	(kJ/kgmole-C)	113.4	115.4	---	
Heat Flow	(kW)	1.2101e+03	-7.2884e+02	1.9389e+03	

DYNAMICS

Dynamic Specifications

Duty	(kW)	1939		Active
Adiabatic Efficiency		85	*	Not Active
Polytropic Efficiency		82		Active
Pressure Increase	(bar)	148.3	*	Not Active

Head	(m)	1.286e+004	Not Active
Fluid Head	(kJ/kg)	126.1	Not Active
Capacity	(ACT_m3/h)	388.4	Not Active
Speed	(rpm)	---	Not Active
Use Characteristic Curves			Not Active

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Licensed to: * Specified by user.

Case Name:	LAES new model 23 real process v12.hsc	
Unit Set:	NewUser2c	
Date/Time:	Mon Jan 31 19:52:04 2022	

Expander: T-402

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
A-404	LNG	CB501"

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
A-405	LNG	CB501"

Energy Stream

STREAM NAME	TO UNIT OPERATION
TE-402	

PARAMETERS

Duty:	1.8172e+03 kW	Speed:	---
Adiabatic Eff.:	85.00 *	PolyTropic Eff.:	82.48
Adiabatic Head:	1.165e+004 m	Polytropic Head:	1.200e+004 m
Adiabatic Fluid Head:	114.2 kJ/kg	Polytropic Fluid Head:	117.7 kJ/kg

Polytropic Exp.	1.338	Isentropic Exp.	1.436	Poly Head Factor	0.9987

User Variables

CONDITIONS

Name		A-404	A-405	TE-402	
Vapour		1.0000	1.0000	---	
Temperature	(C)	110.0000	11.0570	---	
Pressure	(bar)	52.1934	15.0729	---	
Molar Flow	(kgmole/h)	2327.0846	2327.0846	---	
Mass Flow	(kg/h)	67389.0729	67389.0729	---	
Std Ideal Liq Vol Flow	(m3/h)	77.4988	77.4988	---	
Molar Enthalpy	(kcal/kgmole)	543.7	-128.2	---	
Molar Entropy	(kJ/kgmole-C)	125.9	127.7	---	
Heat Flow	(kW)	1.4705e+03	-3.4667e+02	1.8172e+03	

DYNAMICS

Dynamic Specifications

Duty	(kW)	1817		Active
Adiabatic Efficiency		85	*	Not Active
Polytropic Efficiency		82		Active
Pressure Increase	(bar)	37.12	*	Not Active

Head	(m)	1.200e+004	Not Active
Fluid Head	(kJ/kg)	117.7	Not Active
Capacity	(ACT_m3/h)	1427	Not Active
Speed	(rpm)	---	Not Active
Use Characteristic Curves			Not Active

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Licensed to: * Specified by user.

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 19:52:16 2022

Expander: T-403

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
A-406	LNG	CB501"

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
A-407	LNG	CB501"

Energy Stream

STREAM NAME	TO UNIT OPERATION
TE-403	

PARAMETERS

Duty:	1.3409e+03 kW	Speed:	---
Adiabatic Eff.:	85.00 *	PolyTropic Eff.:	83.29
Adiabatic Head:	8593 m	Polytropic Head:	8769 m
Adiabatic Fluid Head:	84.27 kJ/kg	Polytropic Fluid Head:	86.00 kJ/kg

Polytropic Exp.	1.319	Isentropic Exp.	1.408	Poly Head Factor	1.000

User Variables

CONDITIONS

Name		A-406	A-407	TE-403	
Vapour		1.0000	1.0000	---	
Temperature	(C)	105.0000	33.5633	---	
Pressure	(bar)	14.6252	6.0729	---	
Molar Flow	(kgmole/h)	2327.0846	2327.0846	---	
Mass Flow	(kg/h)	67389.0729	67389.0729	---	
Std Ideal Liq Vol Flow	(m3/h)	77.4988	77.4988	---	
Molar Enthalpy	(kcal/kgmole)	544.3	48.54	---	
Molar Entropy	(kJ/kgmole-C)	136.5	137.7	---	
Heat Flow	(kW)	1.4721e+03	1.3128e+02	1.3409e+03	

DYNAMICS

Dynamic Specifications

Duty	(kW)	1341	Active	Head	(m)	8769	Not Active
Adiabatic Efficiency		85 *	Not Active	Fluid Head	(kJ/kg)	86.00	Not Active
Polytropic Efficiency		83	Active	Capacity	(ACT_m3/h)	5004	Not Active
Pressure Increase	(bar)	8.552 *	Not Active	Speed	(rpm)	---	Not Active
				Use Characteristic Curves			Not Active

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Licensed to: * Specified by user.

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 19:52:27 2022

Expander: T-404

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
A-408	LNG	CB501"

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
A-409	Conversion Reactor	R-601'

Energy Stream

STREAM NAME	TO UNIT OPERATION
TE-404	

PARAMETERS

Duty:	3.2489e+02 kW	Speed:	---
Adiabatic Eff.:	85.00 *	PolyTropic Eff.:	84.64
Adiabatic Head:	2082 m	Polytropic Head:	2091 m
Adiabatic Fluid Head:	20.42 kJ/kg	Polytropic Fluid Head:	20.51 kJ/kg

Polytropic Exp.	1.318	Isentropic Exp.	1.399	Poly Head Factor	1.000

User Variables

CONDITIONS

Name		A-408	A-409	TE-404	
Vapour		1.0000	1.0000	---	
Temperature	(C)	100.0000	82.8800	---	
Pressure	(bar)	5.6189	4.6189	---	
Molar Flow	(kgmole/h)	2327.0846	2327.0846	---	
Mass Flow	(kg/h)	67389.0729	67389.0729	---	
Std Ideal Liq Vol Flow	(m3/h)	77.4988	77.4988	---	
Molar Enthalpy	(kcal/kgmole)	518.7	398.6	---	
Molar Entropy	(kJ/kgmole-C)	144.1	144.4	---	
Heat Flow	(kW)	1.4028e+03	1.0779e+03	3.2489e+02	

DYNAMICS

Dynamic Specifications

Duty	(kW)	324.9		Active
Adiabatic Efficiency		85	*	Not Active
Polytropic Efficiency		85		Active
Pressure Increase	(bar)	1.000	*	Not Active

Head	(m)	2091	Not Active
Fluid Head	(kJ/kg)	20.51	Not Active
Capacity	(ACT_m3/h)	1.285e+004	Not Active
Speed	(rpm)	---	Not Active
Use Characteristic Curves			Not Active

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Licensed to:

* Specified by user.

Case Name:	LAES new model 23 real process v12.hsc
Unit Set:	NewUser2c
Date/Time:	Mon Jan 31 19:52:46 2022

Expander: T-501

CONNECTIONS

Inlet Stream

STREAM NAME	FROM UNIT OPERATION	
W-504'	Heat Exchanger	PU-501'

Outlet Stream

STREAM NAME	TO UNIT OPERATION	
W-501'	LNG	CB501"

Energy Stream

STREAM NAME	TO UNIT OPERATION
TE-501'	

PARAMETERS

Duty:	1.0659e+03 kW	Speed:	---
Adiabatic Eff.:	85.00 *	PolyTropic Eff.:	82.70
Adiabatic Head:	3.288e+004 m	Polytropic Head:	3.380e+004 m
Adiabatic Fluid Head:	322.5 kJ/kg	Polytropic Fluid Head:	331.4 kJ/kg

Polytropic Exp.	1.239	Isentropic Exp.	1.300	Poly Head Factor	0.9979

User Variables

CONDITIONS

Name		W-504'	W-501'	TE-501'	
Vapour		1.0000	1.0000	---	
Temperature	(C)	278.1000 *	132.1340	---	
Pressure	(bar)	7.0000 *	1.5000	---	
Molar Flow	(kgmole/h)	777.1258	777.1258	---	
Mass Flow	(kg/h)	14000.0000 *	14000.0000	---	
Std Ideal Liq Vol Flow	(m3/h)	14.0283	14.0283	---	
Molar Enthalpy	(kcal/kgmole)	-5.577e+004	-5.695e+004	---	
Molar Entropy	(kJ/kgmole-C)	178.5	180.7	---	
Heat Flow	(kW)	-5.0369e+04	-5.1435e+04	1.0659e+03	

DYNAMICS

Dynamic Specifications

Duty (kW)	1066		Active
Adiabatic Efficiency	85	*	Not Active
Polytropic Efficiency	83		Active
Pressure Increase (bar)	5.500	*	Not Active

Head	(m)	3.380e+004	Not Active
Fluid Head	(kJ/kg)	331.4	Not Active
Capacity	(ACT_m3/h)	4986	Not Active
Speed	(rpm)	---	Not Active
Use Characteristic Curves			Not Active

Holdup Details

Phase	Accumulation (kgmole/h)	Moles (kgmole)	Volume (m3)
Vapour	0.0000	0.0000	0.0000
Liquid	0.0000	0.0000	0.0000
Aqueous	0.0000	0.0000	0.0000
Total	**0.0000**	**0.0000**	**0.0000**

Licensed to:

* Specified by user.

APPENDIX F

Economic Calculation

To calculate NPV, IRR and payback period, the total capital investment (TCI) and total product cost (TPC) have to be calculated. The calculation of TCI and TPC are illustrated in table F.1 and F.2, respectively. This calculation is based on the assumptions below. Moreover, the Fixed-Capital Investment is estimated by using the average percentage in the ranges of Process-Plant Component Costs.

Assumptions:
1. The plant lifetime is 25 years.
2. Discount rate is 10%.
3. The operating labor is 335 baht/employee.
4. The plant operates 24 hours with the working hours of 8 hours/shift and 3 shifts/day.
5. The tax rate is 0.2.
6. Rental cost of a filled land is at 100,000 baht/rai/year and 20 rai is used.
7. Cost of LNG cold energy utilization is 10 baht per ton of LNG.

Table F.1: Total capital investment (TCI) calculation

Cost	%FCI	Cost (Baht)
Direct cost		
Purchased equipment	20.61	1,529,256,795
Installation	7.63	566,391,406
Instrumentation and controls	5.34	396,473,984
Piping	8.40	623,030,546
Electrical systems	3.82	283,195,703
Buildings	7.63	566,391,406
Yard improvements	3.05	226,556,562
Service facilities	14.50	1,076,143,671
Land	0	0
Indirect cost		
Engineering & Supervision	9.16	679,669,687
Construction expenses	7.63	566,391,406
Legal expenses	1.53	113,278,281
Contractor's fee	3.05	226,556,562
Contingency	7.63	566,391,406
Utility		104,623,551
Fixed capital investment	85% of TCI	7,524,350,964
Working capital	15% of TCI	1,327,826,641
Total capital investment (TCI)		8,852,177,604

Table F.2: Total product cost (TPC) calculation

Item	Default factor	Rate or quantity per year	Cost per rate or quantity unit	Calculated value (THB)
Raw Material				-
Operating labor		54,750	335 baht/employee	18,341,250
Operating supervision	0.15	of operating labor	18,341,250	2,751,188
Maintenance and repairs	0.07	of FCI	7,524,350,964	526,704,567
Operating supplies	0.15	of Maintenance and repairs	526,704,567	79,005,685
Laboratory charges	0.15	of operating labor	18,341,250	2,751,188
Royalties	0	of TPC	8,852,177,604	-
Variable cost				629,553,877
Taxes	0.003	of FCI	7,524,350,964	22,573,053
Insurance	0.01	of FCI	7,524,350,964	75,243,510
Rent		20	100000 Baht/Rai	2,000,000
Fixed Charges				99,816,563
Plant overhead, general	0.6	of labor, supervision and maintenance	547,797,005	328,678,203
Plant Overhead				328,678,203
Manufacturing cost				1,058,048,643
Administration	0.2	of labor, supervision and maintenance	547,797,005	109,559,401
Distribution &selling	0.05	of TPC	1,613,826,464	80,691,323
Research & development	0.04	of TPC	1,613,826,464	64,553,058
General Expense				254,803,782
Total product cost without depreciation = c_0				1,312,852,425
d_j				300,974,039
TPC = $c_0 + d_j$				1,613,826,464