STUDY ON NATURAL GAS LIQUID (NGL) RECOVERY – SIMULATION STUDY

By

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CERTIFICATION OF APPROVAL

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MAY 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABSTRACT

This project is about Natural Gas Liquid (NGL) Recovery in the plant. The main objective of this project is to study on several technologies and process used in NGL recovery nowadays via HYSYS simulation. In this study, the technologies used for simulation are 3-S technology (twister), turbo-expander, and J-T valve expansion. For NGL recovery process, the processes are based on Ortloff Engineer, LTD which is GSP, OHR, RSV, RSVE, IOR, and SCORE.

The effects on different types of technologies used for controlling HCDP and to produce low temperature were investigated. Moreover, the ethane and propane recovery with respect to compression power and CO_2-tolerant for different types on NGL recovery processes were studied.

There are several steps need to be done so that the objectives of this project can be achieved; define the problem, review the critical literature, define operating conditions to the simulation, run the simulation, manipulate the technologies/processes, collect the data for discussion, and draw the conclusion for this project.

Turbo-expander produces much lower temperature to the column compared with twister and J-T valve. RSV and SCORE processes give the highest recovery for the same compression power for ethane and propane recovery process respectively meanwhile RSVE is more CO_2-tolerant compared with other ethane recovery process.

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1.0 INTRODUCTION

1.1 Background

Natural gas liquid (NGL) is a components of natural gas that are liquid at surface in field facilities or in gas-processing plants. NGL can be classified according to their vapour pressures as low (condensate), intermediate (natural gasoline) and high (liquefied petroleum gas) vapour pressure [1]. NGL include ethane, propane, butane, pentane, hexane and heptane since these hydrocarbons need refrigeration to be liquefied. Natural gas liquids recovery refers to the process of removing and gathering ethane, propane, butane and other heavier hydrocarbon products from natural gas.

Nowadays, there is worldwide drive toward to maximize of NGL recovery and the need to minimize energy consumption associated with the process [2-3]. An important requirement in natural gas processing is that the process should be designed to be flexible to accommodate a range of natural gas compositions and maximize the recovery of NGL. The composition of the gas is important in determining the type of separation process to be employed and the most beneficial configuration for NGL recover to be used. The process chose is also guided by the cyclical nature of the market preference for ethane and propane instead using new technologies [4]. The current extraction of NGL from natural gas is generally based on some of the following alternatives: twister, turbo-expander, Joule-Thompson expansion (J-T) valve, external refrigeration, and absorption. In many processing schemes a combination of these effects is used to improve the energy efficiency or to obtain greater recoveries.

There are many types on NGL recovery processes has been developed worldwide. As process engineer, choose a process design which:

1. Meets all product specifications and recovery levels
2. Avoids CO_2 freeze
3. Avoids unstable phase region
4. Requires the least heat and compression costs
5. Provides the required operating flexibility and upgrade potential
6. Minimizes inlet/product treating cost

1.2 Problem Statements

1.2.1 Problem Identification

Most natural gas is processed to remove the heavier hydrocarbon liquids which are NGL from the natural gas stream. Recovery of NGL components in gas not only may be required for hydrocarbon dew point control in a natural gas stream which to avoid the unsafe formation of a liquid phase during transport, but also yields a source of revenue, as NGLs normally have significantly greater value as separate marketable products than as part of the natural gas stream [4]. Lighter NGL fractions, such as ethane, propane, and butanes, can be sold as fuel or feedstock to refineries and petrochemical plants, while the heavier portion can be used as gasoline-blending stock. The price difference between selling NGL as a liquid and as fuel is often dictates from the recovery level desired by the gas processors.

Besides that, many NGL recovery process require removal of CO_2 to avoid solid formation (freezing) in the cold section. Since CO_2 removal equipment can add significantly to both investment cost and the operating cost of the contaminant removal section of the gas processing facility, there is considerable advantage to using a CO_2-tolerant process in the liquid section of NGL recovery facility.

Regardless of the economic incentive, however, gas usually must be processed to meet the specification for safe delivery. Hence, NGL recovery profitability is not the only factor in determining the degree of NGL extraction. The removal of natural gas liquids usually takes place in a relatively centralized processing plant, where the recovered NGLs are then treated to meet commercial specifications before moving into the NGL transportation infrastructure [1].

Based on these problems, the types of NGL recovery process to be used with optimum parameter specification before transporting must be considered carefully. So, this study is one way to evaluate the NGL process operation in maximizing NGL recovery using current technologies.

1.2.2 Significant of the Project

Recovery of NGL from gas field can bring significant additional value to the operations. Depending on the available market distribution routes and the actual compositions of hydrocarbons in the feed, it may face a wide range of processing options. So, with this study on NGL recovery, the results from this project can be proposed to the real NGL recovery plant operation.

With proper design of NGL recovery process, the process plant configuration and NGL recovery can be optimize with safe operation. With the result of this project also, it can minimize capital, labour and material costs to yield low life cycle costs, while improving operating flexibility and reliability.

1.3 Objectives and Scope of Study

The objectives of this study are:

1. To study on several technologies used in NGL recovery plant currently using HYSYS simulation.
2. To study different types of NGL recovery processes currently been used in the plant using HYSYS simulation.

The scopes of studies are narrow down to develop selected processes and technologies respectively. For objective 1, there are three types of technologies is chose:

1. Twister technology
2. Turbo-expander
3. J-T expansion valve

For objective 2, there are six processes are selected for these studies:

1. Gas Subcooled Process (GSP)
2. Overhead Recycle Process (OHR)
3. Recycle Split-Vapour Process (RSV)
4. Recycle Split-Vapour with Enrichment Process (RSVE)
5. Improved Overhead Recycle Process (IOR)
6. Single Column Overhead Recycle Process (SCORE)

1.4 Relevancy of the Project

This project is conducted with the concern of maximizing NGL recovery and the need to minimize energy consumption associated with the process with safe operation. In case of this project, the project focused on developing several NGL recovery process and several technologies used in NGL recovery process.

Thus, it is important to make a study on NGL recovery process so that the unsafe formation of a liquid phase during transport can be solve including make significantly greater value as separate marketable products from natural gas stream. Furthermore, by using current technologies with improving the NGL recovery process will minimize energy consumption associated with the process. This will minimize operation costs to yield low life cycle costs, while improving operating flexibility and reliability.

1.5 Feasibility of study

The project is conducted in simulation where the composition of natural gas and several NGL recovery process used can be found in articles, journals, books, and website. Besides, the production of NGLs from natural gas can be studied using simulation which already made earlier. The study was conducted using Aspen HYSYS V7.1 simulation software.

Regarding this project, many studies are already developed according to the recent NGL recovery process and technologies to maximize NGL recovery and minimize energy consumption associated with the process with safe operation. Those studies will help in developing the simulation stage in this project. The results from simulation will depend on processes and technologies chose earlier using optimum operating condition and parameters into the process. Since this project will be conducted in simulation, the duration for this project is within time limits as most literature review can be found at UTP Information Resource Center (IRC) instead finding it online.

2.0 LITERATURE REVIEW AND THEORY

2.1 Hydrocarbon Dew Point (HCDP)

Dew Point of a natural gas is a reference temperature/pressure at which condensation starts. It is also explained as the temperature to which the gas has to be cooled at a given pressure in order for it to change it state to liquid. It's much like the cold glass sweating on a humid day only the term is used for air while a natural gas is a multi component mixture. It is the heavier weighted compounds in the natural gas that condense first and dictate a dew point of the multi component system. The dew point temperature is also dependant on pressure. The importances of controlling HCDP are:

- There is a better value for the gas if HCDP controlled.
- Gas when HCDP controlled will not produce liquids in pipeline transportation. If liquids produced in pipeline, it will move as a slug, collect in low area, enter into compressor, increases pumping costs, create fires in burners, increases pressure drop, etc.
- HCDP controlled gas will eliminate liquid collection and thus it will decrease the corrosion in pipelines.

Sometimes heavy hydrocarbons drop out in the contactor of a dehydration plant. The outgoing sales gas maybe at the dew point. This depends on the composition of the gas coming off the wells. In such cases there is no need to control the HCDP.

To control HCDP, the process used and composition of the feed must be determined first since liquids are produced/ recovered as a by-product with a HCDP control unit. The richness of liquids recovered depends on the composition of the gas. Therefore gas composition has a major impact on the process selection. Leaner gases have lesser recoverable liquids and require lower temperatures to achieve the recovery efficiency and richer gases need larger refrigeration duties and are capital cost intensive. Sometimes there is no choice for the producer but to go for a HCDP control irrespective of how much liquids will break out. Here is a list of processes for a HCDP control and the technologies used in NGL recovery process:

- J-T valve expansion
- Turbo-expander
- Mechanical refrigeration
- Adsorption on a silica gel bed and regeneration of the bed
- Twister process – a new technology
- Vortex tube device – new technology

For this project, only three technologies will be studies further in the simulation which is 3-S Technology (twister), turbo-expander, and J-T valve expansion.

2.2 Current Technologies in NGL Recovery

2.2.1 3-S Technology

Twister is a 3-S technology which uses the concept that, feed gas passing through a nozzle (restriction), accelerates to supersonic speed, that suffers a pressure and temperature drop, the temperature drop causes condensation of the heavier hydrocarbons (see Figure 1). The Twister technology thermodynamically similar to turbo-expander and combines the following process steps into a compact, tubular device:

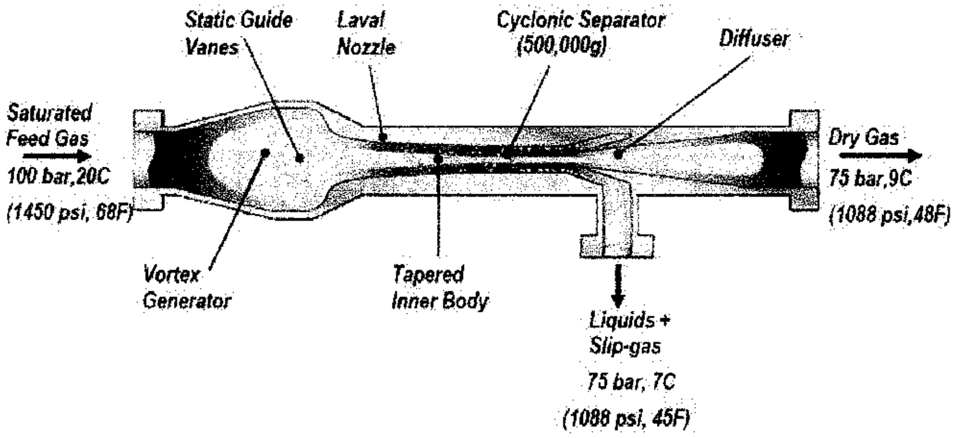

Figure 1: A cross-section view of the tube shows separation elements [8]

i. Expansion: The feed gas passes through a Laval nozzle accelerates to supersonic velocity resulting in a pressure drop, and the temperature drops, this causes heavier hydrocarbons condensates.
ii. Cyclonic Separator: Centrifuge causes a swirl effect which results in gas condensates separation and removal.
iii. Re-compression: The gas is allowed to pass through a diffuser region in order to regain the pressure loss, at which an estimate of 75-85% pressure recovery [8].

In details, the supersonic nozzle separates drops of condensed liquid using centrifugal forces which are formed by vortex generator. This approach to create flow swirling forms a shock wave that heats the gas, creates pressure losses, and creates subsonic flow zones in the separation area. As the flow decelerates, the shock wave produces partial crushing and evaporation of the drops of liquid. This method initiates gas swirling so that the tangential velocities, when combined with the centrifugal forces, separate any liquid drops formed in the supersonic nozzle by cyclonic separator and deliver them to a special extracting device.

This approach minimizes total pressure losses in the shock waves and separates the flow deceleration zone behind the shock wave from the drop separation zone. This method of flow swirling is called 3-S technology (supersonic separation) and the devices designed with this technology are called 3-S separators or Twister.

Whereas in Turbo-expander transform free pressure to shaft power, Twister achieves similar temperature drop by transforming pressure to kinetic energy. The Twister technology is also introduced to achieve higher system efficiency by lowering the dew point as a result of increasing the swirl vorticity to 500,000g [8].

2.2.2 Turbo-expander/Compressor and J-T valve

A Turbo-expander is an expansion turbine which a high pressure gas is expanded to produce work that is typically used to drive a compressor. Because work is extracted from the expanding high pressure gas, the expansion is an isentropic process or in other words, a constant entropy process and the low pressure exhaust gas from the turbine is at a very low temperature, sometimes as low as −90 °C or less [11]. Turbo-expanders are inherently simple devices that recover power from process gas streams. High-pressure gas forced through the expander transfers power to the compressor. Turbo-Expander is a simple and effective way of converting potential energy to kinetic energy via rotating turbine shaft.

In NGL recovery process, it uses the concept of isentropically expanding a feed gas stream to achieve condensation where the effluent of the expander is usually separated in de-methanizer and then return to the compressor section for compression after pre-cooling the feed gas [2]. The natural gas stream undergoes pressure drop and subsequent temperature fall in the expander section. The lost energy as a result of the expansion is then extracted using the coupling section, which is used in compressing the sales gas again. Figure 2 shows industrial-standard single-stage (ISS) process for a typical low temperature turbo-expander process to recover ethane and heavier hydrocarbons from a natural gas stream.

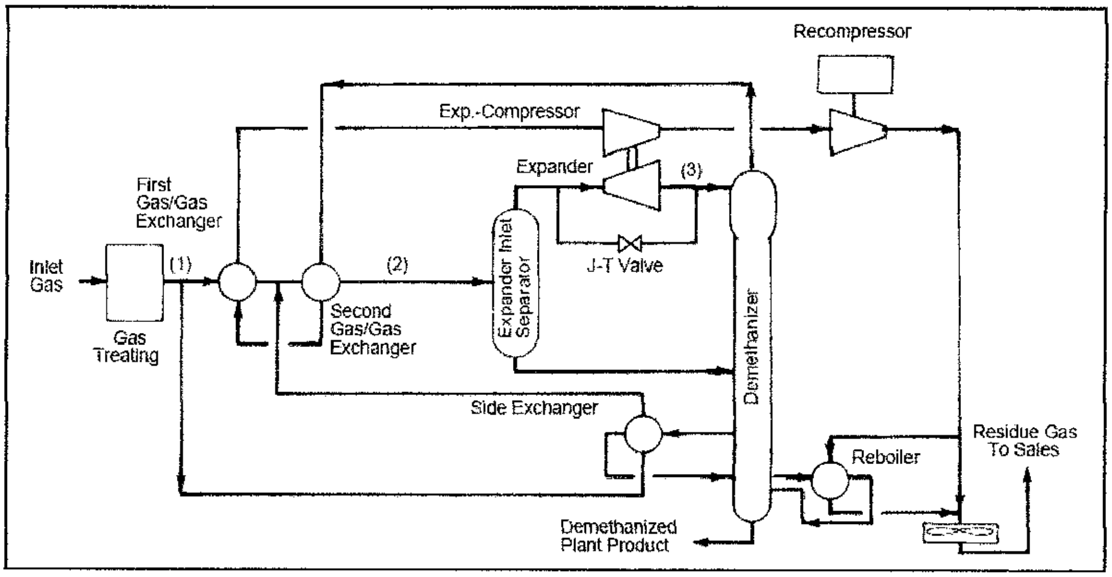

Figure 2: Example expander process [15]

For J-T valve, feed gas expansion across a J-T valve operates based on the first law of thermodynamics, in which it operates at constant enthalpy; this process was studied by Joule-Thompson [15]. In thermodynamics, the J-T effect describes the temperature change of a gas or liquid when it is forced through a valve or porous plug while kept insulated so that no heat is exchanged with the environment. This procedure is called a throttling process or Joule–Thomson process. In practice, the Joule–Thomson effect is achieved by allowing the gas to expand through a throttling device usually a valve which must be very well insulated to prevent any heat loss to or from the gas to the surrounding. No external work is extracted from the gas during the expansion where the gas must not be expanded through a turbine, for example.

For physical mechanism of J-T valve, as gas expands, the average distance between molecules will increases. Because of intermolecular attractive forces, expansion causes an increase in the potential energy of the gas. If no external work is extracted in the process and no heat is transferred, the total energy of the gas remains the same because of the conservation of energy. The increase in potential energy thus implies a decrease in kinetic energy and therefore in temperature.

2.3 Fractionation Column

Fractional columns are the important of unit operation in NGL recovery plant Industrial fractional columns are usually operated at a continuous steady state. Unless disturbed by changes in feed, heat, ambient temperature, or condensing, the amount of feed being added normally equals the amount of product being removed. It should also be noted that the amount of heat entering the column from the reboiler and with the feed must equal the amount heat removed by the overhead condenser and with the products.

De-methanizer in ethane recovery process is a conventional distillation column containing a plurality of vertically spaced trays, one or more packed beds or some combination of trays and packing. The tower consists of two sections; an upper absorbing (rectification) section and a lower stripping section. Absorbing section contains the tray and/or packing to provide the necessary contact between the vapour portions of the expander stream at an intermediate feed position located in the lower region of absorbing section rising upward and cold liquid falling downward to condense and absorbing ethane component and heavier components. Stripping section contains the tray and /or packing to provide the necessary contact between liquids falling download and the vapour which be heated by reboiler rising upward. The de-methanizer section also includes one or more reboilers which heat and vaporize a portion of the liquids flowing down the column to provide the stripping vapour which flow up the column to strip the liquid product of methane and lighter components

The de-ethanizer for propane recovery process have the same philosophy with de-methanizer but for de-ethanizer for ethane rejection, condenser is introduced at the top of the column to give more cooling medium for the liquid which contains mostly ethane discharge from the column. The purpose of the de-ethanizer for ethane rejection is to produce a bottoms product that has a ratio of ethane to propane about 2.0 mol% [5].

The de-propananizer is modeled as a conventional distillation column containing a plurality of vertically spaced trays, one or more packed beds or some combination of trays and packing plus the reboiler and total condenser. It operates typically about 1655 kPa (240 psia) [5]. The purpose of this column is to produce a concentration of propane in the bottoms product to level about 2.0 mole% [5].

2.4 Enhanced NGL Recovery Process

2.4.1 Self-Refrigeration

This recently research process offers significant enhancements to NGL recovery processes. Where a slip stream from or near the bottom of the distillation column (de-methanizer) is utilized as a mixed refrigerant. The mixed refrigerant is in liquid or partially vaporized, providing refrigeration for inlet gas cooling otherwise normally accomplished using a costly external refrigeration system, including compressors, condensers, refrigerant accumulators, economizers and refrigerant storage [3]. The liquid generated from this "self-refrigeration" cycle is specifically tailored to enhance separation efficiency, then is recycled back to the bottom of the tower where it serves as a stripping [3]. The innovation not only reduces or eliminates the need for inlet gas cooling via external refrigeration, but also provides the following enhancements to the de-methanizer operation:

i. Lowers the temperature profile in the tower, thereby permitting better energy integration for inlet gas cooling via reboilers, resulting in reduced heating and refrigeration requirements. It will reduce and/or eliminate the need for external reboiler heat, thereby saving fuel plus refrigeration.

ii. Enhances the relative volatility of the key components in the tower when operated at a typical pressure, thereby improving separation efficiency and NGL recovery; or alternatively allows increased tower pressure at typical recovery efficiency, thereby reducing the residue gas compression requirements.

It is noteworthy that the simplicity of the self-refrigeration scheme can be adapted to most leading NGL recovery technologies to enhance the operational efficiency and reduce capital and operating costs of those processes regardless of the original licensor [3]. Moreover, it can be configured into a simple add-on skid particularly suitable for retrofitting plants to enhance NGL recovery and/or increase gas plant capacity at original recovery levels without additional residue gas compression.

2.4.2 Improved Propane Recovery Methods

The recently Improved Propane Recovery method was developed to achieve high recovery levels of propane in a natural gas feed without the addition of substantial amounts of recompression and/or refrigeration. The method employs sequentially configured first and second distillation columns, like de-methanizer tower followed by a de-ethanizer tower. A cooled gas feed condensate is separated in the first column into methane and a liquid phase comprising ethane and heavier hydrocarbons. The liquid phase is separated in the second column into a gas phase primarily comprising ethane and a second liquid phase primarily comprising the desired C_3+ hydrocarbons. At least a portion of the second gas phase is introduced into the first distillation column as a propane free overhead reflux stream to improve the separation of C_3+ hydrocarbons. The process permits separation and recovery of more than about 99% of the C_3+ hydrocarbons in the gas feed at higher than normal operating pressures [6]. Further, by cooling the second gas phase with a liquid condensed in a lower tray of the first column, significant capital and operating costs may be saved. By employing the self refrigeration system, the need for external refrigeration is eliminated and the separation efficiency is improved in the first column.

2.4.3 Process Enhancement Scheme

While the Process Enhancement Scheme is widely applicable, it offers significant advantages as applied to gas processing plants (existing or new) with the following characteristics:

i. The inlet gas is relatively rich in NGL's and requires refrigeration to obtain required liquid recoveries.
ii. Inlet gas pressure is in the intermediate to high ranges, (above 400 psi with the residue gas delivered at the same pressure as the inlet gas [5])
iii. There is a benefit to maintaining recovery levels when the inlet gas drops in pressure and/or becomes richer over time.
iv. There is a need to process up to 20% more gas in an existing gas plant without sacrificing NGL recovery level or adding additional residue gas compression [5].

2.5 NGL Recovery Process Description

Basically, in NGL recovery processes, the Natural Gas is cooled to extremely low temperatures through a network of heat exchangers. The cooling results in partial liquefaction of the stream may enhance NGL recovery. The cold liquid and vapour are then separated in the Low Temperature Separator (LTS). The liquid stream from LTS is flashed across a J-T valve (in most NGL recovery processes) for additional chilling. For this study, Ortloff's NGL recovery processes are used.

Ortloff Engineers, Ltd. is recognized world-wide as a leader in the areas of cryogenic gas liquids recovery, LNG processing, sulfur recovery, and sour gas processing plant design. They offer a range of consulting/engineering services, tailored to the needs of each client. They can help in improving the competitive position on prospects or with existing plant operations where their expertise applies. Below are several NGL recovery processes using Ortloff method:

2.5.1 Gas Subcooled Process (GSP)

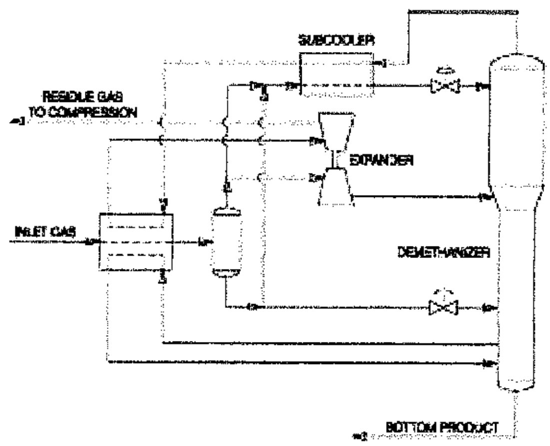

Figure 3: GSP process flow diagram [9]

GSP is the novel split-vapour concept that each employs to generate reflux for the de-methanizer tower. In this process, a portion of the feed gas is expanded to de-methanizer operating pressure and fed to the tower at one or more intermediate feed points. The remainder of the feed gas is also condensed and subcooled, flashed down to the de-methanizer operating pressure and supplied to the tower as its top feed which act as reflux, contacting and rectifying the vapour leaving the expander. The cold liquids supplied to the middle of the tower.

2.5.2 Overhead Recycle (OHR) Process

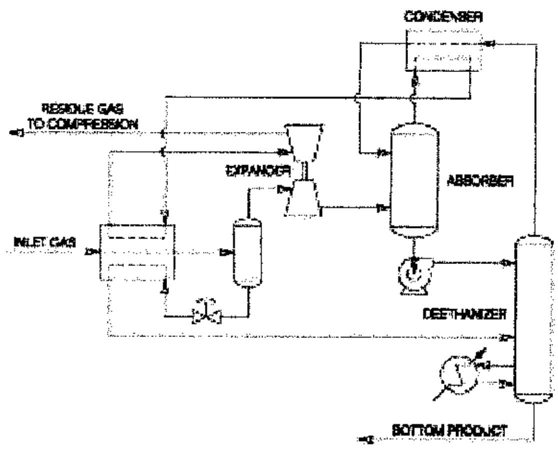

Figure 4: OHR process flow diagram [9]

OHR process has often been used instead of GSP for NGL recovery plants. Although typically employed in a two-column configuration, this process in essence withdraws a vapour stream from an intermediate point in the de-ethanizer tower that is then condenses and used as reflux for upper position of the tower. This produces cold liquids to contact and rectify the vapour leaving the expander.

2.5.3 Recycle Split-Vapour (RSV) Process

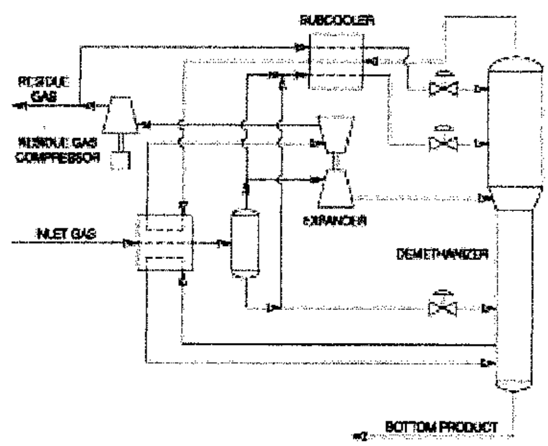

Figure 5: RSV process flow diagram [9]

RSV process is an enhancement of original Gas Subcooled Process (GSP) technology. RSV process uses the split-vapour feed to provide the bulk ethane recovery to the tower. RSV process can provide high ethane recovery and ethane rejection from natural gas streams. It can also be operated to recover only a portion of the ethane depending on market demand.

RSV design incorporates the addition of a small reflux stream generated from residue gas which is used to supplement the usual reflux stream. An additional rectification section is installed above the typical top feed point of the GSP process. The liquefied residue gas stream is then fed as reflux to the top feed of de-methanizer. The lower section of the tower provides bulk recovery of the desired liquid product.

2.5.4 Recycle Split-Vapour with Enrichment (RSVE) Process

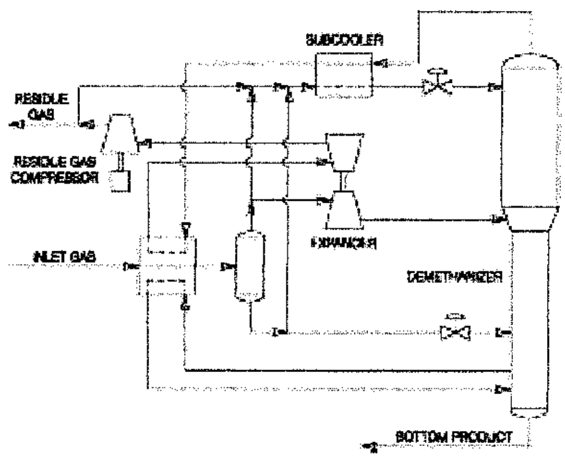

Figure 6: RSVE process flow diagram [9]

A variation of the RSV process is RSVE process. Similar to RSV, a recycle stream is withdrawn from recompressed residue gas but it is mixed with split-vapour feed before being condensed and subcooled so that it does not require a separate or exchanger passage.

2.5.5 Improved Overhead Recycle (IOR) Process

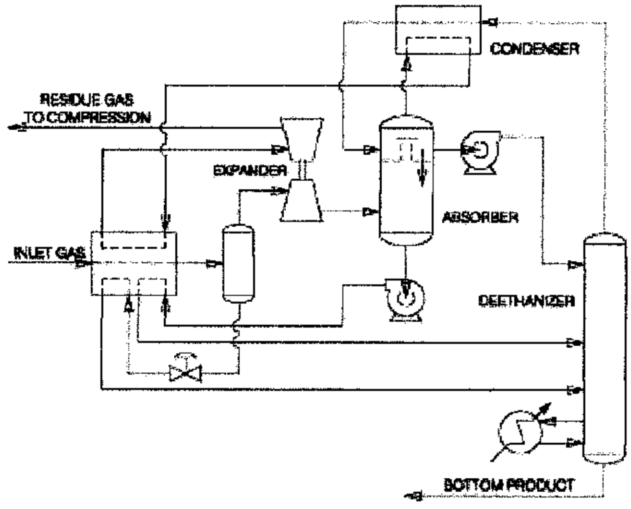

Figure 7: IOR process flow diagram [9]

IOR process is another approach to improve the OHR process by making better use of the refrigeration available in its feed. The cold absorber bottoms liquid is supplied part of the feed gas cooling before entering de-ethanizer. A small portion of top absorber is entered the de-ethanizer as a top feed of the column.

2.5.6 Single Column Overhead Recycle (SCORE) Process

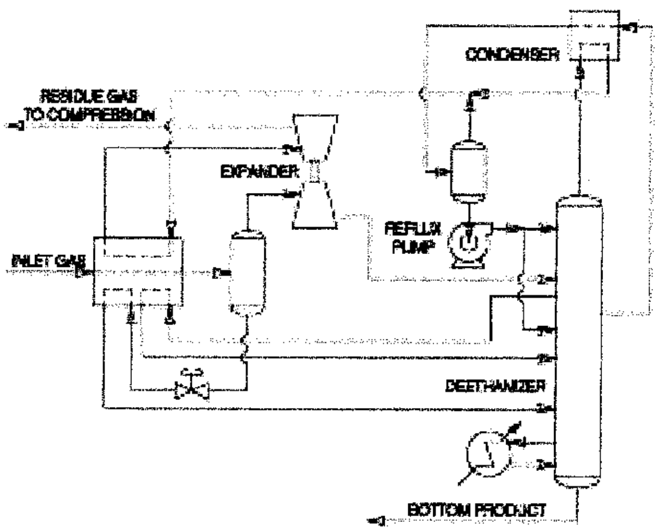

Figure 8: SCORE process flow diagram [9]

SCORE process is a cryogenic gas processing technology suited to the recovery of propane and heavier hydrocarbons from a natural gas stream. The SCORE design is a modification and enhancement of popular OHR process combining extremely high propane recovery with high efficiency.

Reflux for the column is generated by condensing a vapour side draw stream. A liquid side draw is utilized for process cooling to optimize heat integration. With appropriate design features, a plant using the SCORE process can also be switched to operate in an ethane recovery mode utilizing GSP.

3.0 METHODOLOGY

3.1 Research Methodology

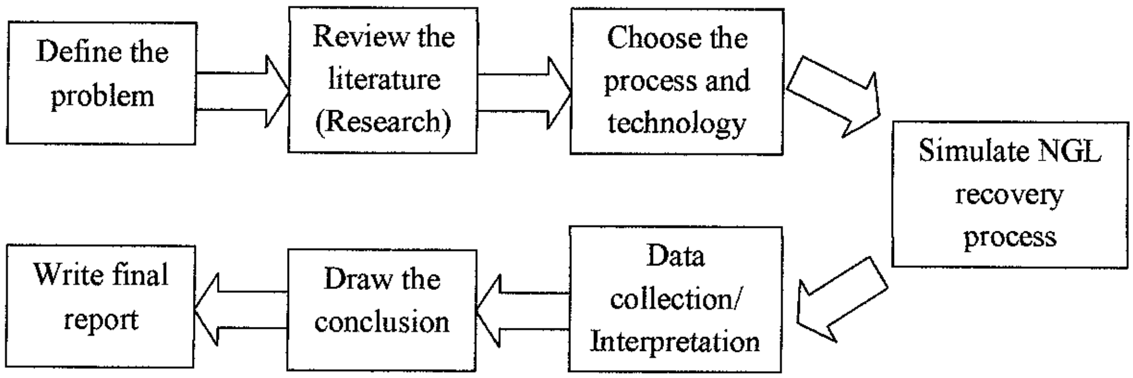

Figure 9: Flow diagram of research methodology

Based on diagram above, there will be seven phases of work focus along this research:

1. ***Define the problems or current issues regarding NGL recovery in the plant.***
   Based on discussion with supervisor and some current issues regarding NGL recovery in the plant, the problems is defined so that proper analysis to overcome it can be done with undergo this project. Later, the objectives of this project are stated based on problem statement which is defined earlier.

2. ***Review the literature regarding NGL recovery process, current technologies used in the plant, and parameter used for the simulation***
   This will be done through reading the articles, books, websites, and many other media as much as possible regarding this project. The important data are extracted from literature review to see overall process of NGL recovery and help in choosing appropriate processes and technologies in this study.

3. ***Choose the appropriate process and technologies which can be used to simulate NGL recovery plant***
   Through good understanding about the subjects of this project from literature review will make the decision easier to choose NGL recovery process and

several technologies used in NGL recovery process. This information is used to develop the simulation and perform the simulation study for this project.

4. ***Do the simulation of NGL recovery in HYSYS***

These activities are done in Aspen HYSYS 2006 simulator. Process flow diagram is designed and developed for selected technologies and processes based on research finding. The parameters will be inserted to simulation is based on literature review. The validity and reliability of simulation must be ensuring first with industrial process so that the result is reliable and practical.

5. ***Collect and analyze the data from simulation***

The data from the simulation for each technology and process will be collected. Several parameters such as component recovery, compression duty and other important parameters in NGL recovery process will be present wisely and effectively. The studies will be conducted based on data collection where the result for each process and technologies will be evaluate to see behaviour in NGL recovery process.

6. ***Draw the conclusion after the studies is carried out***

This will be done after all the study has been carried out. Some recommendation is proposed for further studies to maximize the production and minimize energy consumption of NGL recovery process.

7. ***Write the final report***

After the study on NGL recovery – simulation study is done; final report is prepared to keep the processes, simulation parameters, and all activities done save in one document for future reference.

3.2 HYSYS Simulation Methodology

There are several steps in developing the simulation of NGL recovery process in Aspen HYSYS V 7.1 which are:

1. The fluid package and components of natural gas used are selected based on research finding. For this project, Peng-Robinson is chose as fluid package.
2. Simulation environment is entered.
3. The NGL recovery processes and technologies used to control HCDP are developed based research finding. All the appropriate equipments and operating conditions are inserted into the simulator.
   i. For objective 1, ISS process is developed in the simulation where the technologies used to control HCDP are varies with constant of operating condition.
   ii. For objective 2, five types of NGL recovery processes are developed respectively in the simulation using turbo-expander with same operating condition used.
4. Operating condition used in the simulation is defined and simulation is run.
5. After all unit operations are converged, the appropriate data are taken.
6. Step 4 and 5 are repeated for another parameter or manipulated variables.
7. Discussion is carried out based on data gathering.
8. Based on result and discussion, conclusion of this project is made. Some recommendation is proposed to improve this study in the future.

For objective 2, multiple cases are run which holding the feed composition and inlet and residue pressures constant. The de-methanizer/de-ethanizer (propane recovery) pressure in is changed 100 kPa increments and the recovery changes are taken. Then, the results between ethane/propane recoveries with compression power are plotted.

Since the purpose of the graph is to compare various processes at a given horsepower level, the heat exchanger UA's is hold constant instead of temperature approaches where the same total heat exchanger UA are constant. 5 cases for each process design for constant feed composition are run to develop the graphs.

3.3 Feed Gas Composition and Simulation Parameters

Table 1 lists feed gas composition used in this paper. For this study, only lean gas is considered. Therefore, the external refrigerant is not needed. All simulations in this paper are performed using Aspen HYSYS V7.1. Operating conditions for the simulation is showed in Table 2.

Table 1: Composition of the base case wet gas processed

Component	Mole %
Nitrogen	2.00
Carbon Dioxide	0.40
Methane	88.24
Ethane	5.82
Propane	2.32
i-Butane	0.35
n-Butane	0.46
i-Pentene	0.13
n-Pentane	0.22
Hexane	0.06
Total	100.00

Table 2: Summary of operating conditions employed in the simulation [4]

Inlet Gas	i. Temperature = 35°C ii. Pressure = 1) 60 bar (870.2 psia) = 2) 71.71 bar (1040 psia) iii. Flow rates = 100 MSCFD (4981 kgmole/hr)
Rotating Equipment Efficiencies	i. Compressor = 75% (polytropic) ii. Expander = 82% (adiabatic)
Heat Exchanger	i. Pressure drop = 10 psi ii. Minimum approach = 2°C

De-methanizer	i. 14 theoretical trays ii. Operating pressure = 20 to 35 bar iii. Main and side reboiler flow rates = 500 kgmole/hr iv. C1/C2 ratio < 2.0% mole
De-ethanizer for ethane recovery process	i. 20 theoretical trays with reboiler and condenser ii. Operating pressure = 430 psia iii. Reflux ratio = 2.0 iv. C2/C3 ratio = 2.0% mole
De-ethanizer for propane recovery process	i. 20 theoretical trays with reboiler ii. Operating pressure = 20 to 35 bar iii. Reflux ratio = 4.0
Absorber (for OHR and IOR processes only)	i. 10 theoretical trays ii. Operating pressure = 20 to 35 bar (20 psi lower than de-ethanizer)
De-propanizer	i. 30 theoretical trays with reboiler and condenser ii. Operating pressure = 240 psia iii. Reflux ratio = 2.0 iv. C2/C3 ratio = 2.0% mole
Residue Gas	i. Temperature = 40°C ii. Pressure = 71.71 bar (1040 psia)

3.4 Equipment/Hardware Used

For this project, Aspen HYSYS V7.1 is used to simulate the simulation and perform several studies. HYSYS is powerful engineering simulation tool and uniquely created with respect to the program architecture interface design engineering capabilities. Perhaps even more important is how the HYSYS approach to modelling maximizes the return on simulation time through increased process understanding.

Another tool used in this project is Microsoft Excel. This is powerful tool where it features calculation, graphing tools, tables, and a macro programming language. It also has the basic features of all spreadsheets using a grid of cells arranged in numbered rows and letter-named columns to organize data manipulations like arithmetic operations

3.5 Gantt Chart

Table 3: Gantt chart for FYP I

No.	Detail/Week	1	2	3	4	5	6		7	8	9	10	11	12	13	14
1	Selection of project topic	■	■					Mid-Semester Break								
2	Literature review		■	■	■	■										
3	Project work					■	■									
4	Submission of Progress Report						■									
5	Seminar						■									
6	Project work continue								■	■	■	■	■	■	■	
7	Submission of Interim Report															■
8	Oral Presentation															■

Table 4: Gantt chart for FYP II

No.	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Project work continues	■	■	■	■	■	■	■	Mid-Semester Break								
2	Submission of Progress Report									■							
3	Project work continues									■	■	■	■	■			
4	Pre-EDX												■				
5	Submission of Draft Report													■			
6	Submission of Dissertation (soft bound)														■		
7	Submission of Technical Paper														■		
8	Oral Presentation															■	
9	Submission of Project Dissertation (Hard Bound)																■

4.0 RESULT AND DISCUSSION

4.1 Technologies Controlling HCDP

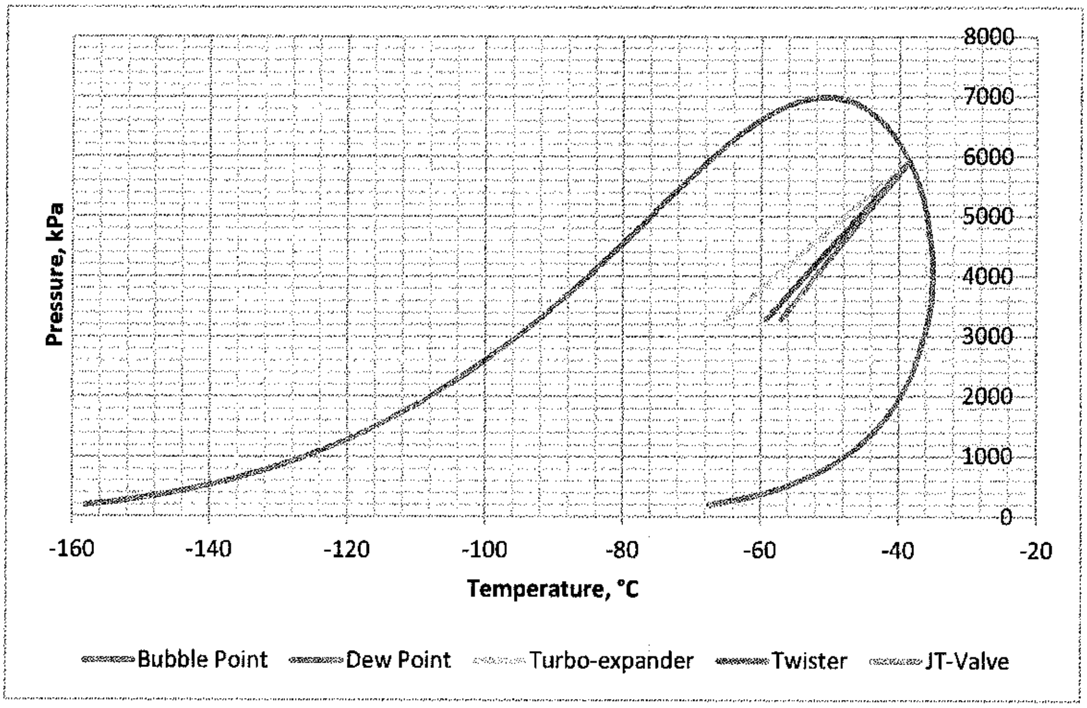

Figure 10: Phase Envelope for J-T valve, expander and twister process

Based on diagram above, at same pressure drop, the temperature drop for J-T valve is not as low as that attained by flow through the expander. This is because J-T valve is adiabatic expansion without the gas doing work. So, the gas does not cool to as low a temperature as expander did. It shows that the expander which is isentropic expansion producing work and thereby cooling the gas is more than the J-T expansion path. For twister, it performs somewhere in between the J-T valve and turbo-expander (about 90% thermodynamically similar).

Based on Figure 11, compare to turbo-expander and J-T valve, twister has different bubble and dew points between inlet and outlet. At primary outlet, the dew and bubble points are the lowest so that the stream can handle cold stream where most methane content at this stream where hydrate and CO_2 freezing are possible to occur.

The secondary outlet has the highest dew and bubble points because most of methane goes to primary outlet which remains most of NGL at secondary outlet.

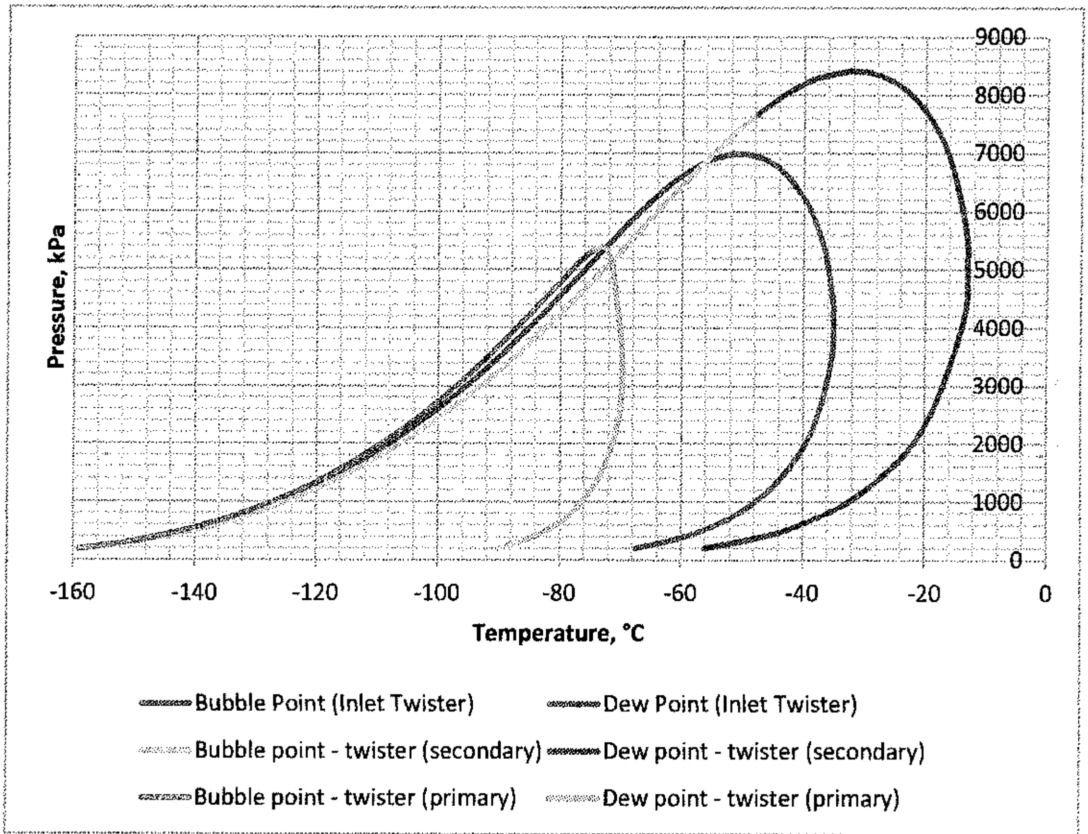

Figure 11: Phase Envelope for inlet and outlets Twister

Table 5: Condition at NGL product and residue gas streams (Operating pressure for de-methanizer = 28 bar)

Technology Used in Simulation	Condition at NGL Product Stream	Condition at Residue Gas Stream
J-T Valve	32.10 °C 192.6 kgmole/hr	3002.54 kW (export compressor)
Turbo-expander	23.23 °C 250.9 kgmole/hr	2057.62 kW (export compressor)
Twister	24.63 °C 258.3 kgmole/hr	2966.60 kW (export compressor)

Based on table above, twister has the highest product recovery compared to turbo-expander and J-T valve because only most of heavier hydrocarbon is entered to de-methanizer from secondary outlet of twister. So, the column need much lower energy/heat to separate the lighter gas as a top product compared to turbo-expander and J-T valve where all the reflux feed goes to the de-methanizer,. The higher temperature with J-T expansion also will results in a reduction of product recovery compare with turbo-expander.

The use of recompressor (using work produced by expander) to boost the residue gas pressure will decrease booster/export compressor duty. Without the expander running (therefore the recompressor also not running), the process cannot restore the de-methanizer overhead vapour to the residue gas pressure using the export compressor alone. Therefore, it will increase compression power in NGL recovery process for twister and J-T valve.

4.2 NGL Recovery Processes

4.2.1 Ethane Recovery Process

In GSP process, the higher concentration of ethane and heavier components in the cold liquids help reduce the amount CO_2 concentrating in the upper and colder section of the tower. This allowing higher ethane recovery levels without CO_2 freezing.

In RSV process, the higher pressure of recycle stream allows the tower overhead gas to be used to provide the condensing and subcooling so that the split-vapour feed can be supplied to the tower. However, combining this reflux with the split-vapour process is resulting in much lower compression horsepower for a given recovery level because a much lower reflux flow is needed to rectify the tower vapour due to the bulk recovery provided by the split-vapour feed. Compared to GSP design operating at the same ethane recovery level, RSV has better CO_2 tolerance than the GSP because the refluxed designs can accommodate higher de-methanizer operating pressures for a given recovery level.

In RSVE process, since some of portion of residue gas is mixed with the split-vapour feed before being subcooling, the ethane content of the top tower feed is richer than RSV process. As the result, the ultimate ethane recovery is limited to slightly lower levels than RSV due to equilibrium effects. Compared to RSV and GSP process, RSVE process is more CO_2-tolerant.Enriching the recycle stream with heavier hydrocarbon s in split-vapour feed raises the bubble temperatures of the liquids in the upper section of the de-methanizer, moving the tower operating conditions away from conditions where CO_2 start freezing (see Figure 12). As a result, the RSVE process can tolerate higher CO_2 concentration in the feed gas for a given ethane recovery level than GSP and RSV processes.

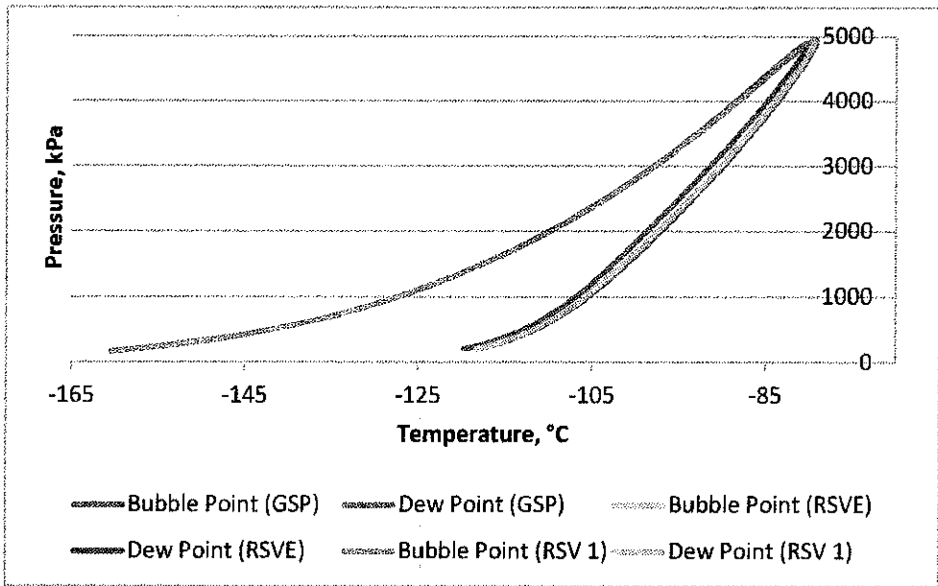

Figure 12: Phase Envelope for split-vapour feed before being subcooling

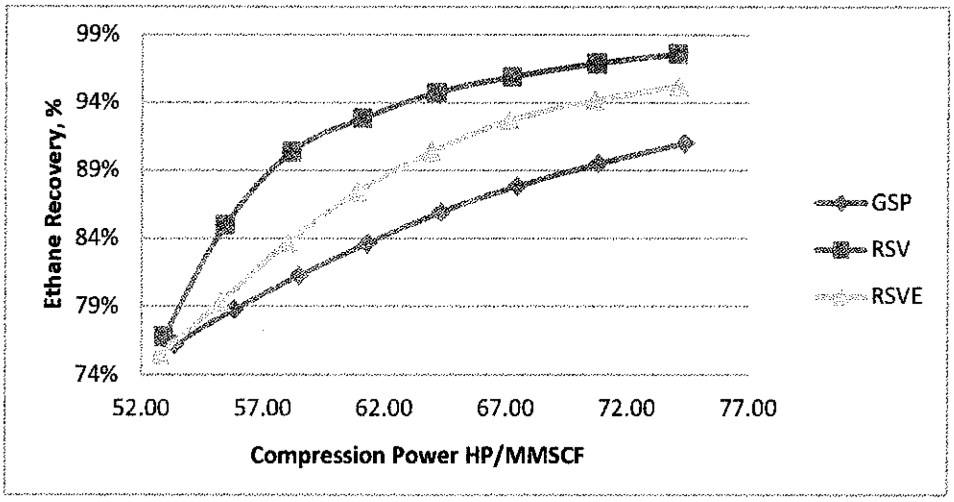

Figure 13: Ethane Recovery Performance

Figure 13 shows the performance of GSP, RSV, and RSVE processes for a given gas composition when operated for ethane recovery. RSV and RSVE processes offer higher recovery for a given amount of compression and less compression for a given recovery level than GSP process. For instance, at an ethane recovery of 84%, the compression power is about 6% and 12% lower than GSP for RSVE and RSV respectively or if the compression available is 62 HP/MMSCFD, the RSVE and RSV designs allow ethane recoveries 5% and 11% higher respectively than GSP design can achieve.

4.2.2 Propane Recovery Process

In OHR process, the cold liquids which entered the absorber then contact and rectify the vapour leaving the expander is absorbing the propane-plus components for recovery in the bottom product to the de-ethanizer. This process provides more efficient recovery of propane and heavier hydrocarbon than GSP process.

In IOR process, the cold absorber bottom liquid which is supplied to feed gas cooling will reduce the cooling load on the front end of the plant and also reduce the de-ethanizer reboiler duty by the same amount. A small portion of the cold reflux produced by the overhead absorber is used to rectify the vapour flowing up the de-ethanizer allowing the absorber bottom stream to be partially vaporized for maximum heat recovery as it provides feed gas cooling.

In SCORE process, the process works in essentially the same philosophy as the IOR process where to make efficient use of the refrigerant available in its feed streams. Since this process employed one column and one pump, it can be considerable advantage in terms of the investment cost for the plant since single column with reflux separator re generally less expensive than the two column used in IOR. The single column design is also more easily adapted to ethane recovery operation.

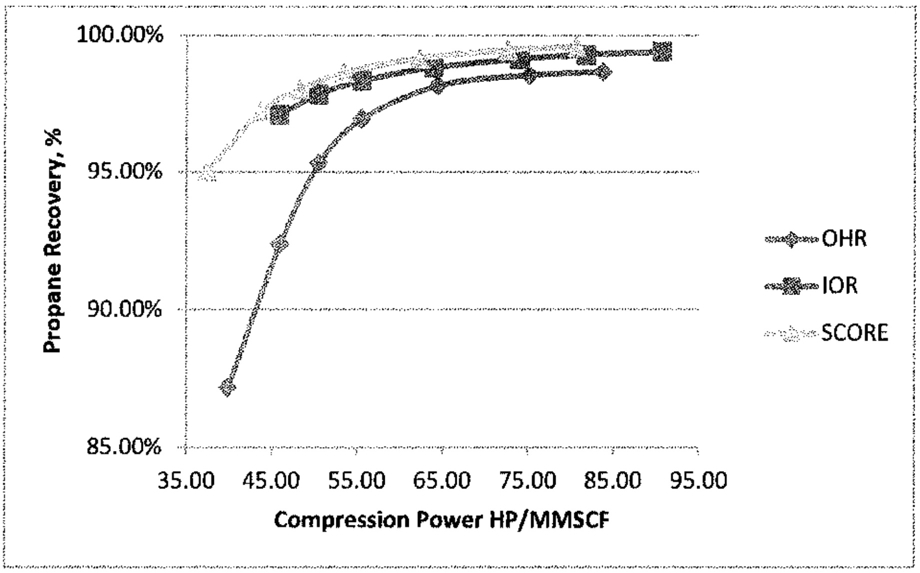

Figure 14: Propane Recovery Performance

Figure 14 shows the performance of OHR, IOR, and SCORE for a given gas composition when operated for propane recovery. Compared to OHR, IOR and SCORE processes offer higher recovery for a given amount of compression, les compression for a given recovery level, or combination of both.

Since SCORE design can adapt more easily to ethane recovery operation utilizing GSP based on demand needed, SCORE gives extra valuable characteristic to gas processing plant. Although switching the SCORE plant to GSP requires additional piping and several valves, additional equipment is not required in most cases. Below the data recovery of the process when switching between SCORE and GSP at same inlet rate, residue compression and total heat exchanger UA.

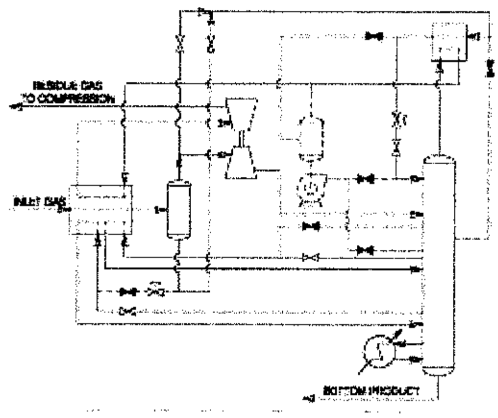

Figure 15: Ethane Recovery Mode [9]

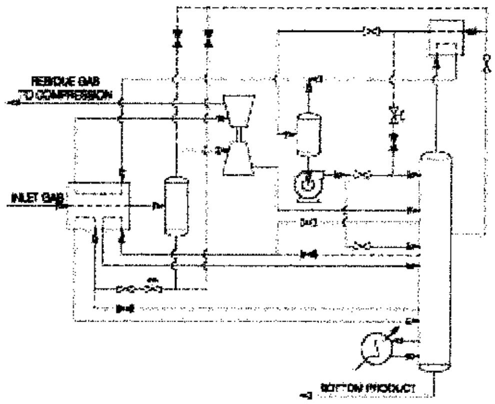

Figure 16: Propane Recovery Mode [9]

Table 6: Recovery Compression between SCORE and GSP (after switching)

Operating Mode	SCORE	GSP
Inlet Rate, MMSCFD	100.00	100
Residue Compression, HP	5103.01	5103.17
Total UA, kJ/C-h	2.697×10^6	2.699×10^6
Expander Outlet Pressure, kPa	2800	2721
Boil-up Ratio	4.000	1.024
Ethane Recovery, %	nil	69.30
Propane Recovery, %	92.00	97.51

5.0 CONCLUSION

The product recovery and NGL production using twister is higher than turbo-expander, and J-T valve since the energy/heat required to separate the lighter gas at de-methanizer as the top product is lower compared using J-T valve and turbo-expander to decrease the temperature. Besides that, using turbo-expander, it will reduce compression power for export compressor since work produced by turbo-expander will generate brake compression to recompressor to increase the pressure at residue gas.

For several processes in NGL recovery, it shows RSV and SCORE processes give the highest recovery for the same compression power and feed composition for ethane and propane recovery process respectively. In term of CO_2-tolerant, RSVE is more CO_2-tolerant compare with other process in ethane recovery process. This finding is help in designing NGL recovery process and which process to choose since the process chose is depends on the gas composition and guided by the cyclical nature of the market preference for ethane and propane where the price difference is often dictates from the recovery level desired by the gas processors.

6.0 RECOMMENDATION

Optimization and improvement of the processes can be done for future studies to maximize NGL recovery and production with less energy consumption especially in make better use of reflux feed and reflux of each tray in de-methanizer to give more refrigeration to the process so that it will increase the recover level without needed higher compression power.

For switching process between SCORE to GSP, since the ethane recovery is not that high when using GSP, RSV process is proposed to switch from SCORE since RSV process can recover much higher ethane. The study need to be conduct thoroughly so that no additional equipment is required when switching between SCORE and RSV but only additional piping and several valves are needed.

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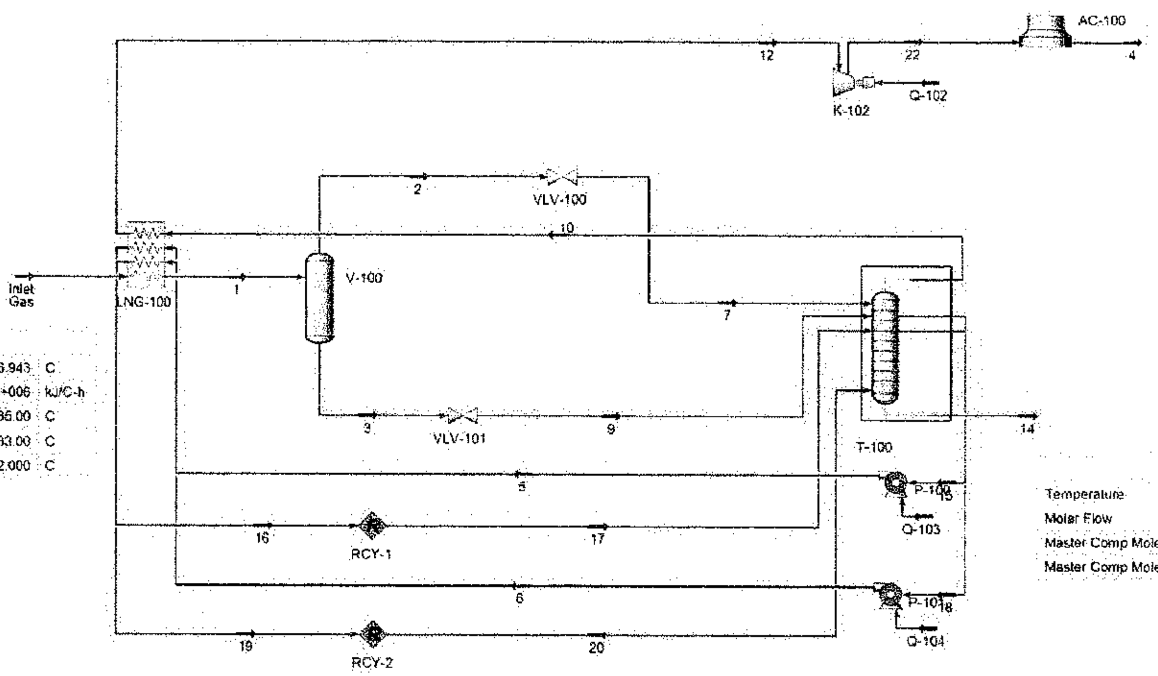
APPENDICES

APPENDIX A

The industrial-standard single-stage (ISS) process for different types of technologies used

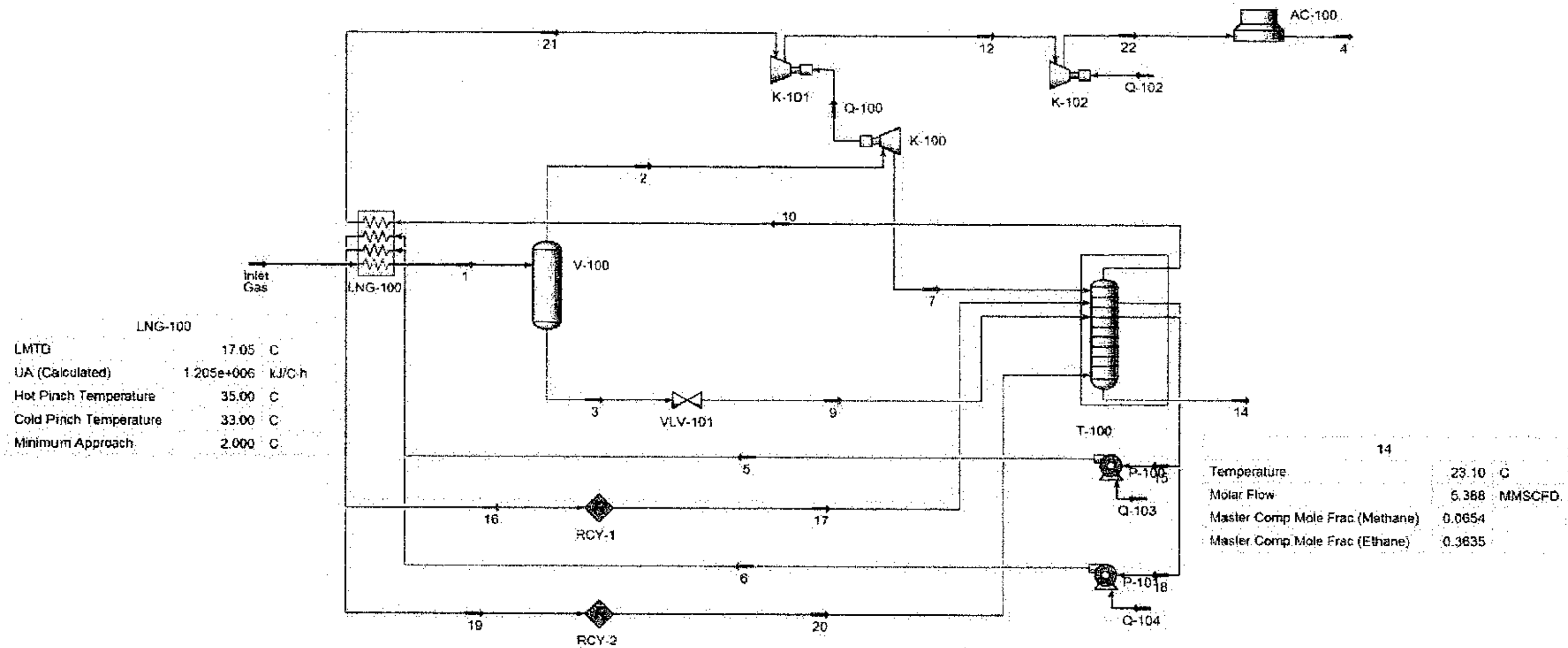
J-T Valve



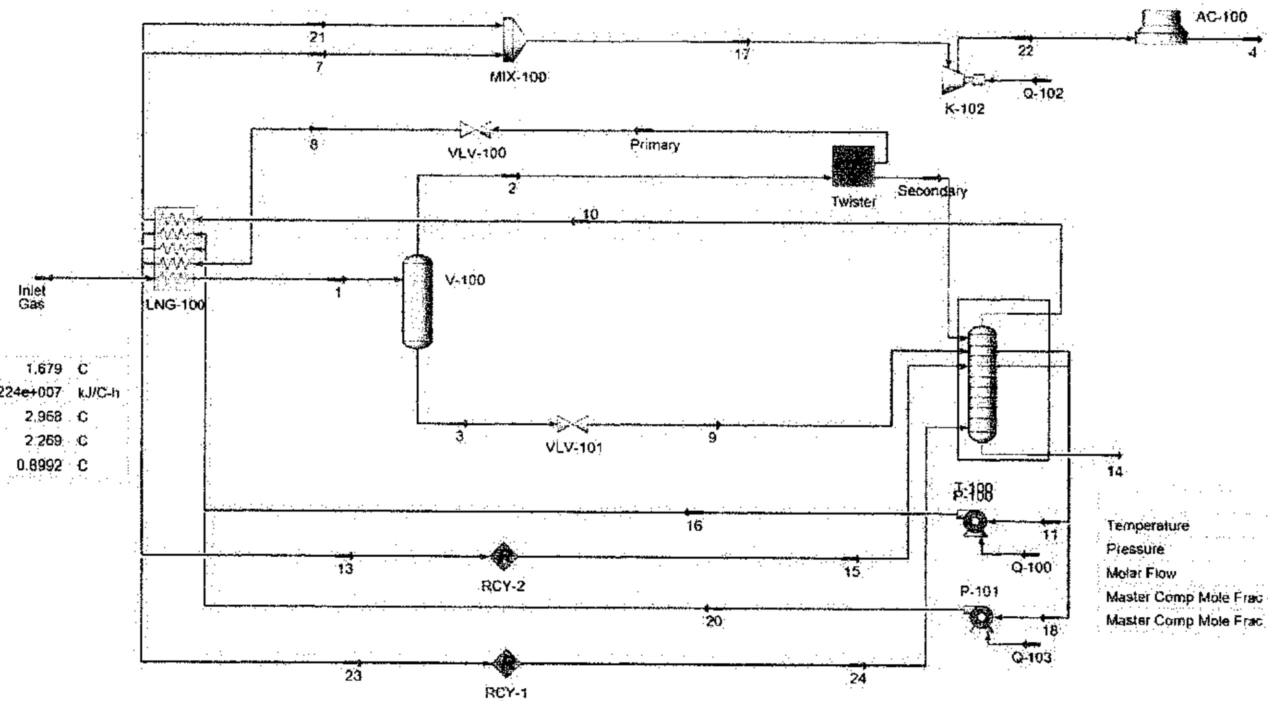
LNG-100		
LMTD	6.943	C
UA (Calculated)	2.960e+006	kJ/C-h
Hot Pinch Temperature	35.00	C
Cold Pinch Temperature	33.00	C
Minimum Approach	2.000	C

14		
Temperature	32.10	C
Molar Flow	3.866	MMSCFD
Master Comp Mole Frac (Methane)	0.0629	
Master Comp Mole Frac (Ethane)	0.2857	

Turbo-expander



Twister



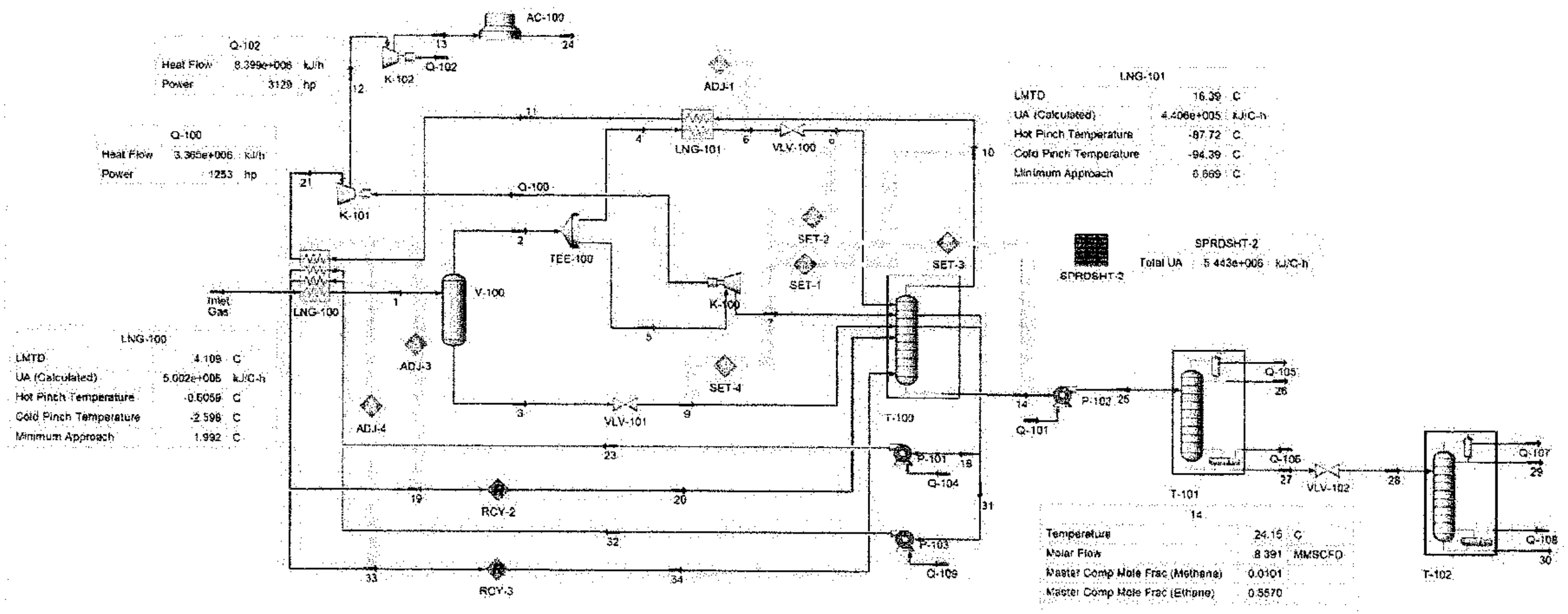
LNG-100		
LMTD	1.679	C
UA (Calculated)	1.224e+007	kJ/C-h
Hot Pinch Temperature	2.968	C
Cold Pinch Temperature	2.269	C
Minimum Approach	0.8992	C

14		
Temperature	24.63	C
Pressure	2800	kPa
Molar Flow	5.186	MMSCFD
Master Comp Mole Frac (Methane)	0.0649	
Master Comp Mole Frac (Ethane)	0.3502	

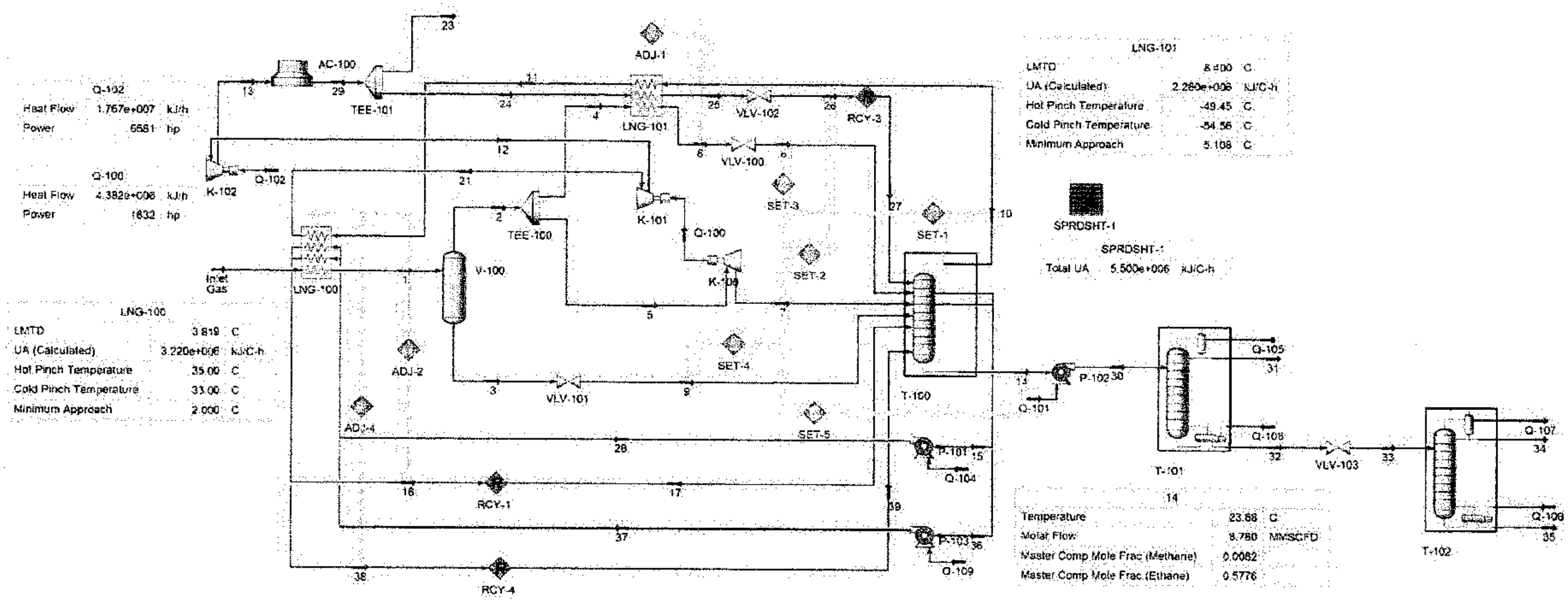
APPENDIX B

Different types of NGL Recovery Processes based on Ortloff Engineer, LTD

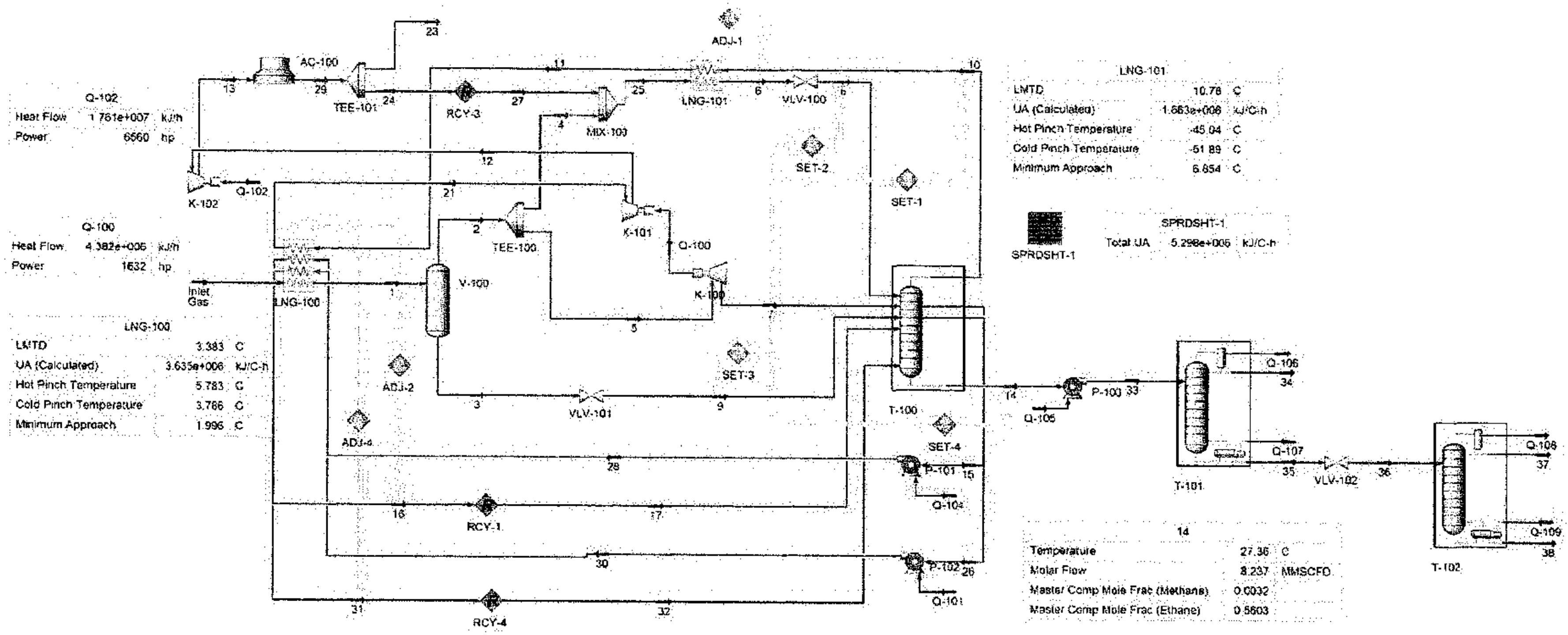
Gas Subcooled Process (GSP)



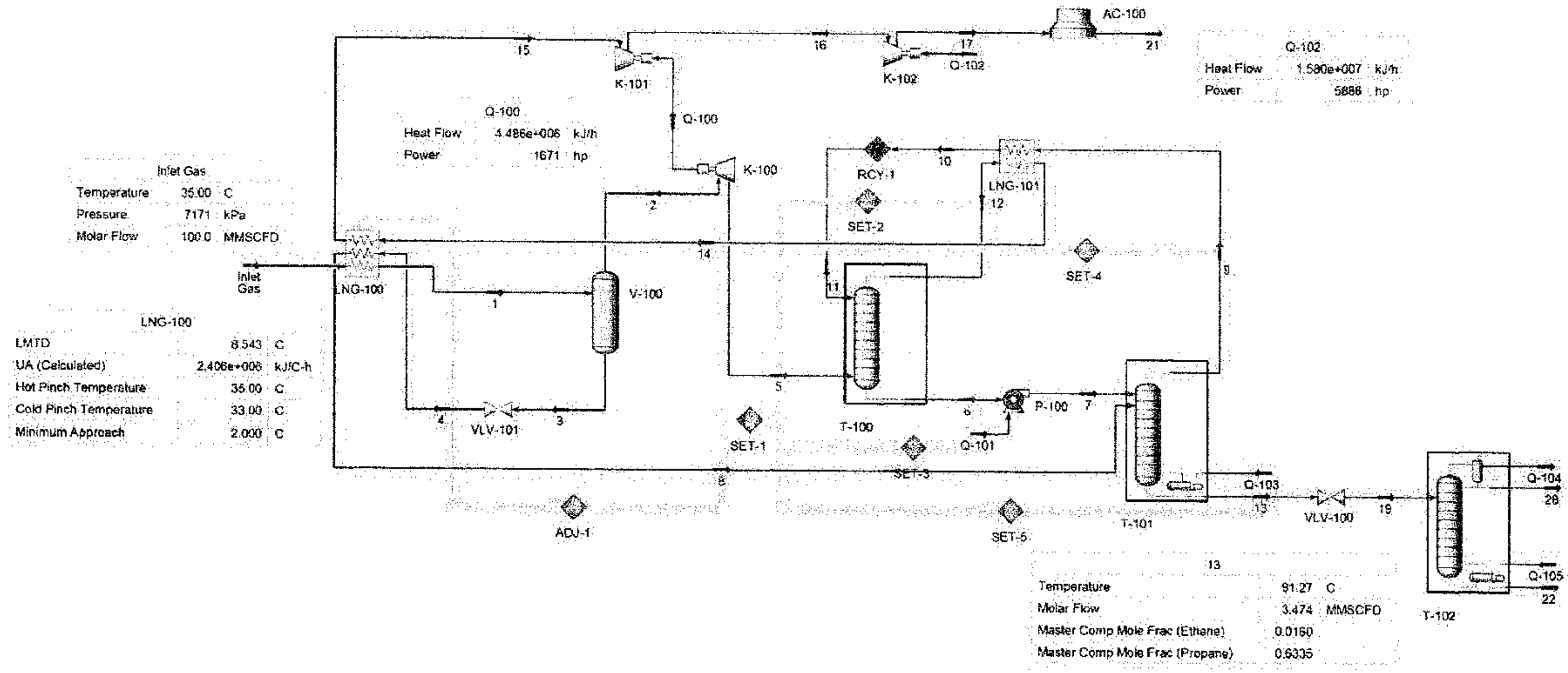
Recycle Split-Vapour (RSV) Process



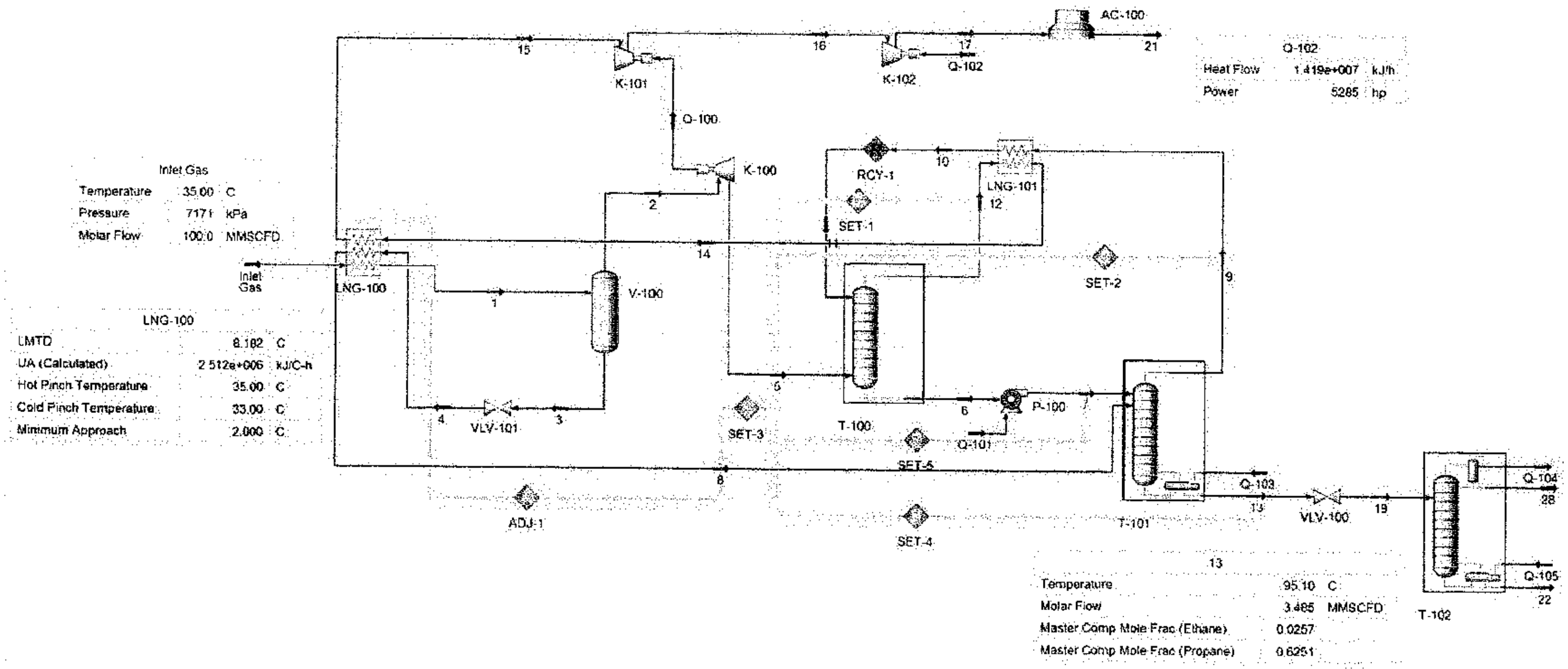
Recycle Split-Vapour Enrichment (RSVE) Process



Overhead Recycle (OHR) Process



Improved Overhead Recycle (IOR) Process



Single Column Overhead Recycle (SCORE) Process