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Using Dividing Wall Columns (DWC) in LNG Production

deviding wall column, double dividing wall
column, prefractionator arrangement,
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Master Thesis

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Preface

This study was carried out within the supervision of Even Solbraa and technically supported by Statoil center in Research, development and Innovation (RDI) in Rotvoll-Trondheim office.

My main word of thank goes to my supervisor Even Solbraa. I would like to thank him for giving me many detailed instructions on my thesis.

I would also like to thank Ivar Haloversen who gave me a lot of information about DWC design and shared generously his great experiences.

And finally I would like to thank professor Olav Boland and all the department personnel who provide me the relevant environment for working academically during this master program.

This section would not be complete without thanking all beloved persons in my life who have been always a great motive to proceed.

Abstract

The Dividing Wall Columns (DWC) distillation has attracted growing interest for fractionation of multicomponent mixture due to reduction of energy consumption, auxiliary equipment and space within fractionation process. Recent developments of the process show considerable energy saving, up to 30%-40%, compared to conventional fractionation schemes. The objective of this thesis is to introduce DWC configurations, governing equations and applications in LNG and gas processing as well as explanation of different methods and processes for industrial production of LNG and LPG. In addition, a consistent and fair comparison between conventional fractionation schemes and two types of DWC i.e. Kaibel and multi-partitioned (Sergant DWC) with respect to energy consumption and other parameters have been conducted. The evaluation was done using Aspen HYSYS simulation program version 7.3 for a typical natural gas feed specification. The study indicates beneficial DWC utilization in terms of energy consumption, auxiliary equipment and duties of condensers and reboilers. Simulation results show energy consumption in LPG extraction process using “Kaibel“ DWC about 31% less than conventional fractionation scheme while “multi-partitioned” configuration of DWC is even better and it can save energy up to 37%.

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"Using Dividing Wall Columns (DWC) in LNG production"

Bruk av Dividing Wall Columns (DWC) i LNG-produksjon.

Background and objective

Dividing Wall Columns (DWC) has gained an increased interest in both the academia and the process industry due to their ability to separate a multicomponent mixture into pure fractions in one single column. For example, the separation of a three-component mixture into its pure fractions in conventional fractionation schemes requires a sequential system with two distillation columns. With a DWC this task can be solved in only one shell by introducing a vertical wall in the middle part of the column.

In addition to space and capital cost savings, large potential energy savings, up to 30%-40%, compared to conventional fractionation schemes are also reported in the literature. Moreover, auxiliary equipment such as reboilers, condensers, reflux pumps, column internals, etc., can be saved.

In LNG production, several distillation columns are used to fractionate the NGL from the scrub column. These fractions are used as make-up for the refrigeration system and also to produce stabilized products such as LPG and condensate. Very few publications exist on the use of DWC for this fractionation.

The following tasks are to be considered:

1. Literature review: Industrial use of DWC and applications in gas processing and LNG.
2. Development of a simulation model for DWC in HYSYS with a focus on applications on natural gas processing
3. Process simulations in HYSYS for different fractionation schemes in DWC.
4. Overall comparison of important parameters (energy requirements, auxiliary equipment, condenser duties, etc) in DWC-schemes with conventional fractionation schemes.

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Nomenclature

Abbreviations

APCI	Air Products & Chemicals Inc.
CDWC	Conventional Divided Wall Columns
DMR	Dual Mixed Refrigerant
DWC	Divided Wall Columns
FLNG	Floating Liquefied Natural Gas
HHV	High Heat Value
J-T	Joule Thomson
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MCHE	Main Cryogenic Heat Exchanger
NG	Natural Gas
PRICO	Single Mixed Refrigerant Process
RVP	Reid Vapor Pressure

Latin letters

b	Flow Rates at Bottom of the Column
d	Flow Rates at Distillate
H	Specific Enthalpy Vapor Phase
h	Specific Enthalpy Liquid Phase
F	Feed Flow
K	Vapor-Liquid Equilibrium Constant
L	Liquid Flow
N	Number of Stages
P	Total System Pressure
q	heat flow into, or removal from, the stage
S	Side Stream
V	Vapor Flow
x	Mole Fraction of Component “i” in the Liquid Streams

Greek letters

α	Average Relative Volatility
ϕ	Vapor Fugacity Coefficient
y	Mole Fraction of Component I In Vapor
f	Standard State Fugacity of the Pure Liquid
γ	Liquid Phase Activity Coefficients

Subscripts

i	component index
n	any stage, numbered from the top of the column
x	mole fraction of component i in the liquid streams
y	mol fraction component i in the vapor streams
z	mole fraction of component i in the feed stream

1 Introduction

Process industries like refineries, petrochemical and chemical plants have a great contribution in energy consumption as fuel. A great proportion of this energy is involved in separation and purification processes among which distillation is the most widely used one. Energy consumption through distillation becomes so important because almost 3% of the total energy consumption of the world is consumed in distillation towers. In addition high energy demands and prices justify working on developing methods and process equipment which are more energy efficient [1].

Divided Wall Columns (DWC), with less energy consumption and capital expenditure are good alternatives for processes using conventional distillation columns. Briefly speaking, the following benefits could be achieved by using DWCs instead of conventional columns wherever applicable [2]:

- Energy saving
- Capital cost saving by reducing quantity of equipment (a train of columns replaced by one , less reboiler and condenser)
- Less plot area and shorter piping and electrical lines which make it relevant for offshore applications
- Less flare load and as a result smaller flare system

1.1 Aim of the study

In this study the following objectives are considered to be addressed:

1. A comprehensive literature review covering industrial use of DWC and its application in gas processing and LNG.
2. Development of a simulation model for DWC in HYSYS with a focus on applications on natural gas processing
3. Process simulations in HYSYS for different fractionation schemes in DWC.
4. Overall comparison of important parameters (energy requirements, auxiliary equipment, condenser duties, etc) in DWC-schemes with conventional fractionation schemes.

To achieve the above objectives, different LNG processes within the industry have been reviewed through sections 2.1.1 to 2.1.3. Then LPG production processes as the main concern of this study have been reviewed through section 2.2 and the energy efficiency concerns in this regard have been discussed. The integrated LPG production as potential application of DWC in a typical LNG plant has been addressed in this section too. In section 2.3 a complete literature review has been presented addressing the track of industrial application of DWC and through section 3, different configurations of the DWC are presented first. Then design parameters for distillation columns in general and for DWCs in specific are discussed to set stage for understanding the design modeling in the next sections.

In section 4, The HYSYS model for three different cases by considering the design parameters addressed in section 3 have been discussed and the obtained results are presented. In this section two different DWC configurations have been simulated. For each case, the design parameters have been optimized with respect to energy consumption and the overall energy usage of them have been compared with the base case which is the conventional fractionation sequence. The overall roadmap and a brief form of this study is presented schematically through Figure 1-1.

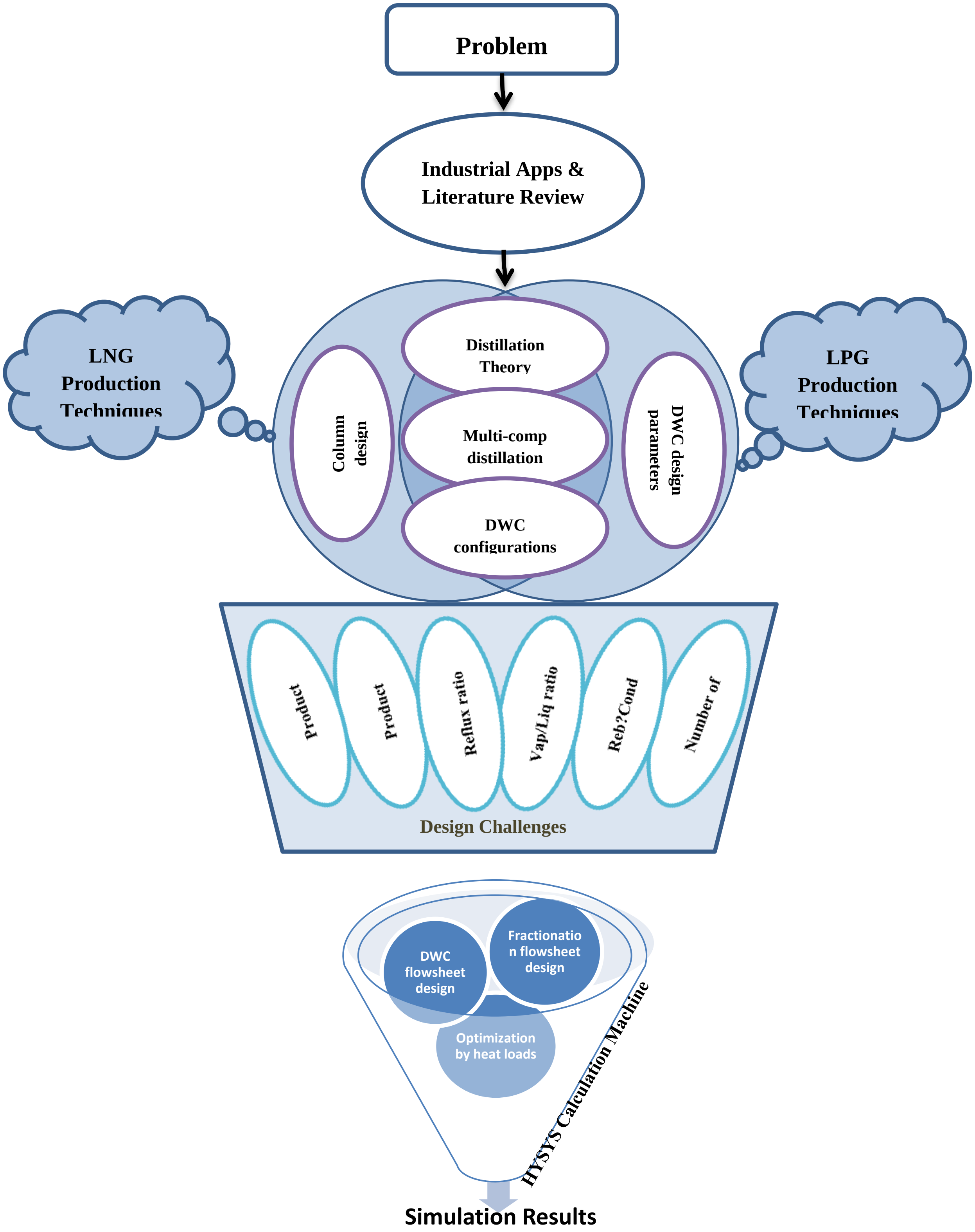


Figure 1-1: The overall methodology and roadmap in this study

2 Industrial Background

In this section different methods and processes for industrial production of LNG and LPG are discussed and the cases for development of DWC as a new method for application in these industries are addressed.

2.1 LNG Production

The reduced volume of Liquefied Natural Gas makes it a great alterative for transporting natural gas resources to the market. There are typically two types of main LNG liquefaction plants:

1. Base load plants: that are large scale liquefaction facilities
2. Peak-shaving plants: smaller scale facilities which are operating at some parts of the year to compensate for the peak loads.

The design objective of base load facilities is the thermodynamic efficiency of the plant while the minimum capital expenditures are the main design driver for peak-shaving plants.

To liquefy natural gas and converting it to LNG; cryogenic temperatures are required. To achieve these temperatures three main liquefaction processes are common in the industry [3, 4]:

- Cascade Refrigeration Process
- Mixed refrigerant Process
- Precooled Mixed Refrigerant Process.

These three main processes are briefly described in the next subsections.

2.1.1 Cascade refrigeration Process

This process which is currently in place by several plants worldwide is basically involves three refrigeration systems through each of them there exist two or three levels of evaporation pressure using multistage compressors. As a result the natural gas liquefies through eight or nine temperature levels by using three different refrigerants which are propane, ethylene and methane. Figure 2-1 shows a simple schematic of the cascade process. First, the feed goes through pretreatment processes then feed gas is cooled to a temperature of around –32°C through a propane refrigeration cycle. In this cycle, the propane refrigerant is condensed at high pressure, using either air or water cooling. The J-T expansion valve then completely vaporizes the refrigerant to cool down gas as well as the methane refrigerant. In addition this cycle is responsible to condense partially the ethylene refrigerant used in the subsequent refrigeration level. The propane vapor then recompressed back to complete the cycle.

In the ethylene cycle, similar mechanism takes place to cool down the temperature of the gas to -96°C. It should be noted that this cycle is responsible to condense methane refrigerant after precooling within the propane cycle. Finally, the high-pressure methane refrigerant in the third cycle followed by the throttling expansion through a J-T valve liquefies the gas to a temperature down to –163°C.

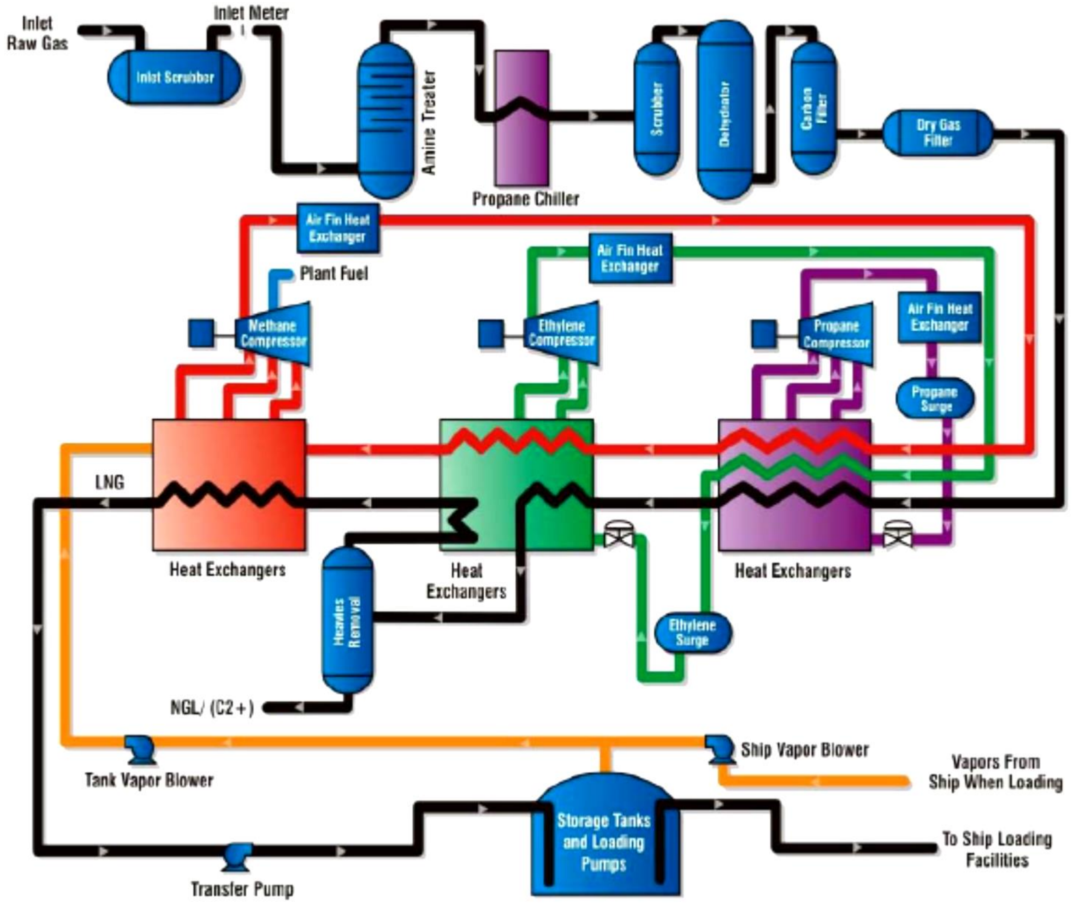


Figure 2-1: Cascade Refrigeration Process

Cascade process has the following advantages:

- It is simple from operational point of view.
- Better control over pure-component refrigerants.

However, this process has also some disadvantages compared to precooled mixed-refrigerant processes [3-5]:

- Lower thermodynamic efficiencies
- Higher compression power and more fuel gas consumption rates
- Complicate compressor and driver selection and maintenance requirements due to unequal distribution of horsepower loads among the three refrigeration cycles

2.1.2 Mixed Refrigerant Process

Instead of using three different refrigerant cycles, this process simply uses a single mixed refrigerant mainly composed of nitrogen, methane, ethane, propane, butane and pentane. In this process natural gas is cooled through a gliding temperature. The whole process design aims to match the boiling curve of the refrigerant with the cooling curve of the natural gas.

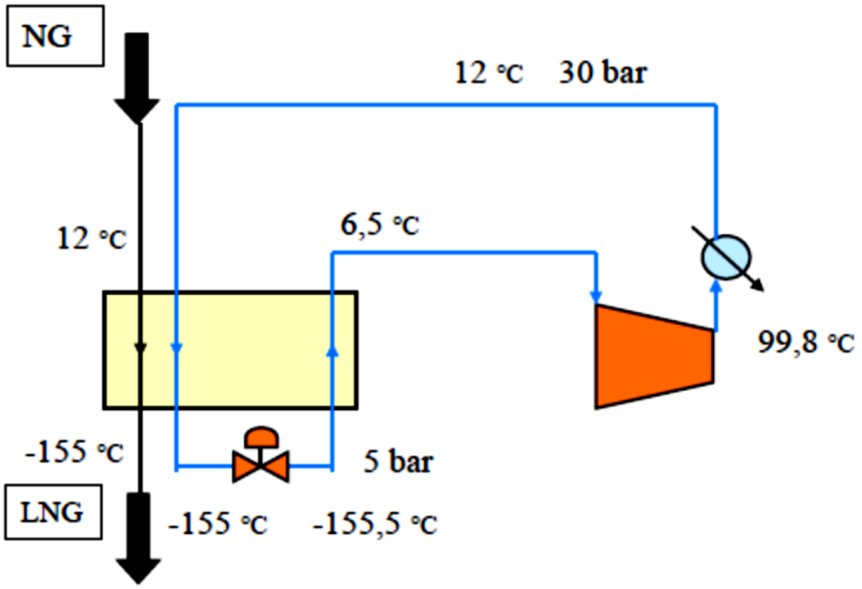


Figure 2-2: Single Mixed Refrigerant Process (PRICO)

Figure 2-2 shows a typical schematic of Prico process as one of the most common simple mixed refrigerant plants. It could be seen that very close temperature approaches are achievable within the cold box of this process. Figure 2-3 shows the T-Q diagram for the above typical Prico process.

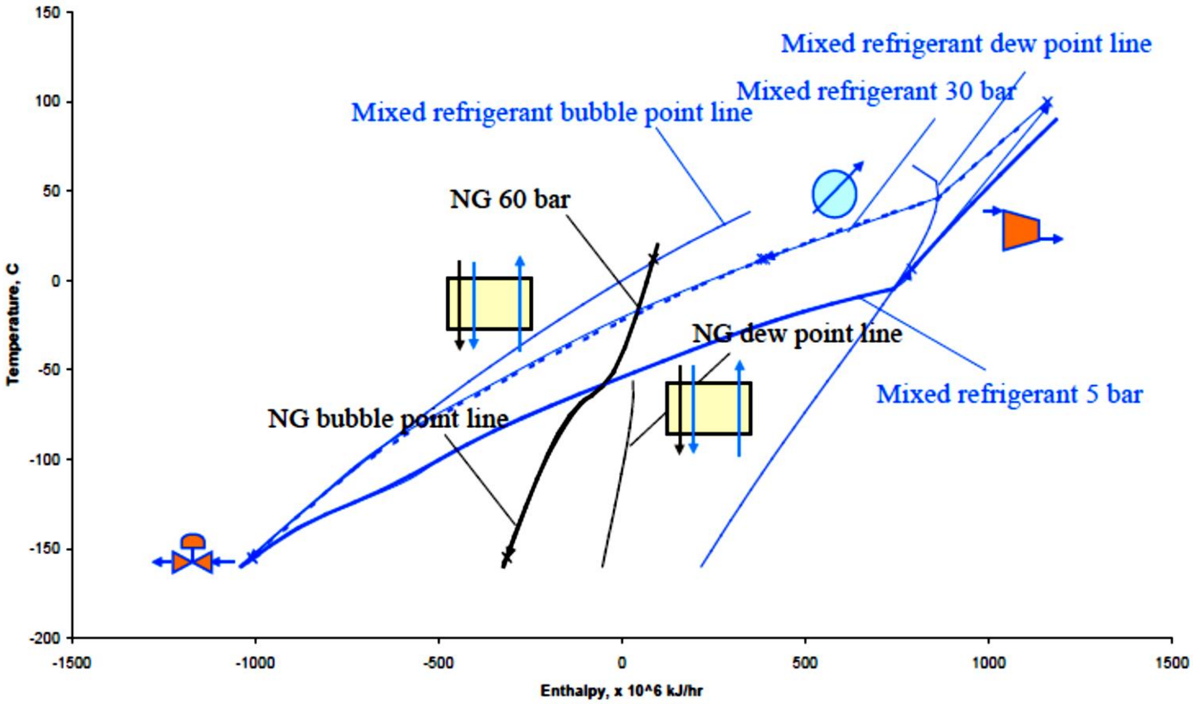


Figure 2-3: Temperature-Enthalpy diagram of Prico process

2.1.3 Precooled Mixed Refrigerant Process

Propane precooled mixed refrigerant process (C3MR) is the most widely used LNG production process which is licensed by Air Products & Chemicals Inc (APCI). C3MR is actually a combination of the cascade and mixed refrigerant processes through which the natural gas feed is precooled by a multi stage pure propane cycle first down to -30°C. This precooling leads to condensing heavier hydrocarbons including LPG components which are separated by scrub column and sent to the fractionation trains. After precooling, the gas liquefies within the Main Cryogenic Heat Exchanger (MCHE) which is a special large spiral wound heat exchanger. The MCHE uses a mixed refrigerant system.

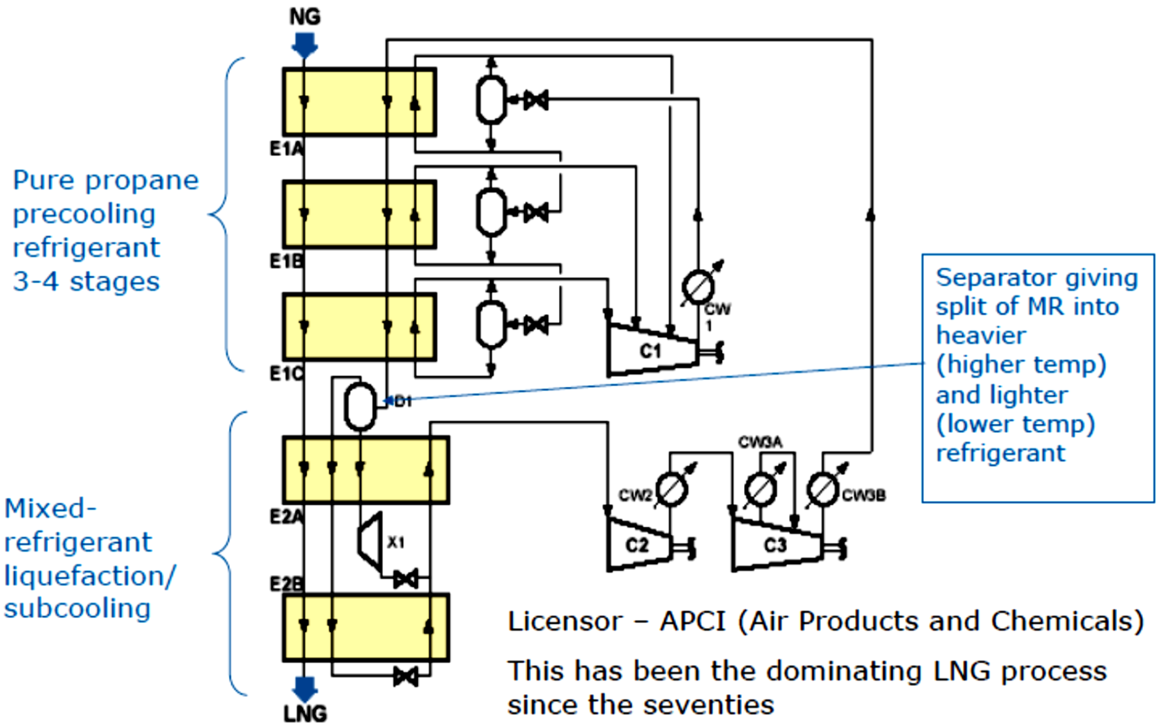


Figure 2-4: C3MR Process

In C3MR process, the C3 cycle load should be high enough to support cooling of both feed gas as well as MR. As a result, this process is limited for production rates up to 5 MTPA. To increase the production capacity, a Nitrogen Brayton cycle could be added to the end of C3MR to form the three cycle process of AP-XTM with a capacity of almost 8 MTPA. Figure 2-5 illustrates a schematic block diagram for this process [6].

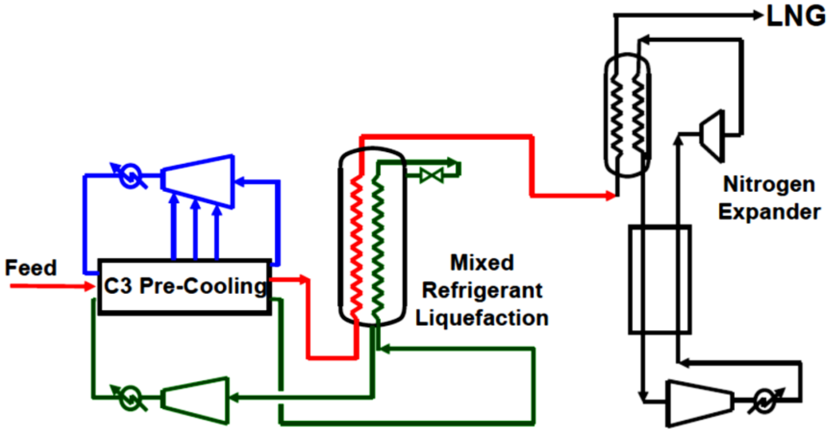


Figure 2-5: The AP-XTM Process

Shell has introduced another process which is called Dual Mixed Refrigerant (DMR). This process has two refrigeration cycles which have their own refrigerants. The first cycle is for precooling through two parallel heat exchangers and the second cycle is for the liquefaction process. The block diagram of this process is shown through Figure 2-6.

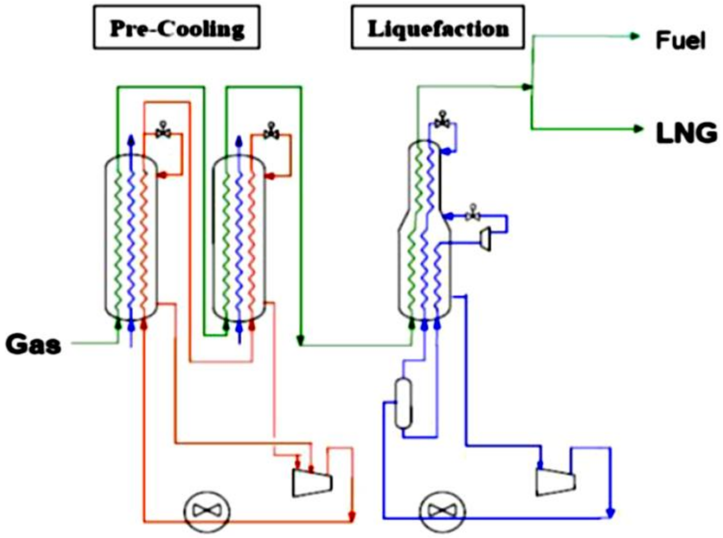


Figure 2-6: Shell DMR Process

This process mainly differs from C3MR in its precooling section through which better power control over compression loads and higher efficiency compression operation would be possible. In addition, the temperature of the precooling portion of the process could be lowered because the critical point constraint imposed by pure propane in C3MR doesn't exist [4, 7].

Although there are several other processes this report is limited to the above processes to get the concept of whole LNG liquefaction process and having a better sense of common equipment used in these processes. Within the next section the need for offshore LNG production and the process alternatives for it are discussed.

2.1.4 Future Developments

Almost one-third of the gas reserves in the world are located offshore which requires to be brought onshore for further processing into LNG product. Traditional onshore LNG plants usually require a platform based process facility to dehydrate condition and compress feed gas according to long distance pipeline specifications. Then a large scale onshore LNG plant with a special harbor for accommodating special LNG vessels was needed. As it could be perceived the whole scheme requires huge amount of capital expenditures. To become agile in responding to the market demand, the concept of Floating LNG (FLNG) emerges recently. The following advantages of this concept make it worth to analyze more:

- Less capital costs by eliminating the need for platform, pipeline and harbor
- Less environmental impact
- Mobility to new locations in the case of depleted reservoir

To select the relevant liquefaction process for FLNGs several factors should be taken into consideration. Main constraints for these facilities include deck space limitations and the challenge of marine movements. So, FLNGs require simpler processes comparing to onshore land-based LNG plants. Considering all of these factors two main criteria are key players in selecting relevant process for FLNGs:

- Compactness and;
- Efficiency

Considering compactness requirement, simple MR processes like Prico is relevant while considering efficiency leading to DMR process. In their paper Lee and Long proposed cycles basically with combination of MR and DMR process. In their proposals a single MR separates into heavy liquid and light vapor (HK,LK) by a separator. Then these two refrigerants have their own refrigeration role separately within the heat exchanger. They proposed process is depicted through Figure 2-7 [4, 6, 7].

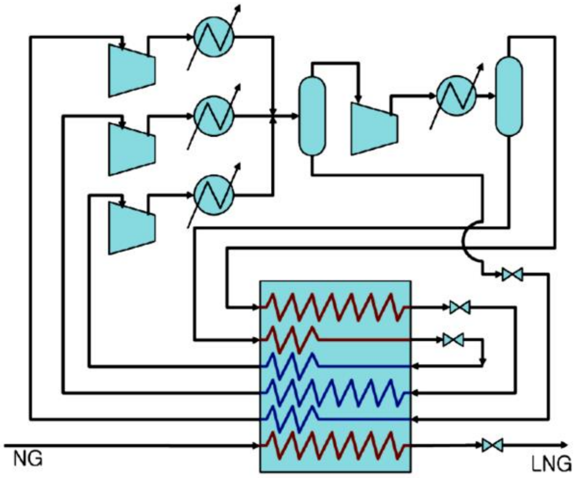


Figure 2-7: The proposed process for FLNG

2.2 LPG extraction and its business case for an LNG plant

There are several reasons that justify the LPG extraction in a typical LNG plant. The followings are the most important reasons for design and implementing such a plant [8]:

- To adjust the heating value of the LNG product specifications
- To remove heavier components which might freeze during the liquefaction process
- To produce valuable LPG products for sale as a separate product
- To supply the main liquefaction process with refrigerant make-ups

The produced LNG needs to be complied with the heating value specifications. This means that for lower HHV specifications deep LPG component (ethane, propane and butane) extraction is required while for higher HHV specifications, lighter LPG component extraction is required. The other alternative to reduce HHV is adding nitrogen to the produced LNG. The investigations done by McCartney have shown that LPG extraction in the LNG production line will increase the total compression power requirements. However because of the LPG products the production rate would be increased, the LPG extraction technology plays a vital role to make it economically viable at least from energy consumption point of view. [9]

There are different process alternatives to extract LPG components among which two major schemes are common in LNG plants. The first scheme is based on a turbo-expander process which is implemented upstream of the main LNG liquefaction process [8]. The second extraction scheme is integrated with natural gas liquefaction by using a so called scrub column. Figure 2-8 shows a block diagram for these two different LPG extraction schemes in a typical LNG plant. A brief description of these two process alternatives are discussed in the next sections and the advantages of integrated approach are also mentioned.

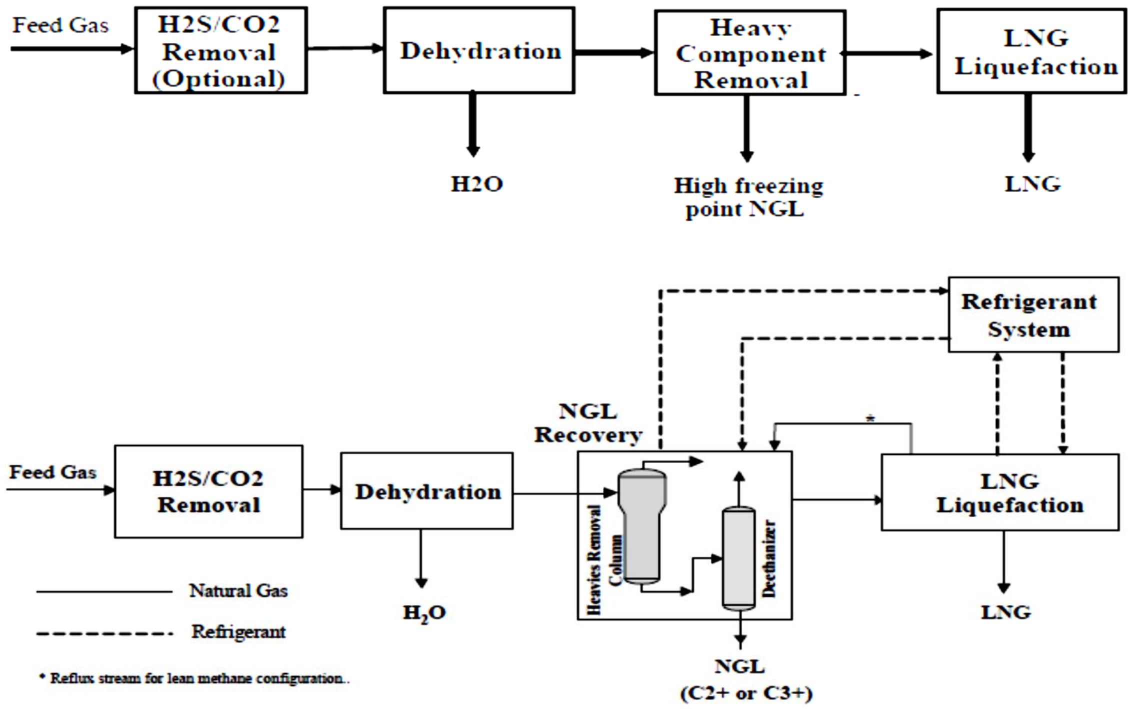


Figure 2-8: LPG recovery schemes in a typical LNG plant

2.2.1 Turbo-expander LPG recovery

To achieve higher recoveries of ethane and propane components, lower cryogenic separation temperatures are required than that achievable by using propane refrigeration cycles. In order to get to these low temperatures, a combined process of expansion and cooling could be used. The following three methods can be deployed to achieve this goal:

- J-T expansion
- Turbo-expander
- Mechanical refrigeration

Among these options turbo-expander process has the most usage among the gas processing facilities. The extent of ethane recovery is related to the following factors which should be taken into consideration:

- The amount of existing inert gases in the feed
- The HHV specification for the residual gas

As it could be guessed, in the case of some existing inert gases in the feed, less deep extraction of ethane is required to compensate for increasing the HHV of the sales gas. Turbo-expander process offers higher efficiencies by using isentropic expansion across turbine compared to J-T process.

Generally, the feed gas goes through the turbo-expander and uses the gas pressure for refrigeration. Turbo-expansion of gas will lead to recovery of some useful work which could be used to run the compression system for recompressing the residual gas. The isentropic nature of expansion across a typical turbo-expander leads to less refrigeration temperatures compared to a J-T valve expansion. A flow diagram for a turbo-expander plant is shown through Figure 2-9. It could be seen that the feed and dried gas is chilled by the residual gas. Sometimes mechanical refrigeration is provided to complement the gas cooling process. Then the chilled gas is fed to the cold separator where hydrocarbon liquids are separated and isenthalpically expanded by a J-T valve and then fed back into the middle of the demethanizer. The vapor phase coming out of the cold separator goes through the expander and isentropically expanded. Then it flows to the top portion of the demethanizer. As mentioned above, isentropic expansion will lead to lower temperatures compared to isenthalpic expansion. Hence, the vapor which expanded by expander goes to the top of the demethanizer.

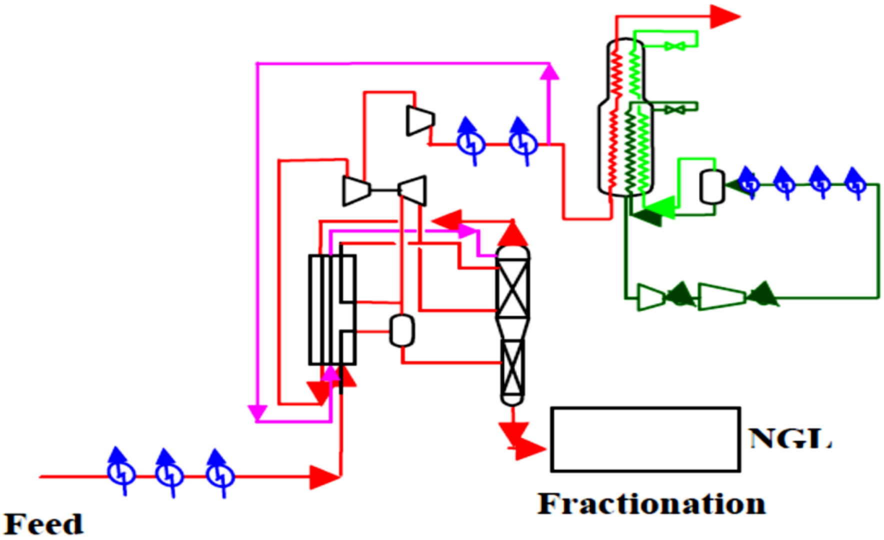


Figure 2-9: Upstream turbo-expander LPG extraction

In addition to being a recovery limit, the need for running this plant at critical conditions imposes instability problems from operational point of view. The ethane recovery for this configuration is limited up to 80%. To increase recovery, low temperatures must be achieved by overcoming to the above limitations. The following modifications have been made to conventional turbo-expander plants to achieve this goal:

- Residue Recycle: through which a portion of the residue gas after recompression to pipeline pressure goes through feed heat exchanger. Then after full condensation recycled back to the demethanizer tower providing more refrigeration. As a result higher Ethane recovery would be achieved.
- Gas Subcooled Process: through which a portion of the gas from the cold separator sent to the overhead exchanger and fully condensed with the overhead stream. Then this stream is flashed and recycled to the top of the demethanizer as the reflux.

In both of these modifications the amount of Ethane recovery enhancement is dependent on the amount of reflux. Figure 2-10 and Figure 2-11 show the expander plant with these two modifications schematically [3, 10].

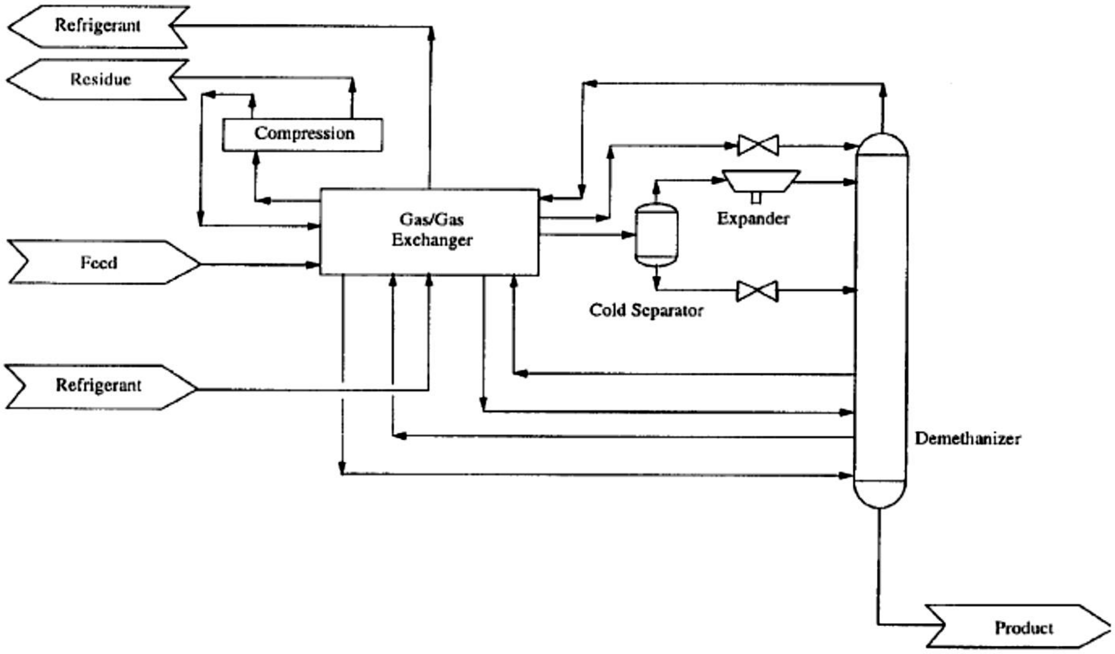


Figure 2-10: Turbo-expander with Residue Recycle

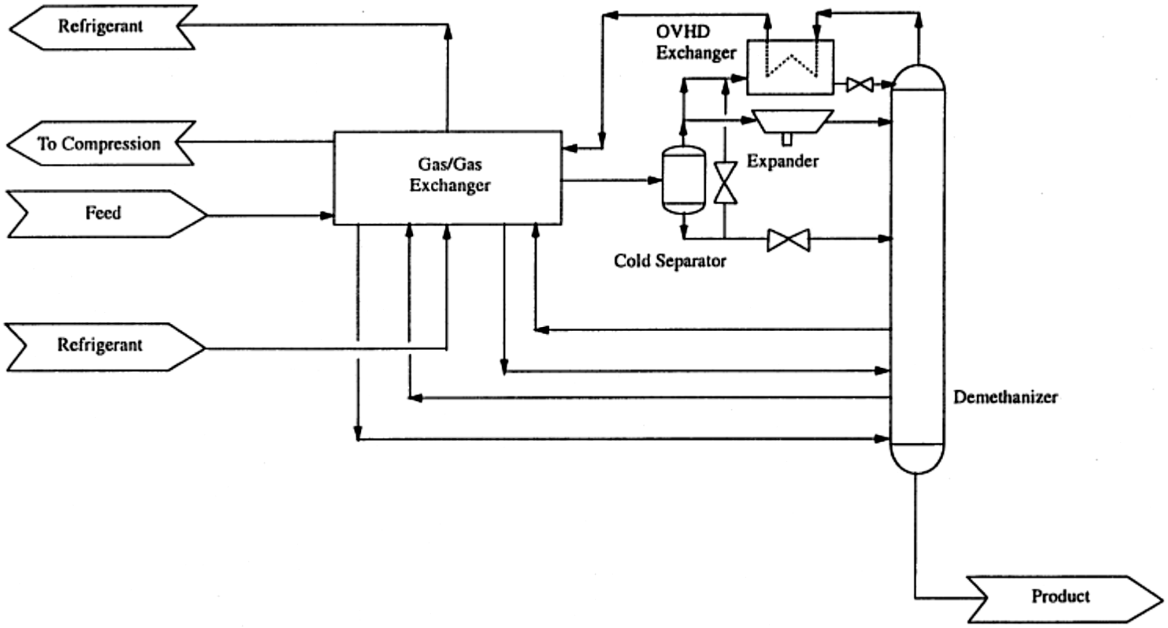


Figure 2-11: Turbo expander with Gas Subcooled Process

2.2.2 Integrated LPG Extraction and LNG Process

Changing world markets toward NGL as well as increasing demand for LNG as an emerging source of energy synergistically increase the motivation towards integrated process approach. Furthermore, almost all natural gas components have higher condensation temperatures compared to methane. So, from technical point of view they could be liquefied within the main LNG liquefaction process. This is a basic overview of integration of NGL recovery with LNG liquefaction process. This recovery method is a form of integrated scrub column process which is operable at feed pressure of the main LNG liquefaction plant. The main characterization of this process is its capability to retain high pressure for efficient LNG liquefaction process. Figure 2-12 shows schematically the integrated LPG extraction processes [11, 12].

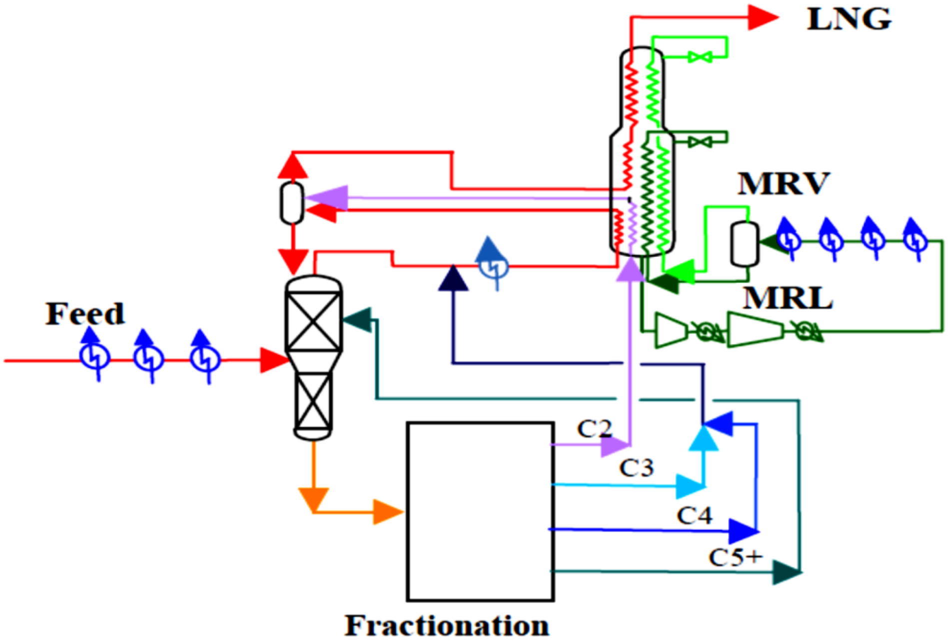


Figure 2-12: Integrated LPG extraction process in an LNG plant

Increasing the LPG extraction by scrub column has some operational difficulties that need to be overcome. First, the scrub column temperature should be reduced to achieve higher LPG extraction. This is achievable by increasing reflux and eliminating reboiler of the scrub column which sends a lot of methane to the downstream fractionation train. So, additional demethanizer is required in the fractionation train as shown through Figure 2-13 [9].

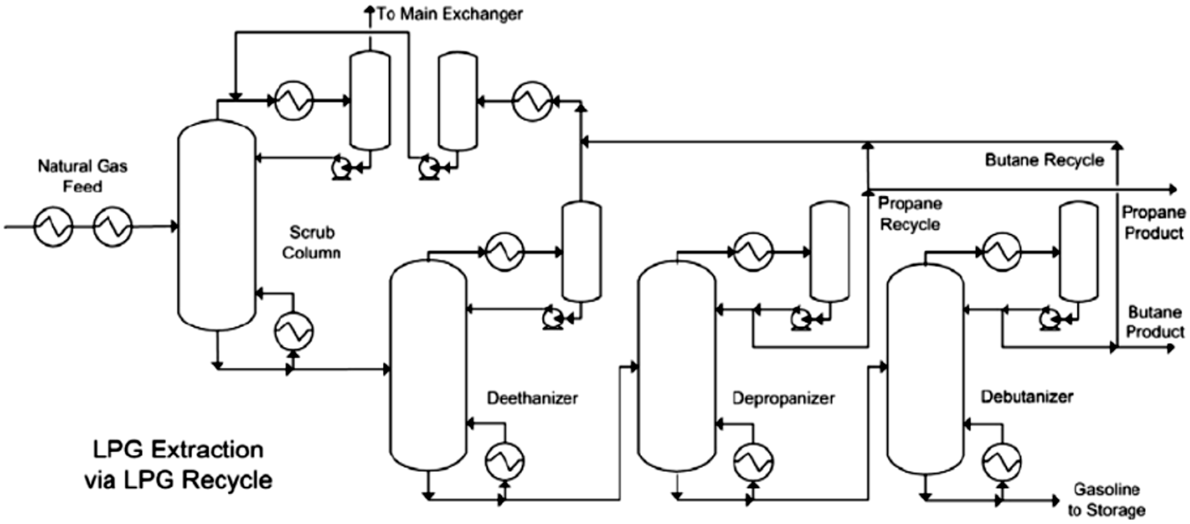


Figure 2-13: LPG Recycle Process

Increasing LPG extraction by lowering column temperature is limited to the critical conditions of the overhead mixtures. Furthermore, increased extraction of propane and butane makes the overhead mixture leaner. As a result, the critical pressure reduced and the scrub column should operate at lower pressure which leads to less efficient liquefaction. To cope with this problem an ethane stream is recycled back to the scrub column resulting in retaining higher critical pressures up to 55 bar. If further extraction is required a recycle of $C5^+$ could also be fed into the column. By deploying these techniques a recovery of 95% of the LPG components can be achieved.

The integrated process approach gets more consideration in the industry. Elliot D. et al has discussed the following advantages for this process[8, 12]:

- Less combined capital and operating costs by avoiding duplication of refrigeration duties and equipment as well as common utility usage
- Higher thermodynamic efficiency leading to reduce specific power consumption
- The opportunity to improving the overall project economy by early production of NGL recovery before commissioning of LNG plant
- Operational flexibility in switching between ethane recovery and ethane rejection modes
- Higher recovery of LPG and aromatic components

2.3 DWC Background and Industrial Applications

The fully thermally coupled systems of distillation columns are among interested process industry issues from several years ago. DWC idea was first presented through a patent by Wright (1949) considering the thermal coupling concept. Then, Petyluk et al. (1965) developed it for separation of ternary mixtures and Petlyuk column introduced. Afterwards, high energy prices as well as the global interest to reduce both capital and operating costs derived many researches to evolve the concept of fully thermally coupled distillation systems from energy saving point of view[13].

The following stories about the industrial application and development of DWCs has been quoted by Premkumar (2008).

- It is announced by Kaibel G. (1988) and European Chemical News (ECN, 1995) that DWC was used first by BASF AG at 1985 and it had successfully installed and operated more than 30 such columns.
- As per M.W. Kellog Limited press release, 11 September 1998, M.W. Kellog Limited in association with BP (later known as BP Amoco), successfully installed a divided wall column at BP's Coryton refinery, UK
- A divided wall column have been developed by Sumitomo Heavy Industries Co. together with Kyowa Yuka, as per Parkinson G. (1998)
- The world's largest divided wall tray column constructed by Linde AG for Sasol at 1999, with 107 m height and 5m in diameter

DWCs could be applied in a wide range of applications. They are suitable for separation of mixtures three or multi component mixtures. Figure 2-14 shows the increasing trend in DWC applications in the chemical industry.

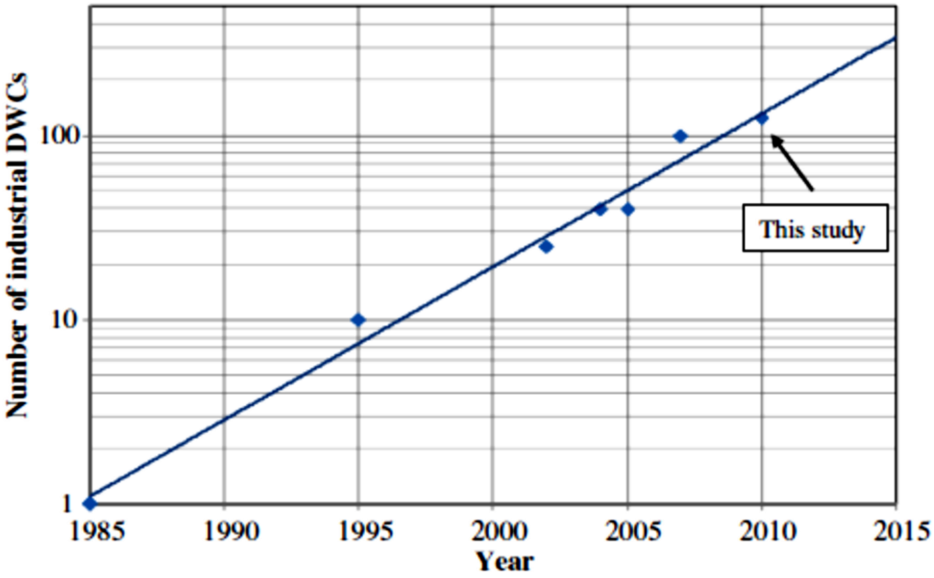
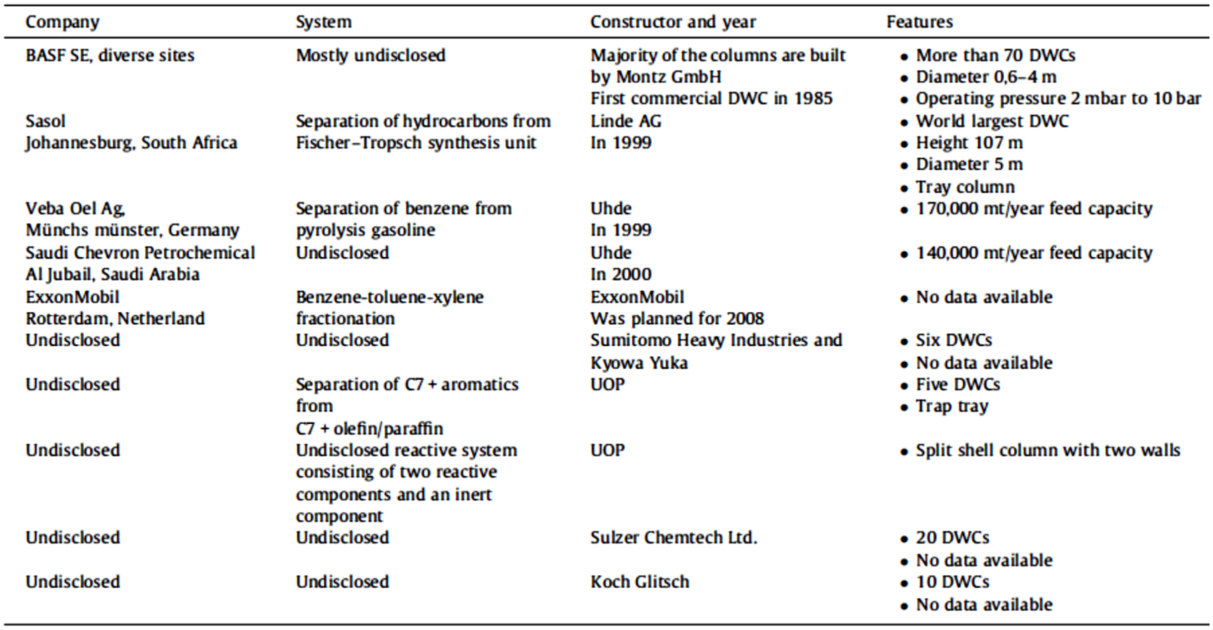


Figure 2-14: Number of reported industrial DWCs over years [14]

Initial application of DWCs were restricted to final distillations through which the medium boiling component was the main component and should be separated from low fractions of light and heavy components. Over the years its applications elaborated in such a fast pace that DWCs were used to produce highest purity grades. These applications are as hydrocarbons, alcohols, aldehydes, ketones, acetals, amines, etc. In addition, DWCs could be used in azeotropic, extractive and reactive distillation.

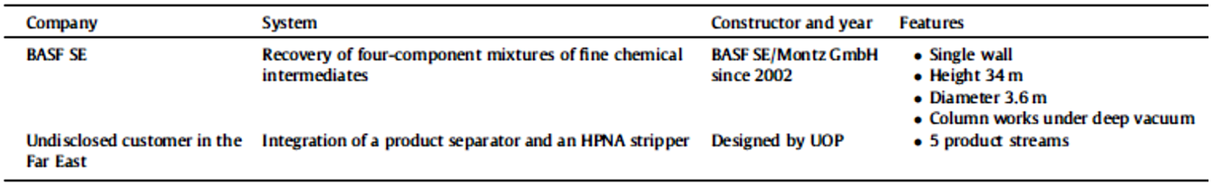
The range of products is wide. It covers hydrocarbons, alcohols, aldehydes, ketones, acetals, amines and others. Obviously there are no restrictions with respect to the type of chemicals. The industrial applications of DWC were reviewed by Yildirim et al. Most of the applications (116 out of 125) are for ternary separations. Based on this article, there are few applications of DWCs for more than three component mixtures which were conducted by BASF SE and UOP. Table 2-1 and Table 2-2 list a number of industrial applications of DWCs for ternary and multi component systems respectively.

Table 2-1: Industrial application of DWCs for ternary systems



Company	System	Constructor and year	Features
BASF SE, diverse sites	Mostly undisclosed	Majority of the columns are built by Montz GmbH First commercial DWC in 1985	• More than 70 DWCs • Diameter 0,6–4 m • Operating pressure 2 mbar to 10 bar
Sasol Johannesburg, South Africa	Separation of hydrocarbons from Fischer–Tropsch synthesis unit	Linde AG In 1999	• World largest DWC • Height 107 m • Diameter 5 m • Tray column
Veba Oel Ag, Münchs münster, Germany	Separation of benzene from pyrolysis gasoline	Uhde In 1999	• 170,000 mt/year feed capacity
Saudi Chevron Petrochemical Al Jubail, Saudi Arabia	Undisclosed	Uhde In 2000	• 140,000 mt/year feed capacity
ExxonMobil Rotterdam, Netherland	Benzene-toluene-xylene fractionation	ExxonMobil Was planned for 2008	• No data available
Undisclosed	Undisclosed	Sumitomo Heavy Industries and Kyowa Yuka	• Six DWCs • No data available
Undisclosed	Separation of C7 + aromatics from C7 + olefin/paraffin	UOP	• Five DWCs • Trap tray
Undisclosed	Undisclosed reactive system consisting of two reactive components and an inert component	UOP	• Split shell column with two walls
Undisclosed	Undisclosed	Sulzer Chemtech Ltd.	• 20 DWCs • No data available
Undisclosed	Undisclosed	Koch Glitsch	• 10 DWCs • No data available

Table 2-2: DWC application for more than three component mixtures



Company	System	Constructor and year	Features
BASF SE	Recovery of four-component mixtures of fine chemical intermediates	BASF SE/Montz GmbH since 2002	• Single wall • Height 34 m • Diameter 3.6 m • Column works under deep vacuum
Undisclosed customer in the Far East	Integration of a product separator and an HPNA stripper	Designed by UOP	• 5 product streams

This history track shows an increasing interest in using DWCs in process industries [13-15].

3 Theory and Literature Review

Having good understanding of the basic principles of distillation would be helpful to optimum application of it through industrial functions. In this section multicomponent distillation and divided wall column (DWC) arrangements are introduced first. Then basic distillation theory and the governing equations are addressed and design procedures are described.

3.1 Multi-component distillation

Industrial application of distillation usually involves multi-component mixtures which need to be separated into salable products. So, distillation theory also needs to be analyzed for multi-component systems. The design of a distillation column for a multicomponent process is much more complex than a binary system through which fixing one component will lead to fixed composition of the other. In this kind of distillation top and bottom products could not be specified independent of each other. So, top and bottom products are separated by putting some limits of two key components between which we intend the separation to occur. The component that is intended to be out of the bottom product is called light key and the one that is intended to be out of top product is called heavy key component. [16]

One feature of multicomponent distillation is that it needs more than two distillation columns to achieve the separation. The general rule is that lighter components than the product should be removed first. Then in the second column, the product will be separated from the heavier components. As a rule, if the feed has N components and complete separation of each component needed, then N-1 column would be required to achieve this separation.[16]

As the number of components increases, number of possible column arrangements increase dramatically. It is obvious that the best alternative is the best economically viable option during its lifecycle. However, the designer could use heuristic rules to select optimum arrangement:

3.1.1 Column Arrangements

Different column arrangements have been developed to reduce both energy and cost demands of conventional distillation. In this section both simple and complex arrangements are described in a brief way. Figure 3-1 shows schematically these various configurations

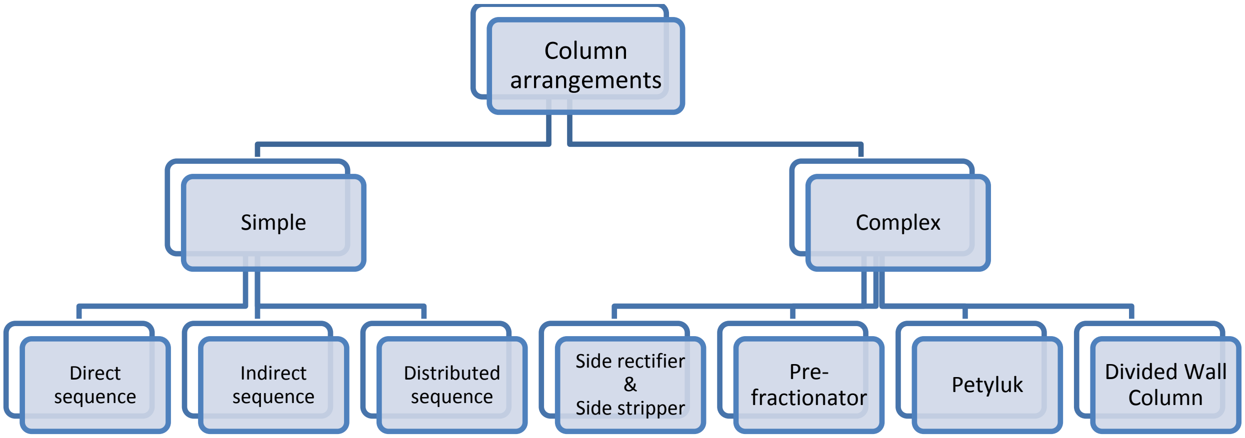


Figure 3-1: Different column arrangements for distillation process

In multicomponent distillation, at least two distillation columns are required to achieve a pure product specification. Common simple conventional configurations with well-known industry records are as follows:

- **Direct Sequence:** In this arrangement the light components are separated first. Through the next columns the heavier components are then separated.
- **Indirect Sequence:** In this arrangement the sequence of separation is against the above one.
- **Distributed Sequence:** Through this arrangement combined splits of light and heavy components go through consecutive columns.

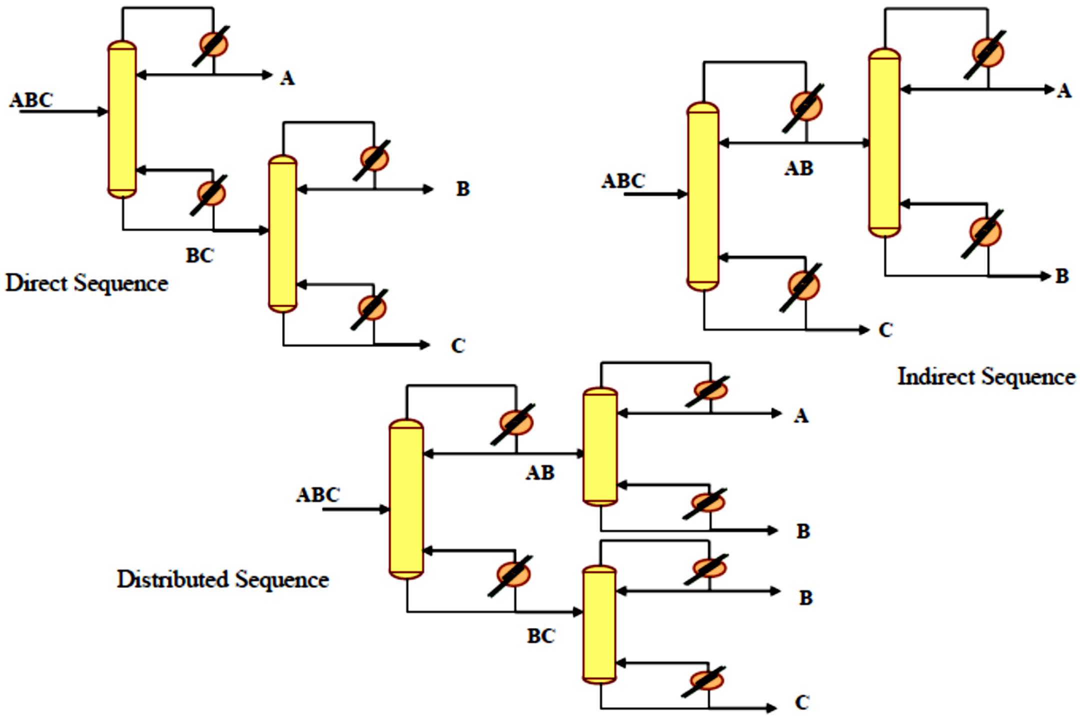


Figure 3-2: Simple column configuration[13]

Different simple column configurations are depicted in Figure 3-2 for a typical 3-component separation process. Simple configurations have some thermal inefficiency. Schultz et al has investigated this inefficiency in his article.

Concentration profile for component B in the first column of direct sequence configuration is shown through Figure 3-3. It could be seen that B reaches into its highest purity in some tray near the bottom. Then because it is not separated within first column it starts to dilution because of increase in concentration of component C. The process of dilution and remixing with C makes this column configuration less efficient from energy point of view[2, 13].

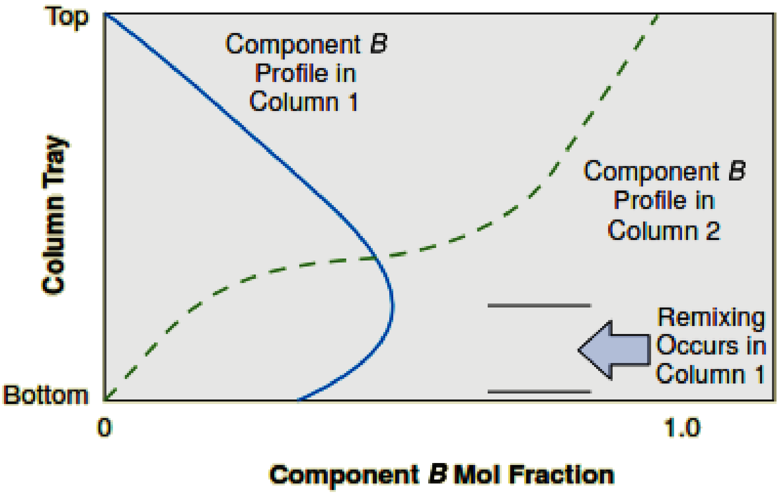


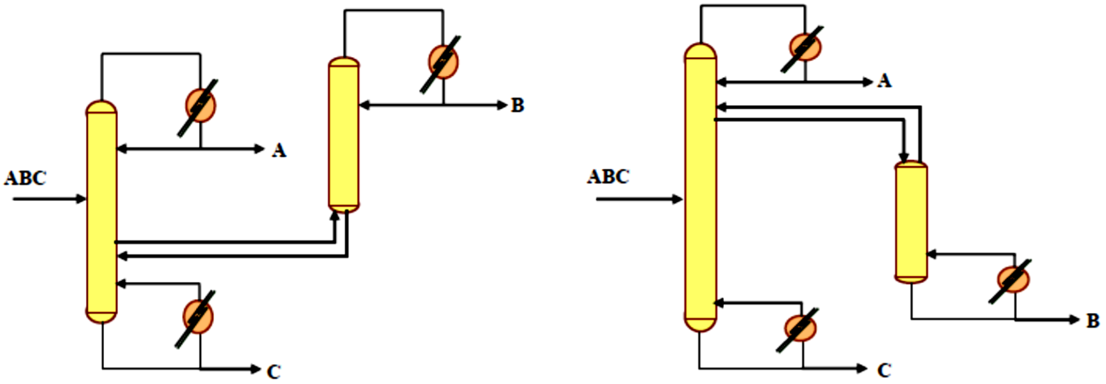
Figure 3-3: Remixing of component B in conventional direct sequence[2]

Other column arrangements are categorized as complex columns. They are normally referred to thermally coupled arrangements through which two-way vapor-liquid flows between different columns of the simple column configurations are set. These configurations eliminates the need for condenser and (or) reboiler in conventional simple arrangements thereby saving energy demands of the whole process. Common complex configurations are as follows:

- **Side Rectifier and Side Stripper:** In these configurations one liquid side stream is withdrawn from above/below feed tray. The purity of the desired product could be increased by either stripping out lighters in side stripper or rectifying heavies in a side rectifier. These columns are also called as Partially Thermally Coupled Distillation Systems.
- **Pre-fractionator arrangement:** This configuration divides the feed in the pre-fractionator into two feeds for the main column. It is like the distributed sequence that is depicted in Figure 3-2. However, using partial condenser in the first column leads to some partial thermal coupling in pre-fractionator.
- **Petlyuk column:** This arrangement is similar to the pre-fractionator. However it does not have reboiler and condenser as the vapor and liquid loads are shared with the second column. As a result, Petyluk column has two columns with one reboiler and one condenser for separating a feed into three products.

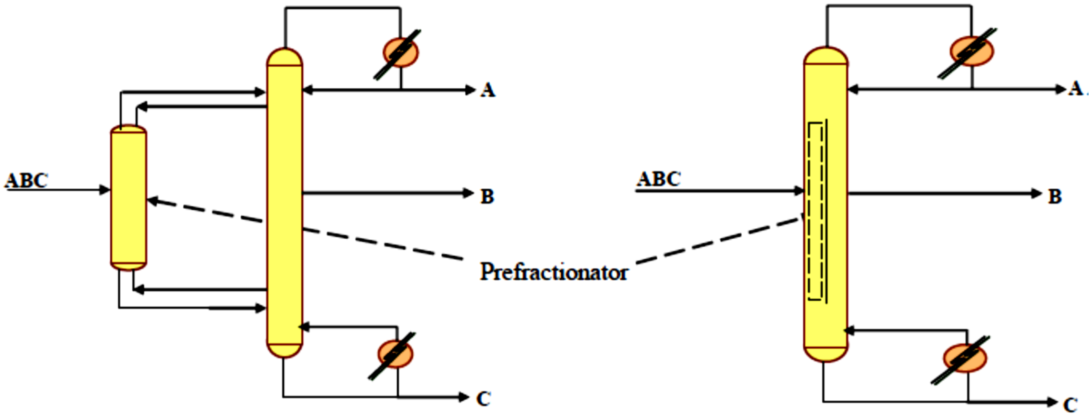
- **Divided Wall Column:** All the concepts in Petyluk column extends into one column which is divided wall column.

Figure 3-4 shows schematically different complex configurations for a typical three component separation process..



Side Rectifier

Side Stripper



Petyluk Column

Divided Wall Column

Figure 3-4: Complex column configuration[13]

3.2 Divided Wall Column (DWC)

In Petlyuk and Divided Wall Column configurations there is a sharp split between A and C in the pre-fractionator column and B are distributed between overhead and bottom of the column. As a result the fraction of B that could be separated in the pre-fractionator could be set by design process by which up to 30% of energy savings could be achieved. The main reason for such energy efficiency is due to remixing avoidance of internal streams which is described in 3.1.1. [2, 13, 14, 17].

3.2.1 DWC Configuration for three component separation

Yildrim et al, has categorized three component DWCs into two different groups. The first type which are called Conventional Divided Wall Columns (CDWC), are originally the first DWC which patented by Wright. In this category, the dividing wall, feed and side streams are almost located in the middle of the column. Figure 3-5 (a) shows a typical basic CDWC. Figure 3-5 (b) and (c) show other CDWCs through which dividing wall is installed in the bottom or overhead section of the shell respectively and are patented by Monro [14].

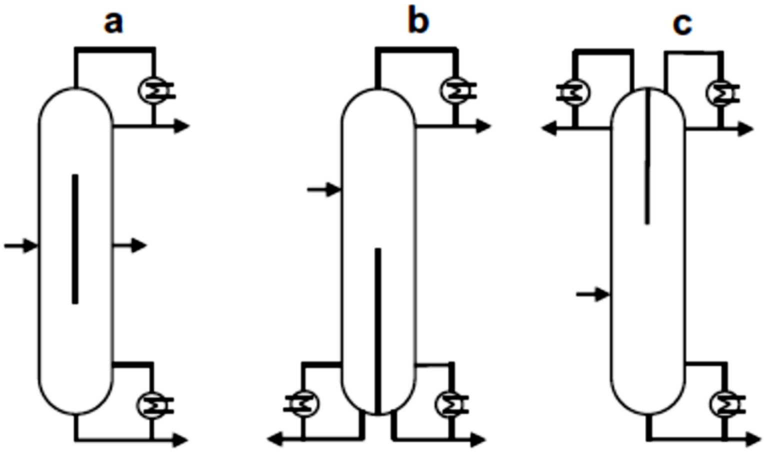


Figure 3-5: Basic types of DWCs

In second category, dividing wall could be moved from the middle of the shell towards the wall. It also could have diagonal shapes as shown through Figure 3-6 (a), (b) and (c).

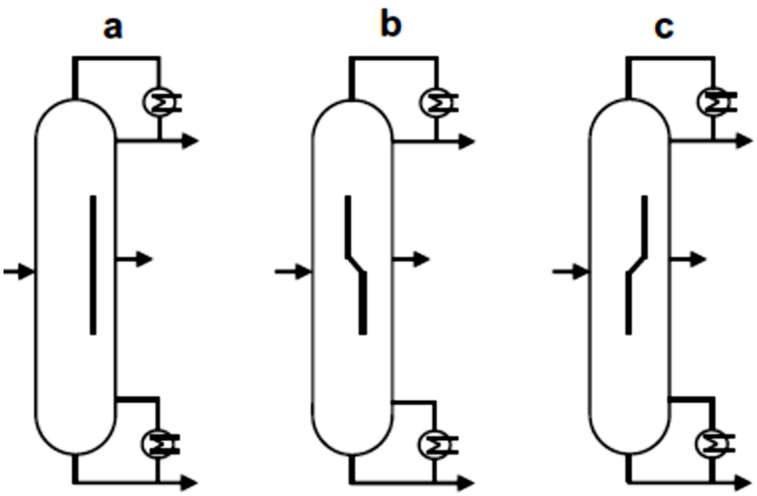


Figure 3-6: Shape and position of the dividing wall

3.2.2 DWC Configuration for four component separation

DWC could also be applied for separating more than three components. Basic DWC that are designed for separating four component mixtures are shown through Figure 3-7. Figure (a) schematically shows Kaibel column through which the separation takes place with a single dividing wall. This configuration is simpler but thermally inefficient. Figure (b) shows Sergent arrangement which is more thermally efficient by column by using three dividing walls. However there is no report addressing its industrial application.

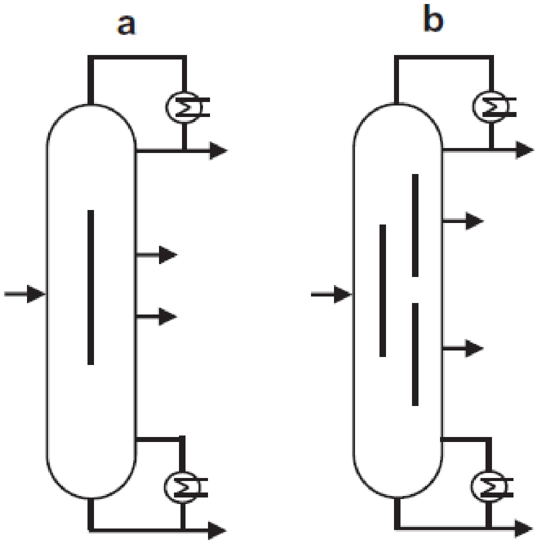
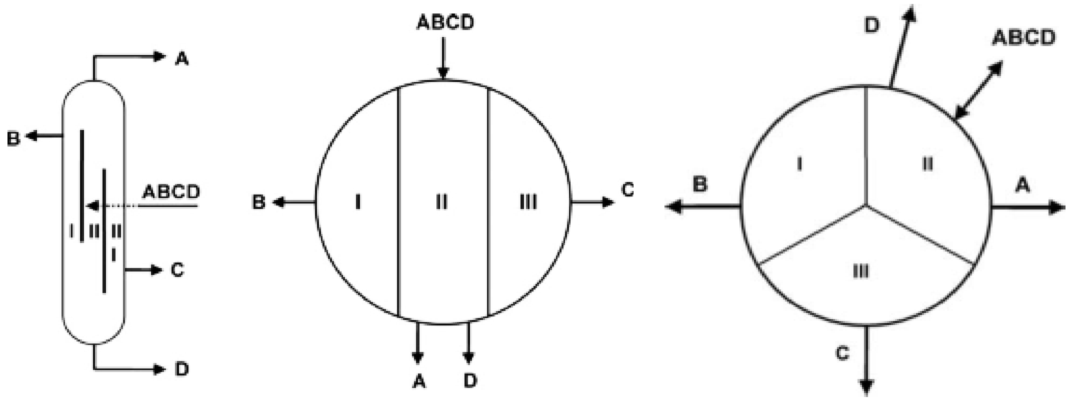


Figure 3-7: DWC for separating four component mixtures

3.2.3 Other configurations

Other configurations especially for four component separation could be possible. Agrawal arrangement and its top view are depicted through Figure 3-8 (a) and (b) while top view of triangular wall structures is depicted through Figure 3-8 (c).



(a) (b) (c)

Figure 3-8: Agrawal arrangement (a,b) and triangular wall structure (c)

3.3 VLE Equilibrium

Through the following sections basic thermodynamic equations and design parameters for both conventional and DWC columns are addressed. This section is the basis for all the calculations that are required for design purposes. However the level of detail and rigorousness of the formulas are restricted to the scope of this study.

For each individual component of the mixture thermodynamic vapor-liquid equilibrium is defined as the following equation through which f represent component fugacity.

$$f_i^V = f_i^L \tag{3-1}$$

Fugacity could be perceived as escaping tendency and could be expressed as a coefficient of pressure as shown through Equations 3-1and 3-2 [18].

$$f_i^V = y_i \phi_i^V P \qquad 3\text{-}2$$

And for liquid phase:

$$f_i^L = x_i \phi_i^L P \; or \; f_i^L = x_i \gamma_i f_i^0 \qquad 3\text{-}3$$

Where P=total system pressure

ϕ_i=vapor fugacity coefficient

yi=mole fraction of component I in vapor

f_i^0=standard state fugacity of the pure liquid

γ_i=liquid phase activity coefficients

Combining Equations 3-2 and 3-3 into equation 3-1 and then rearranging the formula leads to the following equation which is the basis for all vapor-liquid equilibrium calculations.

$$K_i = \frac{y_i}{x_i} = \frac{\gamma_i f_i^0}{\phi_i^L P} \qquad 3\text{-}4$$

The ratio of K-values of two components measures their relative volatility:

$$\alpha_{ij} = \frac{y_i/x_i}{y_j/x_j} = \frac{K_i}{K_j} \qquad 3\text{-}5$$

Large relative volatilities show larger differences in boiling points and better separation.

A distillation column could be perceived as a series of vapor-liquid equilibrium stages. The concept of equilibrium stage is graphically shown through Figure 3-9 [19].

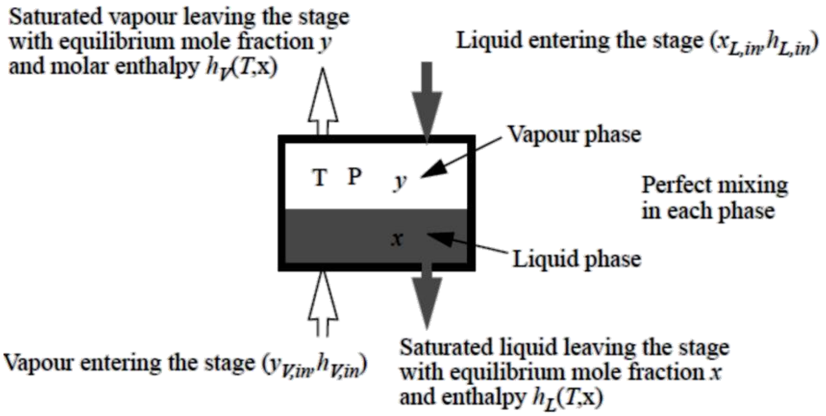


Figure 3-9: Equilibrium stage concept[19]

The following steps show a general step by step approach to design a distillation column:

1. By specifying the product specification determine the extent of required separation
2. Select the operating conditions and operating pressure
3. Determine which contacting mechanism is going to be used
4. Select the number of equilibrium stages and the amount of reflux
5. Do the sizing of the column and determine the real number of stages
6. Design all the required internals for the column
7. Complete the mechanical design and fittings for the column internals

In the process of distillation, material and energy balance could be set over each equilibrium stage.

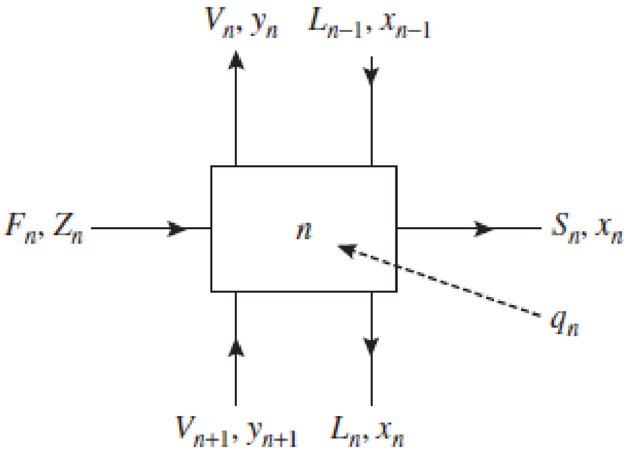


Figure 3-10: Equilibrium stage- Material & Energy balance [16]

$$V_{n+1}y_{n+1} + L_{n-1}x_{n-1} + F_nZ_n = V_ny_n + L_nx_n + S_nx_n \qquad 3\text{-}6$$

$$V_{n+1}H_{n+1} + L_{n-1}h_{n-1} + Fh_f + q_n = V_nH_n + L_nh_n + S_nh_n \qquad 3\text{-}7$$

Where:

V_n= vapor flow from the stage
V_{n+1} = vapor flow into the stage from the stage below
L_n= liquid flow from the stage
L_{n-1} = liquid flow into the stage from the stage above
F_n = any feed flow into the stage
S_n = any side stream from the stage
q_n = heat flow into, or removal from, the stage
n = any stage, numbered from the top of the column
z = mole fraction of component i in the feed stream
x = mole fraction of component i in the liquid streams
y = mol fraction component i in the vapor streams
H = specific enthalpy vapor phase

h = specific enthalpy liquid phase
h_f = specific enthalpy feed (vapor + liquid)

Another equation that is helpful to specify the design of a distillation process is the summation equation:

$$\sum x_{i,n} = \sum y_{i,n} = 1 \qquad 3\text{-}8$$

The four equations 3-43-5, 3-6, 3-7 and 3-8 form the basis for solving the design problem for each stage as well as condenser and reboiler in a distillation column.

Bubble point and dew point calculations are important for estimating the temperature of the condenser and reboiler. So, by definition these temperatures could be obtained by iteration through application of the following equations:

Bubble point: $$\sum y_i = \sum k_i x_i = 1 \qquad 3\text{-}9$$

Dew point: $$\sum x_i = \sum \frac{y_i}{k_i} \qquad 3\text{-}10$$

3.4 Flash Calculations

In a typical flash process, a feed containing vapor and liquid phases would be allowed to be separated. The purpose of this kind of calculation is to evaluate the composition of each individual phase. In a distillation column the following items are main applications of flash calculations:

- To determine the condition of the feed

- To determine the flow of vapor from reboiler or condenser

Figure 3-11 shows graphically a typical flash process. The material and energy balance for this process will lead to equations 3-11 and 3-12 [16].

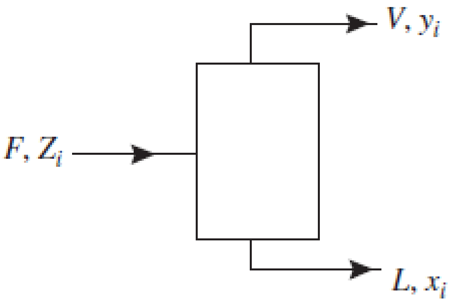


Figure 3-11: Flash distillation

$$Fz_i = Vy_i + Lx_i \tag{3-11}$$

$$Fh_f = VH + Lh \tag{3-12}$$

Using equilibrium constant equations will make the above equations in a more useful form of equations

$$L = \sum_i \frac{Fz_i}{\left[\frac{VK_i}{L} + 1\right]} \tag{3-13}$$

$$L = \sum_i \frac{Fz_i}{\left[\frac{L}{VK_i + 1}\right]} \qquad 3\text{-}14$$

For designing a distillation column some variables need to be specified. The first variable is feed rate which is usually fixed by preliminary design. The other variable which is fixed by early design is column pressure. Generally distillation is happening better at lower pressures because at low pressures relative volatility is higher. However, there should be always a compromise to set column pressure high enough to save energy consumption in reboiler and condenser. Then, number of stages above and below the feed should be specified. At this stage specifying two other independent variables will define the column completely. For example by specifying reflux ratio and boil-up ratio or reflux ratio and distillate rate then there would be a fixed distillate and bottom composition for given column feed. Specifying these pairs could be continued to composition of two key components in distillate or bottom and then getting to a required reflux rate, boil-up rate or flow rate. That would be the same way for recovery or purity of a component in the products[16].

There are several graphical and simple methods for designing distillation columns for binary systems among which Lewis-Sorel and McCabe-Thiele methods could be named. In the following section the design for DWC by using multicomponent distillation design techniques are discussed in more detailed.

3.5 DWC Design Procedures

For designing a DWC, number of degree of freedom is larger than its conventional counterparts. Assuming a three component mixture which is going to be separated by conventional two column sequence, one could notice that every column could be designed independent of the other. It avoids DWC design methods to be straightforward as conventional ones and might be the reason for more conservative acceptance within the industry. The followings are design parameters for a typical three component separation by a Kaibel DWC and are shown schematically through Figure 3-12 [20]:

- Number of stages in 6 different stages
- Liquid split ratio
- Vapor split ratio
- Reflux ratio
- Heat load of the reboiler
- Side-product flow rate

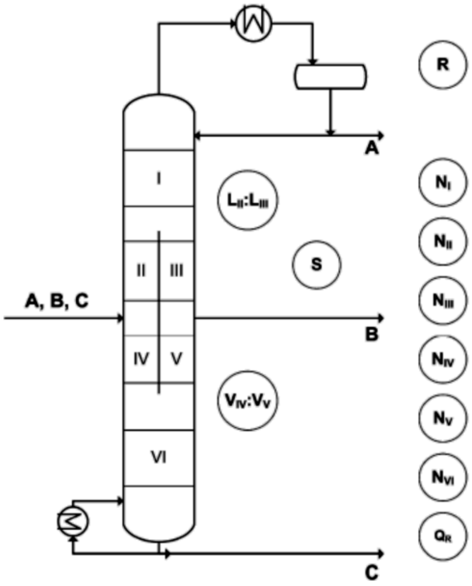


Figure 3-12: Design parameters for a 3-component separation by DWC

The design procedure for DWC is similar to conventional columns at initial steps. It requires defining the column arrangement and determining the operating pressure as well as selecting a thermodynamic VLE model. The next steps for designing DWCs imply more complexity which has been tried to be addressed within the next subsections of this chapter [20].

3.5.1 Heuristic Rules for DWC Design

Like designing conventional columns there are some heuristic rules applicable for designing of DWCs which could be used as initial estimates for simulations:

- Design a conventional column system as a base case (i.e. a three-column system)
- The total number of stages for DWC could be calculated as 80% of the total stages for conventional system.

- The dividing wall could be placed at the middle third of the column (i.e. 33-66% H)
- The internal flow rates within the DWC could be established as 70% of the total duties of condenser or reboiler in conventional sequence.
- Equal vapor and liquid splits could be used as initial estimates.

It is clear that these rules are just to help initial convergence of the DWC model and a lot of adjustment and optimization might be required to achieve optimum design [17].

In the next section, some shortcut methods are described to calculate stage and reflux requirements of multicomponent distillations. These methods are mostly applicable for hydrocarbon applications through oil and gas industry and are based on the constant relative volatility assumption. These methods could also be used for DWC design calculations.

3.5.2 Minimum number of stages (Fenske Equation)

Fenske equation is used to calculate the minimum number of stages needed at total reflux. This equation is as follows:

$$\left[\frac{x_i}{x_r}\right]_d = \alpha_i^{N_{min}} \left[\frac{x_i}{x_r}\right]_b \qquad \text{3-15}$$

Where x_i/x_r is the ratio of each component i concentration to the concentration of a reference one r, and the suffixes d and b refers to the distillate and the bottoms, N_{min} is the minimum number of stages needed at total reflux conditions. α_i is the average relative volatility of the component i compared to the reference component r.

As the separation in multicomponent distillation is specified by key components 3-15 could be rearranged as:

$$N_{min} = \frac{log\left[\frac{x_{LK}}{x_{HK}}\right]_d \left[\frac{x_{HK}}{x_{LK}}\right]_b}{\log \alpha_{LK}} \qquad 3\text{-}16$$

Where α_{LK} is the average relative volatility of light key to the heavy key component and x_{LK} and x_{HK} are light and heavy key component concentrations. The relative volatility is calculated by geometric mean value of volatility at top and bottom temperatures. To have these temperatures an initial estimate of the composition is needed which makes Fenske equation a trial and error way of calculating minimum number of stages. The following formula developed by Winn to estimate the number of stages at total reflux condition [16]:

$$\frac{d_i}{b_i} = \alpha_i^{N_{min}} \left[\frac{d_r}{b_r}\right]_b$$

$$d_i + b_i = f_i \qquad 3\text{-}17$$

Where d and b denoted to flow rates at distillate and bottom of the column.

3.5.3 Minimum Reflux Ratio (Underwood Equation)

The Underwood equation is used to calculate the minimum reflux ratio for multicomponent distillation. This equation is as follows:

$$\sum \frac{\alpha_i x_{i,d}}{\alpha_i - \theta} = R_{min} + 1 \qquad 3\text{-}18$$

Where $x_{i,d}$ is the concentration of component i in the distillate at the reflux ratio and θ is the root of the following equation:

$$\sum \frac{\alpha_i x_{i,f}}{\alpha_i - \theta} = 1 - q \qquad 3\text{-}19$$

Where $x_{i,f}$ is the concentration of component i in the feed and q is the feed condition defined in the McCabe-Thiele method.

$$q = \frac{heat\ to\ vaporize\ 1\ mol\ of\ feed}{molar\ latent\ heat\ of\ feed} \qquad 3\text{-}20$$

Like Fenske equation, geometric average of relative volatilities at temperatures of top and bottom of the column is used. To do that an estimate of the top and bottom compositions is required for which Fenske equation could be used. A better estimate is to replace the number of stages in equation 3-17 by $N_{min}/0.6$ which is a more realistic number of stages [16].

3.5.4 Feed Location

There is an empirical equation developed by Kirkbride to determine the feed location:

$$log\left[\frac{N_r}{N_s}\right] = 0.206\ log\left[\left(\frac{B}{D}\right)\left(\frac{x_{f,HK}}{x_{f,LK}}\right)\left(\frac{x_{b,LK}}{x_{d,HK}}\right)^2\right] \qquad 3\text{-}21$$

where N_r is the number of stages above the feed, N_s is the number of stages below the feed, $x_{f,HK}$ and $x_{f,LK}$ are concentrations of the heavy and light keys in the feed, $x_{d,HK}$ and $x_{b,LK}$ are concentrations of the heavy and light keys in the distillate and bottom products.

3.5.5 V_{min} Diagram Method

This method is a simple graphical method presented by Halvorsen and Skogstad and graphically shows the minimum energy by vapor flow. This method is founded on Underwoods equation and assumes constant molar flow, infinite number of stages, constant relative volatilities. The V_{min} could be calculated by using underwood equation with the following input parameters:

- Feed composition
- Feed quality expressed by liquid fraction

- K-values and,
- Product purities

As stated above this method assumes infinite number of stages and this could be achieved roughly by establishing the number of stages for simulation equal to $4N_{min}$ which N_{min} could be calculated by Fenske equation as presented through Equations 3-153-16. This method could describe the transfer of liquid and vapor through each part of the DWC. The main basis for this method is that the minimum vapor flow that is needed to separate a mixture of n components into its n pure products corresponds to the same flow required to separate the most difficult split. This basis is shown as the highest peak in the diagram associated with the method (V_{min} diagram).

The V_{min} diagram shows the vapor flow rate above the feed (V/F) versus the net flow of the top product (D/F) per unit of feed. Figure 3-13 is a typical V_{min} diagram for a ternary system ABC. It shows how feed components are distributed to the top and bottom products in a simple distillation column without side streams and with infinite stage[17, 19].

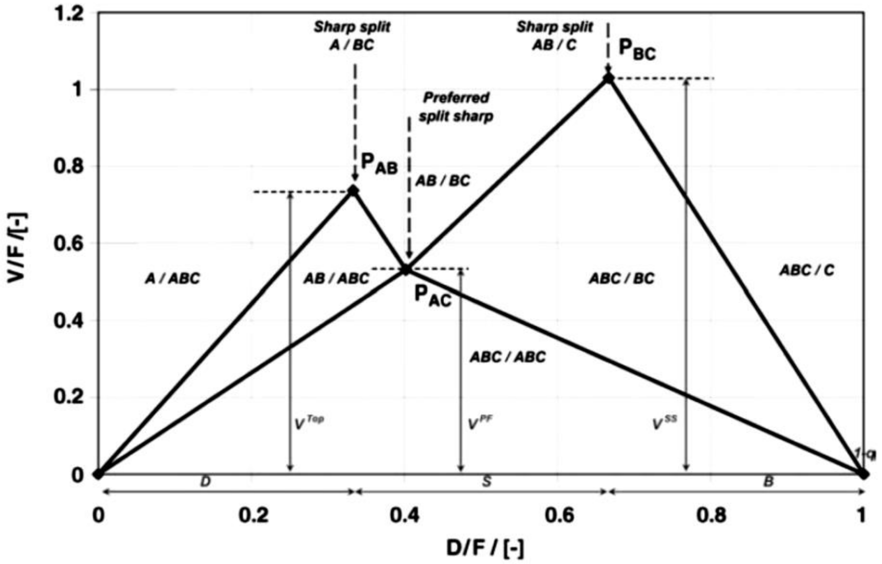


Figure 3-13: V_{min} diagram of a ternary system

4 Methodology and Results

In this section the method for simulating both conventional fractionation and DWC are developed for a typical industrial application for NGL recovery and LPG production.

4.1 Conventional Fractionation model development (Base Case)

As described in section 2.2.2, integrated LPG extraction is one of the modt widely used techniques in LNG plants. The bottom product from the scrub column in the integrated NGL recovery scheme goes into fractionation stages to achieve further separation. This NGL is fractionated by heating and passing through a series of distillation towers (fractionators) which separation takes place mainly with differing boiling points of the various NGL components [21]. As discussed through section 2.2.2 and depicted through Figure 2-13, a demethanizer is required to remove all the methane coming through the scrub column bottom.

4.1.1 Column Performance Parameters

To analyze the performance of a distillation column the following variables are considered [22]:

- Component fractions and recoveries
- Product temperature
- Condenser and reboiler duties

The rates of overhead and bottom products determines the light and heavy key components for each distillation stage in the train [22]

It should be noted that changing the reflux ratio would change the composition of those products that are near the key components. It means that both much heavier and lighter components than key components would be less sensitive to reflux ratio changes. The split location might be changed by changing the distillate rate. This would be happened by changing of light and heavy key components. It is obvious that the condenser and reboiler heat duties will change significantly by varying reflux ratio due to heat load variation. The temperature of the product is also insensitive to changing reflux ratio by keeping the product rate constant. So, the composition of light and heavy key components could be fine-tuned by changing reflux ratio without affecting the product temperature in a great way. Generally speaking, product rates have more effects on the column performance than reflux ratio [22].

The depropanizer has three different products. The top product is mainly propane which could be used both for sale and refrigerant make-up. The second product is LPG which is mainly propane and butane and could be extracted as a side draw stream from the depropanizer column. The third product is condensates which is mainly C_5^+ components and is regarded as natural gasoline. The specifications that are used to simulate depropanizer are presented in Table 4-1 . Depropanizer is called DC3 here in this report.

Table 4-1: DC3 product specifications

Specification	Value
C3 mole fraction @ top product	**0.95**
Max C5+ mole fraction @ LPG product	**0.02**
RVP @ Condensate product (bar)	**0.68**
Operating pressure (bar)	**11**
Number of trays	**40**

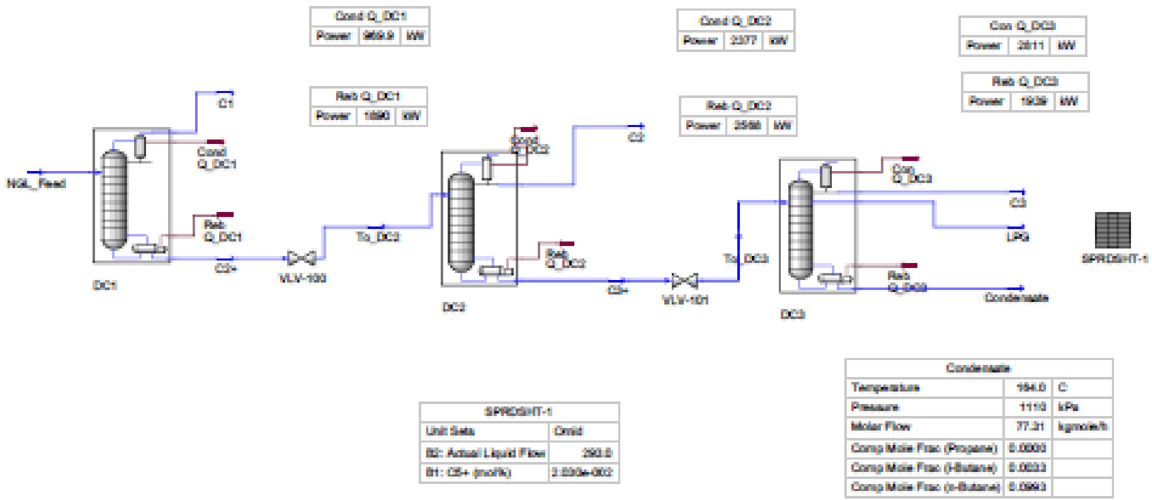
To simulate this column, it is decided to set up the column with its top and bottom specifications first. Then the composition of propane, iso-butane and n-butane were investigated through all the trays to find the best tray for drawing the LPG product with maximum amount of LPG components. The result of this investigation is presented through Table 4-2. Tray number 14 was chosen to draw LPG product from DC3 column.

The addition of side draw product to the column increase degree of freedom to 3 comparing to DC2 and DC1 columns which have 2 degrees of freedom. The following independent variables are selected to converge the column:

- Reflux ratio
- Propane (C3) mole fraction at distillate product
- LPG product rate

Condensate product also requires to be adjusted in its vapor pressure to be storable at atmospheric tanks and usable as a blending component in gasoline. As Reid vapor pressure (RVP) of the condensate increases, more hydrocarbons could be emitted into the environment.

So, its RVP is usually regulated by local environmental standards [23]. The mole fraction specification of C_5^+ in LPG product and bottom product RVP are adjusted simultaneously by changing both reflux ratio and LPG product molar rate. A spreadsheet logical unit operation was used to monitor the C_5^+ mole fraction while changing variables. Figure 4-1 shows the flow datasheet for simulating conventional method of NGL recovery and LPG extraction.



Cond Q_DC1		
Power	969.9	kW

Reb Q_DC1		
Power	1090	kW

Cond Q_DC2		
Power	2377	kW

Reb Q_DC2		
Power	2588	kW

Con Q_DC3		
Power	2811	kW

Reb Q_DC3		
Power	1939	kW

SPRDSHT-1	
Unit Sets	Omid
B2: Actual Liquid Flow	293.0
B1: C5+ (mol%)	3.030e-002

Condensate		
Temperature	164.0	C
Pressure	1110	kPa
Molar Flow	77.31	kgmole/h
Comp Mole Frac (Propane)	0.0000	
Comp Mole Frac (i-Butane)	0.0033	
Comp Mole Frac (n-Butane)	0.0993	

Figure 4-1: Conventional fractionation model using HYSYS for NGL recovery

Table 4-2: LPG component profiles over different trays

	Liquid Phase				Vapor Phase			
	C3	**iC4**	**nC4**	**Sum**	**C3**	**iC4**	**nC4**	**Sum**
T1	0,907062	0,090281	0,000813	**0,998155**	0,950013	0,044129	0,000301	**0,994442**
T2	0,846519	0,150821	0,001716	**0,999056**	0,919441	0,076979	0,000665	**0,997085**
T3	0,773230	0,222869	0,003181	**0,999281**	0,876683	0,119724	0,001304	**0,997712**
T4	0,694595	0,299399	0,005352	**0,999347**	0,825379	0,170143	0,002332	**0,997854**
T5	0,619436	0,371629	0,008311	**0,999376**	0,770783	0,223255	0,003846	**0,997884**
T6	0,554696	0,432615	0,012083	**0,999395**	0,718931	0,273060	0,005900	**0,997891**
T7	0,503466	0,479253	0,016690	**0,999409**	0,674450	0,314931	0,008514	**0,997894**
T8	0,465398	0,511833	0,022188	**0,999419**	0,639333	0,346861	0,011704	**0,997898**
T9	0,438277	0,532462	0,028688	**0,999427**	0,613281	0,369111	0,015509	**0,997900**
T10	0,419396	0,543680	0,036356	**0,999433**	0,594757	0,383138	0,020008	**0,997903**
T11	0,406323	0,547713	0,045401	**0,999437**	0,581910	0,390681	0,025313	**0,997904**
T12	0,397144	0,546237	0,056059	**0,999440**	0,573075	0,393261	0,031568	**0,997905**
T13	0,390463	0,540397	0,068582	**0,999442**	0,566946	0,392025	0,038934	**0,997905**
T14	0,385306	0,530920	0,083218	**0,999444**	0,562568	0,387756	0,047580	**0,997904**
T15	0,381007	0,518244	0,100193	**0,999445**	0,559277	0,380952	0,057673	**0,997903**
T16	0,377123	0,502639	0,119682	**0,999445**	0,556619	0,371918	0,069363	**0,997901**
T17	0,373367	0,484293	0,141781	**0,999442**	0,554293	0,360842	0,082763	**0,997898**
T18	0,369560	0,463397	0,166475	**0,999432**	0,552101	0,347862	0,097929	**0,997892**
T19	0,365604	0,440193	0,193611	**0,999407**	0,549920	0,333121	0,114841	**0,997882**
T20	0,361459	0,415008	0,222877	**0,999345**	0,547681	0,316796	0,133384	**0,997860**
T21	0,357129	0,388268	0,253797	**0,999193**	0,545351	0,299128	0,153334	**0,997813**
T22	0,352637	0,360472	0,285724	**0,998834**	0,542927	0,280421	0,174356	**0,997704**
T23	0,348004	0,332140	0,317837	**0,997981**	0,540429	0,261026	0,195998	**0,997453**
T24	0,343176	0,303699	0,349040	**0,995916**	0,537887	0,241296	0,217681	**0,996865**
T25	0,337834	0,275215	0,377519	**0,990568**	0,535357	0,221495	0,238597	**0,995449**
T26	0,330222	0,245139	0,398148	**0,973509**	0,533095	0,201508	0,257201	**0,991804**
T27	0,306180	0,200148	0,379366	**0,885694**	0,534134	0,179007	0,267256	**0,980396**
T28	0,285368	0,210130	0,390133	**0,885631**	0,506977	0,192281	0,281774	**0,981032**
T29	0,259851	0,222226	0,403238	**0,885316**	0,471737	0,208947	0,299988	**0,980672**
T30	0,230291	0,236145	0,418472	**0,884908**	0,428593	0,229090	0,322127	**0,979810**
T31	0,198008	0,251196	0,435295	**0,884499**	0,378639	0,252184	0,347842	**0,978666**
T32	0,164859	0,266350	0,452930	**0,884140**	0,324156	0,277021	0,376189	**0,977366**
T33	0,132861	0,280419	0,470576	**0,883856**	0,268366	0,301844	0,405805	**0,976015**
T34	0,103731	0,292267	0,487641	**0,883639**	0,214742	0,324671	0,435284	**0,974697**
T35	0,078580	0,300959	0,503913	**0,883451**	0,166194	0,343673	0,463603	**0,973470**
T36	0,057827	0,305768	0,519607	**0,883202**	0,124529	0,357402	0,490408	**0,972340**
T37	0,041333	0,306059	0,535275	**0,882667**	0,090358	0,364779	0,516078	**0,971215**
T38	0,028604	0,301040	0,551514	**0,881157**	0,063350	0,364869	0,541556	**0,969775**
T39	0,018985	0,289211	0,567886	**0,876082**	0,042613	0,356487	0,567871	**0,966970**
T40	0,011766	0,266215	0,577140	**0,855122**	0,027035	0,337444	0,594507	**0,958986**

4.1.2 Simulation Results for Conventional method:

After all three distillation towers are converged to get to the required product specifications; the molar flows shown in Table 4-3 are obtained:

Table 4-3: Product molar flow and specifications in conventional model

Stream Name	C1	C2	C3	LPG
Molar flow	182	135.9	**157.8**	**293**
Mole fraction	0.97	0.95	**0.95**	**0.98**
Component molar flow	176.54	129.1	**149.9**	**287.1**

As the main concern of this study is energy consumption of the condensers and reboilers, the heat duties obtained from this simulation are shown through Table 4-4.

Table 4-4: Energy consumption for the conventional fractionation model (Base case)

Tower Name	T100	DC2	DC3	Total Duty (KW)
Condenser duty (KW)	969.6	2378	**2812**	**6169.6**
Reboiler duty (KW)	1891	2568	**1940**	**6399**

The Hysys produced reports for this simulation case are presented through Appendices 7.1 to 7.4.

4.2 Demethanizer and Kaibel DWC

In this section the whole fractionation process which described in section 4.1, is simulated by a combination of demethanizer and a Kaibel DWC with Aspen Hysys 7.3. Methane is separated from the feed at the first conventional column. Then the rest of the separation will take place in DWC arrangement as seen in Figure 4-2. As DWC is not a predefined unit operation in Hysys, it is tried to simulate it using conventional tower arrangement equivalent to DWC. Finally, our interested parameter which is the total energy consumption are optimized with respect to process variables and compared to the conventional method.

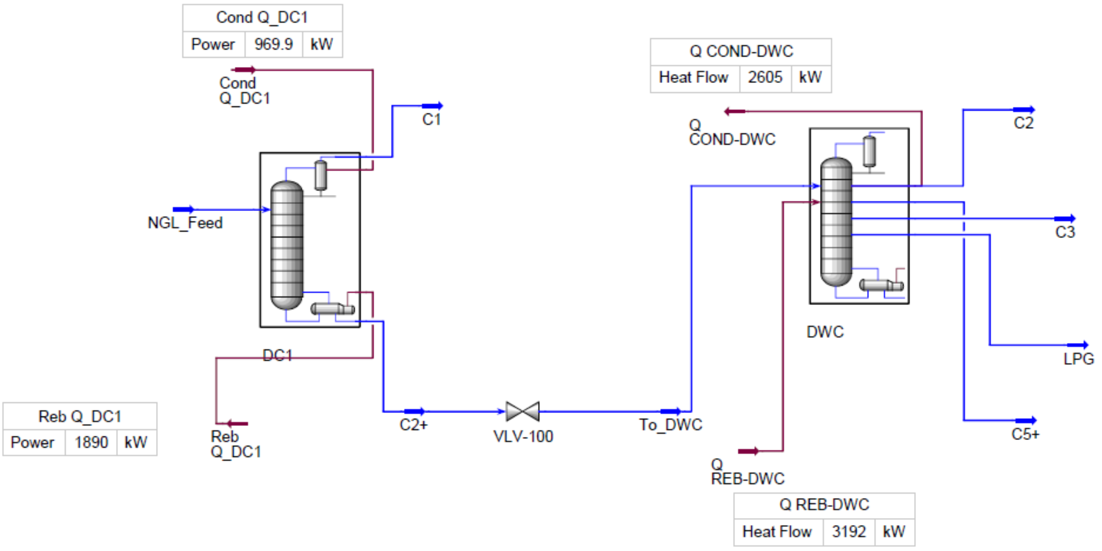


Figure 4-2: The combination of demethanizer and Kaibel DWC

Figure 4-3 shows the flowsheet for the arrangement of towers by which a Kaibel DWC is modeled in Hysys.

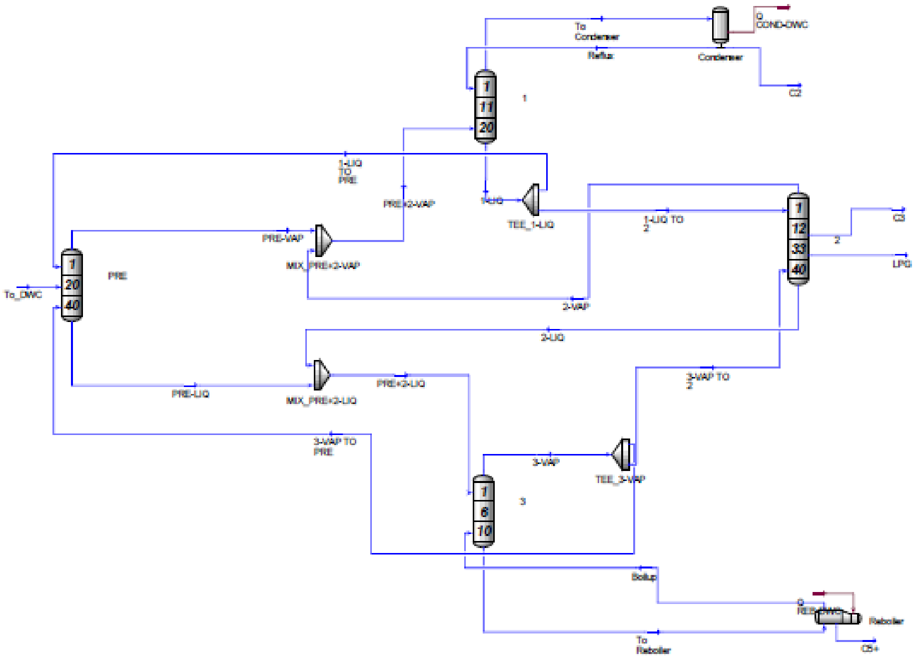


Figure 4-3: Sub flowsheet for Kaibel DWC in Hysys model

Table 4-5 shows the purity and the flow rate of products obtained by this method:

Table 4-5: Product molar flow and specifications in Kaibel model

Stream Name	**C1**	**C2**	**C3**	**LPG**
Molar flow	182	133.7	**170**	**290.4**
Mole fraction	0.97	0.95	**0.85**	**0.96**
Component molar flow	176.5	127	**144.5**	**278.8**

As the main concern of this study is energy consumption of the condensers and reboilers, the heat duties obtained from this simulation are shown through Table 4-6.

Table 4-6: Energy consumption for the Kaibel model

Tower Name	**DC1**	**DWC**	**Total**
Condenser duty (KW)	969.6	3092	**4061.6**
Reboiler duty (KW)	1891	3764	**5655**

The following paragraphs are dealing with optimizing the energy consumption by changing variables like product withdrawal location and flow rate ratio in both sides of DWC.

4.2.1 C3 Withdrawal tray location

The energy consumption for reboiler and condenser of the combined demethanizer and Kaibel column are evaluated with respect to location of propane withdrawal as a product. The results are shown through Table 4-7.

Table 4-7: Tray location for C3 withdrawal in terms of minimum energy consumption

Tray Number	**8**	**9**	**10**	**11**	**12,13**	**14**	**15**	**16**	**17**
DC1 Condenser duty	969.6	969.6	969.6	969.6	**969.6**	969.6	969.6	969.6	969.6
DC1 reboiler duty	1891	1891	1891	1891	1891	1891	1891	1891	1891
DWC condenser duty	3022	3014	3010	3007	**3006**	**3008**	**3011**	**3016**	**3023**
DWC reboiler duty	3690	3682	3677	3675	**3674**	**3676**	**3679**	**3684**	**3691**
Total Duty (KW)	9572.6	9556.6	9547.6	9542.6	**9540.6**	**9544.6**	**9550.6**	**9560.6**	**9547.6**

4.2.2 LPG Withdrawal tray location

After locating the proper tray for withdrawal of propane the same task done for LPG tray location. As it could be seen through Table 4-8, tray number 33 is the optimum location for LPG extraction in terms of minimum energy consumption.

Table 4-8: Tray location for LPG withdrawal in terms of minimum energy consumption

Tray Number	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**
DC1 Condenser duty	969.6	969.6	969.6	969.6	**969.6**	969.6	969.6	969.6	969.6
DC1 reboiler duty	1891	1891	1891	1891	1891	1891	1891	1891	1891
DWC condenser duty	3013	3004	2999	2997	**2997**	**3000**	**3006**	**3017**	**3035**
DWC reboiler duty	3684	3675	3670	3668	**3667**	**3669**	**3674**	**3682**	**3697**
Total Duty (KW)	9557.6	9539.6	9529.6	9525.6	**9524.6**	**9529.6**	**9540.6**	**9559.6**	**9592.6**

4.2.3 Liquid flow rate ratio at both sides of Kaibel DWC

The Kaibel DWC is optimized with respect to the ratio of the liquid flow rates at both sides of DWC. To do this optimization, all other parameters except liquid flow ratios are kept as constant. Then by varying this ratio the energy consumption evaluated. The results are shown through Table 4-9.

Table 4-9: The effect of liquid flow ratio on the energy consumption of the Kaibel model

Liquid ratio	0.9	0.8	0.7	0.69	0.68	0.67
DC1 Condenser duty	969.6	969.6	969.6	969.6	**969.6**	969.6
DC1 reboiler duty	1891	1891	1891	1891	1891	1891
DWC condenser duty	3217	2821	2611	2605	**2605**	**2609**
DWC reboiler duty	3893	3480	3210	3198	**3192**	**3192**
Total Duty (KW)	9970.6	9161.6	8681.6	8663.6	**8657.6**	**8661.6**

4.2.4 C2 flow rate

The flow rate of ethane in the product extracted from condenser is varied to check its effect on the energy consumption of the whole process.

Table 4-10: Effect of C2 flow rate on energy consumption

C2 flow rate	130	129	128	127	126	125	124
DC1 Condenser duty	969.6	969.6	969.6	969.6	**969.6**	969.6	969.6
DC1 reboiler duty	1891	1891	1891	1891	1891	1891	1891
DWC condenser duty	2822	2617	2605	2605	**2613**	**2626**	**2643**
DWC reboiler duty	3470	3218	3198	3192	**3195**	**3205**	**3219**
Total Duty (KW)	9152.6	8695.6	8663.6	8657.6	**8668.6**	**8691.6**	**8722.6**

As it could be seen through Table 4-10 at flow rate of 127 kmol/hr the minimum energy consumption is achieved.

4.2.5 C3 flow rate

The flow rate of propane product is varied to check its effect on the energy consumption of the whole process.

Table 4-11: The effect of C3 flow rate on energy consumption

C3 flow rate	**145**	**146**	**147**	**148**
DC1 Condenser duty	969.6	969.6	969.6	969.6
DC1 reboiler duty	1891	1891	1891	1891
DWC condenser duty	2605	2651	2701	2753
DWC reboiler duty	3192	3248	3307	3370
Total Duty (KW)	8657.6	8759.6	8868.6	8983.6

As it could be seen through Table 4-11 at flow rate of 145 kmol/hr the minimum energy consumption is achieved.

4.2.6 LPG flow rate

The flow rate of LPG product is varied to check its effect on the energy consumption of the whole process.

Table 4-12: The effect of LPG flow rate on energy consumption

LPG flow rate	**280**	**281**	**282**	**283**	**284**	**285**
DC1 Condenser duty	969.6	969.6	969.6	969.6	**969.6**	969.6
DC1 reboiler duty	1891	1891	1891	1891	1891	1891
DWC condenser duty	2582	2586	2610	2636	**2663**	**2690**
DWC reboiler duty	3166	3168	3198	3229	**3261**	**3295**
Total Duty (KW)	8608.6	8614.6	8668.6	8725.6	**8784.6**	**8845.6**

As it could be seen through Table 4-12 at flow rate of 280 kmol/hr the minimum energy consumption is achieved.

4.2.7 Final Result for Kaibel Model

By considering all the above optimization which is taken with respect to energy consumption, the following results shown in Table 4-13 for this case are obtained.

Table 4-13: Final summary results for Kaibel DWC model

Stream Name	C1	C2	C3	LPG
Molar flow	182	133.7	**163.1**	**297.2**
Mole fraction	0.97	0.95	**0.889**	**0.942**
Component molar flow	176.5	127	**145**	**280**
Total Condenser dyty	**3552**			
Total reboiler duty	**5057**			
Total Duty (KW)	**8609**			

The results in the above table prove that the energy consumption of the combination of the demethanizer and Kaibel DWC uses less energy. The Total energy consumption in base case is 12559 KW while it goes down to 8609 kw in the Kaibel DWC method. The usage of this new arrangement shows clearly 31.4 % energy saving. The Hysys produced reports for this simulation case are presented through Appendices 7.57.7.

4.3 Multi-partitioned DWC (Sargent arrangement)

As described in section 3.2.2, the Sergent arrangement is considered as a more thermally coupled configuration for DWC designs. As there is no reported application of this arrangement through the available literature, the last part of the simulation study focuses on energy optimization for this configuration. Figure 4-4 shows a typical schematic for multi-partitioned DWC and the products from which we are going to extract.

This tower includes three walls which divide the whole tower into nine different separation units. The main goal for this kind of division is to increase the separation units and decrease the energy usage by deploying just one set of reboiler and condenser. This will happen through decreasing the remixing effect of components that are described through section 3.1.1.

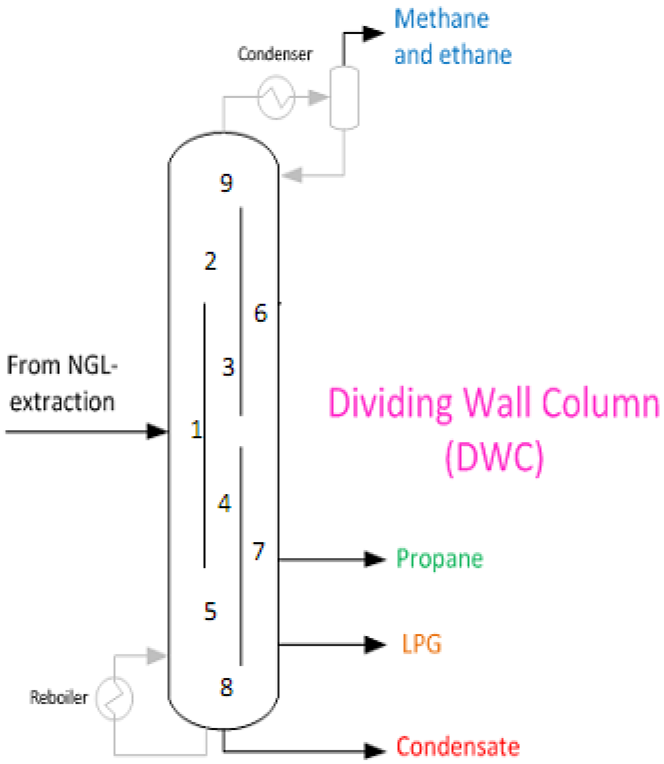


Figure 4-4: Multi-component DWC

As the whole process will be achievable with just one tower instead of three towers in the conventional case, there is also a potential to decrease the capital cost. This saving in capital cost could be analyzed in early study of a typical project to evaluate the best technology relevant for the prospect plant.

To simulate this tower each individual section was considered as a single tower then different sections thermally coupled by connecting their liquid and vapor streams. Figure 4-5 shows the arrangement corresponding to this type of DWC simulated using Aspen Hysys 7.3..

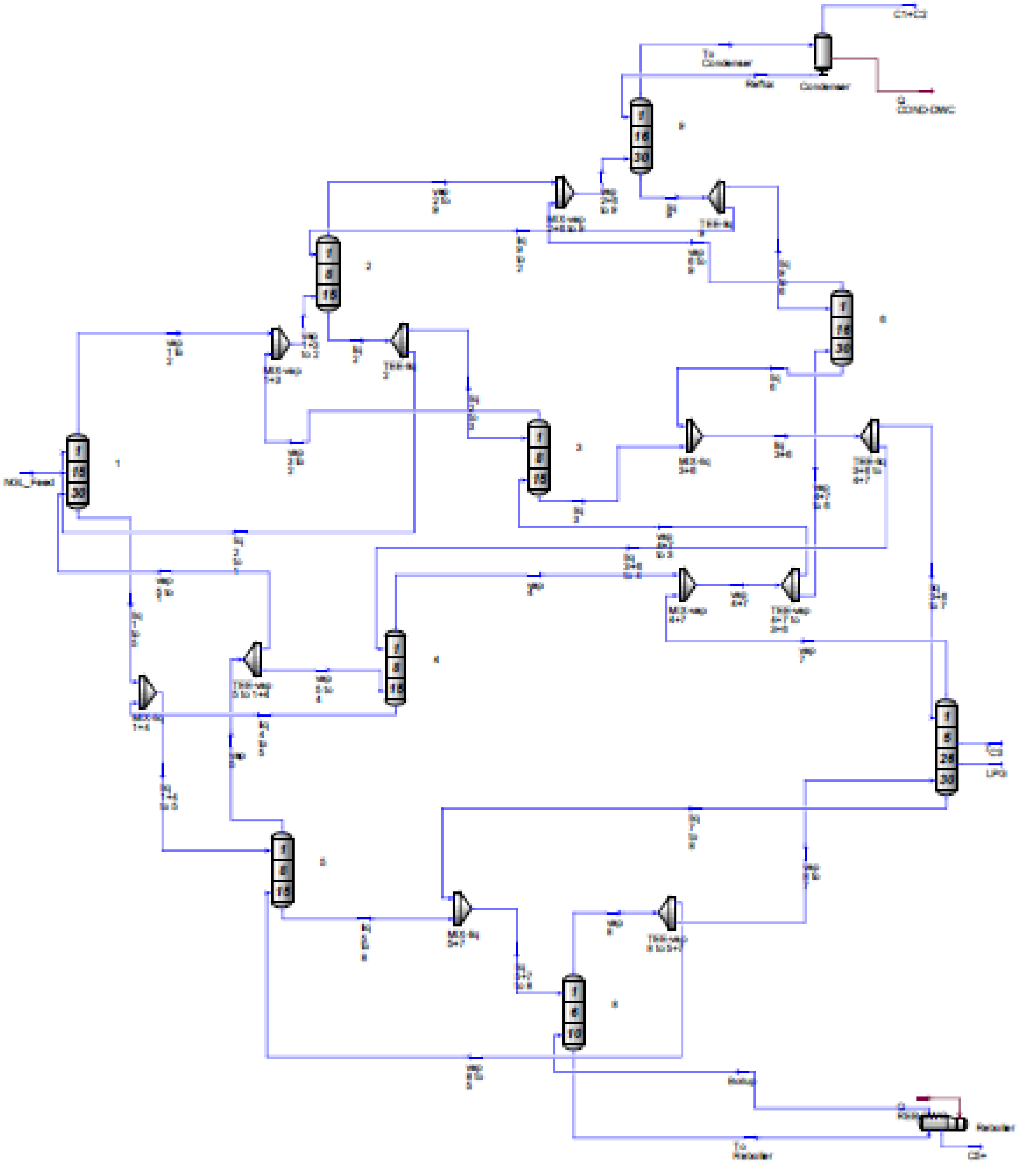


Figure 4-5: Multi-Partitioned DWC arrangement simulated in Aspen Hysys 7.3

In the following sections, important parameters like feed tray location, vapor to liquid flow ratio and the energy consumption are discussed and optimization with respect to minimum energy usage is done.

4.3.1 C3 product withdrawing tray

As the aim of this simulation is to optimize the LPG production in terms of energy consumption, the tray location was determined accordingly. As numbers in Table 4-14 show, the total energy consumption of the DWC is minimized at tray number 5. So this tray was taken to produce propane.

Table 4-14: C3 product withdrawing tray based on minimum energy consumption

Tray Number	no.3	no.4	no.5	o.6	no.7	no.8
Condenser Duty	3797	3793	3787	3789	3801	3821
Reboiler Duty	5526	5522	5516	5519	5531	5552
Total Duty	9323	9315	9303	9308	9332	9373

4.3.2 LPG product withdrawing tray

After evaluating the proper tray for withdrawing propane, the same evaluation was conducted for determining the proper tray to withdraw LPG. In this case, the energy consumption reduces down to tray number 26. From this tray on, the increase in energy consumption was observed. Table 4-15 shows the data depicting tray number 26 as the best one to withdraw LPG product.

Table 4-15: LPG product withdrawing tray based on minimum energy consumption

Tray Number	no.24	no.25	no.26	no.27	no.28	no.29
Condenser Duty	3794	3787	3784	3787	3797	3830
Reboiler Duty	5524	5516	5512	5512	5517	5538
Total Duty	9318	9303	9296	9299	9314	9368

4.3.3 Liquid flow rate ratio at both sides of Sergent DWC

All parameters except the liquid ratios kept constant to evaluate the effect of liquid ratio on energy consumption. The result of this analysis has been presented for different nodes through tables Table 4-16, Table 4-17 and Table 4-18. These nodes are called as Tee-LiQ2, Tee-LiQ9, Tee-LiQ3+6 To 4+7 in the flowsheet.

Table 4-16: Effect of liquid ratio on energy consumption (node Tee-LiQ2)

Liquid Ratio	0.5	0.6	0.7	0.75	0.8	0.9
Condenser Duty	4292	3886	3710	**3674**	**3715**	**4235**
Reboiler Duty	6024	5615	5438	**5402**	**5445**	**5970**
Total Duty	10316	9501	9148	**9076**	**9160**	**10205**

Table 4-17: Effect of liquid ratio on energy consumption (node Tee-LiQ9)

Liquid Ratio	0.5	0.6	0.65	0.7	0.75	0.8
Condenser Duty	3812	3712	3681	**3677**	**3738**	**3892**
Reboiler Duty	5540	5440	5409	**5406**	**5468**	**5624**
Total Duty	9352	9152	9090	**9083**	**9206**	**9516**

Table 4-18: Effect of liquid ratio on energy consumption (node Tee-LiQ3+6 To 4+7)

Liquid Ratio	0.6	0.7	0.8
Condenser Duty	5135	3677	**3324**
Reboiler Duty	6872	5406	**5054**
Total Duty	12007	9083	**8378**

4.3.4 Vapor flow rate ratio at both side of Sergent DWC

Same analysis for vapor ratio was done. All parameters except the vapor ratios kept constant to evaluate its effect on energy consumption. The result of this analysis has been presented for different nodes through Table 4-19, Table 4-20, and Table 4-21. These nodes are called as “Tee-Vap 5 to 1+4”, “Tee-Vap 8 to 5+7” and “Tee-Vap 4+7 to 3+6” in the flowsheet.

Table 4-19: Effect of vapor ratio on energy consumption (node Tee-Vap 8 to 5+7)

Vapor Ratio	0.7	0.8	0.85	0.9	0.95
Condenser Duty	3324	3216	3165	3118	**3072**
Reboiler Duty	5054	4944	4893	4844	**4797**
Total Duty	8378	8160	8058	7962	**7869**

Table 4-20: Effect of vapor ratio on energy consumption (node Tee-Vap 5 to 1+4)

Vapor Ratio	**0.45**	**0.47**	**0.5**
Condenser Duty	3072	3088	3171
Reboiler Duty	4797	4812	4891
Total Duty	7869	7900	8062

Table 4-21: Effect of vapor ratio on energy consumption (node Tee-Vap 4+7 to 3+6)

Vapor Ratio	**0.1**	**0.2**
Condenser Duty	3073	**3072**
Reboiler Duty	4799	**4797**
Total Duty	7872	**7869**

4.3.5 Final Result For Multi-partitioned (Sergent) DWC Model

By considering all the above optimization which is taken with respect to energy consumption, the following results shown in for this case are obtained.

Table 4-22: Final summary results for multi-component DWC

Stream Name	**C1+C2**	**C3**	**LPG**
Molar flow	305.3	**150**	**315.7**
Mole fraction	1	**0.89**	**0.973**
Component molar flow	305.3	**133.5**	**307.17**
Total Condenser dyty	**3072**		
Total Reboiler duty	**4797**		
Total Duty (KW)	**7869**		

The results in Table 4-22 shows the energy consumption of the multi-partitioned DWC uses less energy. The Total energy consumption in base case is 12559 KW while it goes down to 7869 in this kind of DWC design. The usage of this new arrangement shows clearly a 37.3 % energy saving which is even a better performance compared to Kaibel column. This result is in conformance with the literature predictions addressed in section 3.2.2 confirming the better thermally coupling of Sergent DWC with respect to Kaibel. The Hysys produced reports for this simulation case are presented through Appendices 7.17.87.9.

5 Conclusion and Fyrther Study

The defined tasks in the project description have been tracked to achieve the desired results. Literatures have been reviewed in order to present methods and theories about LNG production. The methods of fractionation of natural gas feed for extracting of NGL have been discussed too. More in detail divided wall column (DWC) distillation configurations and governing equations have been described.

As described in sections 4.2 and 4.3Figure 4-2 two types of DWC configuration model, Kaibel and multi-partitioned, are simulated by HYSYS process modelling software for LPG extraction in a typical LNG production plant. The simulation addresses and evaluates the energy consumption of the unit with alternative technology usage. The improvement potentials and energy savings have been presented by optimizing HYSYS models and the results obtained for DWC cases are compared to base case which is the conventional fractionation distillation sequence.

The benefit in terms of energy consumption with equal conditions in LPG extraction process depends on the total duty of distillation's condenser and reboiler. With equal conditions and LPG product specifications, the utilization of the Kaibel and multi-partitioned DWC distillation reduced the energy consumption by 31.4 % and 37.3 %, respectively. The results obtained by this study confirm in a well manner the energy savings which was predicted by the study proposal and literatures.

There are potentials works which need further academic and industrial works. The economic viability of employing this technology in practical industrial applications is dependent both on the capital and operational costs. The main focus of this study is to evaluate the operational savings due to changing the technology while the mechanical and constructability of such a design should also be reviewed very carefully to consider its capital costs. Then, a plant operator has enough decision making tools at hand to evaluate the life cycle cost of the technology to be used. So, CFD analysis of the mechanical design for DWC could be a potential work to go ahead more. In addition more mathematical and rigorous models could be applied to reinsure the validity of the results obtained in this study. Furthermore as discussed in section 2.1.4, the offshore application of DWCs for processing facilities and specially FLNG vessels could be evaluated.

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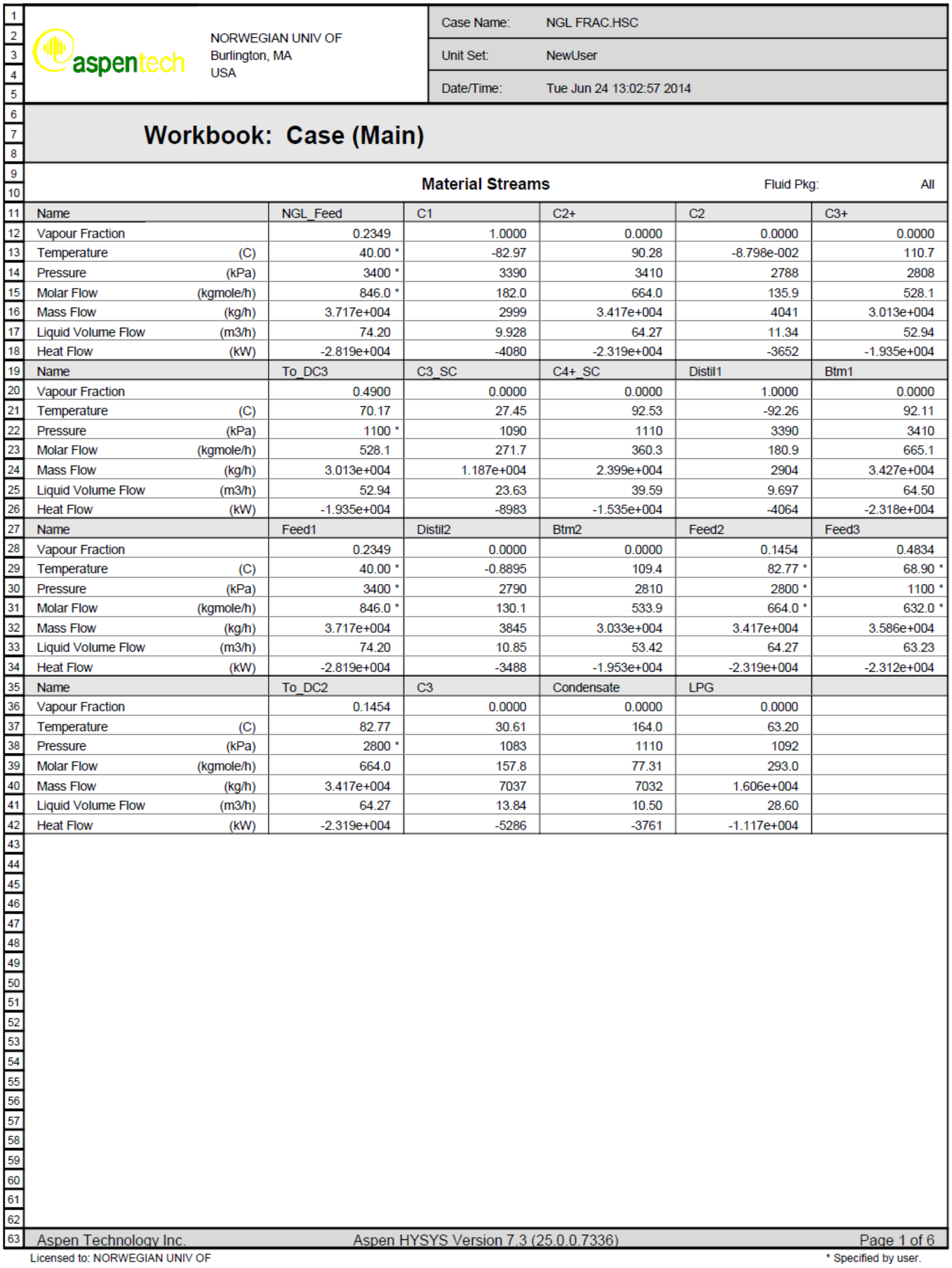
7 Appendices

This section includes the report of the simulation models addressing material and energy balances and column profiles. The following reports are presented:

- Main Workbook Profile Report for NGL Fractionation Model (Base case)
- DC1 column Profile Report for NGL Fractionation Model (Base case)
- DC2 column Profile Report for NGL Fractionation Model (Base case)
- DC3 column Profile Report for NGL Fractionation Model (Base case)
- Main Workbook Profile Report for Kaibel DWC Model
- DC1 Column Profile Report for Kaibel DWC Model
- DWC Column Profile Report for Kaibel DWC Model

7.1 Main Workbook Profile Report for NGL Fractionation Model (Base case)



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Case Name:	NGL FRAC.HSC
Unit Set:	NewUser
Date/Time:	Tue Jun 24 13:02:57 2014

Workbook: Case (Main)

Material Streams Fluid Pkg: All

Name		NGL_Feed	C1	C2+	C2	C3+
Vapour Fraction		0.2349	1.0000	0.0000	0.0000	0.0000
Temperature	(C)	40.00 *	-82.97	90.28	-8.798e-002	110.7
Pressure	(kPa)	3400 *	3390	3410	2788	2808
Molar Flow	(kgmole/h)	846.0 *	182.0	664.0	135.9	528.1
Mass Flow	(kg/h)	3.717e+004	2999	3.417e+004	4041	3.013e+004
Liquid Volume Flow	(m3/h)	74.20	9.928	64.27	11.34	52.94
Heat Flow	(kW)	-2.819e+004	-4080	-2.319e+004	-3652	-1.935e+004

Name		To_DC3	C3_SC	C4+_SC	Distil1	Btm1
Vapour Fraction		0.4900	0.0000	0.0000	1.0000	0.0000
Temperature	(C)	70.17	27.45	92.53	-92.26	92.11
Pressure	(kPa)	1100 *	1090	1110	3390	3410
Molar Flow	(kgmole/h)	528.1	271.7	360.3	180.9	665.1
Mass Flow	(kg/h)	3.013e+004	1.187e+004	2.399e+004	2904	3.427e+004
Liquid Volume Flow	(m3/h)	52.94	23.63	39.59	9.697	64.50
Heat Flow	(kW)	-1.935e+004	-8983	-1.535e+004	-4064	-2.318e+004

Name		Feed1	Distil2	Btm2	Feed2	Feed3
Vapour Fraction		0.2349	0.0000	0.0000	0.1454	0.4834
Temperature	(C)	40.00 *	-0.8895	109.4	82.77 *	68.90 *
Pressure	(kPa)	3400 *	2790	2810	2800 *	1100 *
Molar Flow	(kgmole/h)	846.0 *	130.1	533.9	664.0 *	632.0 *
Mass Flow	(kg/h)	3.717e+004	3845	3.033e+004	3.417e+004	3.586e+004
Liquid Volume Flow	(m3/h)	74.20	10.85	53.42	64.27	63.23
Heat Flow	(kW)	-2.819e+004	-3488	-1.953e+004	-2.319e+004	-2.312e+004

Name		To_DC2	C3	Condensate	LPG	
Vapour Fraction		0.1454	0.0000	0.0000	0.0000	
Temperature	(C)	82.77	30.61	164.0	63.20	
Pressure	(kPa)	2800 *	1083	1110	1092	
Molar Flow	(kgmole/h)	664.0	157.8	77.31	293.0	
Mass Flow	(kg/h)	3.417e+004	7037	7032	1.606e+004	
Liquid Volume Flow	(m3/h)	64.27	13.84	10.50	28.60	
Heat Flow	(kW)	-2.319e+004	-5286	-3761	-1.117e+004	

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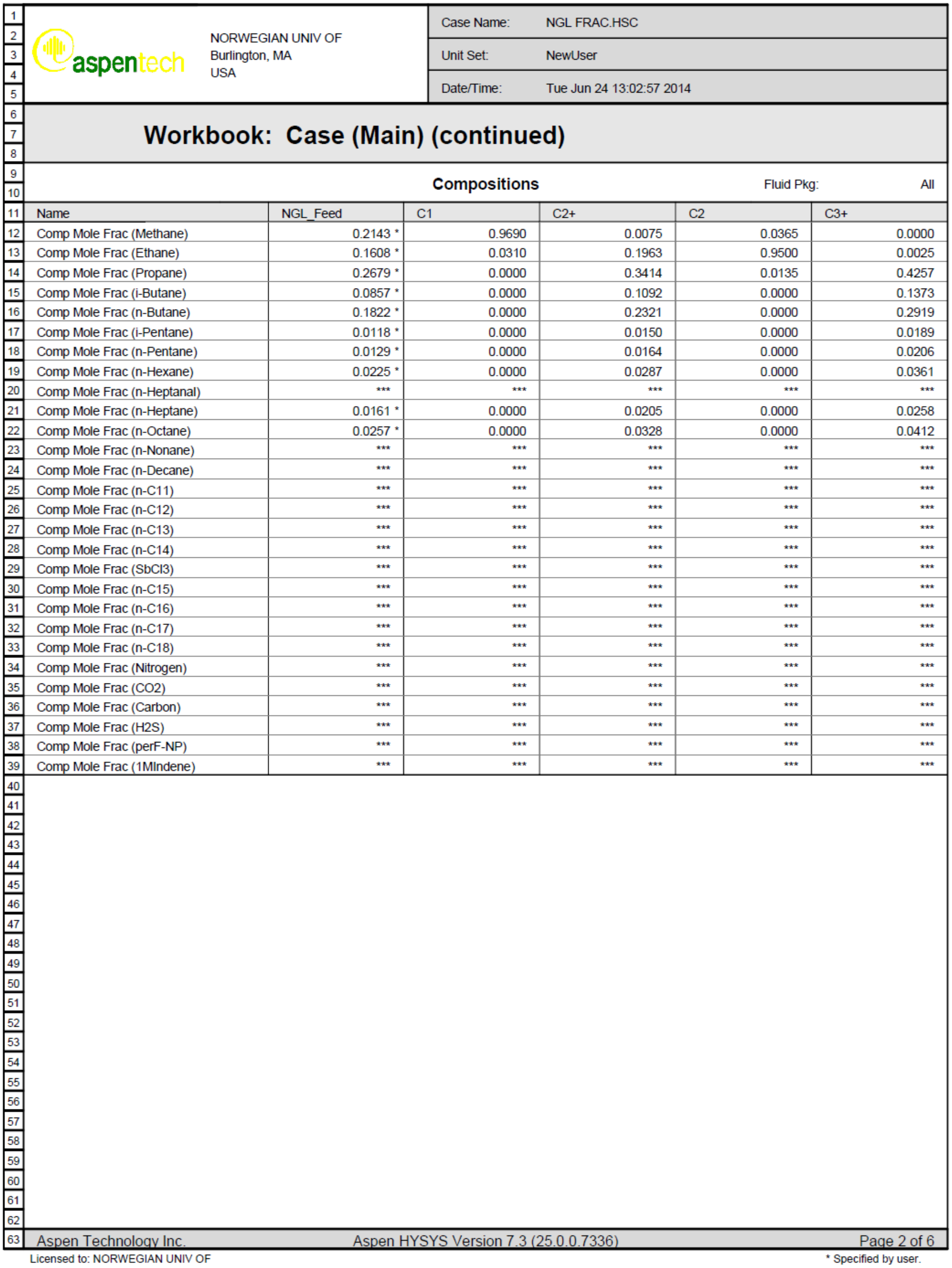

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USA

Case Name:	NGL FRAC.HSC
Unit Set:	NewUser
Date/Time:	Tue Jun 24 13:02:57 2014

Workbook: Case (Main) (continued)

Compositions

Fluid Pkg: All

Name	NGL_Feed	C1	C2+	C2	C3+
Comp Mole Frac (Methane)	0.2143 *	0.9690	0.0075	0.0365	0.0000
Comp Mole Frac (Ethane)	0.1608 *	0.0310	0.1963	0.9500	0.0025
Comp Mole Frac (Propane)	0.2679 *	0.0000	0.3414	0.0135	0.4257
Comp Mole Frac (i-Butane)	0.0857 *	0.0000	0.1092	0.0000	0.1373
Comp Mole Frac (n-Butane)	0.1822 *	0.0000	0.2321	0.0000	0.2919
Comp Mole Frac (i-Pentane)	0.0118 *	0.0000	0.0150	0.0000	0.0189
Comp Mole Frac (n-Pentane)	0.0129 *	0.0000	0.0164	0.0000	0.0206
Comp Mole Frac (n-Hexane)	0.0225 *	0.0000	0.0287	0.0000	0.0361
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0161 *	0.0000	0.0205	0.0000	0.0258
Comp Mole Frac (n-Octane)	0.0257 *	0.0000	0.0328	0.0000	0.0412
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

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Workbook: Case (Main) (continued)

Compositions (continued)

Fluid Pkg: All

Name	To_DC3	C3_SC	C4+_SC	Distil1	Btm1
Comp Mole Frac (Methane)	0.0000	0.0000	0.0000	0.9990	0.0010
Comp Mole Frac (Ethane)	0.0025	0.0296	0.0000	0.0010	0.2042
Comp Mole Frac (Propane)	0.4257	0.9693	0.0100	0.0000	0.3408
Comp Mole Frac (i-Butane)	0.1373	0.0010	0.2372	0.0000	0.1090
Comp Mole Frac (n-Butane)	0.2919	0.0001	0.5057	0.0000	0.2317
Comp Mole Frac (i-Pentane)	0.0189	0.0000	0.0327	0.0000	0.0150
Comp Mole Frac (n-Pentane)	0.0206	0.0000	0.0358	0.0000	0.0164
Comp Mole Frac (n-Hexane)	0.0361	0.0000	0.0625	0.0000	0.0286
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0258	0.0000	0.0448	0.0000	0.0205
Comp Mole Frac (n-Octane)	0.0412	0.0000	0.0714	0.0000	0.0327
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

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	Unit Set:	NewUser
	Date/Time:	Tue Jun 24 13:02:57 2014

Workbook: Case (Main) (continued)

Compositions (continued)

Fluid Pkg: All

Name	Feed1	Distil2	Btm2	Feed2	Feed3
Comp Mole Frac (Methane)	0.2143 *	0.0381	0.0000	0.0075 *	0.0000 *
Comp Mole Frac (Ethane)	0.1608 *	0.9609	0.0100	0.1963 *	0.0127 *
Comp Mole Frac (Propane)	0.2679 *	0.0010	0.4243	0.3414 *	0.4225 *
Comp Mole Frac (i-Butane)	0.0857 *	0.0000	0.1358	0.1092 *	0.1356 *
Comp Mole Frac (n-Butane)	0.1822 *	0.0000	0.2887	0.2321 *	0.2883 *
Comp Mole Frac (i-Pentane)	0.0118 *	0.0000	0.0187	0.0150 *	0.0187 *
Comp Mole Frac (n-Pentane)	0.0129 *	0.0000	0.0204	0.0164 *	0.0204 *
Comp Mole Frac (n-Hexane)	0.0225 *	0.0000	0.0357	0.0287 *	0.0356 *
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0161 *	0.0000	0.0256	0.0205 *	0.0255 *
Comp Mole Frac (n-Octane)	0.0257 *	0.0000	0.0408	0.0328 *	0.0407 *
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

* Specified by user.

Workbook: Case (Main) (continued)

Compositions (continued)

Fluid Pkg: All

Name	To_DC2	C3	Condensate	LPG	
Comp Mole Frac (Methane)	0.0075	0.0000	0.0000	0.0000	
Comp Mole Frac (Ethane)	0.1963	0.0073	0.0000	0.0005	
Comp Mole Frac (Propane)	0.3414	0.9500	0.0000	0.2557	
Comp Mole Frac (i-Butane)	0.1092	0.0388	0.0033	0.2257	
Comp Mole Frac (n-Butane)	0.2321	0.0039	0.0993	0.4977	
Comp Mole Frac (i-Pentane)	0.0150	0.0000	0.0837	0.0120	
Comp Mole Frac (n-Pentane)	0.0164	0.0000	0.1094	0.0083	
Comp Mole Frac (n-Hexane)	0.0287	0.0000	0.2463	0.0000	
Comp Mole Frac (n-Heptanal)	***	***	***	***	
Comp Mole Frac (n-Heptane)	0.0205	0.0000	0.1765	0.0000	
Comp Mole Frac (n-Octane)	0.0328	0.0000	0.2815	0.0000	
Comp Mole Frac (n-Nonane)	***	***	***	***	
Comp Mole Frac (n-Decane)	***	***	***	***	
Comp Mole Frac (n-C11)	***	***	***	***	
Comp Mole Frac (n-C12)	***	***	***	***	
Comp Mole Frac (n-C13)	***	***	***	***	
Comp Mole Frac (n-C14)	***	***	***	***	
Comp Mole Frac (SbCl3)	***	***	***	***	
Comp Mole Frac (n-C15)	***	***	***	***	
Comp Mole Frac (n-C16)	***	***	***	***	
Comp Mole Frac (n-C17)	***	***	***	***	
Comp Mole Frac (n-C18)	***	***	***	***	
Comp Mole Frac (Nitrogen)	***	***	***	***	
Comp Mole Frac (CO2)	***	***	***	***	
Comp Mole Frac (Carbon)	***	***	***	***	
Comp Mole Frac (H2S)	***	***	***	***	
Comp Mole Frac (perF-NP)	***	***	***	***	
Comp Mole Frac (1MIndene)	***	***	***	***	

Energy Streams

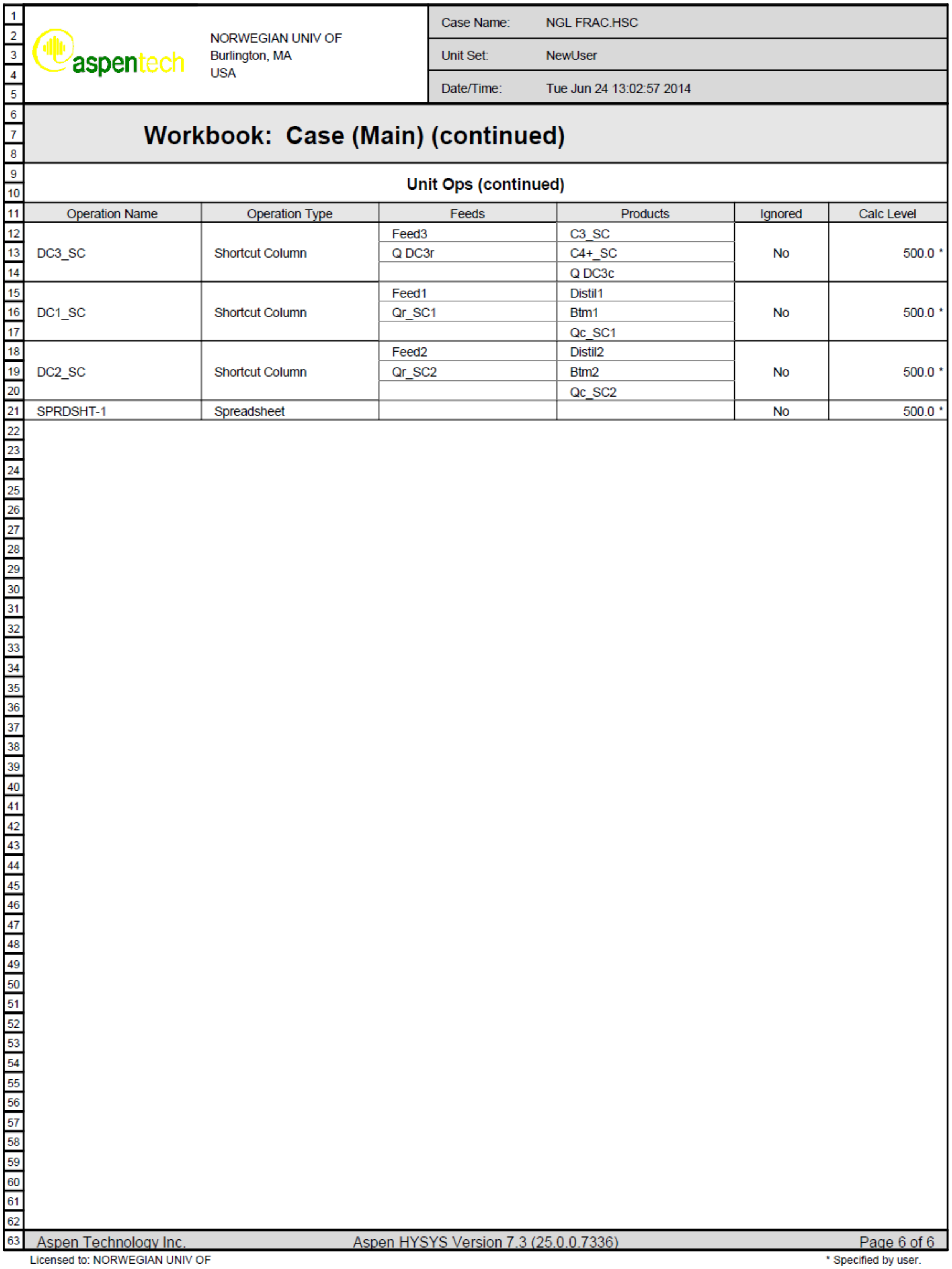
Fluid Pkg: All

Name	Reb Q_DC1	Cond Q_DC1	Cond Q_DC2	Reb Q_DC2	Q DC3r
Heat Flow (kW)	1890	969.9	2377	2568	2362
Name	Q DC3c	Qc_SC1	Qr_SC1	Qc_SC2	Qr_SC2
Heat Flow (kW)	3579	288.5	1238	1456	1626
Name	Con Q_DC3	Reb Q_DC3			
Heat Flow (kW)	2811	1939			

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc Level
DC1	Distillation	NGL_Feed Reb Q_DC1	C2+ C1 Cond Q_DC1	No	2500 *
DC2	Distillation	To_DC2 Reb Q_DC2	C3+ C2 Cond Q_DC2	No	2500 *
DC3	Distillation	To_DC3 Reb Q_DC3	Condensate C3 LPG Con Q_DC3	No	2500 *
VLV-100	Valve	C2+	To_DC2	No	500.0 *
VLV-101	Valve	C3+	To_DC3	No	500.0 *

* Specified by user.



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Case Name:	NGL FRAC.HSC
Unit Set:	NewUser
Date/Time:	Tue Jun 24 13:02:57 2014

Workbook: Case (Main) (continued)

Unit Ops (continued)

Operation Name	Operation Type	Feeds	Products	Ignored	Calc Level
DC3_SC	Shortcut Column	Feed3 Q DC3r	C3_SC C4+_SC Q DC3c	No	500.0 *
DC1_SC	Shortcut Column	Feed1 Qr_SC1	Distil1 Btm1 Qc_SC1	No	500.0 *
DC2_SC	Shortcut Column	Feed2 Qr_SC2	Distil2 Btm2 Qc_SC2	No	500.0 *
SPRDSHT-1	Spreadsheet			No	500.0 *

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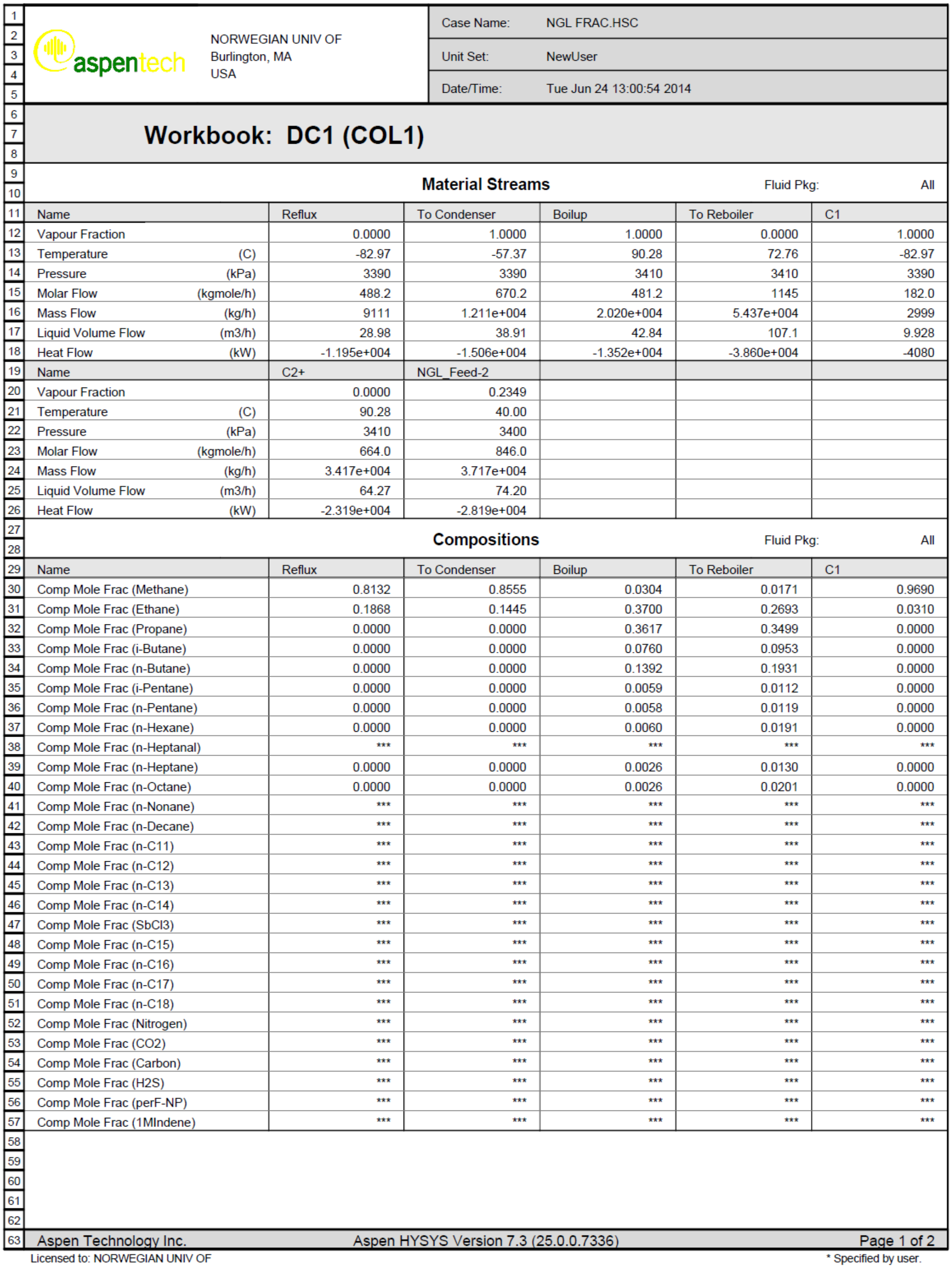
7.2 DC1 column Profile Report for NGL Fractionation Model (Base case)



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Case Name: NGL FRAC.HSC
Unit Set: NewUser
Date/Time: Tue Jun 24 13:00:54 2014

Workbook: DC1 (COL1)

Material Streams

Fluid Pkg: All

Name		Reflux	To Condenser	Boilup	To Reboiler	C1
Vapour Fraction		0.0000	1.0000	1.0000	0.0000	1.0000
Temperature	(C)	-82.97	-57.37	90.28	72.76	-82.97
Pressure	(kPa)	3390	3390	3410	3410	3390
Molar Flow	(kgmole/h)	488.2	670.2	481.2	1145	182.0
Mass Flow	(kg/h)	9111	1.211e+004	2.020e+004	5.437e+004	2999
Liquid Volume Flow	(m3/h)	28.98	38.91	42.84	107.1	9.928
Heat Flow	(kW)	-1.195e+004	-1.506e+004	-1.352e+004	-3.860e+004	-4080
Name		C2+	NGL_Feed-2			
Vapour Fraction		0.0000	0.2349			
Temperature	(C)	90.28	40.00			
Pressure	(kPa)	3410	3400			
Molar Flow	(kgmole/h)	664.0	846.0			
Mass Flow	(kg/h)	3.417e+004	3.717e+004			
Liquid Volume Flow	(m3/h)	64.27	74.20			
Heat Flow	(kW)	-2.319e+004	-2.819e+004			

Compositions

Fluid Pkg: All

Name	Reflux	To Condenser	Boilup	To Reboiler	C1
Comp Mole Frac (Methane)	0.8132	0.8555	0.0304	0.0171	0.9690
Comp Mole Frac (Ethane)	0.1868	0.1445	0.3700	0.2693	0.0310
Comp Mole Frac (Propane)	0.0000	0.0000	0.3617	0.3499	0.0000
Comp Mole Frac (i-Butane)	0.0000	0.0000	0.0760	0.0953	0.0000
Comp Mole Frac (n-Butane)	0.0000	0.0000	0.1392	0.1931	0.0000
Comp Mole Frac (i-Pentane)	0.0000	0.0000	0.0059	0.0112	0.0000
Comp Mole Frac (n-Pentane)	0.0000	0.0000	0.0058	0.0119	0.0000
Comp Mole Frac (n-Hexane)	0.0000	0.0000	0.0060	0.0191	0.0000
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0000	0.0000	0.0026	0.0130	0.0000
Comp Mole Frac (n-Octane)	0.0000	0.0000	0.0026	0.0201	0.0000
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

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* Specified by user.

Workbook: DC1 (COL1) (continued)

Compositions (continued)

Fluid Pkg: All

Name	C2+	NGL_Feed-2			
Comp Mole Frac (Methane)	0.0075	0.2143			
Comp Mole Frac (Ethane)	0.1963	0.1608			
Comp Mole Frac (Propane)	0.3414	0.2679			
Comp Mole Frac (i-Butane)	0.1092	0.0857			
Comp Mole Frac (n-Butane)	0.2321	0.1822			
Comp Mole Frac (i-Pentane)	0.0150	0.0118			
Comp Mole Frac (n-Pentane)	0.0164	0.0129			
Comp Mole Frac (n-Hexane)	0.0287	0.0225			
Comp Mole Frac (n-Heptanal)	***	***			
Comp Mole Frac (n-Heptane)	0.0205	0.0161			
Comp Mole Frac (n-Octane)	0.0328	0.0257			
Comp Mole Frac (n-Nonane)	***	***			
Comp Mole Frac (n-Decane)	***	***			
Comp Mole Frac (n-C11)	***	***			
Comp Mole Frac (n-C12)	***	***			
Comp Mole Frac (n-C13)	***	***			
Comp Mole Frac (n-C14)	***	***			
Comp Mole Frac (SbCl3)	***	***			
Comp Mole Frac (n-C15)	***	***			
Comp Mole Frac (n-C16)	***	***			
Comp Mole Frac (n-C17)	***	***			
Comp Mole Frac (n-C18)	***	***			
Comp Mole Frac (Nitrogen)	***	***			
Comp Mole Frac (CO2)	***	***			
Comp Mole Frac (Carbon)	***	***			
Comp Mole Frac (H2S)	***	***			
Comp Mole Frac (perF-NP)	***	***			
Comp Mole Frac (1MIndene)	***	***			

Energy Streams

Fluid Pkg: All

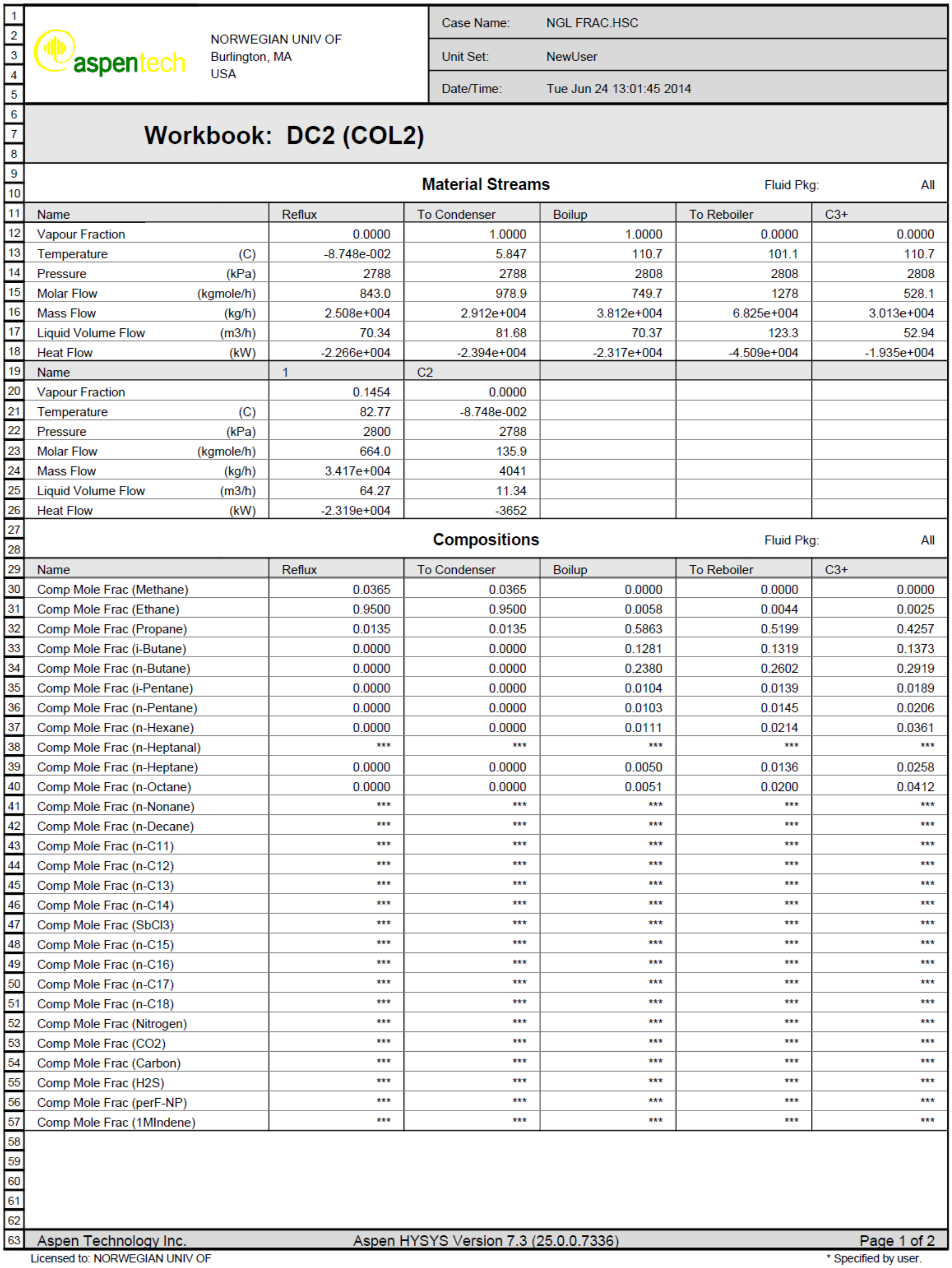
Name		Cond Q_DC1	Reb Q_DC1			
Heat Flow	(kW)	969.9	1890			

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc Level
Condenser	Partial Condenser	To Condenser Cond Q_DC1	C1 Reflux Cond Q_DC1	No	500.0 *
Reboiler	Reboiler	To Reboiler Reb Q_DC1	C2+ Boilup	No	500.0 *
Main TS	Tray Section	Reflux Boilup NGL_Feed-2	To Reboiler To Condenser	No	500.0 *

* Specified by user.

7.3 DC2 column Profile Report for NGL Fractionation Model (Base case)



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Burlington, MA
USA

Case Name: NGL FRAC.HSC
Unit Set: NewUser
Date/Time: Tue Jun 24 13:01:45 2014

Workbook: DC2 (COL2)

Material Streams Fluid Pkg: All

Name		Reflux	To Condenser	Boilup	To Reboiler	C3+
Vapour Fraction		0.0000	1.0000	1.0000	0.0000	0.0000
Temperature	(C)	-8.748e-002	5.847	110.7	101.1	110.7
Pressure	(kPa)	2788	2788	2808	2808	2808
Molar Flow	(kgmole/h)	843.0	978.9	749.7	1278	528.1
Mass Flow	(kg/h)	2.508e+004	2.912e+004	3.812e+004	6.825e+004	3.013e+004
Liquid Volume Flow	(m3/h)	70.34	81.68	70.37	123.3	52.94
Heat Flow	(kW)	-2.266e+004	-2.394e+004	-2.317e+004	-4.509e+004	-1.935e+004

Name		1	C2			
Vapour Fraction		0.1454	0.0000			
Temperature	(C)	82.77	-8.748e-002			
Pressure	(kPa)	2800	2788			
Molar Flow	(kgmole/h)	664.0	135.9			
Mass Flow	(kg/h)	3.417e+004	4041			
Liquid Volume Flow	(m3/h)	64.27	11.34			
Heat Flow	(kW)	-2.319e+004	-3652			

Compositions Fluid Pkg: All

Name	Reflux	To Condenser	Boilup	To Reboiler	C3+
Comp Mole Frac (Methane)	0.0365	0.0365	0.0000	0.0000	0.0000
Comp Mole Frac (Ethane)	0.9500	0.9500	0.0058	0.0044	0.0025
Comp Mole Frac (Propane)	0.0135	0.0135	0.5863	0.5199	0.4257
Comp Mole Frac (i-Butane)	0.0000	0.0000	0.1281	0.1319	0.1373
Comp Mole Frac (n-Butane)	0.0000	0.0000	0.2380	0.2602	0.2919
Comp Mole Frac (i-Pentane)	0.0000	0.0000	0.0104	0.0139	0.0189
Comp Mole Frac (n-Pentane)	0.0000	0.0000	0.0103	0.0145	0.0206
Comp Mole Frac (n-Hexane)	0.0000	0.0000	0.0111	0.0214	0.0361
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0000	0.0000	0.0050	0.0136	0.0258
Comp Mole Frac (n-Octane)	0.0000	0.0000	0.0051	0.0200	0.0412
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

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* Specified by user.

Workbook: DC2 (COL2) (continued)

Compositions (continued)

Fluid Pkg: All

Name	1	C2
Comp Mole Frac (Methane)	0.0075	0.0365
Comp Mole Frac (Ethane)	0.1963	0.9500
Comp Mole Frac (Propane)	0.3414	0.0135
Comp Mole Frac (i-Butane)	0.1092	0.0000
Comp Mole Frac (n-Butane)	0.2321	0.0000
Comp Mole Frac (i-Pentane)	0.0150	0.0000
Comp Mole Frac (n-Pentane)	0.0164	0.0000
Comp Mole Frac (n-Hexane)	0.0287	0.0000
Comp Mole Frac (n-Heptanal)	***	***
Comp Mole Frac (n-Heptane)	0.0205	0.0000
Comp Mole Frac (n-Octane)	0.0328	0.0000
Comp Mole Frac (n-Nonane)	***	***
Comp Mole Frac (n-Decane)	***	***
Comp Mole Frac (n-C11)	***	***
Comp Mole Frac (n-C12)	***	***
Comp Mole Frac (n-C13)	***	***
Comp Mole Frac (n-C14)	***	***
Comp Mole Frac (SbCl3)	***	***
Comp Mole Frac (n-C15)	***	***
Comp Mole Frac (n-C16)	***	***
Comp Mole Frac (n-C17)	***	***
Comp Mole Frac (n-C18)	***	***
Comp Mole Frac (Nitrogen)	***	***
Comp Mole Frac (CO2)	***	***
Comp Mole Frac (Carbon)	***	***
Comp Mole Frac (H2S)	***	***
Comp Mole Frac (perF-NP)	***	***
Comp Mole Frac (1MIndene)	***	***

Energy Streams

Fluid Pkg: All

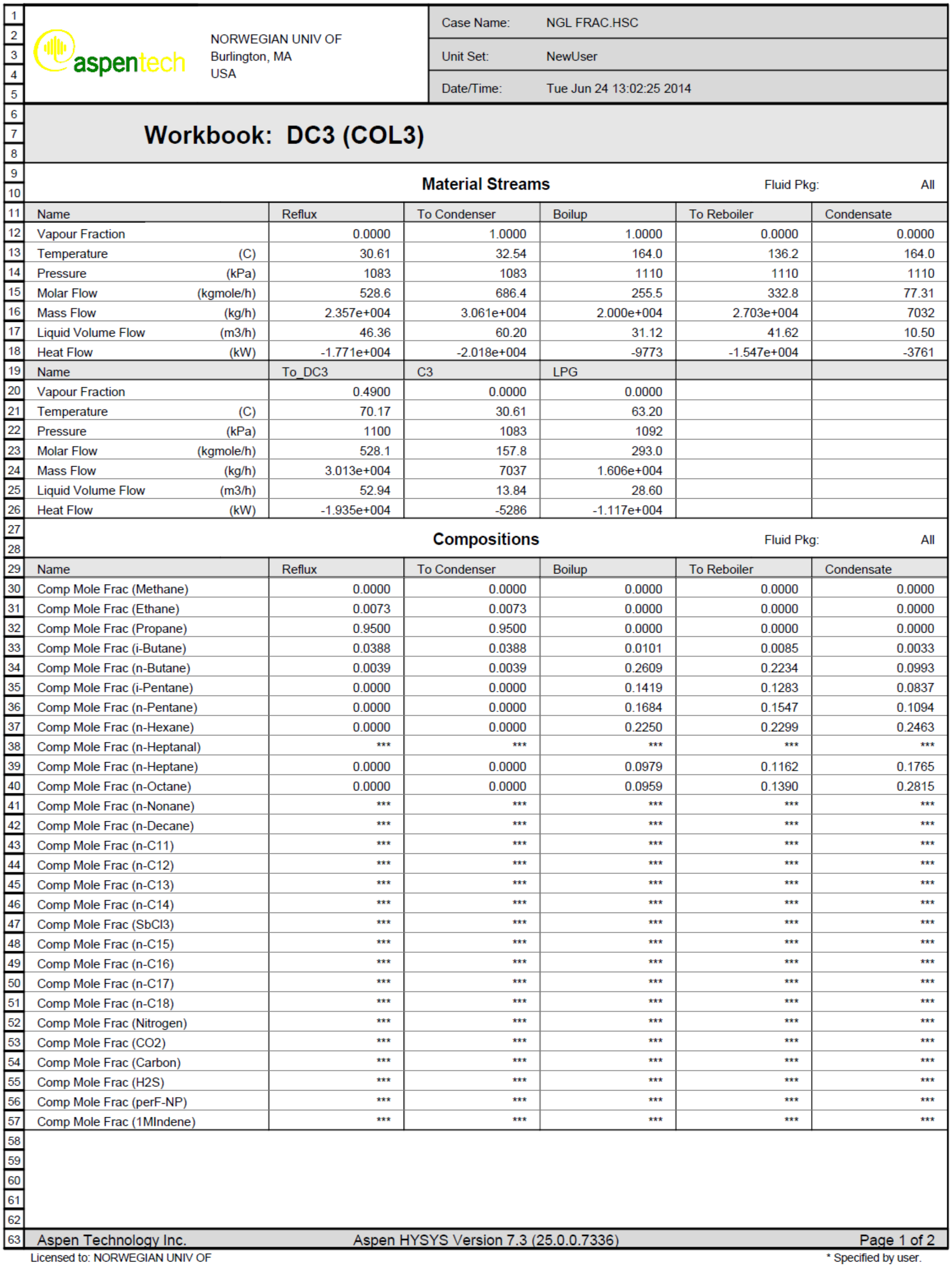
Name		Cond Q_DC2	Reb Q_DC2
Heat Flow	(kW)	2377	2568

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc Level
Reboiler	Reboiler	To Reboiler Reb Q_DC2	C3+ Boilup	No	500.0 *
Main TS	Tray Section	Reflux Boilup 1	To Reboiler To Condenser	No	500.0 *
Condenser	Total Condenser	To Condenser Cond Q_DC2	C2 Reflux Cond Q_DC2	No	500.0 *

* Specified by user.

7.4 DC3 column Profile Report for NGL Fractionation Model (Base case)



NORWEGIAN UNIV OF
Burlington, MA
USA

Case Name:	NGL FRAC.HSC
Unit Set:	NewUser
Date/Time:	Tue Jun 24 13:02:25 2014

Workbook: DC3 (COL3)

Material Streams Fluid Pkg: All

Name		Reflux	To Condenser	Boilup	To Reboiler	Condensate
Vapour Fraction		0.0000	1.0000	1.0000	0.0000	0.0000
Temperature	(C)	30.61	32.54	164.0	136.2	164.0
Pressure	(kPa)	1083	1083	1110	1110	1110
Molar Flow	(kgmole/h)	528.6	686.4	255.5	332.8	77.31
Mass Flow	(kg/h)	2.357e+004	3.061e+004	2.000e+004	2.703e+004	7032
Liquid Volume Flow	(m3/h)	46.36	60.20	31.12	41.62	10.50
Heat Flow	(kW)	-1.771e+004	-2.018e+004	-9773	-1.547e+004	-3761
Name		To_DC3	C3	LPG		
Vapour Fraction		0.4900	0.0000	0.0000		
Temperature	(C)	70.17	30.61	63.20		
Pressure	(kPa)	1100	1083	1092		
Molar Flow	(kgmole/h)	528.1	157.8	293.0		
Mass Flow	(kg/h)	3.013e+004	7037	1.606e+004		
Liquid Volume Flow	(m3/h)	52.94	13.84	28.60		
Heat Flow	(kW)	-1.935e+004	-5286	-1.117e+004		

Compositions Fluid Pkg: All

Name	Reflux	To Condenser	Boilup	To Reboiler	Condensate
Comp Mole Frac (Methane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (Ethane)	0.0073	0.0073	0.0000	0.0000	0.0000
Comp Mole Frac (Propane)	0.9500	0.9500	0.0000	0.0000	0.0000
Comp Mole Frac (i-Butane)	0.0388	0.0388	0.0101	0.0085	0.0033
Comp Mole Frac (n-Butane)	0.0039	0.0039	0.2609	0.2234	0.0993
Comp Mole Frac (i-Pentane)	0.0000	0.0000	0.1419	0.1283	0.0837
Comp Mole Frac (n-Pentane)	0.0000	0.0000	0.1684	0.1547	0.1094
Comp Mole Frac (n-Hexane)	0.0000	0.0000	0.2250	0.2299	0.2463
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0000	0.0000	0.0979	0.1162	0.1765
Comp Mole Frac (n-Octane)	0.0000	0.0000	0.0959	0.1390	0.2815
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

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* Specified by user.

Workbook: DC3 (COL3) (continued)

Compositions (continued)

Fluid Pkg: All

Name	To_DC3	C3	LPG		
Comp Mole Frac (Methane)	0.0000	0.0000	0.0000		
Comp Mole Frac (Ethane)	0.0025	0.0073	0.0005		
Comp Mole Frac (Propane)	0.4257	0.9500	0.2557		
Comp Mole Frac (i-Butane)	0.1373	0.0388	0.2257		
Comp Mole Frac (n-Butane)	0.2919	0.0039	0.4977		
Comp Mole Frac (i-Pentane)	0.0189	0.0000	0.0120		
Comp Mole Frac (n-Pentane)	0.0206	0.0000	0.0083		
Comp Mole Frac (n-Hexane)	0.0361	0.0000	0.0000		
Comp Mole Frac (n-Heptanal)	***	***	***		
Comp Mole Frac (n-Heptane)	0.0258	0.0000	0.0000		
Comp Mole Frac (n-Octane)	0.0412	0.0000	0.0000		
Comp Mole Frac (n-Nonane)	***	***	***		
Comp Mole Frac (n-Decane)	***	***	***		
Comp Mole Frac (n-C11)	***	***	***		
Comp Mole Frac (n-C12)	***	***	***		
Comp Mole Frac (n-C13)	***	***	***		
Comp Mole Frac (n-C14)	***	***	***		
Comp Mole Frac (SbCl3)	***	***	***		
Comp Mole Frac (n-C15)	***	***	***		
Comp Mole Frac (n-C16)	***	***	***		
Comp Mole Frac (n-C17)	***	***	***		
Comp Mole Frac (n-C18)	***	***	***		
Comp Mole Frac (Nitrogen)	***	***	***		
Comp Mole Frac (CO2)	***	***	***		
Comp Mole Frac (Carbon)	***	***	***		
Comp Mole Frac (H2S)	***	***	***		
Comp Mole Frac (perF-NP)	***	***	***		
Comp Mole Frac (1MIndene)	***	***	***		

Energy Streams

Fluid Pkg: All

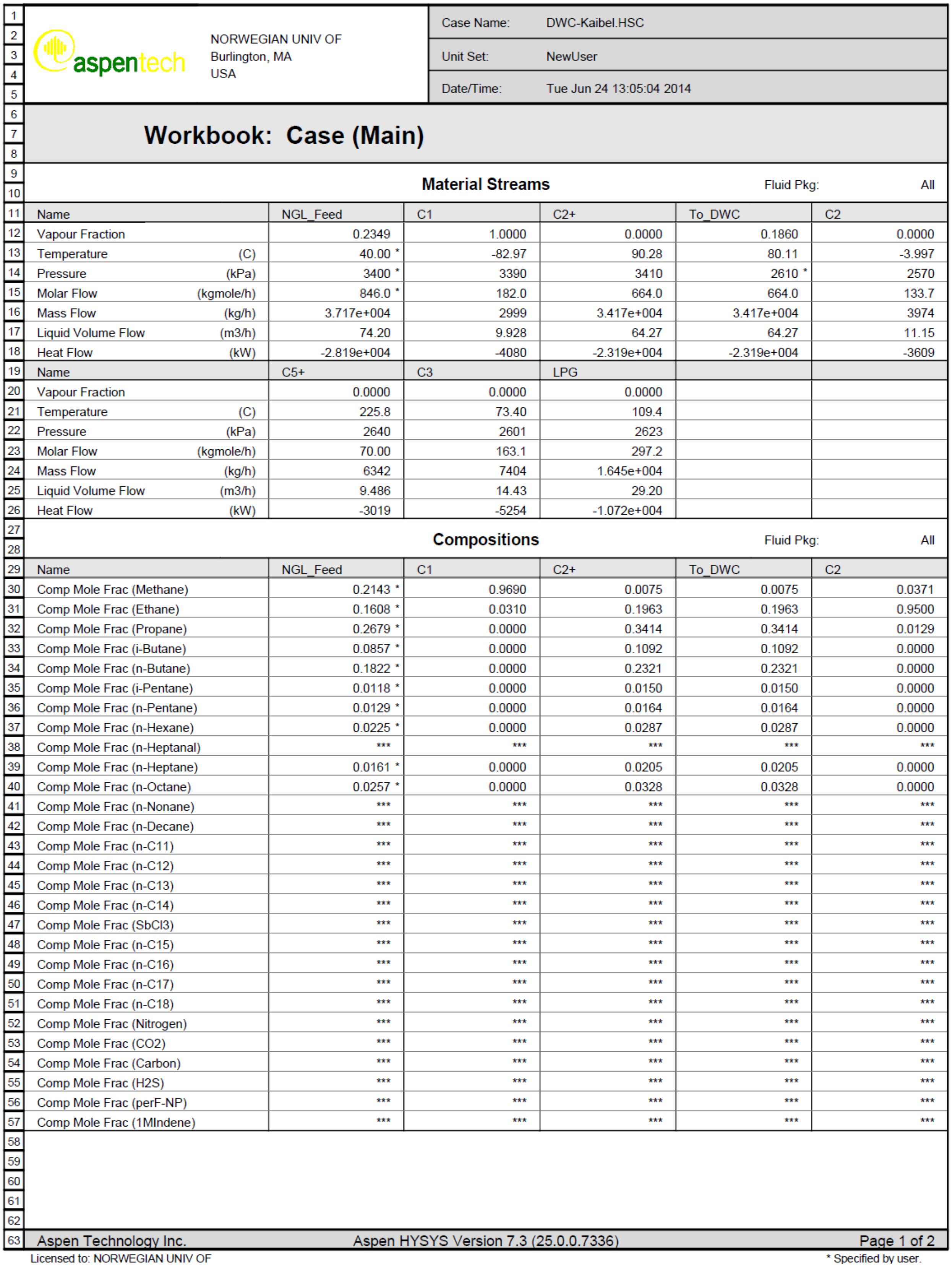
Name	Con Q_DC3	Reb Q_DC3			
Heat Flow (kW)	2811	1939			

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc Level
Reboiler	Reboiler	To Reboiler Reb Q_DC3	Condensate Boilup	No	500.0 *
Main TS	Tray Section	Reflux Boilup To_DC3	To Reboiler To Condenser LPG	No	500.0 *
Condenser	Total Condenser	To Condenser Con Q_DC3	C3 Reflux Con Q_DC3	No	500.0 *

* Specified by user.

7.5 Main Workbook Profile Report for Kaibel DWC Model



NORWEGIAN UNIV OF
Burlington, MA
USA

Case Name: DWC-Kaibel.HSC
Unit Set: NewUser
Date/Time: Tue Jun 24 13:05:04 2014

Workbook: Case (Main)

Material Streams Fluid Pkg: All

Name	NGL_Feed	C1	C2+	To_DWC	C2
Vapour Fraction	0.2349	1.0000	0.0000	0.1860	0.0000
Temperature (C)	40.00 *	-82.97	90.28	80.11	-3.997
Pressure (kPa)	3400 *	3390	3410	2610 *	2570
Molar Flow (kgmole/h)	846.0 *	182.0	664.0	664.0	133.7
Mass Flow (kg/h)	3.717e+004	2999	3.417e+004	3.417e+004	3974
Liquid Volume Flow (m3/h)	74.20	9.928	64.27	64.27	11.15
Heat Flow (kW)	-2.819e+004	-4080	-2.319e+004	-2.319e+004	-3609

Name	C5+	C3	LPG		
Vapour Fraction	0.0000	0.0000	0.0000		
Temperature (C)	225.8	73.40	109.4		
Pressure (kPa)	2640	2601	2623		
Molar Flow (kgmole/h)	70.00	163.1	297.2		
Mass Flow (kg/h)	6342	7404	1.645e+004		
Liquid Volume Flow (m3/h)	9.486	14.43	29.20		
Heat Flow (kW)	-3019	-5254	-1.072e+004		

Compositions Fluid Pkg: All

Name	NGL_Feed	C1	C2+	To_DWC	C2
Comp Mole Frac (Methane)	0.2143 *	0.9690	0.0075	0.0075	0.0371
Comp Mole Frac (Ethane)	0.1608 *	0.0310	0.1963	0.1963	0.9500
Comp Mole Frac (Propane)	0.2679 *	0.0000	0.3414	0.3414	0.0129
Comp Mole Frac (i-Butane)	0.0857 *	0.0000	0.1092	0.1092	0.0000
Comp Mole Frac (n-Butane)	0.1822 *	0.0000	0.2321	0.2321	0.0000
Comp Mole Frac (i-Pentane)	0.0118 *	0.0000	0.0150	0.0150	0.0000
Comp Mole Frac (n-Pentane)	0.0129 *	0.0000	0.0164	0.0164	0.0000
Comp Mole Frac (n-Hexane)	0.0225 *	0.0000	0.0287	0.0287	0.0000
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0161 *	0.0000	0.0205	0.0205	0.0000
Comp Mole Frac (n-Octane)	0.0257 *	0.0000	0.0328	0.0328	0.0000
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

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Workbook: Case (Main) (continued)

Compositions (continued)

Fluid Pkg: All

Name	C5+	C3	LPG		
Comp Mole Frac (Methane)	0.0000	0.0000	0.0000		
Comp Mole Frac (Ethane)	0.0000	0.0090	0.0064		
Comp Mole Frac (Propane)	0.0015	0.8892	0.2686		
Comp Mole Frac (i-Butane)	0.0191	0.0561	0.2087		
Comp Mole Frac (n-Butane)	0.1223	0.0458	0.4647		
Comp Mole Frac (i-Pentane)	0.0694	0.0000	0.0172		
Comp Mole Frac (n-Pentane)	0.0919	0.0000	0.0150		
Comp Mole Frac (n-Hexane)	0.2257	0.0000	0.0109		
Comp Mole Frac (n-Heptanal)	***	***	***		
Comp Mole Frac (n-Heptane)	0.1765	0.0000	0.0043		
Comp Mole Frac (n-Octane)	0.2937	0.0000	0.0040		
Comp Mole Frac (n-Nonane)	***	***	***		
Comp Mole Frac (n-Decane)	***	***	***		
Comp Mole Frac (n-C11)	***	***	***		
Comp Mole Frac (n-C12)	***	***	***		
Comp Mole Frac (n-C13)	***	***	***		
Comp Mole Frac (n-C14)	***	***	***		
Comp Mole Frac (SbCl3)	***	***	***		
Comp Mole Frac (n-C15)	***	***	***		
Comp Mole Frac (n-C16)	***	***	***		
Comp Mole Frac (n-C17)	***	***	***		
Comp Mole Frac (n-C18)	***	***	***		
Comp Mole Frac (Nitrogen)	***	***	***		
Comp Mole Frac (CO2)	***	***	***		
Comp Mole Frac (Carbon)	***	***	***		
Comp Mole Frac (H2S)	***	***	***		
Comp Mole Frac (perF-NP)	***	***	***		
Comp Mole Frac (1MIndene)	***	***	***		

Energy Streams

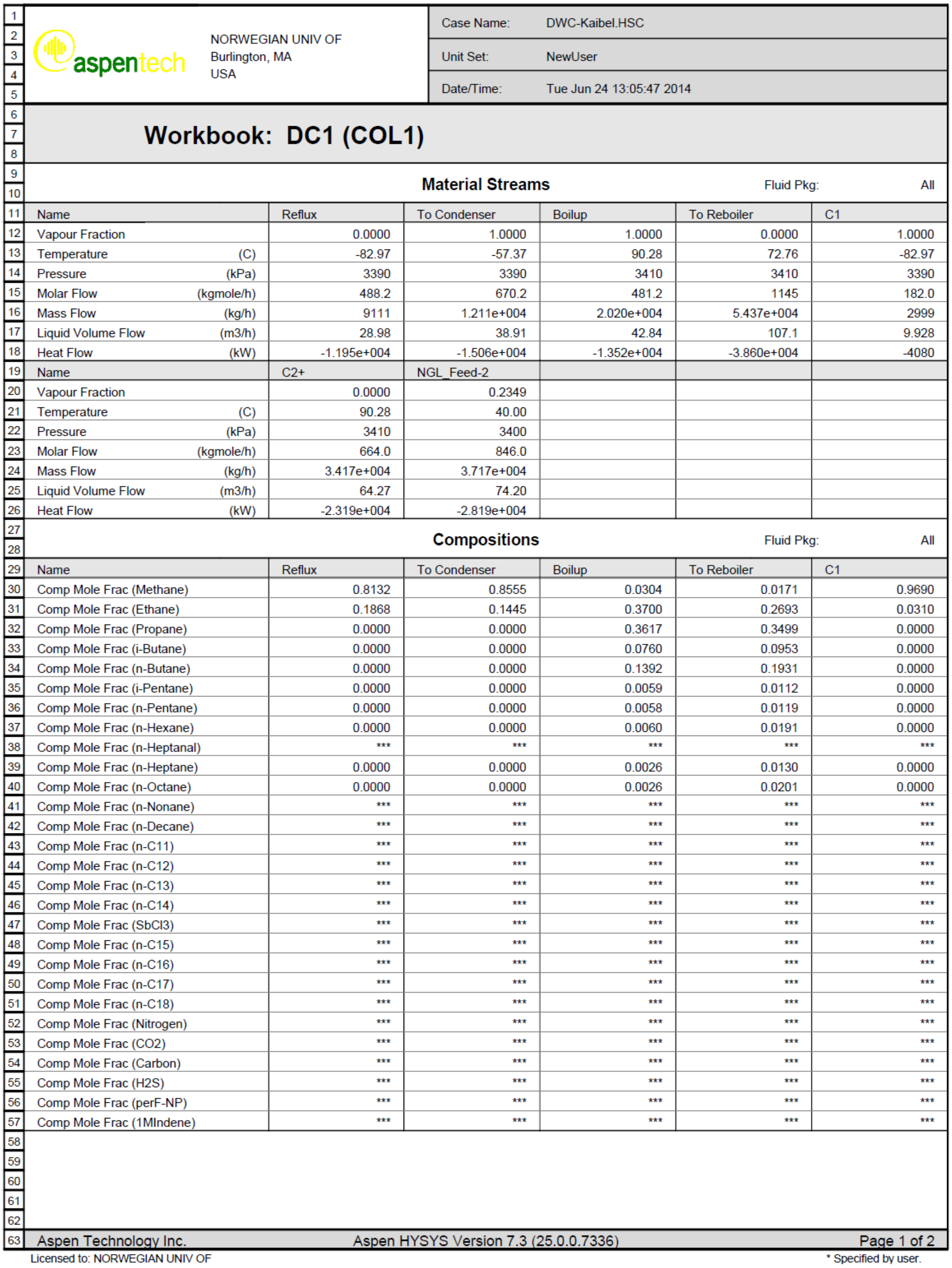
Fluid Pkg: All

Name	Reb Q_DC1	Cond Q_DC1	Q COND-DWC	Q REB-DWC	
Heat Flow (kW)	1890	969.9	2605	3192	

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc Level
DC1	Distillation	NGL_Feed Reb Q_DC1	C2+ C1 Cond Q_DC1	No	2500 *
VLV-100	Valve	C2+	To_DWC	No	500.0 *
DWC	Column Sub-Flowsheet	To_DWC Q REB-DWC	C2 C3 LPG C5+ Q COND-DWC	No	2500 *

7.6 DC1 Column Profile Report for Kaibel DWC Model



NORWEGIAN UNIV OF
Burlington, MA
USA

Case Name: DWC-Kaibel.HSC

Unit Set: NewUser

Date/Time: Tue Jun 24 13:05:47 2014

Workbook: DC1 (COL1)

Material Streams

Fluid Pkg: All

Name	Reflux	To Condenser	Boilup	To Reboiler	C1
Vapour Fraction	0.0000	1.0000	1.0000	0.0000	1.0000
Temperature (C)	-82.97	-57.37	90.28	72.76	-82.97
Pressure (kPa)	3390	3390	3410	3410	3390
Molar Flow (kgmole/h)	488.2	670.2	481.2	1145	182.0
Mass Flow (kg/h)	9111	1.211e+004	2.020e+004	5.437e+004	2999
Liquid Volume Flow (m3/h)	28.98	38.91	42.84	107.1	9.928
Heat Flow (kW)	-1.195e+004	-1.506e+004	-1.352e+004	-3.860e+004	-4080

Name	C2+	NGL_Feed-2			
Vapour Fraction	0.0000	0.2349			
Temperature (C)	90.28	40.00			
Pressure (kPa)	3410	3400			
Molar Flow (kgmole/h)	664.0	846.0			
Mass Flow (kg/h)	3.417e+004	3.717e+004			
Liquid Volume Flow (m3/h)	64.27	74.20			
Heat Flow (kW)	-2.319e+004	-2.819e+004			

Compositions

Fluid Pkg: All

Name	Reflux	To Condenser	Boilup	To Reboiler	C1
Comp Mole Frac (Methane)	0.8132	0.8555	0.0304	0.0171	0.9690
Comp Mole Frac (Ethane)	0.1868	0.1445	0.3700	0.2693	0.0310
Comp Mole Frac (Propane)	0.0000	0.0000	0.3617	0.3499	0.0000
Comp Mole Frac (i-Butane)	0.0000	0.0000	0.0760	0.0953	0.0000
Comp Mole Frac (n-Butane)	0.0000	0.0000	0.1392	0.1931	0.0000
Comp Mole Frac (i-Pentane)	0.0000	0.0000	0.0059	0.0112	0.0000
Comp Mole Frac (n-Pentane)	0.0000	0.0000	0.0058	0.0119	0.0000
Comp Mole Frac (n-Hexane)	0.0000	0.0000	0.0060	0.0191	0.0000
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0000	0.0000	0.0026	0.0130	0.0000
Comp Mole Frac (n-Octane)	0.0000	0.0000	0.0026	0.0201	0.0000
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

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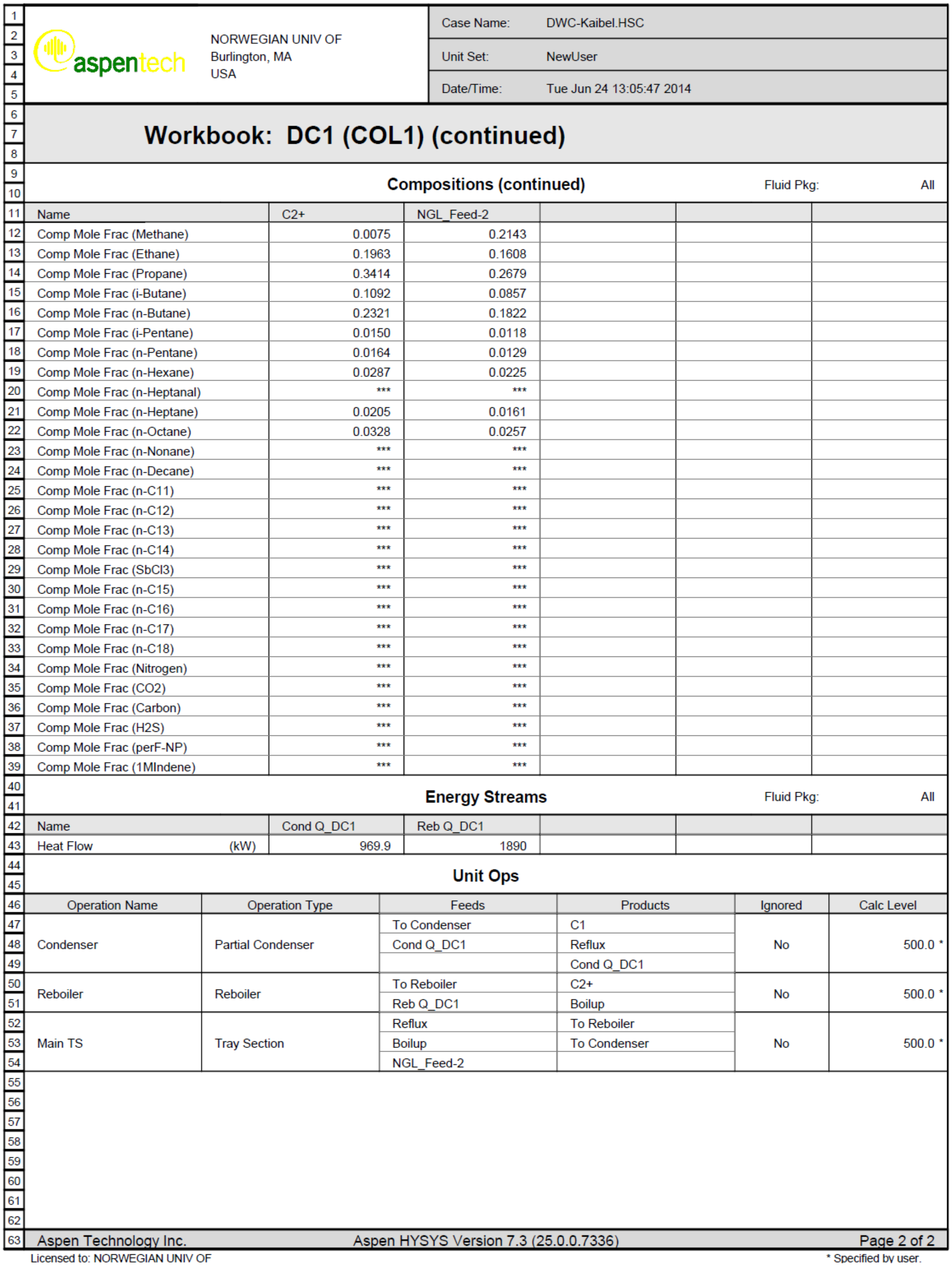

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Burlington, MA
USA

Case Name: DWC-Kaibel.HSC
Unit Set: NewUser
Date/Time: Tue Jun 24 13:05:47 2014

Workbook: DC1 (COL1) (continued)

Compositions (continued)

Fluid Pkg: All

Name	C2+	NGL_Feed-2			
Comp Mole Frac (Methane)	0.0075	0.2143			
Comp Mole Frac (Ethane)	0.1963	0.1608			
Comp Mole Frac (Propane)	0.3414	0.2679			
Comp Mole Frac (i-Butane)	0.1092	0.0857			
Comp Mole Frac (n-Butane)	0.2321	0.1822			
Comp Mole Frac (i-Pentane)	0.0150	0.0118			
Comp Mole Frac (n-Pentane)	0.0164	0.0129			
Comp Mole Frac (n-Hexane)	0.0287	0.0225			
Comp Mole Frac (n-Heptanal)	***	***			
Comp Mole Frac (n-Heptane)	0.0205	0.0161			
Comp Mole Frac (n-Octane)	0.0328	0.0257			
Comp Mole Frac (n-Nonane)	***	***			
Comp Mole Frac (n-Decane)	***	***			
Comp Mole Frac (n-C11)	***	***			
Comp Mole Frac (n-C12)	***	***			
Comp Mole Frac (n-C13)	***	***			
Comp Mole Frac (n-C14)	***	***			
Comp Mole Frac (SbCl3)	***	***			
Comp Mole Frac (n-C15)	***	***			
Comp Mole Frac (n-C16)	***	***			
Comp Mole Frac (n-C17)	***	***			
Comp Mole Frac (n-C18)	***	***			
Comp Mole Frac (Nitrogen)	***	***			
Comp Mole Frac (CO2)	***	***			
Comp Mole Frac (Carbon)	***	***			
Comp Mole Frac (H2S)	***	***			
Comp Mole Frac (perF-NP)	***	***			
Comp Mole Frac (1MIndene)	***	***			

Energy Streams

Fluid Pkg: All

Name	Cond Q_DC1	Reb Q_DC1			
Heat Flow (kW)	969.9	1890			

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc Level
Condenser	Partial Condenser	To Condenser Cond Q_DC1	C1 Reflux Cond Q_DC1	No	500.0 *
Reboiler	Reboiler	To Reboiler Reb Q_DC1	C2+ Boilup	No	500.0 *
Main TS	Tray Section	Reflux Boilup NGL_Feed-2	To Reboiler To Condenser	No	500.0 *

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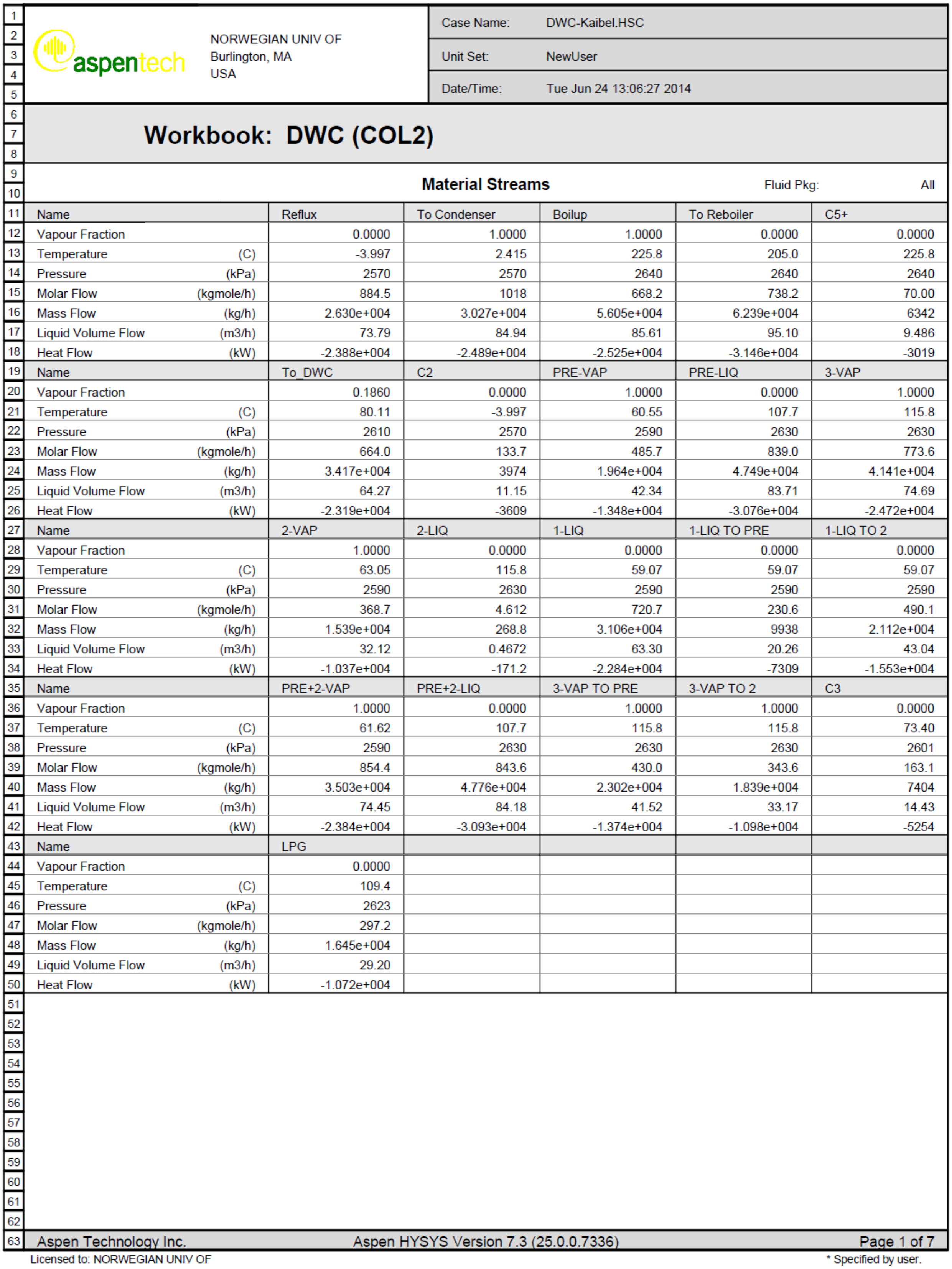
7.7 DWC Column Profile Report for Kaibel DWC Model



NORWEGIAN UNIV OF
Burlington, MA
USA

Case Name: DWC-Kaibel.HSC
Unit Set: NewUser
Date/Time: Tue Jun 24 13:06:27 2014

Workbook: DWC (COL2)

Material Streams Fluid Pkg: All

Name		Reflux	To Condenser	Boilup	To Reboiler	C5+
Vapour Fraction		0.0000	1.0000	1.0000	0.0000	0.0000
Temperature	(C)	-3.997	2.415	225.8	205.0	225.8
Pressure	(kPa)	2570	2570	2640	2640	2640
Molar Flow	(kgmole/h)	884.5	1018	668.2	738.2	70.00
Mass Flow	(kg/h)	2.630e+004	3.027e+004	5.605e+004	6.239e+004	6342
Liquid Volume Flow	(m3/h)	73.79	84.94	85.61	95.10	9.486
Heat Flow	(kW)	-2.388e+004	-2.489e+004	-2.525e+004	-3.146e+004	-3019

Name		To_DWC	C2	PRE-VAP	PRE-LIQ	3-VAP
Vapour Fraction		0.1860	0.0000	1.0000	0.0000	1.0000
Temperature	(C)	80.11	-3.997	60.55	107.7	115.8
Pressure	(kPa)	2610	2570	2590	2630	2630
Molar Flow	(kgmole/h)	664.0	133.7	485.7	839.0	773.6
Mass Flow	(kg/h)	3.417e+004	3974	1.964e+004	4.749e+004	4.141e+004
Liquid Volume Flow	(m3/h)	64.27	11.15	42.34	83.71	74.69
Heat Flow	(kW)	-2.319e+004	-3609	-1.348e+004	-3.076e+004	-2.472e+004

Name		2-VAP	2-LIQ	1-LIQ	1-LIQ TO PRE	1-LIQ TO 2
Vapour Fraction		1.0000	0.0000	0.0000	0.0000	0.0000
Temperature	(C)	63.05	115.8	59.07	59.07	59.07
Pressure	(kPa)	2590	2630	2590	2590	2590
Molar Flow	(kgmole/h)	368.7	4.612	720.7	230.6	490.1
Mass Flow	(kg/h)	1.539e+004	268.8	3.106e+004	9938	2.112e+004
Liquid Volume Flow	(m3/h)	32.12	0.4672	63.30	20.26	43.04
Heat Flow	(kW)	-1.037e+004	-171.2	-2.284e+004	-7309	-1.553e+004

Name		PRE+2-VAP	PRE+2-LIQ	3-VAP TO PRE	3-VAP TO 2	C3
Vapour Fraction		1.0000	0.0000	1.0000	1.0000	0.0000
Temperature	(C)	61.62	107.7	115.8	115.8	73.40
Pressure	(kPa)	2590	2630	2630	2630	2601
Molar Flow	(kgmole/h)	854.4	843.6	430.0	343.6	163.1
Mass Flow	(kg/h)	3.503e+004	4.776e+004	2.302e+004	1.839e+004	7404
Liquid Volume Flow	(m3/h)	74.45	84.18	41.52	33.17	14.43
Heat Flow	(kW)	-2.384e+004	-3.093e+004	-1.374e+004	-1.098e+004	-5254

Name		LPG				
Vapour Fraction		0.0000				
Temperature	(C)	109.4				
Pressure	(kPa)	2623				
Molar Flow	(kgmole/h)	297.2				
Mass Flow	(kg/h)	1.645e+004				
Liquid Volume Flow	(m3/h)	29.20				
Heat Flow	(kW)	-1.072e+004				

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Workbook: DWC (COL2) (continued)

Compositions

Fluid Pkg: All

Name	Reflux	To Condenser	Boilup	To Reboiler	C5+
Comp Mole Frac (Methane)	0.0371	0.0371	0.0000	0.0000	0.0000
Comp Mole Frac (Ethane)	0.9500	0.9500	0.0000	0.0000	0.0000
Comp Mole Frac (Propane)	0.0129	0.0129	0.0032	0.0030	0.0015
Comp Mole Frac (i-Butane)	0.0000	0.0000	0.0330	0.0316	0.0191
Comp Mole Frac (n-Butane)	0.0000	0.0000	0.1988	0.1916	0.1223
Comp Mole Frac (i-Pentane)	0.0000	0.0000	0.0918	0.0897	0.0694
Comp Mole Frac (n-Pentane)	0.0000	0.0000	0.1171	0.1147	0.0919
Comp Mole Frac (n-Hexane)	0.0000	0.0000	0.2266	0.2265	0.2257
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0000	0.0000	0.1412	0.1445	0.1765
Comp Mole Frac (n-Octane)	0.0000	0.0000	0.1884	0.1984	0.2937
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

* Specified by user.

Workbook: DWC (COL2) (continued)

Compositions (continued)

Fluid Pkg: All

Name	To_DWC	C2	PRE-VAP	PRE-LIQ	3-VAP
Comp Mole Frac (Methane)	0.0075	0.0371	0.0109	0.0000	0.0000
Comp Mole Frac (Ethane)	0.1963	0.9500	0.3302	0.0143	0.0155
Comp Mole Frac (Propane)	0.3414	0.0129	0.5673	0.3416	0.3718
Comp Mole Frac (i-Butane)	0.1092	0.0000	0.0451	0.1616	0.1746
Comp Mole Frac (n-Butane)	0.2321	0.0000	0.0465	0.3690	0.3918
Comp Mole Frac (i-Pentane)	0.0150	0.0000	0.0000	0.0197	0.0153
Comp Mole Frac (n-Pentane)	0.0164	0.0000	0.0000	0.0198	0.0133
Comp Mole Frac (n-Hexane)	0.0287	0.0000	0.0000	0.0277	0.0098
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0205	0.0000	0.0000	0.0183	0.0040
Comp Mole Frac (n-Octane)	0.0328	0.0000	0.0000	0.0279	0.0039
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

Workbook: DWC (COL2) (continued)

Compositions (continued)

Fluid Pkg: All

Name	2-VAP	2-LIQ	1-LIQ	1-LIQ TO PRE	1-LIQ TO 2
Comp Mole Frac (Methane)	0.0020	0.0000	0.0015	0.0015	0.0015
Comp Mole Frac (Ethane)	0.2087	0.0062	0.1531	0.1531	0.1531
Comp Mole Frac (Propane)	0.7451	0.2512	0.7611	0.7611	0.7611
Comp Mole Frac (i-Butane)	0.0246	0.1733	0.0430	0.0430	0.0430
Comp Mole Frac (n-Butane)	0.0197	0.4435	0.0414	0.0414	0.0414
Comp Mole Frac (i-Pentane)	0.0000	0.0255	0.0000	0.0000	0.0000
Comp Mole Frac (n-Pentane)	0.0000	0.0245	0.0000	0.0000	0.0000
Comp Mole Frac (n-Hexane)	0.0000	0.0290	0.0000	0.0000	0.0000
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0000	0.0186	0.0000	0.0000	0.0000
Comp Mole Frac (n-Octane)	0.0000	0.0280	0.0000	0.0000	0.0000
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

Workbook: DWC (COL2) (continued)

Compositions (continued)

Fluid Pkg: All

Name	PRE+2-VAP	PRE+2-LIQ	3-VAP TO PRE	3-VAP TO 2	C3
Comp Mole Frac (Methane)	0.0071	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (Ethane)	0.2777	0.0142	0.0155	0.0155	0.0090
Comp Mole Frac (Propane)	0.6440	0.3411	0.3718	0.3718	0.8892
Comp Mole Frac (i-Butane)	0.0362	0.1617	0.1746	0.1746	0.0561
Comp Mole Frac (n-Butane)	0.0349	0.3694	0.3918	0.3918	0.0458
Comp Mole Frac (i-Pentane)	0.0000	0.0197	0.0153	0.0153	0.0000
Comp Mole Frac (n-Pentane)	0.0000	0.0198	0.0133	0.0133	0.0000
Comp Mole Frac (n-Hexane)	0.0000	0.0278	0.0098	0.0098	0.0000
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0000	0.0183	0.0040	0.0040	0.0000
Comp Mole Frac (n-Octane)	0.0000	0.0279	0.0039	0.0039	0.0000
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

Workbook: DWC (COL2) (continued)

Compositions (continued)

Fluid Pkg: All

Name	LPG				
Comp Mole Frac (Methane)	0.0000				
Comp Mole Frac (Ethane)	0.0064				
Comp Mole Frac (Propane)	0.2686				
Comp Mole Frac (i-Butane)	0.2087				
Comp Mole Frac (n-Butane)	0.4647				
Comp Mole Frac (i-Pentane)	0.0172				
Comp Mole Frac (n-Pentane)	0.0150				
Comp Mole Frac (n-Hexane)	0.0109				
Comp Mole Frac (n-Heptanal)	***				
Comp Mole Frac (n-Heptane)	0.0043				
Comp Mole Frac (n-Octane)	0.0040				
Comp Mole Frac (n-Nonane)	***				
Comp Mole Frac (n-Decane)	***				
Comp Mole Frac (n-C11)	***				
Comp Mole Frac (n-C12)	***				
Comp Mole Frac (n-C13)	***				
Comp Mole Frac (n-C14)	***				
Comp Mole Frac (SbCl3)	***				
Comp Mole Frac (n-C15)	***				
Comp Mole Frac (n-C16)	***				
Comp Mole Frac (n-C17)	***				
Comp Mole Frac (n-C18)	***				
Comp Mole Frac (Nitrogen)	***				
Comp Mole Frac (CO2)	***				
Comp Mole Frac (Carbon)	***				
Comp Mole Frac (H2S)	***				
Comp Mole Frac (perF-NP)	***				
Comp Mole Frac (1MIndene)	***				

Energy Streams

Fluid Pkg: All

Name	Q COND-DWC	Q REB-DWC			
Heat Flow (kW)	2605	3192			

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc Level
Reboiler	Reboiler	To Reboiler Q REB-DWC	C5+ Boilup	No	500.0 *
PRE	Tray Section	1-LIQ TO PRE 3-VAP TO PRE To_DWC	PRE-LIQ PRE-VAP	No	500.0 *
1	Tray Section	Reflux PRE+2-VAP	1-LIQ To Condenser	No	500.0 *
2	Tray Section	1-LIQ TO 2 3-VAP TO 2	2-LIQ 2-VAP C3 LPG	No	500.0 *
3	Tray Section	PRE+2-LIQ Boilup	To Reboiler 3-VAP	No	500.0 *
Condenser	Total Condenser	To Condenser Q COND-DWC	C2 Reflux Q COND-DWC	No	500.0 *

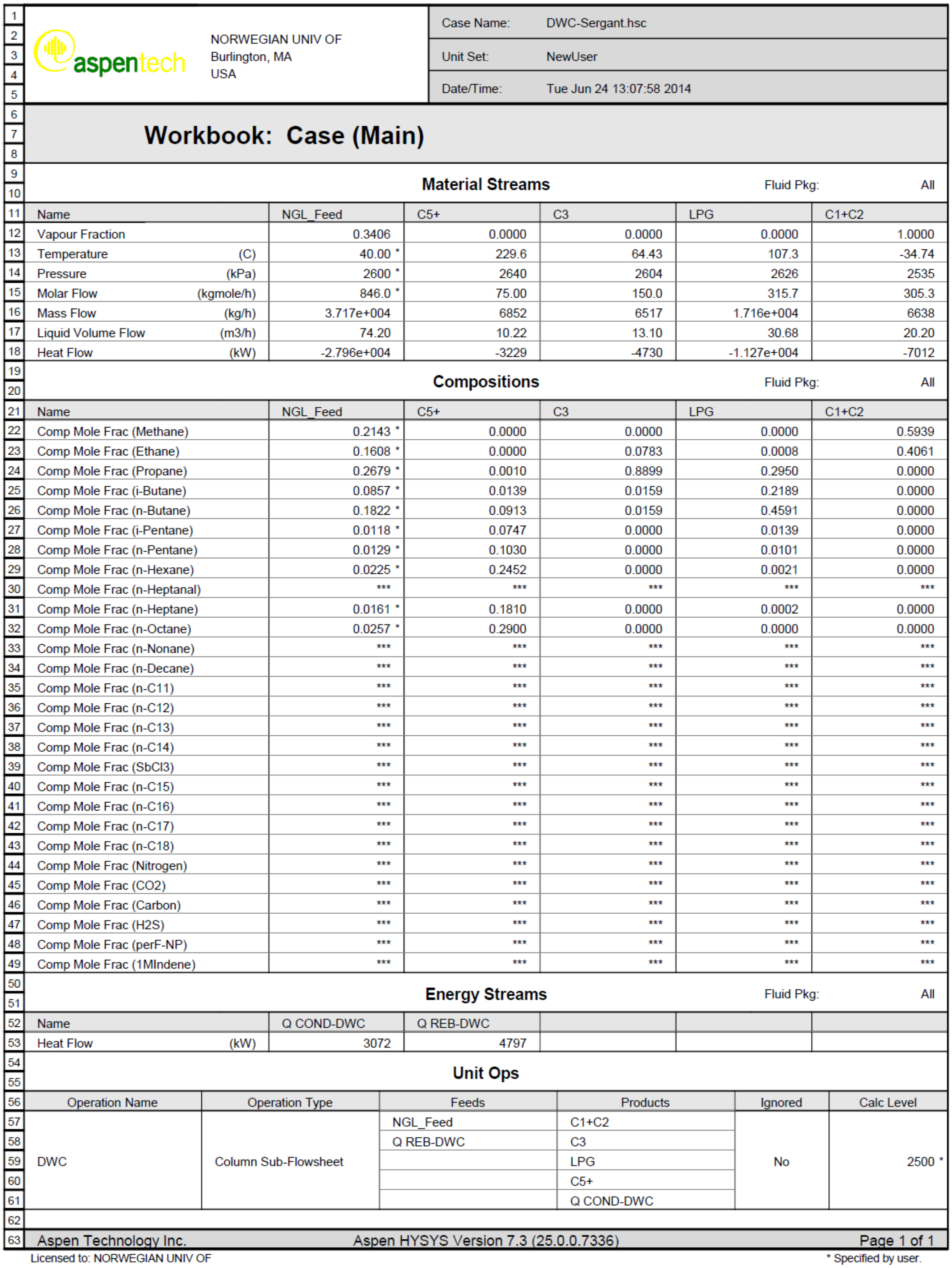
* Specified by user.

Workbook: DWC (COL2) (continued)

Unit Ops (continued)

Operation Name	Operation Type	Feeds	Products	Ignored	Calc Level
TEE_1-LIQ	Tee	1-LIQ	1-LIQ TO PRE 1-LIQ TO 2	No	500.0 *
TEE_3-VAP	Tee	3-VAP	3-VAP TO PRE 3-VAP TO 2	No	500.0 *
MIX_PRE+2-VAP	Mixer	PRE-VAP 2-VAP	PRE+2-VAP	No	500.0 *
MIX_PRE+2-LIQ	Mixer	2-LIQ PRE-LIQ	PRE+2-LIQ	No	500.0 *

7.8 Main Workbook Profile Report for Multi-Partitioned DWC Model



NORWEGIAN UNIV OF
Burlington, MA
USA

Case Name:	DWC-Sergant.hsc
Unit Set:	NewUser
Date/Time:	Tue Jun 24 13:07:58 2014

Workbook: Case (Main)

Material Streams Fluid Pkg: All

Name		NGL_Feed	C5+	C3	LPG	C1+C2
Vapour Fraction		0.3406	0.0000	0.0000	0.0000	1.0000
Temperature	(C)	40.00 *	229.6	64.43	107.3	-34.74
Pressure	(kPa)	2600 *	2640	2604	2626	2535
Molar Flow	(kgmole/h)	846.0 *	75.00	150.0	315.7	305.3
Mass Flow	(kg/h)	3.717e+004	6852	6517	1.716e+004	6638
Liquid Volume Flow	(m3/h)	74.20	10.22	13.10	30.68	20.20
Heat Flow	(kW)	-2.796e+004	-3229	-4730	-1.127e+004	-7012

Compositions Fluid Pkg: All

Name	NGL_Feed	C5+	C3	LPG	C1+C2
Comp Mole Frac (Methane)	0.2143 *	0.0000	0.0000	0.0000	0.5939
Comp Mole Frac (Ethane)	0.1608 *	0.0000	0.0783	0.0008	0.4061
Comp Mole Frac (Propane)	0.2679 *	0.0010	0.8899	0.2950	0.0000
Comp Mole Frac (i-Butane)	0.0857 *	0.0139	0.0159	0.2189	0.0000
Comp Mole Frac (n-Butane)	0.1822 *	0.0913	0.0159	0.4591	0.0000
Comp Mole Frac (i-Pentane)	0.0118 *	0.0747	0.0000	0.0139	0.0000
Comp Mole Frac (n-Pentane)	0.0129 *	0.1030	0.0000	0.0101	0.0000
Comp Mole Frac (n-Hexane)	0.0225 *	0.2452	0.0000	0.0021	0.0000
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0161 *	0.1810	0.0000	0.0002	0.0000
Comp Mole Frac (n-Octane)	0.0257 *	0.2900	0.0000	0.0000	0.0000
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

Energy Streams Fluid Pkg: All

Name		Q COND-DWC	Q REB-DWC
Heat Flow	(kW)	3072	4797

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc Level
DWC	Column Sub-Flowsheet	NGL_Feed Q REB-DWC	C1+C2 C3 LPG C5+ Q COND-DWC	No	2500 *

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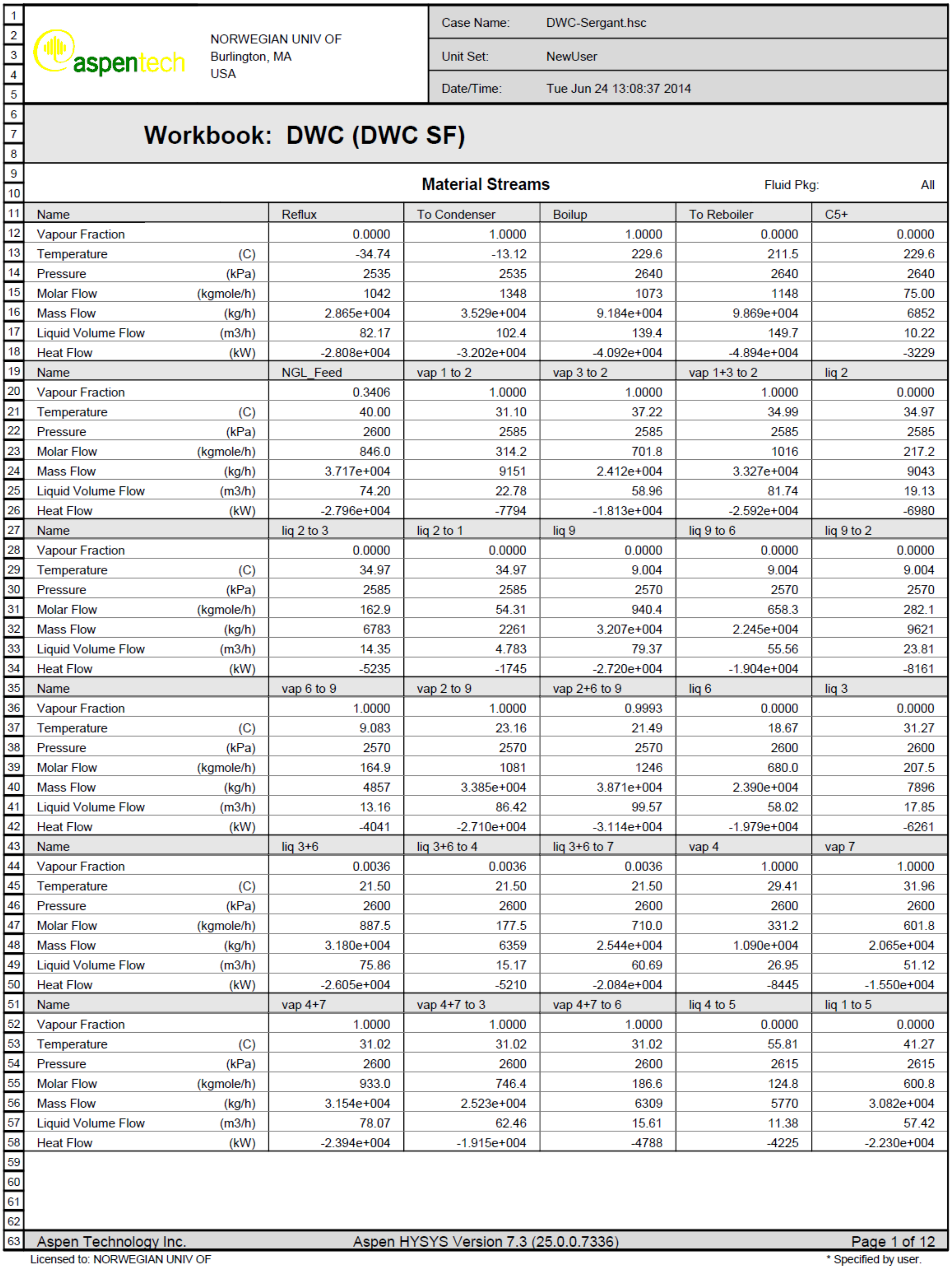
7.9 DWC Column Profile Report for Multi-Partitioned DWC Model



aspentech

NORWEGIAN UNIV OF
Burlington, MA
USA

Case Name: DWC-Sergant.hsc
Unit Set: NewUser
Date/Time: Tue Jun 24 13:08:37 2014

Workbook: DWC (DWC SF)

Material Streams Fluid Pkg: All

Name		Reflux	To Condenser	Boilup	To Reboiler	C5+
Vapour Fraction		0.0000	1.0000	1.0000	0.0000	0.0000
Temperature	(C)	-34.74	-13.12	229.6	211.5	229.6
Pressure	(kPa)	2535	2535	2640	2640	2640
Molar Flow	(kgmole/h)	1042	1348	1073	1148	75.00
Mass Flow	(kg/h)	2.865e+004	3.529e+004	9.184e+004	9.869e+004	6852
Liquid Volume Flow	(m3/h)	82.17	102.4	139.4	149.7	10.22
Heat Flow	(kW)	-2.808e+004	-3.202e+004	-4.092e+004	-4.894e+004	-3229
Name		NGL_Feed	vap 1 to 2	vap 3 to 2	vap 1+3 to 2	liq 2
Vapour Fraction		0.3406	1.0000	1.0000	1.0000	0.0000
Temperature	(C)	40.00	31.10	37.22	34.99	34.97
Pressure	(kPa)	2600	2585	2585	2585	2585
Molar Flow	(kgmole/h)	846.0	314.2	701.8	1016	217.2
Mass Flow	(kg/h)	3.717e+004	9151	2.412e+004	3.327e+004	9043
Liquid Volume Flow	(m3/h)	74.20	22.78	58.96	81.74	19.13
Heat Flow	(kW)	-2.796e+004	-7794	-1.813e+004	-2.592e+004	-6980
Name		liq 2 to 3	liq 2 to 1	liq 9	liq 9 to 6	liq 9 to 2
Vapour Fraction		0.0000	0.0000	0.0000	0.0000	0.0000
Temperature	(C)	34.97	34.97	9.004	9.004	9.004
Pressure	(kPa)	2585	2585	2570	2570	2570
Molar Flow	(kgmole/h)	162.9	54.31	940.4	658.3	282.1
Mass Flow	(kg/h)	6783	2261	3.207e+004	2.245e+004	9621
Liquid Volume Flow	(m3/h)	14.35	4.783	79.37	55.56	23.81
Heat Flow	(kW)	-5235	-1745	-2.720e+004	-1.904e+004	-8161
Name		vap 6 to 9	vap 2 to 9	vap 2+6 to 9	liq 6	liq 3
Vapour Fraction		1.0000	1.0000	0.9993	0.0000	0.0000
Temperature	(C)	9.083	23.16	21.49	18.67	31.27
Pressure	(kPa)	2570	2570	2570	2600	2600
Molar Flow	(kgmole/h)	164.9	1081	1246	680.0	207.5
Mass Flow	(kg/h)	4857	3.385e+004	3.871e+004	2.390e+004	7896
Liquid Volume Flow	(m3/h)	13.16	86.42	99.57	58.02	17.85
Heat Flow	(kW)	-4041	-2.710e+004	-3.114e+004	-1.979e+004	-6261
Name		liq 3+6	liq 3+6 to 4	liq 3+6 to 7	vap 4	vap 7
Vapour Fraction		0.0036	0.0036	0.0036	1.0000	1.0000
Temperature	(C)	21.50	21.50	21.50	29.41	31.96
Pressure	(kPa)	2600	2600	2600	2600	2600
Molar Flow	(kgmole/h)	887.5	177.5	710.0	331.2	601.8
Mass Flow	(kg/h)	3.180e+004	6359	2.544e+004	1.090e+004	2.065e+004
Liquid Volume Flow	(m3/h)	75.86	15.17	60.69	26.95	51.12
Heat Flow	(kW)	-2.605e+004	-5210	-2.084e+004	-8445	-1.550e+004
Name		vap 4+7	vap 4+7 to 3	vap 4+7 to 6	liq 4 to 5	liq 1 to 5
Vapour Fraction		1.0000	1.0000	1.0000	0.0000	0.0000
Temperature	(C)	31.02	31.02	31.02	55.81	41.27
Pressure	(kPa)	2600	2600	2600	2615	2615
Molar Flow	(kgmole/h)	933.0	746.4	186.6	124.8	600.8
Mass Flow	(kg/h)	3.154e+004	2.523e+004	6309	5770	3.082e+004
Liquid Volume Flow	(m3/h)	78.07	62.46	15.61	11.38	57.42
Heat Flow	(kW)	-2.394e+004	-1.915e+004	-4788	-4225	-2.230e+004

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Workbook: DWC (DWC SF) (continued)

Material Streams (continued)

Fluid Pkg: All

Name		liq 1+4 to 5	vap 5	vap 5 to 1	vap 5 to 4	liq 5 to 8
Vapour Fraction		0.0000	1.0000	1.0000	1.0000	0.0000
Temperature	(C)	43.86	61.54	61.54	61.54	109.5
Pressure	(kPa)	2615	2615	2615	2615	2630
Molar Flow	(kgmole/h)	725.6	293.1	14.66	278.5	1127
Mass Flow	(kg/h)	3.659e+004	1.085e+004	542.5	1.031e+004	6.354e+004
Liquid Volume Flow	(m3/h)	68.80	24.37	1.219	23.15	112.0
Heat Flow	(kW)	-2.653e+004	-7852	-392.6	-7460	-4.113e+004
Name		liq 7 to 8	liq 5+7 to 8	vap 8	vap 8 to 5	vap 8 to 7
Vapour Fraction		0.0000	0.0004	1.0000	1.0000	1.0000
Temperature	(C)	115.6	110.4	117.5	117.5	117.5
Pressure	(kPa)	2630	2630	2630	2630	2630
Molar Flow	(kgmole/h)	211.0	1338	1263	694.8	568.5
Mass Flow	(kg/h)	1.204e+004	7.558e+004	6.872e+004	3.780e+004	3.093e+004
Liquid Volume Flow	(m3/h)	21.06	133.1	122.8	67.56	55.27
Heat Flow	(kW)	-7714	-4.884e+004	-4.081e+004	-2.245e+004	-1.837e+004
Name		C1+C2	C3	LPG		
Vapour Fraction		1.0000	0.0000	0.0000		
Temperature	(C)	-34.74	64.43	107.3		
Pressure	(kPa)	2535	2604	2626		
Molar Flow	(kgmole/h)	305.3	150.0	315.7		
Mass Flow	(kg/h)	6638	6517	1.716e+004		
Liquid Volume Flow	(m3/h)	20.20	13.10	30.68		
Heat Flow	(kW)	-7012	-4730	-1.127e+004		

* Specified by user.

Workbook: DWC (DWC SF) (continued)

Compositions

Fluid Pkg: All

Name	Reflux	To Condenser	Boilup	To Reboiler	C5+
Comp Mole Frac (Methane)	0.1846	0.2773	0.0000	0.0000	0.0000
Comp Mole Frac (Ethane)	0.8154	0.7227	0.0000	0.0000	0.0000
Comp Mole Frac (Propane)	0.0000	0.0000	0.0021	0.0020	0.0010
Comp Mole Frac (i-Butane)	0.0000	0.0000	0.0238	0.0232	0.0139
Comp Mole Frac (n-Butane)	0.0000	0.0000	0.1474	0.1437	0.0913
Comp Mole Frac (i-Pentane)	0.0000	0.0000	0.0993	0.0977	0.0747
Comp Mole Frac (n-Pentane)	0.0000	0.0000	0.1321	0.1302	0.1030
Comp Mole Frac (n-Hexane)	0.0000	0.0000	0.2511	0.2507	0.2452
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0000	0.0000	0.1496	0.1517	0.1810
Comp Mole Frac (n-Octane)	0.0000	0.0000	0.1946	0.2008	0.2900
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

Workbook: DWC (DWC SF) (continued)

Compositions (continued)

Fluid Pkg: All

Name	NGL_Feed	vap 1 to 2	vap 3 to 2	vap 1+3 to 2	liq 2
Comp Mole Frac (Methane)	0.2143	0.4503	0.0653	0.1844	0.0355
Comp Mole Frac (Ethane)	0.1608	0.2487	0.6128	0.5002	0.3273
Comp Mole Frac (Propane)	0.2679	0.2186	0.2718	0.2554	0.4152
Comp Mole Frac (i-Butane)	0.0857	0.0298	0.0147	0.0194	0.0608
Comp Mole Frac (n-Butane)	0.1822	0.0525	0.0353	0.0406	0.1612
Comp Mole Frac (i-Pentane)	0.0118	0.0000	0.0000	0.0000	0.0001
Comp Mole Frac (n-Pentane)	0.0129	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Hexane)	0.0225	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0161	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Octane)	0.0257	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

Workbook: DWC (DWC SF) (continued)

Compositions (continued)

Fluid Pkg: All

Name	liq 2 to 3	liq 2 to 1	liq 9	liq 9 to 6	liq 9 to 2
Comp Mole Frac (Methane)	0.0355	0.0355	0.0385	0.0385	0.0385
Comp Mole Frac (Ethane)	0.3273	0.3273	0.6558	0.6558	0.6558
Comp Mole Frac (Propane)	0.4152	0.4152	0.2856	0.2856	0.2856
Comp Mole Frac (i-Butane)	0.0608	0.0608	0.0104	0.0104	0.0104
Comp Mole Frac (n-Butane)	0.1612	0.1612	0.0098	0.0098	0.0098
Comp Mole Frac (i-Pentane)	0.0001	0.0001	0.0000	0.0000	0.0000
Comp Mole Frac (n-Pentane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Hexane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Octane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

* Specified by user.

Workbook: DWC (DWC SF) (continued)

Compositions (continued)

Fluid Pkg: All

Name	vap 6 to 9	vap 2 to 9	vap 2+6 to 9	liq 6	liq 3
Comp Mole Frac (Methane)	0.1639	0.1762	0.1746	0.0132	0.0124
Comp Mole Frac (Ethane)	0.7190	0.5756	0.5946	0.6326	0.4399
Comp Mole Frac (Propane)	0.1136	0.2311	0.2156	0.3334	0.5144
Comp Mole Frac (i-Butane)	0.0020	0.0087	0.0078	0.0107	0.0133
Comp Mole Frac (n-Butane)	0.0014	0.0083	0.0074	0.0101	0.0200
Comp Mole Frac (i-Pentane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Pentane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Hexane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Octane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

Workbook: DWC (DWC SF) (continued)

Compositions (continued)

Fluid Pkg: All

Name	liq 3+6	liq 3+6 to 4	liq 3+6 to 7	vap 4	vap 7
Comp Mole Frac (Methane)	0.0130	0.0130	0.0130	0.1331	0.0153
Comp Mole Frac (Ethane)	0.5875	0.5875	0.5875	0.5405	0.6748
Comp Mole Frac (Propane)	0.3758	0.3758	0.3758	0.3184	0.3023
Comp Mole Frac (i-Butane)	0.0113	0.0113	0.0113	0.0046	0.0041
Comp Mole Frac (n-Butane)	0.0124	0.0124	0.0124	0.0035	0.0035
Comp Mole Frac (i-Pentane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Pentane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Hexane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Octane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

Workbook: DWC (DWC SF) (continued)

Compositions (continued)

Fluid Pkg: All

Name	vap 4+7	vap 4+7 to 3	vap 4+7 to 6	liq 4 to 5	liq 1 to 5
Comp Mole Frac (Methane)	0.0571	0.0571	0.0571	0.0290	0.0735
Comp Mole Frac (Ethane)	0.6271	0.6271	0.6271	0.1871	0.1345
Comp Mole Frac (Propane)	0.3080	0.3080	0.3080	0.4194	0.3085
Comp Mole Frac (i-Butane)	0.0043	0.0043	0.0043	0.1285	0.1120
Comp Mole Frac (n-Butane)	0.0035	0.0035	0.0035	0.2149	0.2459
Comp Mole Frac (i-Pentane)	0.0000	0.0000	0.0000	0.0069	0.0167
Comp Mole Frac (n-Pentane)	0.0000	0.0000	0.0000	0.0062	0.0182
Comp Mole Frac (n-Hexane)	0.0000	0.0000	0.0000	0.0050	0.0318
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0000	0.0000	0.0000	0.0017	0.0227
Comp Mole Frac (n-Octane)	0.0000	0.0000	0.0000	0.0014	0.0362
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

* Specified by user.

Workbook: DWC (DWC SF) (continued)

Compositions (continued)

Fluid Pkg: All

Name	liq 1+4 to 5	vap 5	vap 5 to 1	vap 5 to 4	liq 5 to 8
Comp Mole Frac (Methane)	0.0659	0.1630	0.1630	0.1630	0.0000
Comp Mole Frac (Ethane)	0.1435	0.3521	0.3521	0.3521	0.0020
Comp Mole Frac (Propane)	0.3275	0.3270	0.3270	0.3270	0.3318
Comp Mole Frac (i-Butane)	0.1148	0.0558	0.0558	0.0558	0.1734
Comp Mole Frac (n-Butane)	0.2406	0.0925	0.0925	0.0925	0.3953
Comp Mole Frac (i-Pentane)	0.0150	0.0031	0.0031	0.0031	0.0208
Comp Mole Frac (n-Pentane)	0.0161	0.0028	0.0028	0.0028	0.0196
Comp Mole Frac (n-Hexane)	0.0271	0.0022	0.0022	0.0022	0.0220
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0191	0.0008	0.0008	0.0008	0.0140
Comp Mole Frac (n-Octane)	0.0302	0.0006	0.0006	0.0006	0.0211
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

Workbook: DWC (DWC SF) (continued)

Compositions (continued)

Fluid Pkg: All

Name	liq 7 to 8	liq 5+7 to 8	vap 8	vap 8 to 5	vap 8 to 7
Comp Mole Frac (Methane)	0.0000	0.0000	0.0000	0.0000	0.0000
Comp Mole Frac (Ethane)	0.0008	0.0018	0.0019	0.0019	0.0019
Comp Mole Frac (Propane)	0.2289	0.3156	0.3343	0.3343	0.3343
Comp Mole Frac (i-Butane)	0.1860	0.1754	0.1850	0.1850	0.1850
Comp Mole Frac (n-Butane)	0.4898	0.4102	0.4292	0.4292	0.4292
Comp Mole Frac (i-Pentane)	0.0316	0.0225	0.0194	0.0194	0.0194
Comp Mole Frac (n-Pentane)	0.0282	0.0209	0.0160	0.0160	0.0160
Comp Mole Frac (n-Hexane)	0.0192	0.0215	0.0083	0.0083	0.0083
Comp Mole Frac (n-Heptanal)	***	***	***	***	***
Comp Mole Frac (n-Heptane)	0.0080	0.0130	0.0031	0.0031	0.0031
Comp Mole Frac (n-Octane)	0.0077	0.0190	0.0029	0.0029	0.0029
Comp Mole Frac (n-Nonane)	***	***	***	***	***
Comp Mole Frac (n-Decane)	***	***	***	***	***
Comp Mole Frac (n-C11)	***	***	***	***	***
Comp Mole Frac (n-C12)	***	***	***	***	***
Comp Mole Frac (n-C13)	***	***	***	***	***
Comp Mole Frac (n-C14)	***	***	***	***	***
Comp Mole Frac (SbCl3)	***	***	***	***	***
Comp Mole Frac (n-C15)	***	***	***	***	***
Comp Mole Frac (n-C16)	***	***	***	***	***
Comp Mole Frac (n-C17)	***	***	***	***	***
Comp Mole Frac (n-C18)	***	***	***	***	***
Comp Mole Frac (Nitrogen)	***	***	***	***	***
Comp Mole Frac (CO2)	***	***	***	***	***
Comp Mole Frac (Carbon)	***	***	***	***	***
Comp Mole Frac (H2S)	***	***	***	***	***
Comp Mole Frac (perF-NP)	***	***	***	***	***
Comp Mole Frac (1MIndene)	***	***	***	***	***

Workbook: DWC (DWC SF) (continued)

Compositions (continued)

Fluid Pkg: All

Name	C1+C2	C3	LPG		
Comp Mole Frac (Methane)	0.5939	0.0000	0.0000		
Comp Mole Frac (Ethane)	0.4061	0.0783	0.0008		
Comp Mole Frac (Propane)	0.0000	0.8899	0.2950		
Comp Mole Frac (i-Butane)	0.0000	0.0159	0.2189		
Comp Mole Frac (n-Butane)	0.0000	0.0159	0.4591		
Comp Mole Frac (i-Pentane)	0.0000	0.0000	0.0139		
Comp Mole Frac (n-Pentane)	0.0000	0.0000	0.0101		
Comp Mole Frac (n-Hexane)	0.0000	0.0000	0.0021		
Comp Mole Frac (n-Heptanal)	***	***	***		
Comp Mole Frac (n-Heptane)	0.0000	0.0000	0.0002		
Comp Mole Frac (n-Octane)	0.0000	0.0000	0.0000		
Comp Mole Frac (n-Nonane)	***	***	***		
Comp Mole Frac (n-Decane)	***	***	***		
Comp Mole Frac (n-C11)	***	***	***		
Comp Mole Frac (n-C12)	***	***	***		
Comp Mole Frac (n-C13)	***	***	***		
Comp Mole Frac (n-C14)	***	***	***		
Comp Mole Frac (SbCl3)	***	***	***		
Comp Mole Frac (n-C15)	***	***	***		
Comp Mole Frac (n-C16)	***	***	***		
Comp Mole Frac (n-C17)	***	***	***		
Comp Mole Frac (n-C18)	***	***	***		
Comp Mole Frac (Nitrogen)	***	***	***		
Comp Mole Frac (CO2)	***	***	***		
Comp Mole Frac (Carbon)	***	***	***		
Comp Mole Frac (H2S)	***	***	***		
Comp Mole Frac (perF-NP)	***	***	***		
Comp Mole Frac (1MIndene)	***	***	***		

Energy Streams

Fluid Pkg: All

Name	Q COND-DWC	Q REB-DWC			
Heat Flow (kW)	3072	4797			

Unit Ops

Operation Name	Operation Type	Feeds	Products	Ignored	Calc Level
Reboiler	Reboiler	To Reboiler Q REB-DWC	C5+ Boilup	No	500.0 *
1	Tray Section	liq 2 to 1 vap 5 to 1 NGL_Feed	liq 1 to 5 vap 1 to 2	No	500.0 *
9	Tray Section	Reflux vap 2+6 to 9	liq 9 To Condenser	No	500.0 *
6	Tray Section	liq 9 to 6 vap 4+7 to 6	liq 6 vap 6 to 9	No	500.0 *
8	Tray Section	liq 5+7 to 8 Boilup	To Reboiler vap 8	No	500.0 *
2	Tray Section	liq 9 to 2 vap 1+3 to 2	liq 2 vap 2 to 9	No	500.0 *
5	Tray Section	liq 1+4 to 5 vap 8 to 5	liq 5 to 8 vap 5	No	500.0 *
3	Tray Section	liq 2 to 3	liq 3	No	500.0 *

* Specified by user.

Workbook: DWC (DWC SF) (continued)

Unit Ops (continued)

Operation Name	Operation Type	Feeds	Products	Ignored	Calc Level
3	Tray Section	vap 4+7 to 3	vap 3 to 2	No	500.0 *
4	Tray Section	liq 3+6 to 4 vap 5 to 4	liq 4 to 5 vap 4	No	500.0 *
7	Tray Section	liq 3+6 to 7 vap 8 to 7	liq 7 to 8 vap 7 C3 LPG	No	500.0 *
Condenser	Partial Condenser	To Condenser Q COND-DWC	C1+C2 Reflux Q COND-DWC	No	500.0 *
MIX-vap 1+3	Mixer	vap 1 to 2 vap 3 to 2	vap 1+3 to 2	No	500.0 *
MIX-vap 2+6 to 9	Mixer	vap 2 to 9 vap 6 to 9	vap 2+6 to 9	No	500.0 *
MIX-liq 3+6	Mixer	liq 3 liq 6	liq 3+6	No	500.0 *
MIX-vap 4+7	Mixer	vap 4 vap 7	vap 4+7	No	500.0 *
MIX-liq 1+4	Mixer	liq 1 to 5 liq 4 to 5	liq 1+4 to 5	No	500.0 *
MIX-liq 5+7	Mixer	liq 7 to 8 liq 5 to 8	liq 5+7 to 8	No	500.0 *
TEE-liq 2	Tee	liq 2	liq 2 to 3 liq 2 to 1	No	500.0 *
TEE-liq 9	Tee	liq 9	liq 9 to 6 liq 9 to 2	No	500.0 *
TEE-liq 3+6 to 4+7	Tee	liq 3+6	liq 3+6 to 4 liq 3+6 to 7	No	500.0 *
TEE-vap 4+7 to 3+6	Tee	vap 4+7	vap 4+7 to 3 vap 4+7 to 6	No	500.0 *
TEE-vap 5 to 1+4	Tee	vap 5	vap 5 to 1 vap 5 to 4	No	500.0 *
TEE-vap 8 to 5+7	Tee	vap 8	vap 8 to 5 vap 8 to 7	No	500.0 *

* Specified by user.

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