BENEFITS OF INTEGRATING NGL EXTRACTION AND LNG LIQUEFACTION TECHNOLOGY

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Abstract

The combination of changing global markets for natural gas liquids (NGL) with the simultaneous increase in global demand for liquefied natural gas (LNG) has stimulated an interest in the integration of NGL recovery technology with LNG liquefaction technologies. Historically, the removal of "heavy" or high-freezing-point hydrocarbons from the feed to LNG plants has been characterized as "gas conditioning" and achieved using one or more distillation columns. While some attempts to provide reflux to the distillation columns marginally enhanced NGL recovery, little emphasis was placed on maximizing NGL recovery as a product from the LNG process. As such, the integration of the two processes was not a priority. Integrating state-of-the art NGL recovery technology within the *CoP LNG^{SM} Process*[1], formerly the Phillips Optimized Cascade LNG Process, results in a significant reduction in the specific power required to produce LNG, while maximizing NGL recovery. This corresponds to a production increase in both LNG and NGL for comparable compression schemes as compared to stand-alone LNG liquefaction and NGL extraction facilities. In addition, there are potential enhancements to the overall facility availability and project economics using the integrated concept. This integrated concept has been applied to three ongoing international NGL/LNG projects using the CoP LNG Process. In these cases, LNG production has increased by approximately 7%, while using the same process horsepower.

1.0 Introduction

Due to clean burning characteristics and the ability to meet stringent environmental requirements, the demand for natural gas has increased considerably over the past few years. Projections reflect a continued increase for the next several years. However, it is a clean burning methane rich gas that is in demand as opposed to the typical raw gas that exists in nature, which often includes additional components such as heavier hydrocarbons and other impurities. The heavier hydrocarbons, once separated from natural gas, are referred to as Liquefied Petroleum Gas (LPG) and Natural Gas Liquids (NGL). Impurities may include carbon dioxide, hydrogen sulfide, mercaptans, nitrogen, helium, water, and even trace contaminants such as mercury and trimethylarsine. Natural gas must be "conditioned" prior to liquefaction to remove undesired components. This "conditioning" normally takes place in separate or stand-alone facilities and typically includes the extraction of heavier hydrocarbons such as LPG and NGL. The "conditioned" gas is then typically fed to pipelines for distribution.

However, transportation to distant markets through gas pipelines is not always economically or technically feasible. As such, natural gas liquefaction has become a viable and widely accepted alternative. The economics of liquefying natural gas is feasible due mainly to the great volume reduction achieved upon liquefying, which creates the ability to store and transport large volumes. The demand for Liquefied Natural Gas (LNG) in North America has increased considerably as energy demands have increased at the same time wellhead gas supply to pipelines has decreased. LNG is a natural alternative to supplement gas pipelines as the infrastructure to process and burn the gas is largely in place. In addition, LNG is a highly reliable source of gas. For instance, ConocoPhillips' Kenai, Alaska facility, which utilizes the CoP LNG Process, has supplied LNG to Japan for over thirty-five years without missing a single cargo.

Figure 1 is an aerial view of the recently constructed Atlantic LNG facility located in Point Fortin, Trinidad, comprised of three trains and a fourth under construction, all utilizing a modernized version of the CoP LNG Process.

Figure 1 – The Atlantic LNG Facility – Artist Rendition, Courtesy of Atlantic LNG Company of Trinidad & Tobago

Pentanes and heavier hydrocarbons, including aromatics having a high freezing point, must be substantially removed to an extremely low level in order to prevent freezing and subsequent plugging of process equipment in the course of liquefaction. In addition, heavy components must also be removed in order to meet BTU requirements of the LNG product. The heavy hydrocarbons separated from LNG, may then be utilized as petrochemical sales or for gasoline blending. In fact, NGL and/or LPG liquids may command a greater value than LNG. Many efforts have focused on recovery of these heavy hydrocarbons. However, most of the effort has been placed on removal of the heavy hydrocarbons in a separate NGL plant, located upstream of the LNG liquefaction facility.

Alternatively, since all components having a higher condensing temperature than methane will be liquefied in the liquefaction process, it becomes technically practical to integrate NGL recovery within LNG liquefaction. Duplication of processing equipment and refrigeration requirements are avoided with an integrated approach. In fact, a substantial cost savings may be achieved when NGL recovery is effectively integrated within the liquefaction process.

There have been attempts for NGL recovery within the LNG facility.(1) For example, lighter NGL components are recovered in conjunction with the removal of C_5+ hydrocarbons using a scrub column in a propane pre-cooled mixed refrigerant process, as disclosed in the literature.(2, 3) The NGL recovery column is often required to operate at a relatively high pressure (typically above 550 psig) in order to conserve refrigeration compression horsepower requirements. Although refrigeration horsepower is conserved utilizing a high-pressure column, separation efficiency is often significantly reduced due to less favorable operating conditions, *i.e.* lower relative volatility.

With careful integration of the NGL recovery and LNG processes, the overall efficiency of the integrated process can be significantly improved, thereby increasing NGL recovery and reducing specific power consumption.(4) This paper provides examples of NGL recovery technology integrated within the CoP LNG Process, while also presenting recovery and efficiency performance.

2.0 Traditional Stand-Alone Gas Plant Upstream of Liquefaction Plant

A number of NGL recovery processes have been developed for natural gas and other gas streams.(5, 6, 7) Among various NGL recovery processes, the cryogenic expansion process has become the preferred process for deep hydrocarbon liquid recovery from natural gas streams. Figure 2 depicts a typical cryogenic expansion process configuration. In the conventional turbo-expander process, feed gas at elevated pressure is pretreated for removal of acid gases, water, mercury and other contaminants to produce a purified gas suitable for cryogenic temperatures. The treated gas is typically partially condensed utilizing heat exchange with other process streams and/or external propane refrigeration, depending upon the gas composition. The resulting condensed liquid, containing the less volatile components, is then separated and fed to a medium or low-pressure fractionation column for recovery of the heavy hydrocarbon components. The remaining non-condensed vapor, containing the more volatile components, is expanded to the lower pressure of the column using a turbo-expander, resulting in further cooling and additional liquid condensation. With the expander discharge pressure essentially the same as the column pressure, the resulting two-phase stream is fed to the top section of the fractionation column. The cold liquid portion acts as reflux, enhancing recovery of heavier hydrocarbon components. The vapor portion combines with the gas in the overhead of the column. The combined gas exits the column overhead as a residue gas. After recovery of available refrigeration, the residue gas is then recompressed to a higher pressure, suitable for pipeline delivery or for LNG liquefaction.

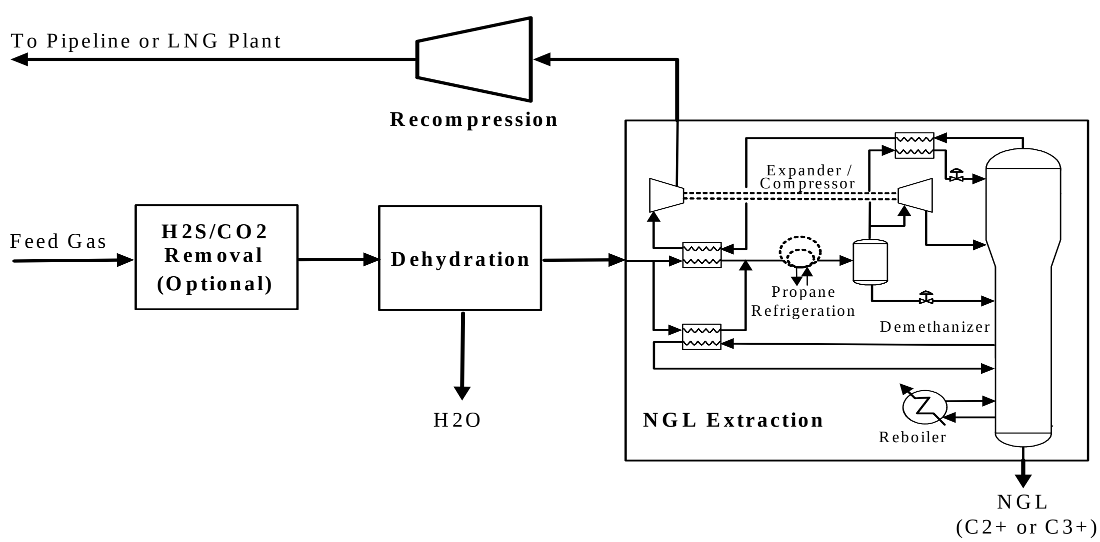

Figure 2 - Block diagram for typical NGL extraction plant

The fractionation column (as described) acts essentially as a stripping column since expander discharge vapors are not subject to rectification. As such, a significant quantity of heavy components remains in the gas stream. These components could be further recovered if subjected to rectification. In an attempt to achieve greater liquid recoveries, recent efforts have focused on the addition of a rectification section and methods to effectively generate an optimal rectification reflux stream, e.g. the gas subcooled reflux illustrated in Figure 2.

Figure 3 illustrates a typical block diagram of the LNG facility. Gas comprising predominantly methane enters the LNG facility at elevated pressures and is pretreated to produce a feedstock suitable for liquefaction at cryogenic temperatures. Pretreatment typically includes the removal of acid gases (hydrogen sulfide and carbon dioxide), mercaptans, water, mercury, and other contaminants. The treated gas is then subjected to a plurality of cooling stages by indirect heat exchange with one or more refrigerants, whereby the gas is progressively reduced in temperature until complete liquefaction. The pressurized LNG is further expanded and sub-cooled in one or more stages to facilitate storage at slightly above atmospheric pressure. Flashed vapors and boil off gas are recycled within the process.

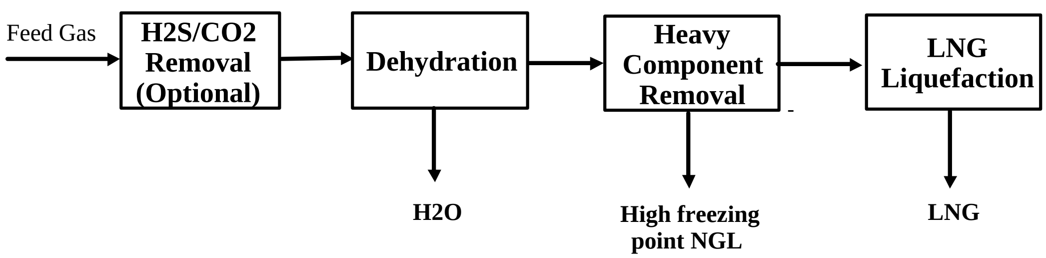

Figure 3 - Block diagram for typical LNG plant

Because LNG liquefaction requires a significant amount of refrigeration energy, the refrigeration system(s) represent a large portion of a LNG facility. A number of liquefaction processes have been developed with the differences mainly residing on the type of refrigeration cycles employed. The most commonly utilized LNG technologies are:

1) ***CoP LNG^{SM} Process*****(8)** This process, formerly known as the Phillips Optimized Cascade LNG Process, utilizes essentially pure refrigerant components in an integrated cascade arrangement. The process offers high efficiency and reliability. Brazed aluminum exchangers are largely used for heat transfer area, providing for a robust facility that is easy to operate and maintain. Refrigerants typically employed are propane, ethylene and methane.

2) **Propane pre-cooled mixed refrigerant process(9, 10)** This mixed refrigerant process provides an efficient process utilizing a multi-component mixture of hydrocarbons typically comprising propane, ethane, methane, and optionally other light components in one cycle. A large spiral wound exchanger is utilized for the majority of heat transfer area. A separate

propane refrigeration cycle is utilized to pre-cool the natural gas and mixed refrigerant streams to approximately –35 °F.

3) **Single mixed refrigerant process(11)** This process includes heavier hydrocarbons in the multi-component mixture, *e.g.* butanes and pentanes, and eliminates the pre-cooled propane refrigeration cycle. The process presents the simplicity of single compression, which is advantageous for small LNG plants.

Historically, the removal of heavy hydrocarbons from natural gas is considered part of feed conditioning. In most cases, the residue gas (comprising primarily of methane) from a NGL recovery plant is delivered to the LNG facility for liquefaction. It is common practice for NGL extraction to stand-alone as a separate plant from LNG liquefaction facilities for various commercial or geographical reasons. One such commercial reason is when NGL recovery and sales are desired well in advance of LNG. There may also be geographical reasons to take this approach such as cases where NGL liquids are required in a different location than LNG and where a long gas pipeline separates the two plants. As still another reason, the NGL recovery plant may already exist, prior to consideration of a LNG facility.

3.0 Process Description of an Integrated NGL and LNG plant

A block diagram for an integrated LNG and NGL process is presented in Figure 4. For the purposes of this paper, the CoP LNG Process was used for the LNG liquefaction technology. Treated natural gas is first cooled by utilizing refrigeration from within the liquefaction process in one or more stages and then introduced into a distillation column, or Heavies Removal Column. Figure 4 represents the simplest embodiment of NGL integration, where the Heavies Removal Column is not refluxed other than with condensed liquids contained within the column feed. Once the feed has entered the column, it is separated or in this case stripped. A bottoms stream, primarily comprised of NGL components, and a methane rich overhead stream are formed. The methane rich overhead stream is chilled, condensed, and in most cases subcooled within the liquefaction process. Once liquefied and subcooled, the stream is subsequently flashed to near atmospheric pressure in one or more steps in preparation for LNG storage. Flashed vapor is used as a methane recycle refrigerant with a portion heated and compressed for fuel. The liquid stream from the Heavies Removal Column is introduced to a second distillation column in one or more feed trays, depicted in Figure 4 as a Deethanizer. In the second column, the liquid stream is separated into a bottoms stream and a vapor overhead stream, primarily comprised of ethane and lighter components. The second column acts primarily as a deethanizer or partial deethanizer or in some cases a depropanizer or partial depropanizer, depending on the desired BTU level of the LNG product and desired level of propane and/or ethane recovery. The second column bottoms stream may be routed to further fractionation in order to separate the NGL and/or LPG liquids into the desired product slate.

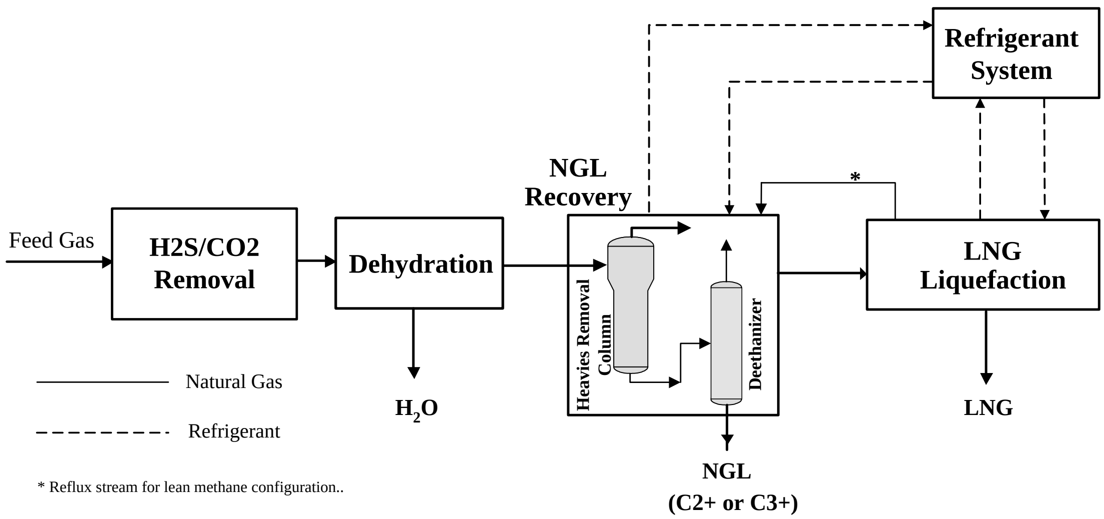

Figure 4 - Block diagram showing the integrated NGL and LNG process

NGL recovery integration not only reduces capital investment through re-utilizing essentially all equipment in the NGL facility for LNG production, but also improves overall thermodynamic efficiency. There are significant advantages in the following aspects:

- The overall integrated process reduces combined capital and operating costs.
- The integrated process reduces combined CO_2 and NO_X emissions by improving the thermodynamic efficiency of the overall process.
- Higher recovery of propane (and ethane) is achievable.
- Most NGL process equipment is already utilized in LNG liquefaction plants.

In the integrated process for cryogenically recovering ethane, propane, and heavier components, the Heavies Removal Column in the LNG facility replaces the NGL recovery column in the NGL plant, thereby reducing capital expenditure. Through adjusting operating conditions, the level of NGL recovery can be optimized in accordance with required specifications and the relative market prices of LNG, LPG and NGL. Only one common utility is required in the integrated plant, resulting in additional savings in capital expenditure. If well planned, the NGL recovery portion of the plant may be constructed at an earlier stage and later integrated into the LNG liquefaction plant. The opportunity for early NGL sales may significantly improve LNG project economics. The flexible design of an integrated plant allows for an easy transition between ethane recovery or ethane rejection, which is useful given relatively frequent changes in ethane demand.

Since integration of NGL recovery into the natural gas liquefaction process allows for higher recovery of heavier hydrocarbon components, the removal of liquefaction contaminants such as cyclohexane and benzene are also improved. This is important since these particular components, even at relatively low concentrations, may create freezing problems in the colder sections of the LNG process. Thus higher NGL recovery and less operational concerns are achieved at the same time that the front-end NGL plant is eliminated.

4.0 Variations of the Integrated Plants

Greater recovery of LPG and NGL products is possible by supplying a rectification section to the Heavies Removal Column and selecting an optimal method of reflux. Various configurations exist, depending on the component selected for recovery as well as the desired recovery level. Of course, multiple streams within the liquefaction section may be utilized for reflux to this column. The cases that follow are not an exhaustive list but rather the more common choices as integrated within the CoP LNG Process.

Case 1 No-reflux case

The simplest embodiment of integrated NGL recovery utilizes a Heavies Removal Column with the only reflux essentially from liquids contained within the column feed.

Case 2 Lean Methane Reflux Scheme

A lean methane stream is condensed within the liquefaction process and introduced as reflux to the Heavies Removal Column. In the CoP LNG Process, there are multiple sources that may be used for lean methane reflux, each containing extremely low concentrations of heavy components. Lean methane used as reflux enhances NGL recovery efficiency within the column, subsequently reducing NGL components in the overhead stream to a minimum. Thus, a higher NGL recovery is achieved even at relatively high operating pressures, in the range of 600 psig. Of course, lean methane reflux is more advantageous for ethane recovery operations.

Case 3 Deethanizer overhead reflux scheme

In this configuration, Heavies Removal Column reflux is generated from the deethanizer overhead. Refer to Figure 4. The deethanizer overhead is partially condensed with the liquids or a portion of the liquids introduced to the top of the deethanizer as normal reflux. The vapor or a portion of the vapor is compressed, partially condensed and introduced to the Heavies Removal Column as reflux. This reflux stream is rich in ethane, which provides an excellent choice for propane recovery. It is possible to operate the deethanizer as a demethanizer, providing a methane rich reflux to the Heavies Removal Column. Thus, operation may be easily switched between propane and ethane recovery simply by adjusting operating parameters.

5.0 Case Study Assumptions

The cases described above; no-reflux, lean methane reflux, and deethanizer overhead reflux were studied with the results presented in this paper. Each integration configuration was modeled at varying levels of propane recovery. For propane recovery specifications, a 2.0 mole% maximum C2:C3 ratio was used, consistent with commercial-quality propane. A case was modeled for ethane recovery as well, assuming an 85% ethane recovery target. For ethane recovery specifications, a 2.0 mole% maximum C1:C2 ratio was used, consistent with commercial-quality ethane.

The LNG production rate for each case examined assumes that gas turbine drivers are utilized to provide refrigeration requirements for the liquefaction process. The available power is based on 25^{o}C (77^{o}F) ambient air temperature. For consistency, gas-treating requirements are identical in all cases as well as the gas turbine horsepower. Table 1 summarizes the parameters for the case studies.

Table 1: Process Parameters for Case Studies

Feed Gas Composition			**Heat Sink for Cooling**	
Component	Mole Percent		Cooling Medium	Ambient Air
Nitrogen	0.10		Temperature (^{o}F)	77
Carbon Dioxide	0.01			
Methane	85.99		**Inlet Feed Gas Pressure**	
Ethane	7.50		Pressure (psig)	1100
Propane	3.50			
i-Butane	1.00		**Liquefaction Cycle CoP LNG Process**	
n-Butane	1.00			
i-Pentane	0.30			
n-Pentane	0.20			
Hexane Plus	0.40			
Total	100.00			

The Net Present Value (NPV) calculation is based on a 20-year production life assuming a 10% discount rate. Installation costs for storage tanks, compressors, turbines, and other common equipment were assumed to be the same for all cases. The following premises are used for NPV comparisons.

- The no-reflux integration case requires the lowest capital expenditures. As such, it provides a convenient basis for comparison. Installation costs for the no-reflux integration or base case are assumed at $200 MM for 0% propane recovery.
- Installation costs for small changes in feed rates are estimated using the six-tenths rule.
- The stand-alone or non-integrated NGL recovery case required $5 MM for additional equipment and $5 MM for external propane refrigeration for a total of $10 MM over the base case.
- The lean methane reflux integration case required $4 MM for additional equipment over the base case.
- The deethanizer overhead reflux case includes $5 MM for additional equipment over the bases case.

6.0 Comparison of Non-Integrated Facilities With Integrated Facilities

Propane Recovery Cases

Table 2 compares the performance of the stand-alone or non-integrated case and three different integrated cases, no-reflux, lean methane reflux, and deethanizer overhead reflux. Incremental NPV calculations are included. For clarification of terms, the definition of specific power consumption is the required compressor power divided by feed gas flow rate (HP/MMSCFD Feed). As revealed in Table 2, the specific power consumption of the deethanizer overhead reflux case is about 4% lower than that of the stand-alone non-integrated case. The comparison also reveals that from the aspect of specific power consumption, integrated configurations utilizing no-reflux and lean methane reflux do not result in significant advantages. In fact, the results reveal that the integrated process with no-reflux requires more specific power than the non-integrated case. On the other hand, the integrated case utilizing deethanizer overhead as reflux resulted in higher LNG and NGL production capacities as compared to the other cases.

The study revealed that liquid recovery cases for integrated facilities utilizing no-reflux or lean methane reflux were not as efficient for propane recovery and did not allow for optimal heat integration. The integrated process utilizing deethanizer overhead as reflux overcame these limitations, allowing for higher efficiency and liquid recovery. In addition, since efficiency is improved and installation costs remain lower, a higher NPV is realized as compared to the non-integrated case, where NGL recovery is achieved in a stand-alone facility. This effectively demonstrates the economic advantage of integrating NGL recovery within LNG liquefaction. The cases presented efficiently integrated NGL recovery into LNG liquefaction technology while allowing for higher overall propane recovery as well as that of heavier components, in excess of 95% from the feed gas. The optimized integrated process allows for recovery of over 99% for propane and heavier hydrocarbon. Higher propane and NGL recovery is achieved while requiring less energy and also eliminating the stand-alone NGL plant, leading to significant savings in operating as well as capital costs.

Ethane Recovery

As revealed above, the integrated case using deethanizer overhead as reflux for the Heavies Removal Column is effective for high propane recovery. The operating parameters may also be modified quite easily for enhanced ethane recovery. Table 2 illustrated the results of the integration operation for ethane recovery conditions using the same feed conditions listed in Table 1. Ethane recovery above 85% was easily achievable for this integration case. Again, multiple sources of lean methane reflux may be utilized with comparable results.

The price of liquid ethane is historically cyclical, depending heavily on petrochemical feedstock demands. When liquid ethane demand is high, increasing ethane recovery may generate additional revenue. On the other hand, it is often desirable to leave ethane in the LNG product, while maintaining high propane recovery when the ethane market is depressed. Due to the cyclic nature of the liquid ethane, a facility providing flexibility to easily switch between propane and ethane recovery allows producers to quickly respond to market conditions.

Table 2: Performance of Non-Integrated and Integrated Cases

Case Description	Propane Recovery							Ethane Recovery
	Base	Integrated NGL and LNG Facilities						Integrated Facilities
		Integration With No-Reflux		Lean Methane Reflux		Deethanizer Overhead Reflux		Lean Methane Reflux
	Standalone		Deviation		Deviation		Deviation	
Overall Performance								
Feed Gas, MMSCFD	660	603	-8.7%	661	0.0%	690	4.5%	705
Ethane Recovery, %								85.8%
Propane Recovery, %	98.5%	95.0%	-3.6%	95.0%	-3.6%	95.0%	-3.6%	100.0%
Relative LNG Production @ 93% Availability, MTPA	100	93	-7.0%	102	2.4%	107	7.2%	90
Relative NGL Recovery, BPD	100	89	-11.2%	97	-2.6%	102	1.8%	
Relative Specific Power, HP/MMSCFD Feed	**100**	**110**	**9.5%**	**100**	**0.0%**	**96**	**-4.3%**	**94**
Incremental NPV (20 yrs, 10%), $MM		**-266**		**52**		**217**		

Economic Basis: LNG – $2.5/MMBTU; NGL - $17/BBL; Feed - $0.5/MMBTU

Comparison of Reflux Schemes in Integrated Processes

The relative specific power consumption for the three integrated configurations are compared and presented in Figure 5. For the no-reflux case, relative specific power first decreases but then increases as propane recovery increases. Once propane recovery is higher than about 75%, relative specific power becomes a strong function of the desired propane recovery level. Essentially, this is due to the fact that the liquid recovery section of the no-reflux scheme is not very efficient, requiring additional horsepower to achieve high propane recovery.

By comparison, the relative specific power of the deethanizer overhead reflux case continues to decreases as propane recovery increases. Given the same conditions, the deethanizer overhead reflux case requires the lowest specific power consumption with the no-reflux case requiring the highest. The trend is more evident at higher propane recoveries. At 95% propane recovery, the specific power of the deethanizer overhead reflux case is 4% less than the lean methane reflux case and 12% less than the no-reflux case. Of course, as propane recovery increases, the NGL product rate also increases. Generating natural gas liquids (NGL) requires less refrigeration than liquefying methane-rich natural gas (LNG). Therefore, the deethanizer overhead reflux configuration requires less specific power (HP/MMSCFD) at high propane recoveries and also improves overall facility thermal efficiency.

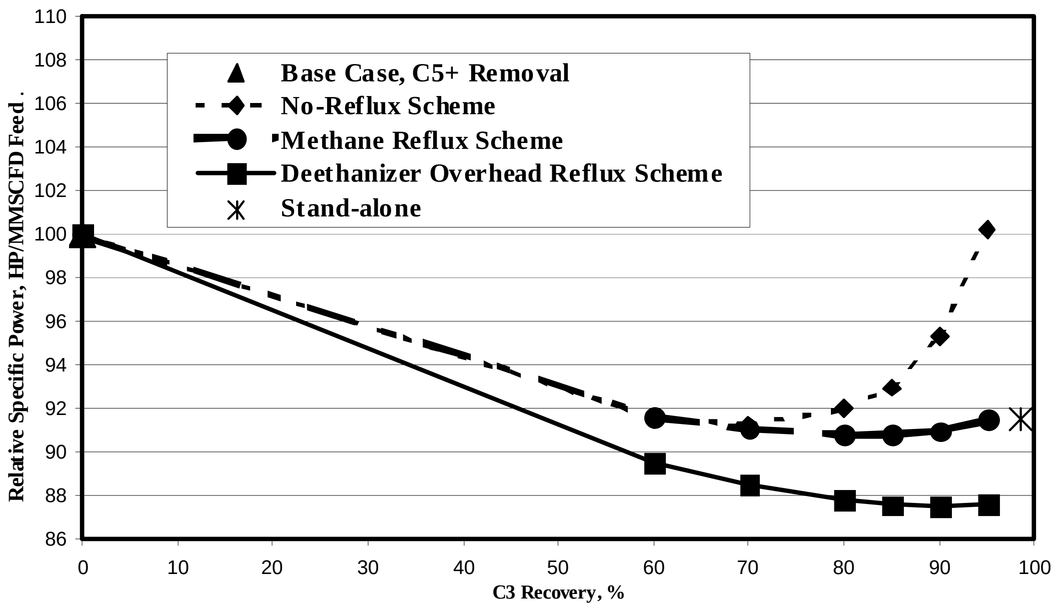

Figure 5 - Comparison of Relative Specific Power Requirements at Varying Propane Recovery for Different NGL Integration Cases

Figure 6 illustrates the dependence of incremental NPV on propane recovery level for the three different NGL recovery configurations. The basis for comparison of incremental NPV is the no-reflux case at 0% propane recovery. For the no-reflux base case, incremental NPV first increases but then decreases as propane recovery is increased. As one would expect from the specific power requirements results revealed in Figure 5, the incremental NPV of the deethanizer reflux case continues to increase as propane recovery increases. While, NPV for the lean methane reflux case is higher than the no-reflux case, the deethanizer overhead reflux case is clearly a better choice for high propane recovery requirements.

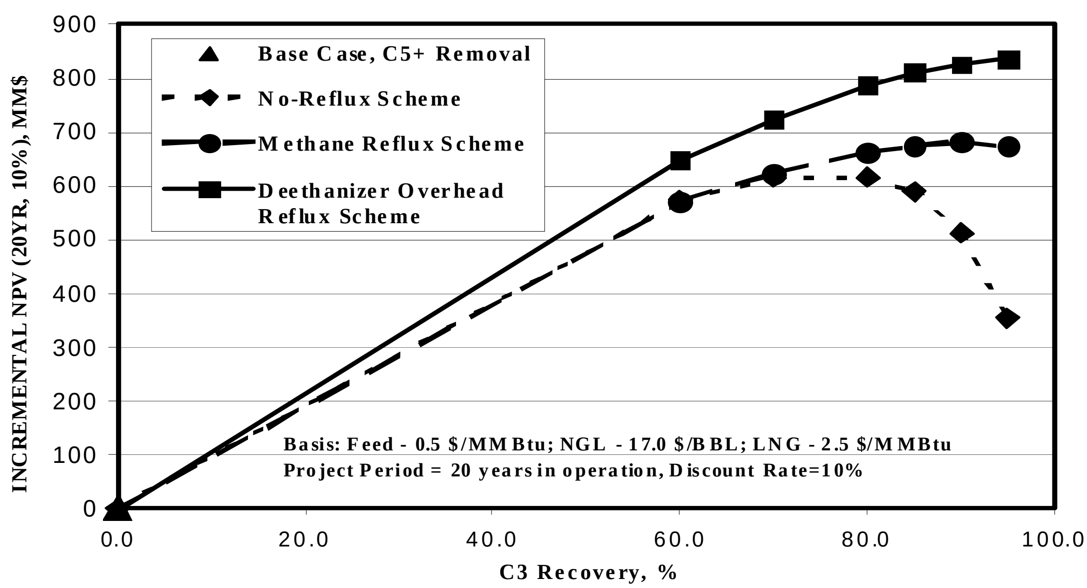

Figure 6 - Incremental NPV at Varying Propane Recovery for Differing Integrated Cases

Table 3: Comparison of Lean Methane Reflux and Deethanizer Overhead Reflux

Case Description	Lean Methane Reflux	Deethanizer Overhead Reflux
C3 Recovery, %	95	95
Heavies Removal Column Reflux		
Relative Flow Rate, M^3/Hr	226	100
C2 Content, mol%	4.6	56.3
Critical Pressure, Psia	769	978
Critical Temperature, ^oF	-100	35
Heavies Removal Column Top Tray		
C2 Content, mol%	5.4	10.1
Critical Pressure, Psia	793	865
Critical Temperature, F	-94	-78
Relative Specific Power, HP/MMSCFD Feed	**104.3**	**100**

Operating pressure of the Heavies Removal Column is ultimately limited by the critical pressure of the hydrocarbon mixture in the column. As the column pressure approaches the critical pressure, relative volatility decreases significantly, resulting in a decreased capacity for fractionation. However, the deethanizer overhead reflux configuration is capable of providing an ethane-rich reflux stream to the top of the Heavies Removal Column, driving the column further away from the critical pressure, thereby enhancing relative volatility. Therefore, overall separation efficiency is improved. Therefore, in order to achieve the same propane recovery levels as the lean methane reflux case, much less reflux is required, further resulting capital and operating cost savings. Table 3 provides a more detailed comparison of the deethanizer overhead reflux and the lean methane reflux configurations.

The deethanizer overhead reflux case allows higher-pressure operation of the Heavies Removal Column as compared to the lean methane reflux case. This is due to the fact that the deethanizer overhead reflux configuration results in a higher critical pressure for the Heavies Removal Column. This allows for separation at higher column pressures, which accordingly allows for more efficient use of refrigeration within the liquefaction (LNG) process. The end result is lower operating costs. Of course, the lower operating costs combined with lower installation costs results in overall improved project economics. It is clear that proper integration of deethanizer overhead reflux to the Heavies Removal Column provides for efficient propane recovery within LNG liquefaction technology.

7.0 Conclusions

Proper integration of NGL recovery technology within LNG liquefaction technology results in significant advantages by lowering overall capital cost requirements and improving both LNG and NGL production. Through careful process selection and heat integration, the integrated LNG/NGL facility results in lower specific power consumption and increased NPV as compared to non-integrated facilities. As demonstrated in this paper, given the same horsepower, an approximate 7% LNG production gain is realized through careful integration.

Utilization of deethanizer overhead as reflux to the Heavies Removal Column improves separation efficiency while maintaining higher column pressures for efficient and economical utilization of mechanical refrigeration. For high propane recovery, the deethanizer overhead reflux configuration requires less specific power and results in improved project economics when compared to configurations using lean methane reflux or no reflux to the Heavies Removal Column.

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9.0 Endnotes

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