ECONOMICAL OPTIONS FOR RECOVERING NGL / LPG AT LNG RECEIVING TERMINALS

Presented at the
86th Annual Convention
of the
Gas Processors Association
March 13, 2007
San Antonio, Texas

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ABSTRACT

A number of LNG receiving terminals are now in the planning or construction phases around the world. Many of these new terminals will be sited in highly industrialized nations where a significant infrastructure already exists for utilizing lighter liquid hydrocarbons (ethane and propane) as feedstock for chemicals production and fuel usage. This provides a strong economic incentive for recovering these components from the LNG prior to vaporization, with the added benefit of making the resulting gas more compatible with existing gas transmission pipelines by reducing its heating value.

Fractionation to separate the heavier hydrocarbons from the methane in LNG has not yet been practiced on an industrial scale. Nevertheless, the concepts involved are much the same as those that have been employed in cryogenic NGL and LPG recovery plants for decades. As such, extension of this more familiar "gas plant" technology to LNG fractionation provides significant economic benefit for the receiving terminal while adding very little project risk.

Ortloff has developed a number of processing schemes for efficient fractionation of LNG to produce NGL and/or LPG. The optimum processing scheme generally depends on several factors, including the desired product slate, the value of the products compared to the value of natural gas and the cost of energy, and the receiving and delivery conditions. In many LNG terminals, design parameters for existing pumping and vaporization equipment are also important constraints on the process design. This paper presents examples and discusses the relative merits of these new processing schemes.

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INTRODUCTION

LNG (liquefied natural gas) receiving terminals have been designed and built at many locations around the world for storing and vaporizing LNG cargos for delivery to existing pipeline infrastructures. The composition and heating value of the vaporized LNG sent to pipeline is determined by the properties of the LNG produced at the source. Since most pipeline contracts specify a range of acceptable heating values for gas delivered into a particular market, the variability of the inlet cargo properties can be a problem. In many instances, the heating value of LNG shipped to market is higher than acceptable in a specific pipeline grid. Some options available to reduce the heating value include: blending with other gas streams; injecting an inert gas (typically nitrogen) into the vaporized stream; or vaporizing the rich LNG stream and sending it to a conventional NGL / LPG (natural gas liquids / liquefied petroleum gas) recovery plant for processing prior to flowing to the pipeline grid.

In most cases, there is not an abundance of natural gas available for blending to adequately lower the heating value of a rich LNG stream. Nitrogen injection is usually very expensive and generally provides no other economic benefit besides lowering the heating value of the sales stream. Also, there are usually specifications covering total inert content which may not allow enough nitrogen injection to adequately lower the heating value. Vaporization of the gas stream and then processing in a conventional gas plant does provide the economic advantage of selling the higher value heavier components separately (i.e., typical gas plant economics), but generally at a high operating cost. When LNG is vaporized, heated, and then processed in a conventional gas plant, a significant amount of compression is required to re-refrigerate the gas (via expansion) in order to recover the hydrocarbon components and then re-inject the residue gas at pipeline pressure.

A better method for controlling the delivery heating value is to recover NGL or LPG by integrating the recovery step into the vaporization step, eliminating the need for recompression and taking advantage of the refrigeration available in the LNG. This provides the lowest capital and operating cost alternative for controlling heating value, while also providing a significant additional revenue stream.

In most LNG liquefaction plants, heavy hydrocarbon removal (generally C_5+) is considered a feed conditioning step for the liquefaction process, so the resultant LNG will contain most of the hydrocarbon components lighter than pentane. For more than 30 years, Ortloff has been developing technology for recovering liquids from natural gas that offers higher recovery, better efficiency, greater simplicity, and better reliability than other available processes. This natural gas liquids recovery technology can be extended to allow efficient liquids recovery in LNG terminals through integration of the recovery step with the re-vaporization step.

The Ortloff **L**NG **F**ractionation **P**rocesses (LFP) eliminate the need for recompression in the liquids recovery step, reducing the overall power required by as much as 90% or more compared to processing in a conventional gas plant. An additional benefit of LFP is that process performance is not sensitive to changes in inlet LNG composition, providing the terminal operator with maximum flexibility in processing LNG cargos from essentially anywhere in the world. This paper presents the results of case studies conducted by Ortloff to determine the recovery and efficiency performance of the LFP liquids recovery technology when applied to a typical LNG feedstock.

TRADITIONAL RE-GASIFICATION FACILITIES

Two processing schemes that have been used for traditional re-gasification facilities are shown in Figures 1 and 2 below. Neither scheme includes heavy hydrocarbon removal, so the entire LNG stream is vaporized and sent to the pipeline. The scheme in Figure 1 uses submerged combustion vaporizers (SCVs) to provide the heat for the vaporization step. Figure 2 shows a scheme using the LNG Smart® Air Vaporization system offered by Mustang Engineering. This second scheme uses ambient air to provide much of the process heat required for the vaporization step, allowing a significant reduction in plant fuel usage and plant emissions in warmer climates.

There are several other LNG vaporization methods in addition to those shown below, but the basic plant arrangement is much the same for all of them. Nearly all of these vaporization processes can be integrated easily with Ortloff's LFP designs for recovering NGL (the C_2+ hydrocarbon fraction) and/or LPG (the C_3+ hydrocarbon fraction) from the LNG stream being vaporized.

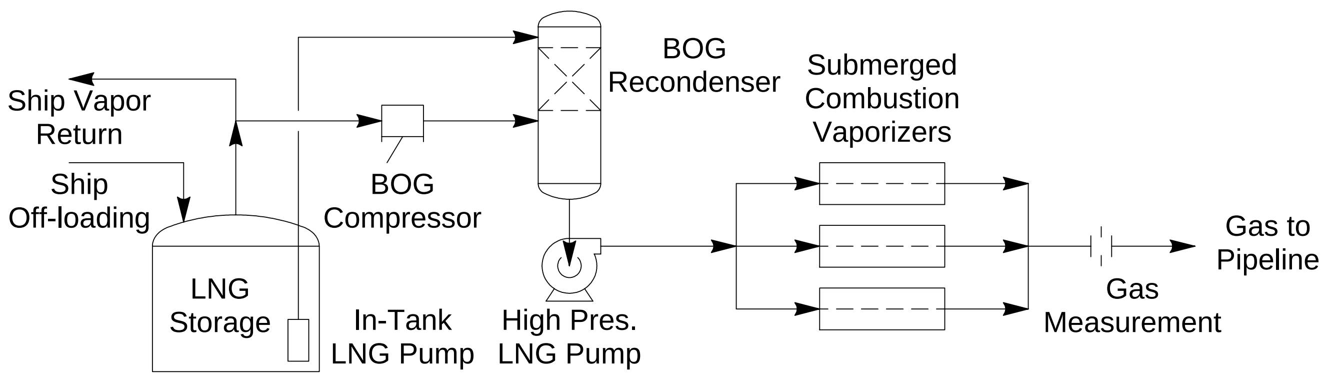

Figure 1 — Vaporizer Unit using Submerged Combustion

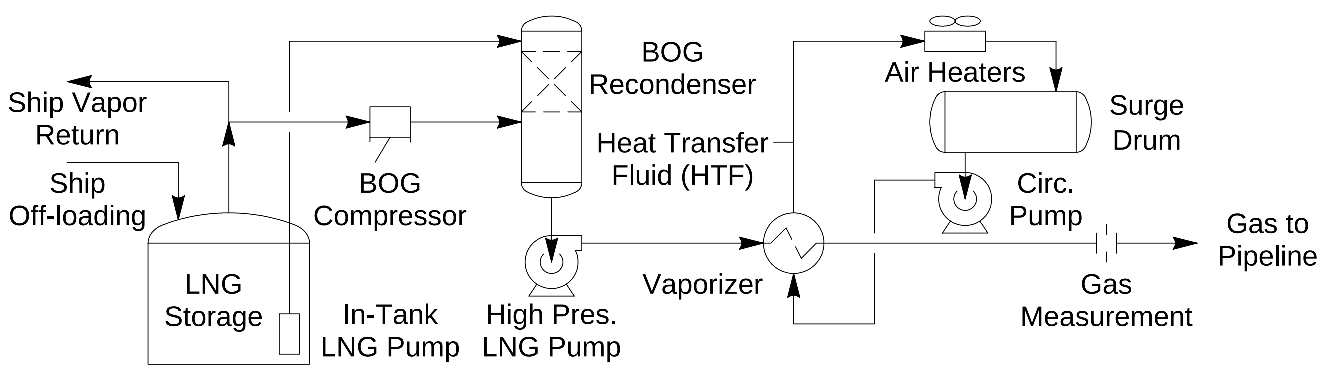

Figure 2 — Vaporizer Unit using Air Vaporization

TRADITIONAL GAS PROCESSING

Over the past 30 years, Ortloff has developed a number of processes for efficient recovery of hydrocarbon liquids from natural gas and other gas streams.[1] These processes offer many advantages over other processes available to gas processors, including higher recovery, better efficiency, greater simplicity, and better reliability.

These processes typically involve cooling an inlet gas stream prior to work expansion of the stream to provide some or all of the refrigeration required for the process. For rich gas streams, external refrigeration may also be applied in addition to the refrigeration provided by the turboexpander. The power recovered by the turboexpander is typically used to provide partial recompression of the residue gas stream following separation of the lighter and heavier components in a distillation column. Reflux streams appropriate for the type of product recovery required are provided to the distillation column. These reflux streams overcome the vapor-liquid equilibrium effects that limit the recovery potential of many processes. A typical gas processing scheme that can be used for both LPG and NGL recovery is shown in Figure 3 below.

These processes have been successfully used in plants as small as 10 MMSCFD and as large as 2,100 MMSCFD. This size range brackets the processing capacity of all re-gasification facilities that are presently in existence, in the design phase, or under construction. Further, the processing conditions around typical gas plant demethanizers/deethanizers are essentially the same as those used for LNG fractionation columns. So, although LNG fractionation has not yet been practiced on an industrial scale, the separation technology involved is well proven.

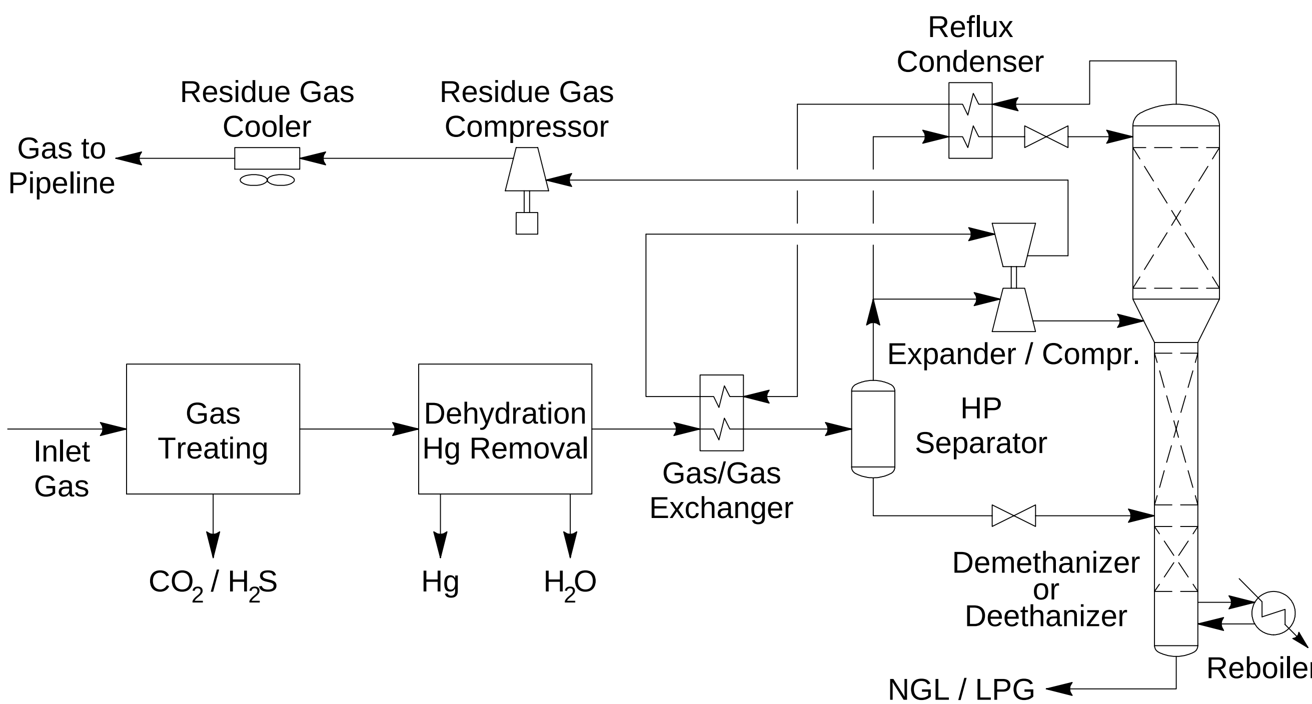

Figure 3 — Conventional Gas Processing Plant (GSP)

LNG FRACTIONATION

Ortloff has developed a number of processes for efficient recovery of hydrocarbon liquids from LNG streams.[2,3] These LFP designs are able to recover extremely high levels of hydrocarbon liquids (either NGL or LPG) with no external compression and with flexible and reliable operation.

One of the main advantages of integrating the liquids recovery into the vaporization step is that there is more than enough refrigeration available in the LNG stream to supply the requirements for liquids recovery. While a typical natural gas plant must generate refrigeration via expansion and recompression to provide the duty required to make the component separation, the integrated LFP designs require no additional refrigeration beyond that already present in the LNG. Although turboexpanders are used in some of these designs, their purpose is simply power recovery rather than generating additional refrigeration. Application of a turboexpander/compressor can be especially useful in a straddle-plant-type application where the LNG is delivered to the liquids recovery unit at high pressure.

Separation of heavier hydrocarbons from a predominately methane stream must be carried out at relatively low pressure due to phase behavior characteristics, and the residual methane stream must leave the overhead of the distillation column as a vapor to avoid excessive refrigeration requirements. As a result, a significant portion of the inlet LNG stream must be vaporized either upstream of the distillation column or within the column itself. It is important to note that the overall heat duty of the vaporization process is essentially the same whether the liquids recovery unit is in service or if the LNG stream is being vaporized directly into the pipeline. Thus, the system can be integrated so that the heat transfer fluid can be directed to provide heat to either the liquids recovery unit or the vaporizer units, depending on the mode of plant operation. This type of process is very suitable for an air vaporization facility since the majority of the heat is required at low temperatures and can be supplied by atmospheric heat. The only heat duty in the liquids recovery unit that must be supplied at higher temperature is that of the distillation column reboiler, a small percentage of the overall heat duty required. An LFP design is presently being integrated in this fashion into a U.S. plant which uses a combination of air vaporization and SCVs for process heat and final LNG vaporization.

In the LFP designs, the residue gas (primarily methane) from the demethanizer (or deethanizer) is condensed and subcooled so that it can be pumped to pipeline pressure and then re-vaporized. This is accomplished by cross exchange of the residue gas stream with inlet LNG to condense and subcool the residue gas stream, and also to preheat the inlet LNG stream before it feeds the distillation column. To achieve this, the operating conditions of the inlet LNG and the residue gas must be such that the cooling curve characteristics are appropriate for the cross heat exchange step. In some instances, it can be advantageous to work expand the high pressure vaporized inlet to the distillation column and apply the power recovered to the residue gas prior to condensing and subcooling. This serves to ensure that total condensation of the residue stream can be accomplished, and minimizes the amount of power required to increase the stream to the required pipeline pressure by using pumping rather than compression.

A Mollier diagram illustrating the theoretical steps of an LFP design for ethane recovery is shown in Figure 4 on the following page. In the traditional re-gasification process, the cold LNG in the storage tank (A) is pumped to pipeline pressure (B) and then heated to vaporize it before it flows to the pipeline (C). When the LFP plant is integrated into the facility, a portion of the high pressure LNG is heated to an intermediate temperature (D) and supplied to the distillation column as a liquid reflux stream. The remainder of the LNG is heated to higher temperature (E), then work expanded in a turboexpander to the column operating pressure (F) to generate power per the enthalpy change along path E-F. After fractionation, the residue gas leaving the top of the column (G) is partially recompressed (H) in the booster compressor connected to the turboexpander, cooled (I) as it heats the cold LNG, pumped to pipeline pressure (J), and then flows to the vaporizers to be heated before flowing to the gas transmission pipeline (C).

For ethane recovery designs, compressing the column overhead to intermediate pressure before cooling it can substantially reduce the duty required to make the fluid suitable for pumping. Contrast the enthalpy change for path H-I to what would be required if the column overhead is cooled instead (path G-I'). In addition, the pumping power (path I-J) is now quite small, making the power requirements of LFP very low. Note that the power required to compress the column overhead to this intermediate pressure (path G-H) is small, so only a portion of the incoming LNG is required to power the turboexpander. This allows optimizing the power recovery more or less independently of the liquids recovery level.

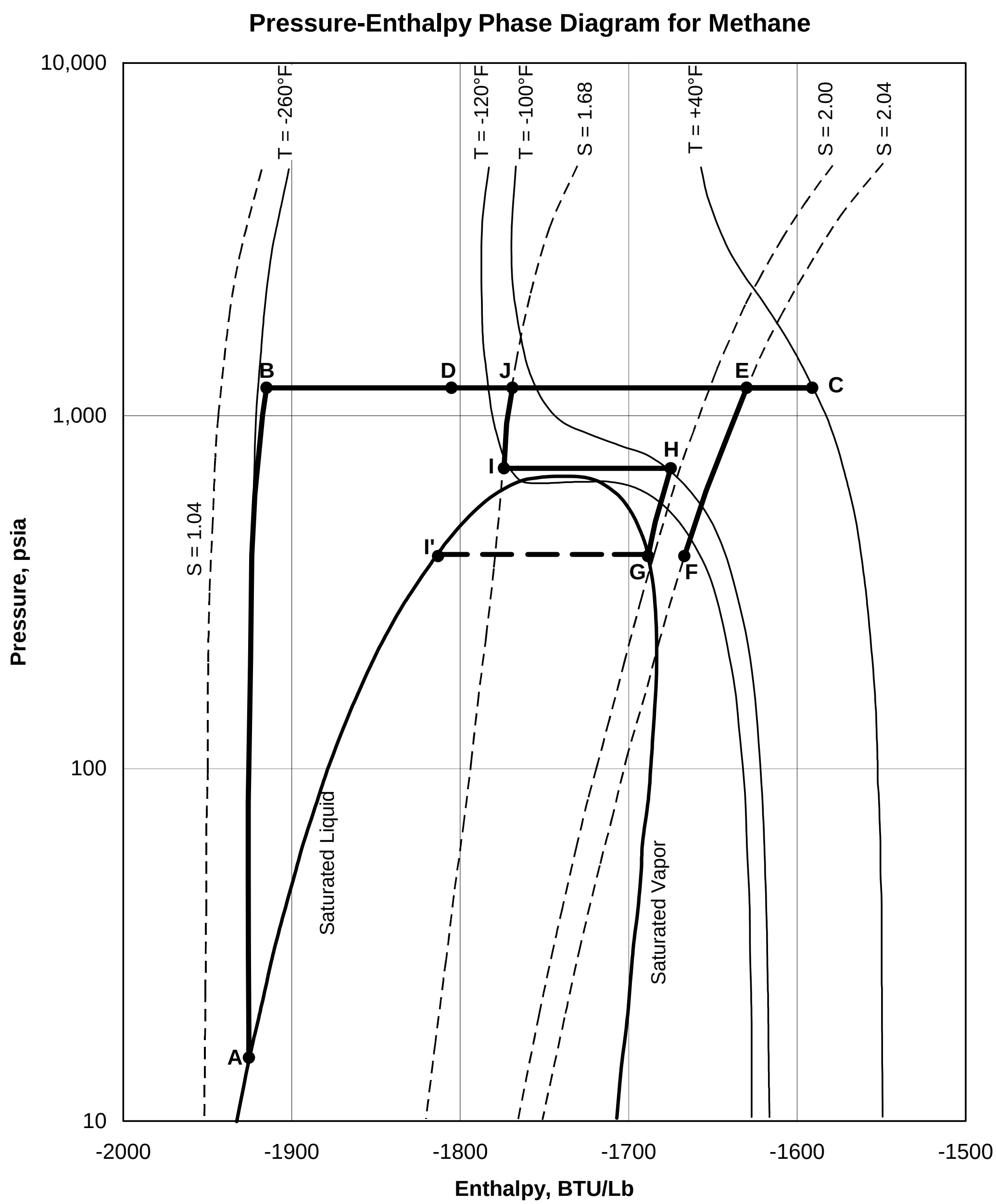

Figure 4 — Theoretical LFP Operation

A block diagram for a typical LFP processing scheme integrated with air vaporization is shown in Figure 5 below. Note that the LFP plant can be completely bypassed when necessary, so that operation of the vaporizers and delivery to the gas transmission pipeline is never interrupted. When liquids recovery is desired, the block valves are repositioned to send the "rich" LNG to the LFP plant, with the "lean" LNG it produces flowing to the vaporizers and then to pipeline.

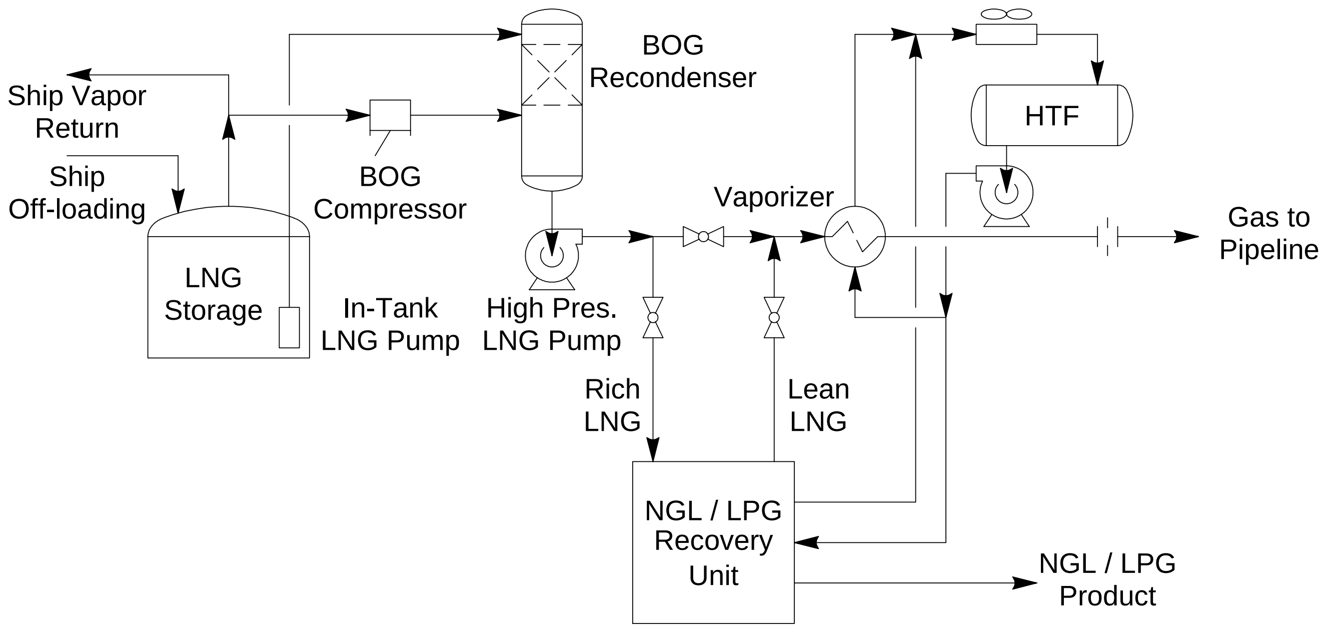

Figure 5 — Liquids Recovery Integrated with Air Vaporization

CASE STUDIES

To illustrate the advantages of integrating the liquids recovery unit with the vaporization section of an LNG re-vaporization terminal, case studies are presented in the remainder of this paper. Although these case studies are based on a single typical LNG composition, sensitivity studies have been completed for LNG compositions from nearly all available LNG cargos on the world market. These sensitivity studies have shown that LFP is very flexible, and a single plant design can efficiently process these different LNG cargos with very little change in plant operating parameters. This is due to the large amount of refrigeration available in the LNG. Since processing different LNG feeds is mainly a matter of adjusting the external heat addition (rather than creating refrigeration as in a conventional gas plant), variability of the LNG composition can be accommodated simply by varying the external heat input to the process.

Case Study 1 — NGL or LPG Recovery

The first case study is based on an ethane recovery design with full ethane rejection capability. This is an actual design case for a plant being designed and constructed in the U.S. It includes a turboexpander/compressor for power recovery within the process. Inlet LNG pressure to the plant was fixed by existing high pressure LNG pumps. Vaporization of the LNG is accomplished using a mixture of SCVs and air vaporization units. The heating medium for the NGL recovery section of the plant is provided from the closed loop air vaporization system (tempered for cold weather operation) that is integrated into the final vaporization step. Heating medium flow is automatically directed to the NGL recovery section or the final vaporization step depending on the mode of operation. The heating medium for column reboiling is from a heated glycol/water loop. A block diagram of the overall process with a summary of the process performance is shown in Figures 6a and 6b below.

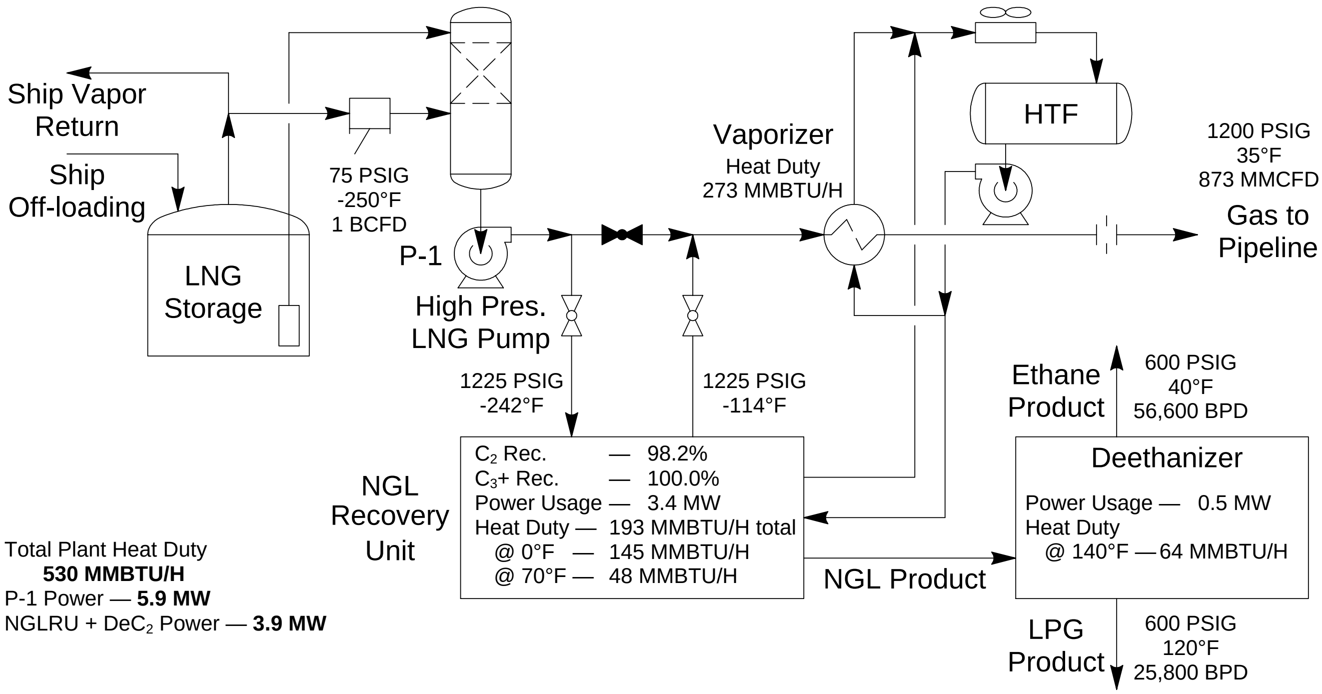

Figure 6a — Case Study 1 – NGL Recovery

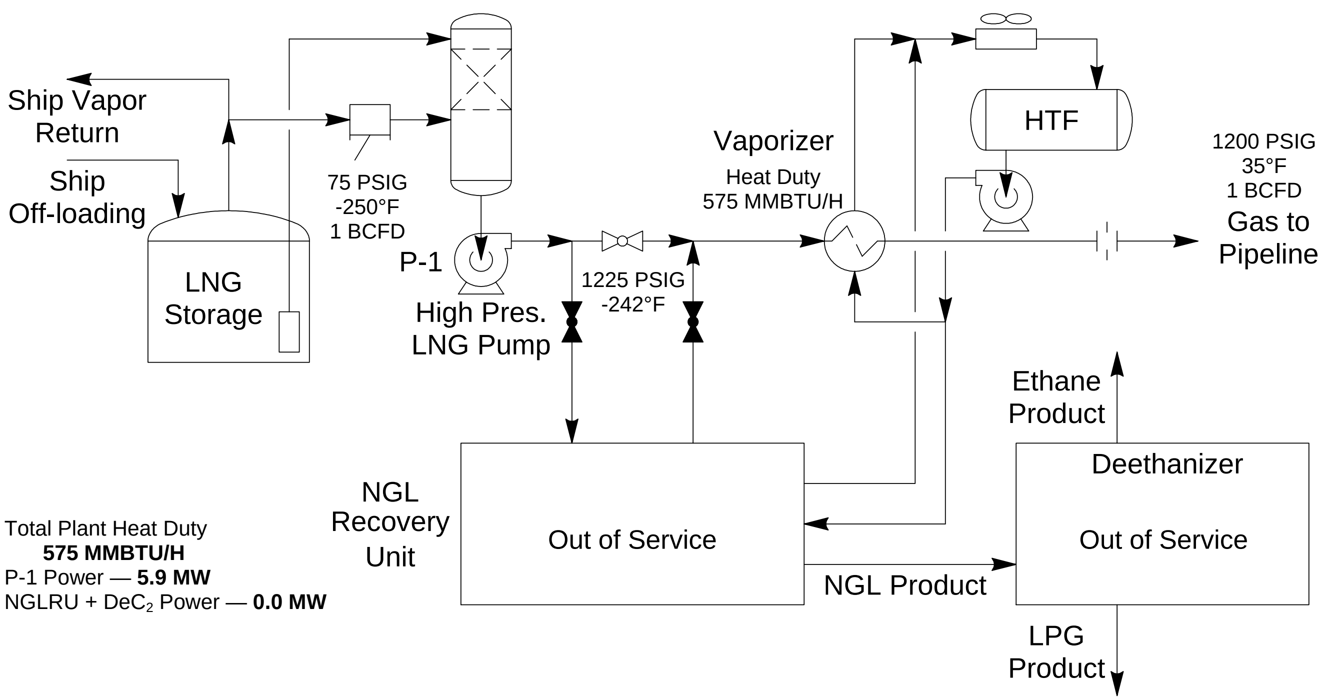

Figure 6b — Case Study 1 – NGL Recovery Unit Bypassed

This design produces a C_2+ stream (NGL recovery) that is then fractionated into a purity ethane stream and a C_3+ stream (Figure 6a). The demethanizer column bottom temperature is controlled to provide a typical C_1:C_2 NGL product specification, while the deethanizer column bottom temperature is controlled to provide a typical C_2:C_3 LPG product specification. The LFP plant is operated the same whether in ethane recovery or ethane rejection mode. In ethane rejection mode, all or a portion of the ethane is re-injected back into the lean LNG stream before being vaporized and sent to pipeline. This allows the plant operator to easily fix the heating value of the vaporized residue gas to provide pipeline-quality gas at the most economical conditions. There is little additional operating cost for continuous operation of the deethanizer column since all of its overhead cooling and condensing is provided by the inlet LNG and no external refrigeration power is required.

This plant is designed for ultra-high ethane recovery (98%). As discussed above, the actual ethane recovery is variable from approximately 2% (the amount allowed in the LPG product) to the maximum 98%. For an inlet LNG rate of 1 BCFD (gas equivalent), the power required within the NGL recovery unit is 3.9 MW for pumping the lean LNG to the vaporizers for final vaporization. There is no external compression used in the process. By comparison, the power requirement for residue gas recompression in a conventional gas plant processing the vaporized LNG would be approximately 46.6 MW, illustrating the much greater efficiency of LNG fractionation relative to refrigerating natural gas to recover the liquids.

Figure 6b shows operation of the re-gasification terminal with the LFP plant bypassed. Note that the total external heating duty when recovering liquids (530 MMBTU/H) is actually lower than when the LFP plant is bypassed (575 MMBTU/H). This is mainly because a significant portion of the incoming LNG remains in the liquid state as purity ethane and LPG when the LFP plant is operating.

It is worth pointing out that the LFP plant in Figure 6a can process all of the LNG while delivering the lean LNG it produces to the vaporizers at pipeline pressure. Some of the other LNG fractionation processes described in the literature can only process part of the LNG when recovering ethane, as the remainder is needed to help condense the lean LNG product.[4] Since LFP does not require bypassing any of the LNG, the valuable C_2+ or C_3+ hydrocarbons in all of the LNG can be recovered, generating significant revenue for the terminal operator.

Case Study 2 — LPG Recovery

The second case study is based on an ultra-high C_3+ (LPG) recovery design with no ethane recovery. For this case, the main LNG pumps are provided in two stages, allowing the LFP plant to takes its feed from the low pressure pumps and return lean LNG to the high pressure pumps. As a result, less power is required in the LFP section because of the lower head on the lean LNG pump.

This case is also integrated with a tempered air vaporization system for process heat duty within the LPG recovery unit as well as final LNG vaporization. Heat for reboiling of the deethanizer column is provided by a heated glycol/water loop. A block diagram of the overall process with a summary of the process performance is shown in Figures 7a and 7b on the following page.

For an inlet LNG rate of 1 BCFD (gas equivalent) and a propane recovery of 99.9%, the power required within the LPG recovery process is 1.7 MW. This is the pumping power required to return the lean LNG to the vaporizers for final vaporization. No compression of any type is required within the process (which is typical for LPG recovery with LFP). If the vaporized LNG was instead processed in a conventional gas plant for this level of LPG recovery, the power requirement for residue gas recompression would be approximately 38.9 MW.

Figure 7b shows operation of the re-gasification terminal when the LFP plant is bypassed. Note that the total external heating duty when recovering liquids (579 MMBTU/H) is essentially the same as when the LFP plant is bypassed (575 MMBTU/H). The only additional energy consumption when the LFP plant is recovering liquids is that required to pump the lean LNG.

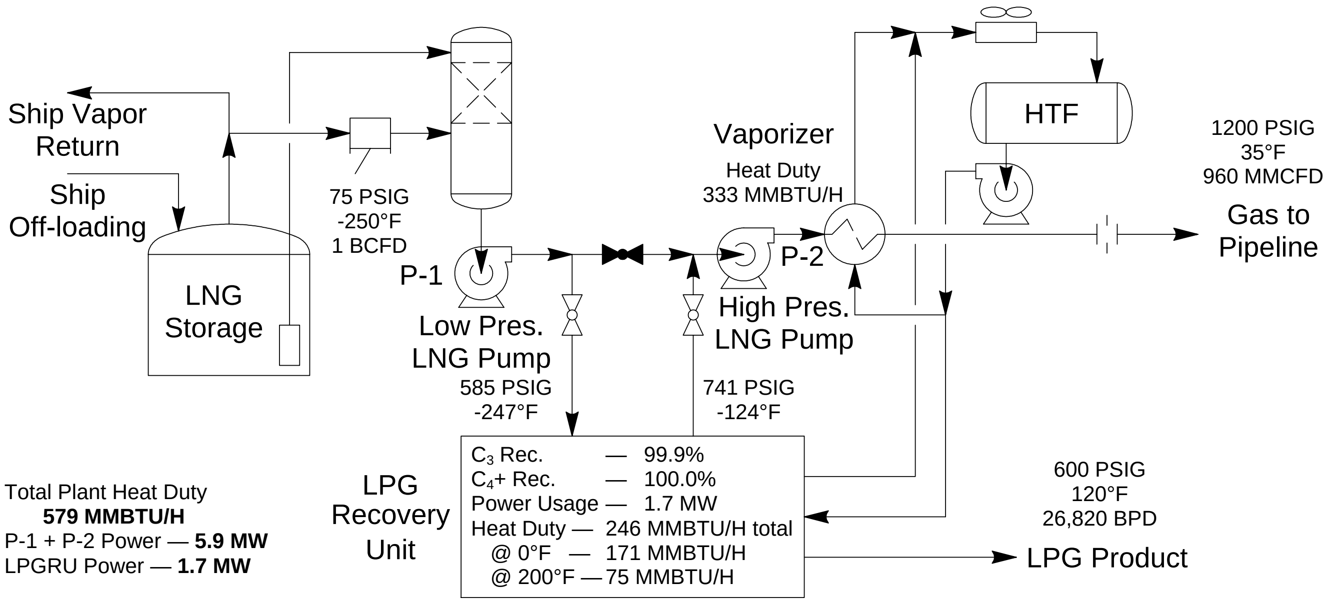

Figure 7a — Case Study 2 — LPG Recovery

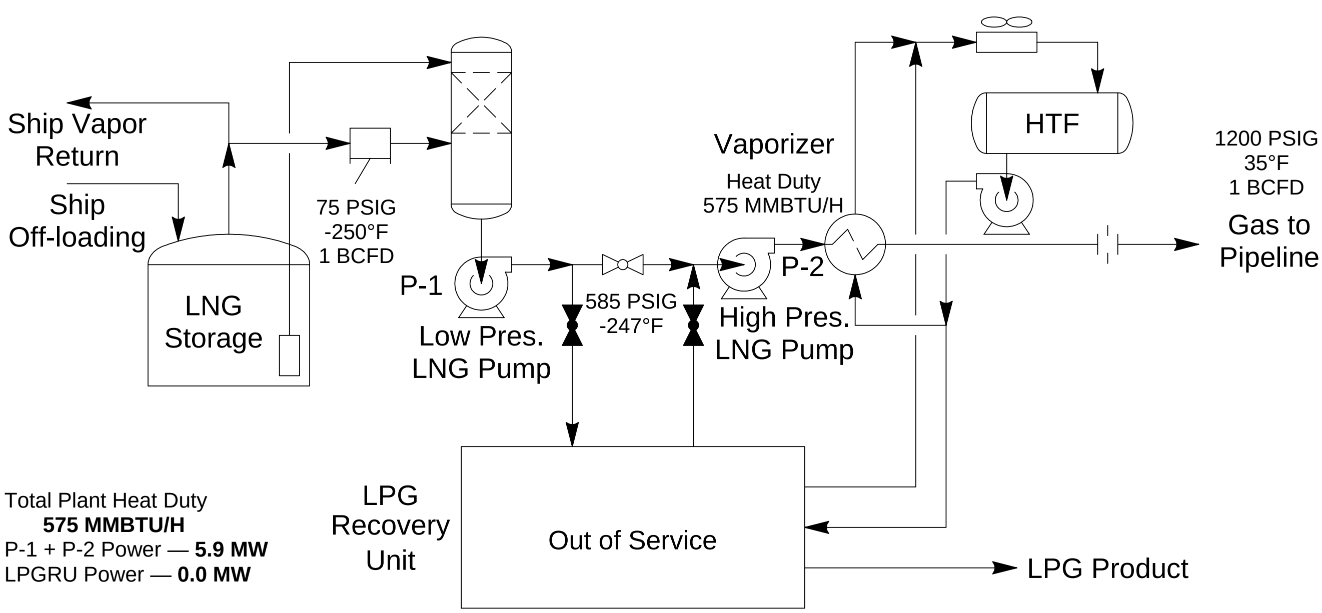

Figure 7b — Case Study 2 — LPG Recovery Unit Bypassed

CONCLUSIONS

As shown by the case studies presented in this paper, NGL or LPG recovery can be integrated very efficiently into the vaporization process at an LNG receiving terminal. The benefits of integrating this new liquids recovery technology with the vaporization step include the following:

- Extremely high NGL and/or LPG recovery can be achieved, providing the flexibility to produce a wide range of residue gas heating values depending on economic conditions. Pipeline heating value specifications can be met while producing a second valuable revenue stream.
- Changing LNG composition is easily handled by the processes. Since there is adequate refrigeration available in the LNG feed, wide ranges in the LNG composition can be processed with the same plant design simply by varying the heat input. This gives the terminal operator the flexibility to process LNG cargos from anywhere in the world.
- Unlike conventional gas processing plants, no external compression is required. By taking advantage of the refrigeration available in the LNG itself, the external compression step is eliminated to make the overall energy requirements very low for the processes.
- The overall heat input is essentially the same whether liquids are recovered or the entire LNG stream is vaporized. As a result, the required heat input to the LNG terminal does not increase with the addition of an NGL or LPG recovery process.
- The LFP processes can be easily integrated into nearly all existing vaporization processes. LFP integrates very well with air vaporization since the majority of the heat required is at temperatures suitable for a heat transfer fluid heated by ambient air. This can reduce plant fuel usage and terminal emissions significantly.

Process configurations are available to provide maximum efficiency for a given product or to allow efficient adjustment of product recovery levels if economics are variable. The process efficiency and heat integration provided by this liquids recovery technology allows for processing LNG cargos of varying composition with the same process design and nearly constant operating parameters.

The LFP liquids recovery technology provides a very economical means of meeting pipeline heating value specifications while providing additional revenue streams. This technology can be designed to recover NGL and LPG in new plant applications or as a retrofit for existing re-vaporization terminals.

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