GAS PLANT IN A BOTTLE ™

John D. Wilkinson, P.E., Hank M. Hudson, P.E.,
Joe T. Lynch, P.E., Steve J. Munden, and Scott A. Miller
Ortloff Engineers, Ltd.
Midland, Texas, USA

Kyle T. Cuellar
Ortloff Engineers, Ltd.
Katy, Texas, USA

Andrew F. Johnke and W. Larry Lewis, P.E.
SME Products, L.P.
Houston, Texas, USA

Abstract

A new process design and equipment concept has been developed for reducing the cost and plot space required for gas processing. Through innovative use of integrated heat and mass transfer equipment, most of the processing equipment found in a typical cryogenic gas plant can now be placed inside a single vertical tower or "bottle".

With the "bottle" concept, the cryogenic plant is reduced to a single processing assembly coupled to an adjoining turbo-expander module, significantly reducing the cryogenic plant footprint. Much of the piping used to join the equipment items together in a typical gas plant is eliminated by placing the equipment services inside the tower, including most of the residue gas piping. All of the heat transfer devices are inside the tower, eliminating the external reboilers, the often troublesome thermosiphon reboiler piping, and issues with heat exchanger thermal stress sometimes found in standard gas plants.

Among the advantages of this concept are lower plant cost, less plot space, less piping, reduced pressure drop with resulting lower compression power, fewer flanged connections reducing the potential sources of leaks and atmospheric emissions, fewer foundations meaning less civil work, and shorter construction schedules.

***Gas Plant in a Bottle* ™** (GPB) designs can use state-of-the-art Ortloff natural gas liquids or liquefied petroleum gas (NGL / LPG) technologies, which offer the highest efficiencies for extracting liquids from natural gas, or industry standard open-art technology, such as Ortloff's Gas Subcooled Process (GSP) design. Technology selection is based on the processing requirements and product economics for each plant site.

Introduction

Recent market forecasts and surveys indicate the production of natural gas liquids (NGL - defined as ethane, LPG, and heavier hydrocarbons), both within the United States and globally, is expected to increase through 2015.[1,2,3,4] Further development of gas processing technology that is more cost effective, operationally efficient, and environmentally responsible becomes critical for the investing company.[3]

Gas processing projects can generally be divided into two categories: contaminant removal and liquids recovery.[5] Within the liquids recovery category, the criteria to be considered for any project are initial capital investment, ongoing processing costs, operating efficiency, safety and environmental considerations, tolerance to carbon dioxide (CO_2) contamination, and operating flexibility to either recover or reject ethane without sacrificing operating efficiency, propane recovery, or the flexibility to operate at turndown conditions.

Ortloff Engineers, Ltd. (OEL) and SME Products, L.P. (SME-P) have teamed up to develop the next generation of gas processing liquids extraction plants which incorporate the operational efficiency of OEL's state-of-the-art liquids recovery technology, OEL's process design know-how, and SME-P's equipment design and packaging expertise. ***Gas Plant in a Bottle* ™** (GPB) is a new, innovative technology developed with gas processing companies in mind who are seeking an even further improvement in overall NGL profit margins while reducing potential environmental emissions sources. The process details and benefits of the GPB technology will be described further in the remainder of this paper.

The "Bottle" Concept

***Gas Plant in a Bottle* ™** (GPB) uses a combination of heat and mass transfer devices all within the fractionation assembly. Most, if not all, of the heat exchange, component separation, and mass transfer/distillation equipment are in one processing assembly. One key feature of the GPB is the Heat and Mass Transfer (HMT) module which is incorporated into the stripping section of the fractionation column, providing external heat input to generate stripping vapors and mass transfer contact within the HMT module to improve the fractionation.

The "Bottle" Process

A typical cryogenic gas plant process design for ethane recovery will be used to illustrate the differences between a traditional turbo-expander gas processing plant design and the new GPB design. For this illustration, Ortloff's Gas Subcooled Process (GSP) design will be the process used for comparison to the ***Gas Subcooled Process in a Bottle***™ (GSP-B™) in an ethane recovery arrangement.[6] GSP-B™ is one of several processes that can be constructed using OEL's "bottle" technology. All process flow paths for the "bottle" technology are identical to an equivalent, traditional gas processing technology; however, the location of the equipment is changed or eliminated completely in OEL's "bottle" processes. The simplified process flow diagrams shown below illustrate both the GSP (Figure 1) and GSP-B™ (Figure 2) arrangements.

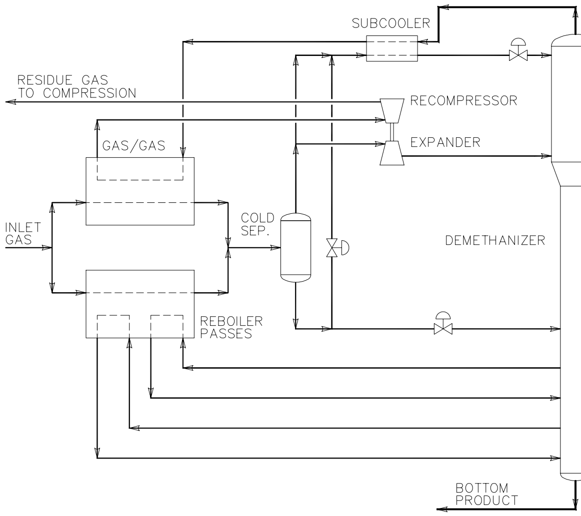

Figure 1 – GSP Process Arrangement

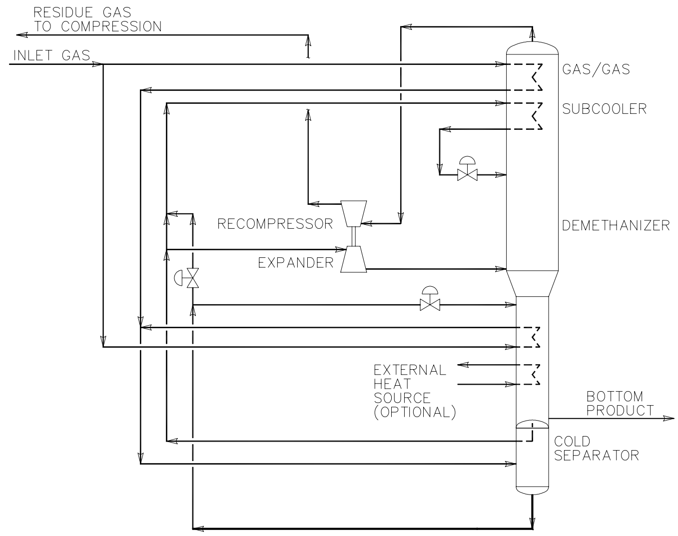

Figure 2 – GSP-B™ Process Arrangement

The key equipment in the ethane recovery design arrangement for both GSP and GSP-B™ are the gas/gas heat exchanger (typically a brazed aluminum heat exchanger or BAHE), cold separator, turbo-expander, recompressor, demethanizer fractionation column, subcooler, demethanizer reboilers. For GSP-B™, a Heat and Mass Transfer (HMT) module replaces the traditional reboilers and mass transfer stripping section. These equipment items and their locations will be further discussed to compare the process differences between GSP and GSP-B™.

Heat Exchanger Assembly

In most designs, all heat exchange equipment (i.e. gas/gas exchanger, subcooler, and the column side/bottom reboilers) for the GSP is located at grade-level. For the bottle arrangement, the equipment is located within the pressurized vessel assembly above and below the demethanizer absorber section. For both GSP and GSP-B™, the inlet feed flow is divided into two streams. Instead of both GSP feed streams exchanging heat in the gas/gas exchanger and reboilers at grade-level, one GSP-B™ feed stream enters the feed pass of the gas/gas exchanger near the top of the processing assembly, and the second feed stream flows through the HMT module at the base of the demethanizer stripping section. The GSP-B™ demethanizer overhead flows through the residue gas pass of the subcooler and gas/gas exchanger prior to exiting the pressurized vessel assembly, instead of exiting the demethanizer column and flowing into the GSP cold box assembly to pass through the subcooler and gas/gas exchanger at grade-level.

Demethanizer Fractionation Column

The fractionation section of the demethanizer column is located within the GSP-B™ process assembly below the BAHE equipment and above the cold separator as shown in Figure 2. The GSP-B™ demethanizer absorption section and reflux system, located above the expander feed, is similar to a traditional GSP design. The traditional demethanizer stripping section below the expander feed is replaced with a HMT module using the heat from the inlet feed stream to vaporize the light ends such as methane from the liquid entering the HMT module.

Traditional Thermosiphon Reboilers versus a Heat and Mass Transfer Module

The GSP-B™ arrangement replaces all traditional thermosiphon reboilers and mass transfer components in the stripping section of the demethanizer column. Both side and bottoms reboilers, along with fractionation column internals, either packing or trays, are replaced with a novel concept integrating both heat and mass transfer into a single module located in the stripping section of the demethanizer column below the expander feed. As stated earlier, one portion of the feed stream will enter the column at the base of the HMT module and provide heat input to the demethanizer to strip light ends from the liquids in the lower section of the column, while simultaneously using the cold liquid within the demethanizer to cool and partially condense this portion of the feed gas before it enters the cold separator.

Cold Separator Vessel

For both the GSP and GSP-B™ arrangements, the split feed streams exit the gas/gas exchanger and reboiler/HMT module to recombine as cold feed gas prior to entering the cold separator vessel. The GSP-B™ cold separator is located within the process assembly below the demethanizer sump. This location has become common practice even in traditional GSP plants for designers that want to reduce the footprint at grade, opting instead to increase the overall demethanizer/cold separator column assembly height.

Turbo-Expander and Recompressor

The turbo-expander and recompressor assembly is located at grade on a separate skid adjacent to the demethanizer column for both the traditional GSP and GSP-B™ process. No changes have been made to the functionality or location of this assembly.

Benefits of the "Bottle" Technology

As a result of this innovative arrangement for processing natural gas for liquids recovery, the "bottle" process has numerous benefits when compared to a traditional gas processing plant.

<u>*GPB Process Benefits*</u>

The compact GPB arrangement significantly reduces the power consumption required to achieve a given recovery level, thereby increasing the process efficiency, reducing fuel consumption, and reducing the operating cost of the facility. The reduction in power consumption is a result of lower system pressure drop due to eliminating interconnecting pipe, and the performance efficiency of the HMT module. Residue gas compression power is typically reduced by 5% to 9% when compared to a traditional liquids recovery plant.

Integrating the heat and mass transfer into a single module below the expander feed provides several process benefits. The HMT module eliminates all traditional thermosiphon reboilers and associated thermosiphon piping, thereby eliminating all design problems associated with the thermosiphon piping (i.e., erratic flow, thermal cycling, etc.). All hardware associated with thermosiphon reboiler draws and returns, such as reboiler downcomers and flash galleries, are eliminated as well, reducing the height of the fractionation column.

Use of the HMT module instead is more efficient than the traditional thermosiphon reboiler arrangement by providing heat and mass transfer across the entire module. The HMT module is analogous to having multiple side reboilers throughout the fractionator stripping section improving the overall heat integration of the plant. The improved efficiency in the stripping section of the fractionator results in a reduction in power consumption or an improvement in product recovery compared to a traditional liquids recovery plant.

Testing by OEL and SME-P at the University of Texas J.J. Pickle Research Facility in Austin, Texas has demonstrated the HMT module HETP (Height Equivalent to a Theoretical Plate) is very comparable to traditional random packing resulting in similar separation efficiencies to traditional separation equipment. It is Ortloff's experience that traditional random packing used in the stripping section of high pressure demethanizer and deethanizer columns typically have a HETP range of 12-20 inches based on a packing ring size of 1-inch or 1.5-inches. The HMT module testing was administered using a cyclo-hexane and normal heptane hydrocarbon mixture resulting in HETPs identical to or better in some cases than traditional HETPs over a broad range of process conditions.

The HMT module is designed for low thermal stress and minimal pressure drop. This proprietary design allows greater thermal differentials and increases the allowable thermal ramp rate at startup, shutdown, and during plant upset conditions. The HMT module also reduces tower internal requirements within the stripping section of the fractionation column below the expander feed.

Refrigeration needs can be easily incorporated into the GPB design for richer gas streams, either externally for cooling the inlet feed stream or within the cold separator vessel by use of a runback chiller. The GPB design also allows for an optional external heating source, such as steam or hot oil, within the HMT module for processes which require higher temperatures for stripping within the fractionator than can be provided by the inlet feed gas stream.

GPB Construction Benefits

By incorporating all of the processing equipment into a common processing assembly, the GPB has a significantly smaller plot plan, reducing the number of foundations required and reducing the amount of interconnecting pipe and insulation when compared to the cryogenic section of a traditional gas processing plant. The simplified plot plan of the liquids recovery plant shown below in Figure 3 depicts the approximate amount of plot spaced saved as a result of using GPB.

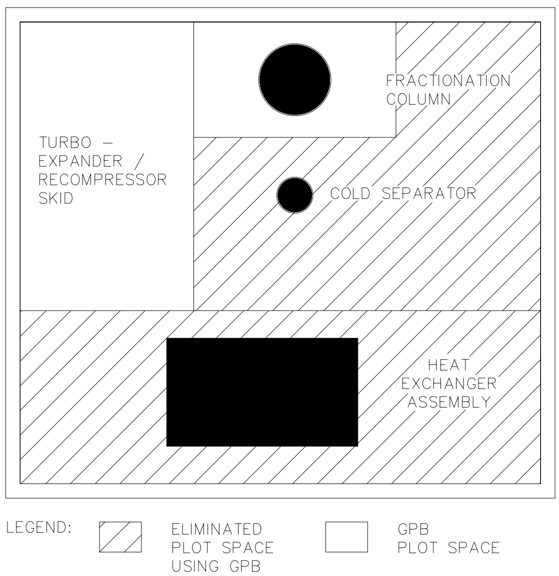

Figure 3 – Liquids Recovery Plant Plot Space Comparison

The GPB is constructed at an off-site fabrication facility, reducing the required amount of on-site construction components and on-site construction work. All process piping associated with the liquids recovery portion of the gas plant is pre-engineered and pre-fit to minimize on-site field labor. The single process housing concept reduces the required number of components to be shipped to the plant site and allows the GPB to be easily relocated to a different plant site if desired.

The GPB construction also has the advantage of eliminating the residue gas headers on the BAHE when the BAHE is installed within the pressurized process assembly. Eliminating the residue gas headers reduces BAHE nozzle stresses, reduces the pressure drop across the BAHE residue gas pass, and may reduce BAHE fabrication costs significantly.

GPB Environmental Benefits

As previously mentioned, the more compact arrangement of the GPB design eliminates much of the piping used to interconnect the individual process equipment in traditional liquids recovery plant designs. Because piping flanges are a potential leak source for hydrocarbons and other process gas components, eliminating these flanges reduces the number of leak sources and the potential for atmospheric emissions.

Example "Bottle" Technology Comparison – Gas Subcooled Process (GSP)

An example design comparing recoveries, compression requirements, and capital costs for a 200 million standard cubic feet per day (MMSCFD) GSP liquids recovery plant is given in this section. The feed conditions, residue gas delivery conditions, and NGL product specification for both the GSP and GSP-B™ are listed in Table 1 below for this example, and the inlet gas composition is shown in Table 2.

Table 1 – Design Conditions

Inlet Gas	
Temperature [ºF]	100
Pressure [psia]	915
Flow [MMSCFD]	200
Residue Gas Delivery	
Pressure [psia]	915
Temperature [ºF]	120
NGL Product	
Molar C_1/C_2 Ratio	1.9%

Table 2- Inlet Gas Composition

Component Mole Fractions	
Nitrogen	0.007
Carbon Dioxide	0.019
Methane	0.900
Ethane	0.040
Propane Plus	0.034

Product recoveries, required compression power, and approximate uninstalled cost are shown in Table 3. The liquids recovery portion of a gas processing plant consists of the associated process equipment downstream of the gas conditioning equipment (i.e., downstream of the amine contactor, dehydrators, etc.), and includes the turbo-expander/recompressor assembly.

Table 3 – GSP Comparison (200 MMSCFD Gas Plant)

	Standard GSP	GSP-B™	% difference
Ethane Recovery	88.5%	88.6%	+ 0.1%
Propane Recovery	97.7%	97.7%	-
Butanes-Plus Recovery	99.6%	99.6%	-
Residue Gas Compression [hp]	8,278	7,726	-6.7%
Gallons of ethane recovered per unit hp	0.95	1.02	+ 7.3%
Approximate Uninstalled Cost [$US]	$9,000,000	$7,000,000	-22.0%

The approximate costs shown in Table 3 for GSP and GSP-B™ reflect uninstalled costs only. Items included in this cost are all process equipment purchases and off-site fabrication, the purchase of a turbo-expander/recompressor assembly, all interconnecting pipe and valves (both manual and automated valves), and insulation materials. The uninstalled costs do not reflect any field installation costs, costs associated with on-site civil and foundation work, or on-site structural steel costs; for instance, the costs associated with the construction of pipe racks. Residue compression is also not included in this cost estimate.

The capital cost savings are a significant advantage when choosing the GSP-B™ option. The majority of the cost savings is a result of less construction materials needed to construct a "bottle" plant, such as less interconnecting pipe, reduction in BAHE materials, and complete elimination of reboilers and reboiler piping. These capital savings are realized with no adverse effect on operating flexibility or efficiency. In fact, the GSP process efficiency improves by 6% to 8% depending on the GSP-B™ process design arrangement chosen. Again, the improved efficiency is a result of the reduction in system pressure drop due to less interconnecting piping between processing equipment and the performance efficiency of the HMT Module.

"Bottle" Processes Using Ortloff Process Technology

The ***Gas Plant in a Bottle™*** product line includes many of Ortloff's proven process technologies.[7,8,9,10] These process technologies can be adapted to cover a wide range of process feed conditions and offer process options for ethane recovery, propane recovery, or the ultimate flexibility to recover or reject ethane with a single process design.

GSP-B™ – Derived from the *Gas Subcooled Process* (GSP), this process provides both high ethane recovery or ethane rejection modes of operation while reducing the recompression horsepower required. The GSP process has proven its CO_2 tolerance in numerous applications.

RSV-B™ – Derived from the proven *Recycle Split Vapor* (RSV) process, it provides ultra-high ethane recovery with the flexibility to operate at ultra-high propane recovery.

SCORE-B™ – Derived from the proven *Single Column Overhead REcycle* (SCORE) process, it provides very high propane and heavier component recovery with very low compression horsepower.

SFR-B™ and SRP-B™ – Derived from the *Split Flow Reflux* (SFR) process and *Supplemental Rectification Process* (SRP), these processes provide the ultimate flexibility for either ethane recovery or ethane rejection operation.

For each of these GPB process technologies, Table 4 below quantifies several of the benefits described in this paper. The actual benefit realized depends on the final design arrangement needed for a particular gas processing application.

Table 4 – "Bottle" Technology Comparisons

	Reduction in Compression Power	Reduction in Capital Costs	Reduction in Installation Costs	Reduction in Footprint
GSP vs. GSP-B™	6% to 8%	15% to 30%	40% to 50%	30% to 60%
SCORE vs. SCORE-B™	5% to 8%			
RSV vs. RSV-B™	6% to 8%			
SRP vs. SRP-B™	5% to 8%			
SFR vs. SFR-B™	4% to 6%			

"Bottle" Process Simulations

The integrated heat and mass transfer simulation models are different from a traditional simulation model for a gas processing plant. OEL's process design know-how and expertise coupled with SME-P's equipment design expertise have been used to rigorously model the integrated HMT module in order to predict the number of theoretical stages needed to provide adequate fractionation while simultaneously providing sufficient heat transfer for cooling the feed stream.

"Bottle" Retrofit Applications

Whether the owner/operator desires to increase an existing plant's capacity, improve product recovery, or both, the GPB is an excellent design choice for retrofit applications. GPB minimizes retrofit downtime due to the reduced amount of on-site field construction. The single GPB process assembly minimizes the plot space needed, as well as the piping and foundation modifications required for retrofitting a gas plant.

Conclusion

In today's business climate, the successful gas processors will be those who can tailor the performance of their NGL/LPG recovery plants to maximize product margins as market conditions change, while still maintaining efficient operation.[5] The ***Gas Plant in a Bottle™*** NGL/LPG recovery processes described in this paper are the next generation of processes for reducing capital costs and operating costs while still maintaining maximum process flexibility, efficiency, and product recovery. The "bottle" design is now available for purchase through SME Products, L.P. to provide gas processors the competitive edge needed to succeed today and in the future.

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