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NEXT GENERATION PROCESSES FOR NGL/LPG RECOVERY

Presented at the

77th Annual Convention

of the

Gas Processors Association

March 16, 1998

Dallas, Texas

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Abstract

Up to now, Ortloff's **G**as **S**ubcooled **P**rocess (GSP) and **O**ver**H**ead **R**ecycle Process (OHR) have been the state-of-the-art for efficient NGL/LPG recovery from natural gas, particularly for those gases containing significant concentrations of carbon dioxide (CO_2). Ortloff has recently developed new NGL recovery processes that advance the state-of-the-art by offering higher recovery levels, improved efficiency, and even better CO_2 tolerance.

The simplicity of the new process designs and the significantly lower gas compression requirements of the new processes reduce the investment and operating costs for gas processing plants. For gas streams containing significant amounts of carbon dioxide, the CO_2 removal equipment upstream of the NGL recovery plant can be smaller or eliminated entirely, reducing both the investment cost and the operating cost for gas processing companies. In addition, the new liquids extraction processes can be designed to efficiently recover or reject ethane, allowing the gas processor to respond quickly to changing market conditions.

This next generation of NGL/LPG recovery processes is now being applied to natural gas processing here in the U.S. and abroad. Two of the new plants currently under construction provide practical examples of the benefits of the new processes.

Introduction

The production and consumption of natural gas is on the rise throughout the world as a result of its wide availability, ease of transportation and use, and clean-burning characteristics. Buying and selling of natural gas is often handled electronically now like many other commodities. The emerging commodity nature of natural gas, however, has created increasingly tighter competition among natural gas processors for processing rights, and has resulted in increasingly narrow operating margins between the processing costs and the market price for which the recovered liquids can be sold.

The processing costs for gas processors can generally be divided into two categories: contaminant removal and liquids recovery. Carbon dioxide (CO_2) is a particularly troublesome contaminant often found in natural gas, including many of the newly discovered natural gas reservoirs. Although most gas transportation companies and gas consumers will accept a CO_2 concentration of several percent in natural gas streams, many NGL recovery processes require removal of the CO_2 to avoid solids formation (freezing) in the cold sections of the processing plant. Since CO_2 removal equipment can add significantly to both the investment cost and the operating cost of the contaminant removal section of the gas processing facility, there is considerable advantage to using a CO_2-tolerant process in the liquids recovery section of an NGL/LPG recovery facility.

Within the liquids recovery section of the facility, there are both operating cost and operating flexibility issues that directly impact the processing cost. While it is easily recognized that the efficiency of the selected liquids recovery process is an important factor in the processing cost, the flexibility of operating the process to either recover or reject ethane without sacrificing efficiency or propane recovery is often the critical factor in determining the profitability of a gas processing plant. With the historically cyclic nature of ethane values as a petrochemical feedstock, it is absolutely vital for gas processors to be able to quickly respond to changing market conditions in order to maximize profits. When the value of ethane as a liquid is high, maximum ethane recovery gives the gas processor more income. When the value of ethane as a liquid is low, selling the ethane in the residue gas for its BTU value gives higher income, so efficient ethane rejection without sacrificing propane recovery (since the value of liquid propane has almost always been higher than its gas BTU value) is the key to plant profitability when the liquids market is depressed.

During the 1970s, Ortloff developed and subsequently patented several processes for liquids recovery that were more efficient or more CO_2-tolerant, and often both.[1,2] The defining feature of these processes is the novel split-vapor concept that each employs to generate reflux for the demethanizer or deethanizer tower. For ethane recovery plants, the most widely employed version of split-vapor process has been the **G**as **S**ubcooled **P**rocess (GSP) shown in Figure 1.[3,4] In this process, a portion of the feed gas is condensed and subcooled, flashed down to the tower operating pressure, and supplied to the tower as its top feed. The remainder of the feed gas is also expanded to lower pressure (typically using a turboexpander for vapor streams) and fed to the tower at one or more intermediate feed points. The cold liquids supplied to the top of the tower act as reflux, contacting and rectifying the vapor leaving the expander by absorbing the ethane-plus components for recovery in the tower bottom product. When CO_2 is present in the feed gas, the higher concentrations of C_2+ components in the cold liquids help reduce the amount of CO_2 concentrating in the upper, colder sections of the tower, allowing higher ethane recovery levels without CO_2 freezing. This same process can be operated to reject ethane, but propane recovery efficiency suffers significantly when operated in this mode due mainly to the higher concentration of propane present in the top feed.

The **O**ver**H**ead **R**ecycle Process (OHR) shown in Figure 2 has often been used instead of GSP for LPG recovery plants.[5] Although typically employed in a two-column configuration, this process in essence withdraws a vapor stream from an intermediate point in the composite distillation tower that is then condensed and used as reflux for the upper portion of the composite tower. This again produces cold liquids to contact and rectify the vapor leaving the expander, absorbing the propane-plus components for recovery in the bottom product from the second column. This process provides more efficient recovery of propane and heavier hydrocarbons than the GSP design, but is not suitable for high ethane recovery.

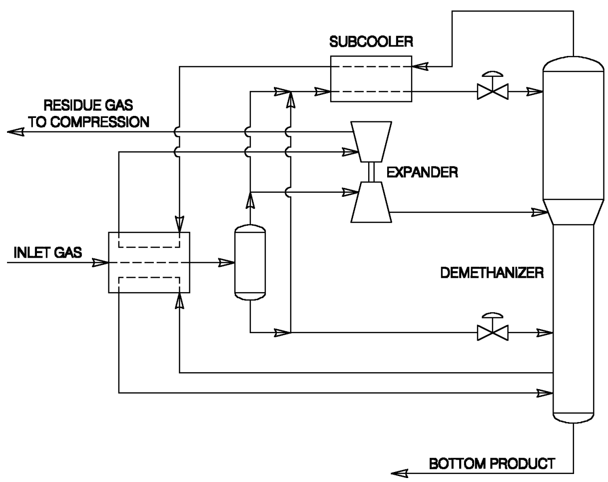

Figure 1 — GSP Process

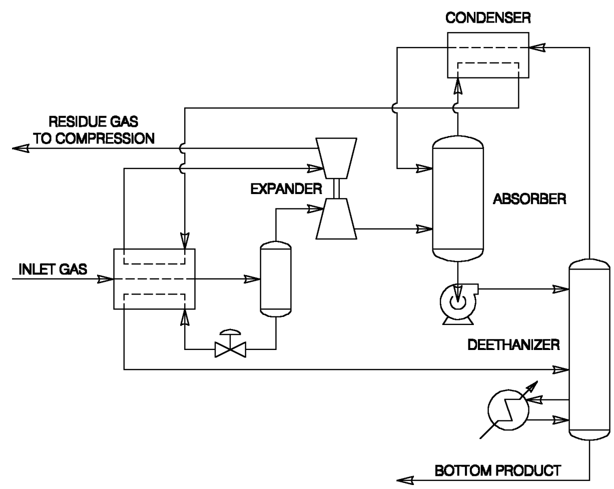

Figure 2 — OHR Process

Both varieties of the split-vapor process are ultimately limited in the recovery levels they can achieve by the composition of the vapor stream that becomes the reflux for the top of the tower. Beginning in the mid-1980s, Ortloff began investigating methods of extending the capabilities of the split-vapor concept that would overcome the equilibrium limitations of the current processes. This development work has culminated in the next generation of processes described in the remainder of this paper.

Evolution of the Next Generation Processes

Ethane Recovery Processes

Early efforts at improving the split-vapor concept, both for ethane recovery and for ethane rejection, focused on making indirect use of the refrigeration available in the subcooled split-vapor stream.[6] When applied to ethane recovery operation, the result was the **C**old **R**esidue **R**eflux process (CRR) shown in Figure 3.[7] The intent was to retain all the advantages of the GSP design while creating a reflux stream that was nearly pure methane. The methane reflux stream could then rectify the tower vapors so that little of the ethane and heavier components escaped in the tower overhead. Although the flashed split-vapor stream is not quite cold enough to liquefy a pure methane stream at the demethanizer operating pressure, a small off-the-shelf compressor can be used to boost a portion of the tower overhead to slightly higher pressure so that the methane can then be condensed by the flashed split-vapor stream. The condensed methane stream is then supplied to the top of the tower, with the slightly warmer split-vapor stream fed below. This allows the split-vapor feed to provide "bulk" ethane recovery by absorbing most of the ethane contained in the expander outlet vapor, so that the much smaller flow of methane reflux can then rectify the residual ethane from the vapors in the upper section of the tower. Ethane recoveries in excess of 99% are possible using this process, using essentially the same recompression horsepower as the GSP design. This process has the further advantage that it can be operated for near complete rejection of ethane while maintaining in excess of 99% propane recovery.

While the CRR process is unmatched in terms of recovery efficiency, the **R**ecycle **S**plit-**V**apor process (RSV) shown in Figure 4 sometimes requires less capital investment.[8] Like the CRR process, the RSV process uses the split-vapor feed to provide the bulk ethane recovery in the tower. The methane reflux stream for the tower is produced by withdrawing a small portion of the recompressed residue gas, condensing and subcooling it, then flashing it down to tower pressure and supplying it as the top feed. The higher pressure of this methane stream (compared to CRR) allows the tower overhead gas to be used to provide the condensing and subcooling, so that the split-vapor feed can be supplied directly to the tower. Condensing a portion of the high pressure residue gas for reflux is similar in concept to the

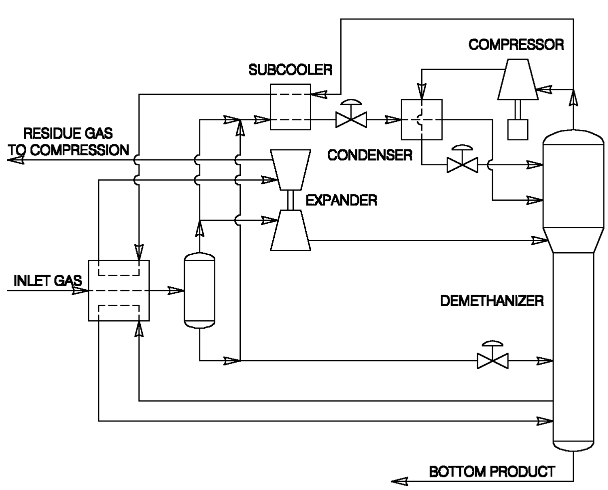

Figure 3 — CRR Process

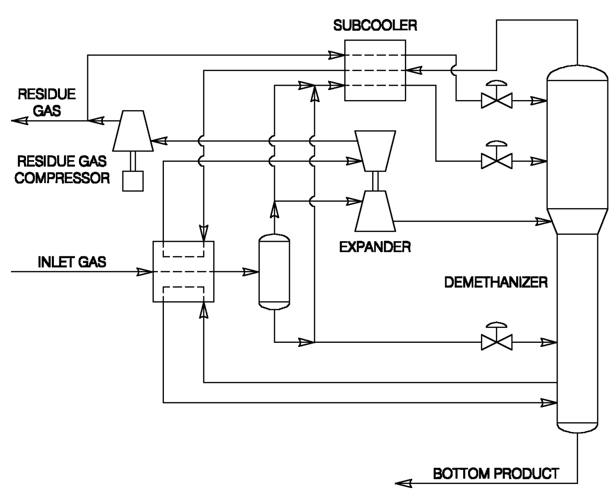

Figure 4 — RSV Process

residue recycle process used in some plants. However, combining this reflux with the split-vapor process results in much lower compression horsepower for a given recovery level because a much lower reflux flow is needed to rectify the tower vapors due to the bulk recovery provided by the split-vapor feed.

Since the main residue gas compressors supply the motive force for the reflux stream, a separate compressor is not needed for the recycle stream with RSV. As shown in Figure 4, when plate-fin exchangers are used, a single exchanger can be used to cool both the reflux stream and the split-vapor feed. In such cases, the incremental investment over the GSP design is almost insignificant. Like CRR, the RSV process is suited to both ethane recovery and ethane rejection operation, and can switch easily between the two operating modes as market prices change. It has the further advantage that it can be operated in GSP mode by discontinuing the reflux flow, allowing the gas processor to process higher inlet volumes at reduced ethane recoveries. Compared to a GSP design operating at the same ethane recovery level, both CRR and RSV have better CO_2 tolerance than the GSP design because the refluxed designs can accommodate higher demethanizer operating pressures for a given recovery level.

A variation of the RSV process is the **R**ecycle **S**plit-**V**apor with **E**nrichment process (RSVE) shown in Figure 5.[9] Similar to RSV, a recycle stream is withdrawn from the recompressed residue gas, but it is mixed with the split-vapor feed before being condensed and subcooled so that it does not require a separate exchanger or exchanger passage. Since the ethane content of the top tower feed is richer than for the RSV process, the ultimate ethane recovery is limited to slightly lower levels than RSV due to equilibrium effects, but the lower capital investment and simplicity of RSVE relative to RSV may justify

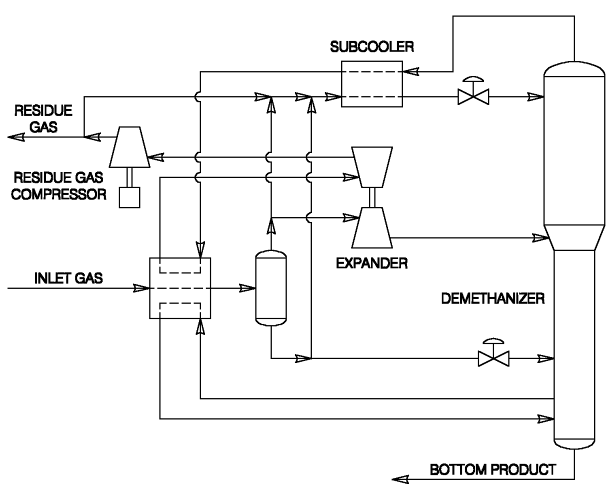

Figure 5 — RSVE Process

the small loss in ethane recovery in some projects.

Like the RSV process, the RSVE process can be operated to efficiently reject ethane while maintaining high propane recoveries. It can also be operated in GSP mode when more inlet gas is available, allowing the gas processor to maximize throughput by sacrificing some amount of ethane recovery. Compared to CRR and RSV designs operating at the same ethane recovery level, the RSVE process is more CO_2-tolerant. Enriching the recycle stream with the heavier hydrocarbons in the split-vapor feed raises the bubble point temperatures of the liquids in the upper section of the demethanizer, moving the tower operating conditions away from conditions at which solid CO_2 begins to form. As a result, an RSVE design can tolerate significantly higher CO_2 concentrations in the feed gas for a given ethane recovery level than GSP, CRR, or RSV designs, making it the most CO_2-tolerant process yet.

The efficiency improvements of these next generation processes compared to the GSP process are quite dramatic. Figures 6 and 7 below show the relative performance of GSP, CRR, RSV, and RSVE for a typical gas stream when operated for ethane recovery and ethane rejection, respectively. Compared to GSP, the new processes offer higher recovery for a given amount of compression, less compression for a given recovery level, or a combination of both. For instance, at an ethane recovery level of 92%, the compression power is 9%, 17%, and 20% lower than GSP for RSVE, RSV, and CRR, respectively. Or, if the horsepower available is 65 HP/MMSCFD, the RSVE, RSV, and CRR designs allow ethane recoveries 2, 6, and 7 percentage points higher, respectively, than the GSP design can achieve. Similar savings are possible when these processes are operated in ethane rejection mode.

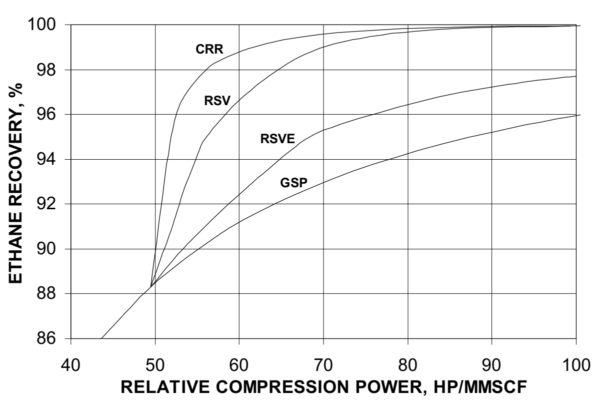

Figure 6 — Ethane Recovery Performance

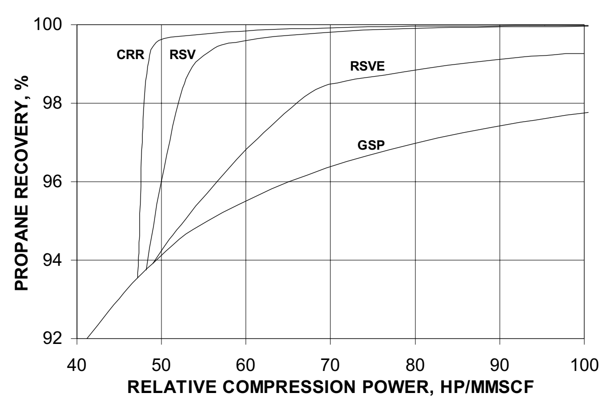

Figure 7 — Ethane Rejection Performance

Propane Recovery Processes

As noted earlier, making indirect use of the refrigeration available in the split-vapor stream of the GSP design is one way to improve recovery efficiency. The GSP design is limited to relatively low propane recovery when operated to reject ethane because of the effect that the heavy hydrocarbons in the split-vapor feed have on equilibrium at the top of the tower. The low temperature of the split-vapor feed is ineffective at retaining propane in the tower because the propane content of the vapor in equilibrium with this stream is so high. One method for overcoming this equilibrium limitation is to use the flashed split-vapor stream in a heat exchanger to cool the tower overhead and generate reflux, the **S**plit-**F**low **R**eflux process (SFR) shown in Figure 8.[10]

Similar to the CRR process, the flashed split-vapor stream is used to cool the tower overhead before being fed to an intermediate point of the tower. Since the tower overhead contains nearly all of the ethane in the feed gas, it condenses at a temperature that is high enough for the split-vapor stream to provide the necessary cooling. The liquid condensed from the overhead is separated and returned to the top of the tower as reflux to provide final rectification of the tower vapors. As before, the split-vapor feed provides the bulk recovery so that only residual amounts of propane must be rectified by the reflux.

Another approach is to improve the OHR process by making better use of the refrigeration available in its feed streams. One such scheme is the **I**mproved **O**verhead **R**ecycle process (IOR) shown in Figure 9.[11] In the OHR design, the cold absorber bottoms liquid is supplied directly to the deethanizer

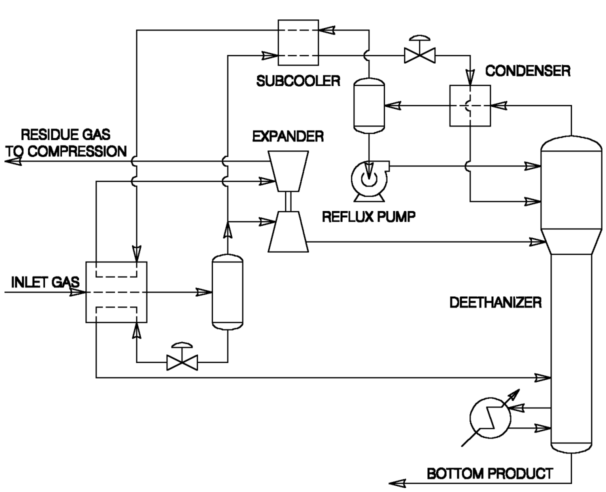

Figure 8 — SFR Process

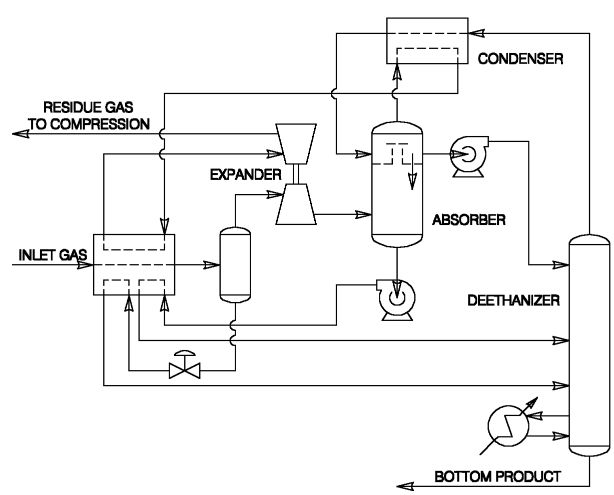

Figure 9 — IOR Process

as its top feed. In the IOR process, this stream is first used to supply part of the feed gas cooling, which not only reduces the cooling load on the front end of the plant, but also reduces the deethanizer reboiler duty by the same amount. A small portion of the cold reflux produced by the overhead condenser is used to rectify the vapors flowing up the deethanizer, allowing the absorber bottoms stream to be partially vaporized for maximum heat recovery as it provides feed gas cooling.

Although both the OHR process and the IOR process have traditionally been employed as two-column systems, the two columns in either process can be visualized conceptually as a single composite column with an intermediate vapor sidedraw. This composite column concept led to the development of the **S**ingle **C**olumn **O**verhead **RE**cycle process (SCORE) shown in Figure 10.[12] Although the SCORE process works in essentially the same fashion as the IOR process to make more efficient use of the refrigeration available in its feed streams, it can have a considerable advantage in terms of the investment cost for the plant. The single, larger column and small reflux drum are generally less expensive than the two columns used in the IOR process, and one less set of cryogenic pumps is required. The single column design is also more easily adapted to ethane recovery operation (discussed later in this paper).

The efficiency improvements of these next generation processes are also quite significant compared to the OHR process. Figure 11 below shows the relative performance of OHR, SFR, IOR, and SCORE for a typical gas stream when operated for propane recovery. (The performance of GSP is also shown for reference.) Compared to OHR, the new processes offer higher recovery for a given amount of compression, less compression for a given recovery level, or a combination of both.

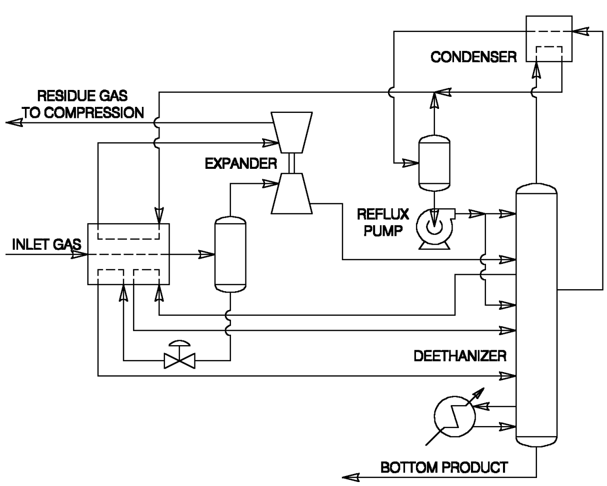

Figure 10 — SCORE Process

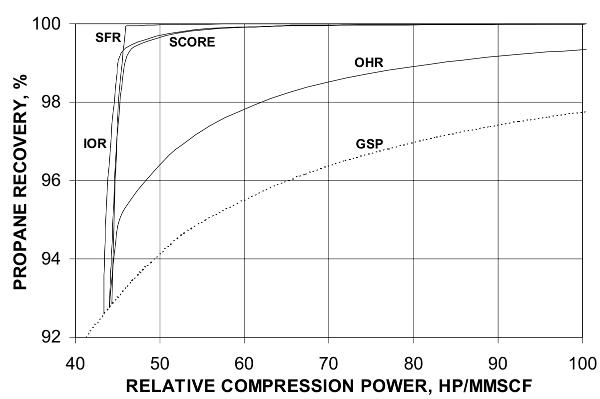

Figure 11 — Propane Recovery Performance

Case Study 1 — High C_2 Recovery plus C_2 Rejection

Figure 12 below shows a block flow diagram for a new gas processing facility on the U.S. Gulf Coast. Feed gas for the plant will come from several sources, mainly offshore intercoastal waters, and will contain significant concentrations of CO_2. The client's initial concept was based on using several processing trains, each processing 250 MMSCFD of feed gas using 18,000 HP of residue gas compression per train. The client desired efficient, high ethane recovery to give a competitive advantage relative to the other gas processing projects planned for this region. In addition, high propane recovery while rejecting ethane was an important design concern so that product revenues could be maximized when ethane margins are low.

The compressor selection was already fixed when the facility design was given to Ortloff for study. After some preliminary evaluations by Ortloff, it was determined that this level of compression could easily allow processing 300-350 MMSCFD per train, so the design basis was revised accordingly. Ortloff then prepared detailed studies of two processing options: a dual-mode plant that could operate as a GSP for ethane recovery or as an IOR for propane recovery, and a dual-mode plant that could operate as an RSV for either ethane recovery or rejection.

The GSP/IOR design was based on a two-column design similar to that shown earlier in Figure 9. When operated for ethane rejection, the lower tower is operated as a deethanizer and the absorber captures nearly all of the propane in the deethanizer overhead. When ethane recovery is desired, the lower column is operated as a demethanizer, while the absorber section functions as the top portion of the GSP design shown in Figure 1. With this process configuration, ethane recovery is limited mainly by the need to avoid CO_2 freezing in the top portion of the absorber.

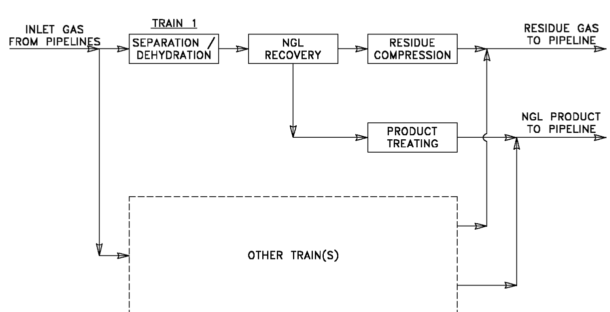

Figure 12 — Block Diagram for Case Study 1

The RSV design is much the same as that shown in Figure 4 earlier. Because the top feed has both low CO_2 content and low ethane content, the top section of the column does not build up CO_2 concentrations as high as the GSP design. As a result, the RSV design can achieve much higher ethane recoveries while maintaining an adequate margin from CO_2 freeze-up. When operated in ethane rejection mode, the process can still maintain very high propane recovery due to the additional rectification provided by the recycle stream to the top of the column. Further, switching from ethane recovery mode to ethane rejection mode is simpler than for the GSP/IOR combination, requiring only adjustment of the tower bottoms temperature control setpoint and one valving change in the feed piping.

Comparison of these two designs is tabulated below for ethane recovery and ethane rejection operation when processing 300 MMSCFD in each train. The RSV design can also be operated as a GSP plant by shutting off the recycle flow, allowing higher throughput at lower ethane recovery. The design selected can operate at inlet rates of 350 MMSCFD or more in this mode, as shown in Table 1. Based on the higher recovery in ethane recovery mode, the high propane recovery in all modes, the better CO_2 tolerance, the flexibility of increasing throughput when gas is available, and the ease in switching from one mode of operation to another, the client selected RSV as the basis for the plant design. The plant equipment has been placed on order and detailed design work is proceeding.

Plant Design	GSP / IOR		RSV			
Operating Mode	GSP	IOR	RSV (C_2)	GSP (C_2)	RSV (C_3)	GSP (C_3)
Inlet Rate, MMSCFD	300	300	300	350	300	350
Residue Compression, HP	18,000	18,000	18,000	18,000	18,000	18,000
Ethane Recovery, %	91.7	nil	97.5	87.6	nil	nil
Propane Recovery, %	98.6	99.3	99.9	98.5	99.8	93.5
Ethane Production, gal/D	332,578	nil	353,614	370,660	nil	nil
Propane Production, gal/D	159,043	160,172	161,140	185,362	160,979	175,953
Incremental Ethane, gal/D	base	nil	21,036	38,082		
Incremental Propane, gal/D	base	base	2,097	26,319	807	15,781

Table 1 — Recovery Comparison for Case Study 1 (RSV vs. GSP / IOR)

Case Study 2 — High C_3 Recovery, Variable C_2 Recovery

A major gas transmission company in Argentina was investigating how best to increase capacity and improve recovery at an existing gas processing facility. During peak usage periods, part of the feed gas available at the facility could not be processed due to plant capacity limitations. Ortloff was able to design GSP retrofits for the two existing trains that would not only raise capacity and improve recovery, but would also free one compression train that could then be used for a new processing train to add still more capacity.[13]

A block flow diagram for the expanded facility is shown below in Figure 13. Feed gas comes from three different gathering systems and is processed for NGL recovery. The residue gas is recompressed and routed to a gas transmission pipeline for use elsewhere in Argentina; the NGL product is fractionated so that the ethane cut can be used as feedstock in a local petrochemical complex. After being retrofit to use the GSP process, the capacity of existing Trains A and B will go from 11 MMm^3/D (389 MMSCFD) per train to 12 MMm^3/D (425 MMSCFD) per train, with the compression required for each train dropping from 36,000 HP to 24,000 HP while the ethane recovery increases from 63% to 80%. Even with this increase in ethane and total NGL production, however, the facility will still not be able to supply all of the ethane feedstock that will be needed in the future by the petrochemical complex. Ortloff was asked to design a new Train C that could provide efficient propane recovery using the 24,000 HP that would be available from the third compression train, with the ability to provide variable ethane recovery as needed to supplement the ethane production from Trains A and B.

As noted earlier, the single column used in the SCORE process for propane recovery can be designed to easily switch to ethane recovery service by operating it as a GSP plant. Propane recovery mode using the

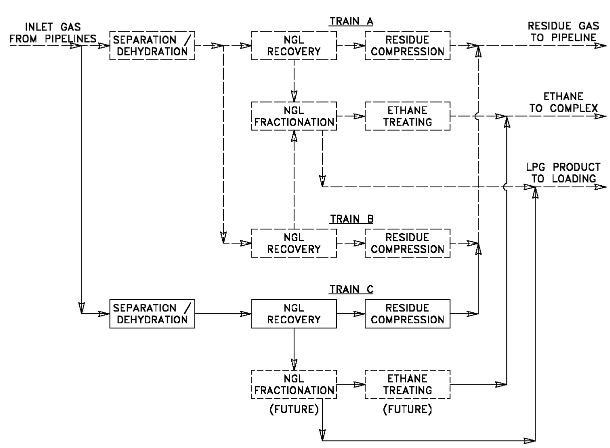

Figure 13 — Block Diagram for Case Study 2

SCORE process is shown in Figure 14 below, while Figure 15 shows the same plant operating as a GSP for ethane recovery. This simple switch from propane recovery to ethane recovery will make it possible for the revamped Trains A and B to operate at steady rates and recovery levels while the new Train C operates as the "swing" plant to provide the required overall ethane recovery. With 24,000 HP available for Train C, a new SCORE/GSP design can process up to 16 MMm^3/D (564 MMSCFD) for high propane recovery with full ethane rejection, moderate ethane recovery, or any ethane recovery level in between.

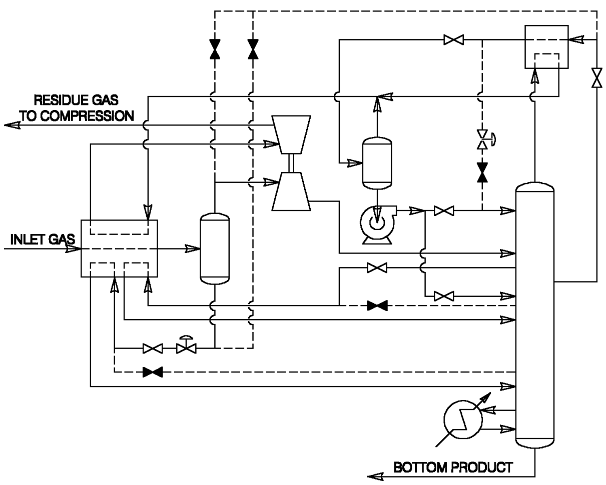

Figure 14 — Propane Recovery Mode

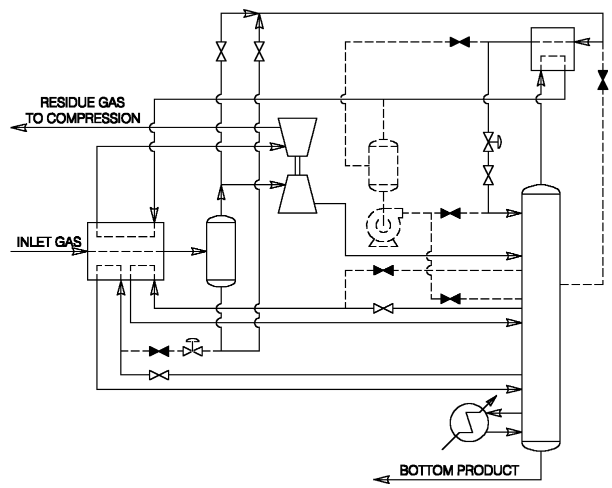

Figure 15 — Ethane Recovery Mode

Since Trains A and B currently use the industry-standard single-stage process (ISS), Ortloff used a new ISS design as a basis for comparison in evaluating the SCORE/GSP design for Train C. The results of these comparison cases are tabulated below. Due to the much higher recovery levels possible with SCORE/GSP and the ease in switching from one operating mode to the other, the SCORE/GSP design was selected for the new Train C currently under construction. Plant completion should occur in mid-1998. The GSP retrofits for Trains A and B will be implemented as soon as ethane demand increases at the petrochemical complex.

Plant Design	ISS		SCORE / GSP	
Operating Mode	ISS (C_3)	ISS (C_2)	SCORE (C_3)	GSP (C_2)
Inlet Rate, MMSCFD	564	564	564	564
Residue Compression, HP	24,000	24,000	24,000	24,000
Ethane Recovery, %	nil	60.0	nil	76.9
Propane Recovery, %	84.0	92.6	99.6	97.1
Ethane Production, gal/D	nil	382,200	nil	495,600
Propane Production, gal/D	202,860	222,600	240,240	235,200
Incremental Ethane, gal/D		base		113,400
Incremental Propane, gal/D	base	base	37,380	12,600

Table 2 — Recovery Comparison for Case Study 2 (SCORE / GSP vs. ISS)

Conclusions

If past performance is any indication at all, operating margins for liquids recovery from natural gas will continue to fluctuate. More and more, the successful gas processors will be those who can tailor the performance of their NGL/LPG recovery plants to maximize product revenues as market conditions change, while still maintaining efficient operation. The next generation NGL/LPG recovery processes described in this paper are now the state-of-the-art for gas processing flexibility and efficiency, and are available for licensing to give gas processors the competitive edge needed to succeed today and in the future.

Acknowledgments

The authors gratefully acknowledge the wisdom, insight, and guidance of Roy E. Campbell, who led the development of this generation of NGL/LPG recovery processes as well as the processes that preceded them. His contributions to the gas processing industry cannot be measured, and his passing has diminished us all.

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