IMPROVED NGL RECOVERY DESIGNS MAXIMIZE OPERATING FLEXIBILITY AND PRODUCT RECOVERIES

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(PREPRINT)

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ABSTRACT

The historically cyclical nature in the market for ethane and propane has demonstrated the need for flexible natural gas liquids (NGL) recovery plants. Newly developed and patented processes are now available which can provide ultra-high recovery of ethane (95%+) when demand for ethane is high and provide essentially complete ethane rejection without the normally concomitant reduction in propane recovery. This provides plant operators the flexibility to respond more readily to NGL market conditions, thus maximizing plant operating profits. The new process designs provide this flexibility without increasing utility requirements. In fact, utility consumption is often lower when compared to conventional designs. This same process technology can also be easily retrofit into existing plants with relatively quick payout of the modifications from both recovery and efficiency improvements.

INTRODUCTION

The last few years have been trying times indeed for gas processing plant operators. There have been times when the market for natural gas liquids (NGL) has been depressed, often coupled with periodic increases in gas prices, causing the processing spread for ethane to disappear in many cases. The processing spread for propane and the heavier liquids also declined during such periods. More recently we have seen increased production of gas reserves, reduced demand for natural gas due to mild weather, and increased demand for NGL as petrochemical feedstock. This has caused many gas processors to focus on increased NGL recovery as the way to maximize plant profitability. While these conditions may be the norm for the foreseeable future, it is clear that the profitability of gas processing plants depends on having the ability to respond efficiently to market conditions, i.e., obtain maximum ethane recovery when its relative value as a liquid is high, but reject ethane when its value as a liquid is low.

Most of the gas plants in operation today were designed to recover ethane, with typical design recoveries ranging from 70-80%. When the processing spread for ethane disappears, many plant operators attempt to increase product revenues by rejecting ethane to the residue gas. Unfortunately, most gas plants cannot reject ethane well, and must sacrifice either propane recovery or operating efficiency when trying to do so. The plant operator is often forced to compromise -- either losing an undesirable amount of propane in order to maximize ethane rejection, or recovering an undesirably high percentage of ethane to avoid propane losses.

For maximum profit, gas plants should be designed to allow the operator to respond easily to changes in the NGL market. During conditions of low ethane processing spread, the operator should be able to reject ethane efficiently to capture its BTU value as residue gas sales. On the other hand, when the ethane market improves, the plant operator must be able recover ethane efficiently so that he can take advantage of its higher value as a liquid product. This processing flexibility, missing from most existing gas processing plants, can be designed into new plants by taking advantage of new ethane rejection/recovery technology that often allows lower capital investment for the processing plant. This same technology can be retrofitted into existing gas plants to improve their profitability as well. This report will describe the technology and demonstrate how the operating flexibility provided by these designs can improve the economics for gas processing.

TYPICAL GAS PROCESSING PLANTS

Many of the NGL recovery plants built during the last twenty years use conventional single-stage turboexpander technology for moderately high ethane recovery.[1] A typical example of the "**I**ndustry-**S**tandard **S**ingle-stage" process (ISS) is shown in Figure 1. After cooling the inlet gas, usually with a combination of cold residue gas and tower liquids, any condensed liquids are separated and fed to the demethanizer. The uncondensed vapor is work expanded and fed to the demethanizer as its top feed, with the liquids formed during expansion serving as reflux liquid for the tower. The work extracted from the inlet gas in the turboexpander is typically used for residue gas compression. ISS plants are usually designed for ethane recoveries of 70-80%. Designing for higher recoveries will usually increase the compression requirements disproportionately due to the nature of the process and is usually avoided.

During periods of low ethane processing spread, the plant operator usually attempts to operate the ISS plant in a manner that minimizes the ethane recovery, the so-called "ethane rejection" mode of operation. Unfortunately, the typical ISS plant does not work very well when trying to reject ethane and must sacrifice some amount of propane recovery in order to reduce ethane recovery. Even ISS plants designed with ethane rejection capability do not operate efficiently in this mode, and rarely can exceed 85% propane recovery when rejecting ethane. The situation is worse still for most existing ISS plants, as lack of reboiler capacity (and the inherent limitations of the ISS process) often forces the plant operator to strike a compromise between reducing ethane recovery and maintaining propane recovery. The result is that many existing plants can typically only reduce the ethane recovery to 25-50% while recovering a reasonable portion of the propane (85% or so). This can hardly be called "ethane rejection", and causes the plant operator to lose income from residue gas sales when ethane is more valuable for its fuel value than it is for its value as a liquid product.

A further drawback to the ISS process is that when ethane prices favor recovery in the liquid product, the plant operator usually cannot increase ethane extraction due to compression horsepower limitations. By the same token, the plant has no capability to increase throughput when gas is available without sacrificing ethane and propane recovery.

NEW TECHNOLOGY

An improvement to the ISS design was developed by Ortloff in the late 1970's and first used in a plant in 1979. This design is based on a split-vapor feed concept and is now recognized as one of the most efficient expander processes for ethane recovery.[2,3] Perhaps what has not been recognized, however, is that the split-vapor feed design and its various improvements described below can provide significant plant operating flexibility. These split-vapor feed designs are suitable not only for new, grass roots projects but for revamping older, existing plants as well.

Figure 2 is an example of Ortloff's **G**as **S**ubcooled **P**rocess (GSP).[4,5] The GSP design provides a rectification (fractionation) section above the turboexpander outlet using the split-vapor feed to reflux the rectification section. A portion of the feed gas is condensed, subcooled, and then flashed into the rectification section as the top liquid feed (reflux). The cold reflux liquid condenses and absorbs ethane and propane rising up through the demethanizer, allowing the high recovery. Since the GSP design does not use the turboexpander as top column feed, the inlet separator can operate at a warmer temperature, providing a net increase in power recovery from the turboexpander despite feeding less gas to the machine.

Figure 1
TYPICAL INDUSTRY-STANDARD SINGLE STAGE PLANT

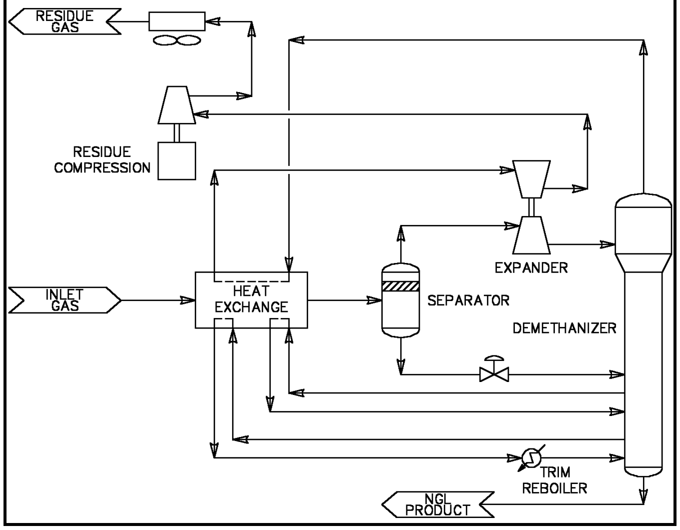
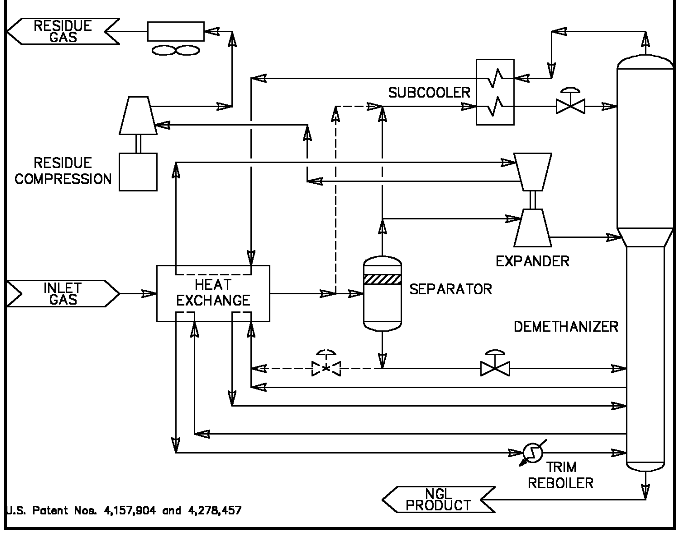


Figure 2
GSP PLANT DESIGN



U.S. Patent Nos. 4,157,904 and 4,278,457

Compared to the ISS process, the GSP design offers lower compression horsepower for the same recovery level, higher recovery for the same compression horsepower, or a combination of both benefits. The GSP design is also more tolerant of CO_2 in the inlet gas than an ISS plant, allowing higher recovery while reducing the risk of CO_2 freezing in the tower.

Recent advances in gas processing technology have been derived from the basic split-vapor feed concept of the GSP design. One of these, particularly well suited for high propane recovery with full ethane rejection, is the Split-Flow Reflux (SFR) process[6] shown in Figure 3. The SFR process overcomes the compositional effects that can limit the recovery performance of the GSP design by using the cold, split-vapor feed to reflux the tower indirectly. After the split-vapor feed is condensed, subcooled, and flashed to near tower pressure, it is used to partially condense the tower overhead before feeding a lower section of the tower. The liquid condensed from the tower overhead is returned to the tower as reflux, rectifying the column vapors to allow propane recoveries in excess of 99% while rejecting essentially all the ethane. The SFR design has the further advantage that process conditions can be altered to recover ethane, at which time the process provides all the benefits of the GSP design.

A second derivative of the split-vapor concept is the Cold Residue Reflux (CRR) process[7] shown in Figure 4. The CRR process can be operated for either high propane recovery with full ethane rejection, or for ultra-high ethane recovery. Like the SFR process, CRR uses the cold, split-vapor feed to condense reflux indirectly. In this design, a compressor is used to boost a portion of the cold tower overhead before it is condensed and subcooled by the split-vapor feed, flashed to tower pressure, and fed to the tower as reflux. The split-vapor feed then enters the tower at a lower feed point. This compressor is typically a small, low head, electric drive unit and uses 160-190 HP for a 100 MMSCFD plant. The rectifying action of the reflux stream allows a very clean separation, with recoveries as high as 99% or more for either ethane or propane. Process conditions can be altered to completely reject ethane while recovering essentially all of the C_3+, or to recover nearly all of the ethane. Moreover, these ultra-high product recoveries are possible using less compression horsepower than an ISS plant designed for much lower ethane recovery.

Compared to an ISS plant, these three processes have all of the benefits of the split-vapor feed concept: higher ethane or propane recovery, lower compression requirements, and increased CO_2 tolerance. Plants designed using these processes will be able to reject ethane, without sacrificing propane recovery, when the ethane processing spread is low or nonexistent. When the ethane processing spread is favorable, process variables can be easily adjusted for high or ultra-high ethane recovery, giving the plant operator the flexibility he needs to respond to market conditions and maximize his profits. Further, plants based on the split-vapor feed concept usually involve less capital investment due to the lower compression requirements.

COMPARISON OF TECHNOLOGYBENEFITS

Several comparison cases have been prepared to illustrate the benefits of the split-vapor feed process designs over an ISS plant. Process simulations were performed for a typical inlet gas stream at a flow rate of 100 MMSCFD, assuming that the plant operates on a nominal 1050 PSIG pipeline. The inlet gas composition is shown in Table 1.

Figure 3
SFR PLANT DESIGN

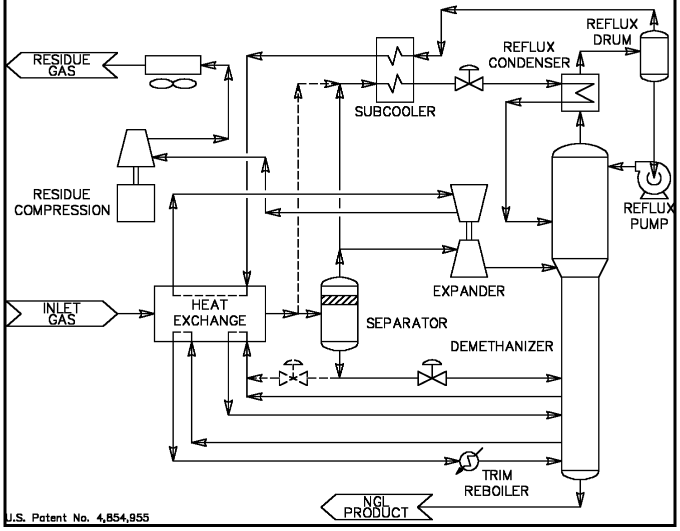


Figure 4
CRR PLANT DESIGN

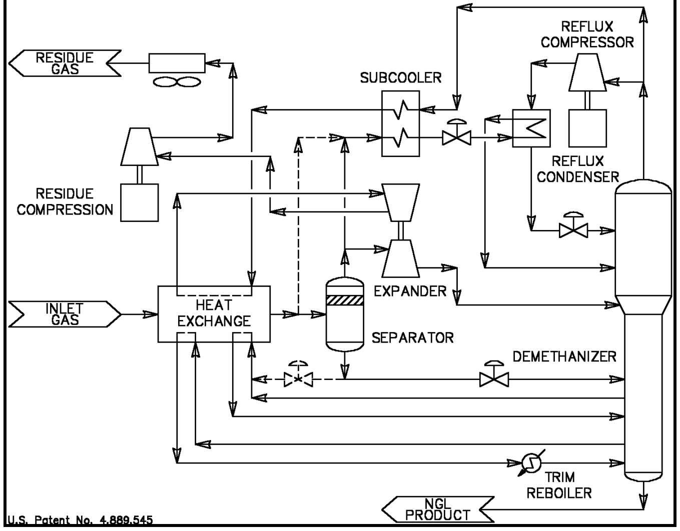


Table 1
Inlet Gas Composition

Component	Mole %
Nitrogen	0.27
Carbon Dioxide	0.50
Methane	92.47
Ethane	4.23
Propane	1.32
i-Butane	0.39
n-Butane	0.32
i-Pentane	0.15
n-Pentane	0.09
Hexane +	0.26
Total	100.00

For each process, a base case design was prepared for the plant in ethane recovery service. This design was used to set the capacity of the inlet heat exchangers, high pressure separator, expander/compressor, demethanizer, and residue gas compressors. The process conditions were then adjusted to reject ethane, subject to the capacity limits established from the ethane recovery design in each case. This method allows realistic estimates of plant performance in both operating modes, and allows meaningful comparisons between the different process designs.

The first part of Table 2 shows the calculated recoveries and compression horsepower of the base case designs for the four processes when operated at maximum ethane recovery. As the table shows, the three split-vapor feed processes offer notable improvements in ethane recovery while also using as much as 20% less residue gas compression horsepower. The improvement offered by the CRR design, increasing ethane recovery by 18 percentage points while using 18% less horsepower than the ISS design, is particularly impressive. These recovery and efficiency improvements are typical of those found during other new plant evaluations.

Table 2 further shows how the processes compare when operated in ethane rejection mode. Although the ISS design can reject essentially all of the ethane, propane recovery suffers due to lack of reflux for the tower. All three split-vapor feed designs have substantially higher propane recovery when rejecting ethane. The GSP design can recover almost 94% of the propane, while the SFR and CRR designs can recover essentially all of the propane due to the improved efficiency of the reflux design. The improvement in recovery is not at the expense of additional compression horsepower, as the three processes used 18-20% less compression. As before, the recovery and efficiency improvements shown for these cases are typical of those found during other new plant evaluations.

During periods of low or nonexistent ethane processing margin, the ability of the split-vapor feed designs to reject ethane can improve plant profits significantly. The lower compression horsepower of the new designs also markedly improves the economics for operating the gas plant.

COST / REVENUE COMPARISONS

As shown in the preceding table, use of one of the split-vapor feed designs instead of the ISS process for a new gas plant can offer important recovery, efficiency, and flexibility advantages. The new plant can realize significantly higher revenues from product sales, regardless of market conditions. Of course, this increase in revenue must be weighed against the capital cost for installing a new plant using one of these processes.

Figure 5 is a plot of the approximate installed costs versus plant capacity for each of the four different processes. The costs

Table 2
New Plant Process Comparison

	ISS (Fig. 1)	GSP (Fig. 2)	SFR (Fig. 3)	CRR (Fig. 4)
Ethane Recovery				
C_2 Recovery, %	79.6	88.0	88.0	98.0
C_3 Recovery, %	96.9	97.8	97.8	100.0
C_4 Recovery, %	99.4	99.4	99.4	100.0
Residue HP	5,774	4,597	4,597	4,732
Incremental kW	0	0	0	158
Ethane Rejection				
C_2 Recovery, %	0.8	0.9	0.9	0.9
C_3 Recovery, %	84.0	93.7	99.9	100.0
C_4 Recovery, %	96.7	98.6	100.0	100.0
Residue HP	5,783	4,590	4,598	4,731
Incremental kW	0	0	4	158

Figure 5
INSTALLED COST OF NEW PLANT DESIGNS

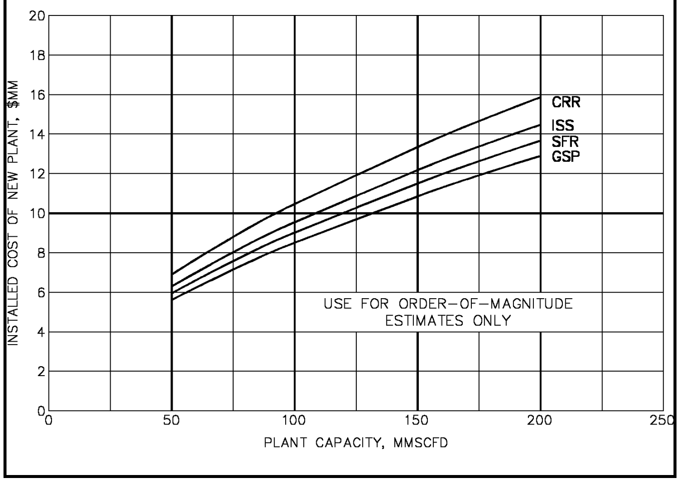


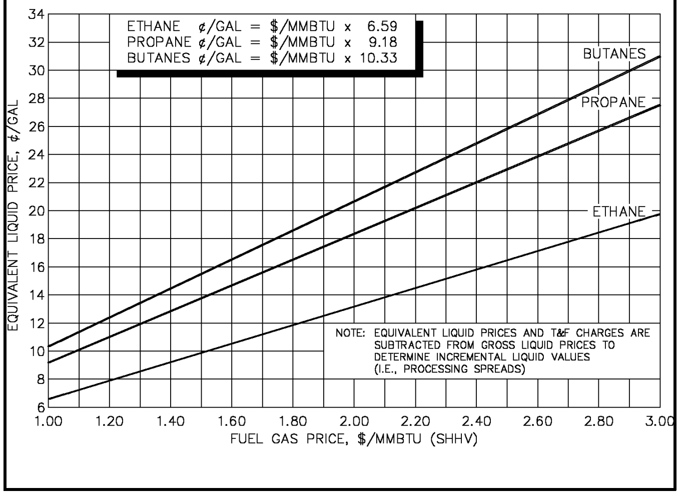
Table 3
Typical Prices and Processing Spreads

Favorable NGL Market		
Fuel Gas Value	1.6 $/MMBtu (SHHV)	
Electricity	5.0 ¢/kW-h	
Product T & F	3.5 ¢/gal (Transportation & Fractionation)	
Ethane Value	20.0 ¢/gal = 6.0	¢/gal processing spread
Propane Value	35.0 ¢/gal = 16.8	¢/gal processing spread
i-Butane Value	45.0 ¢/gal = 25.3	¢/gal processing spread
n-Butane Value	40.0 ¢/gal = 19.6	¢/gal processing spread
Depressed NGL Market		
Fuel Gas Value	1.6 $/MMBtu (SHHV)	
Electricity	5.0 ¢/kW-h	
Product T & F	3.5 ¢/gal (Transportation & Fractionation)	
Ethane Value	11.0 ¢/gal = -3.0	¢/gal processing spread
Propane Value	27.5 ¢/gal = 9.3	¢/gal processing spread
i-Butane Value	35.0 ¢/gal = 15.3	¢/gal processing spread
n-Butane Value	30.0 ¢/gal = 9.6	¢/gal processing spread

compression requirement and how well it fits available compressors can have a significant impact on the actual installed cost.

The payout period for the new designs can be determined by comparing the difference in capital costs from Figure 5 with the increased product revenue from the higher recoveries and efficiencies shown in Table 2. Typical product prices and processing spreads for both favorable and depressed NGL markets are shown in Table 3. Note that when the cost to transport and fractionate the liquid product is included, plants are actually losing money on each gallon of ethane recovered and sold as a liquid under the depressed NGL market conditions. For this reason, it is more economical to leave as much ethane as possible in the residue gas for sale on a BTU basis under these circumstances. (Figure 6 shows how to convert fuel gas value on a BTU basis to equivalent liquid value on a ¢/gallon basis.)

Figure 6
EQUIVALENT LIQUID PRICES VS. FUEL GAS PRICE



These operating costs and processing spreads, when applied to the horsepowers and recoveries shown in Table 2, give the relative cost comparisons shown in Table 4. Please note that the values entered for ethane, propane, and butane sales reflect the incremental value for the quantity of product sold in either the residue or NGL streams. Note also that the incremental revenue values are primarily dependent on fuel and liquid prices. A relatively small change in either of these prices could have significant impact on the incremental revenue comparisons.

As Figure 5 and Table 4 show, the GSP and SFR designs are actually less costly to install than a comparable ISS plant. And, with the lower horsepower requirements and higher product recoveries of these two designs, they generate more income for the plant operator. The CRR design costs about 10% more to install than the ISS plant, but its lower operating cost and higher product revenue pay out the incremental investment in less than two years based on the favorable NGL market conditions, or about three years for the depressed market conditions.

All three split-vapor feed designs show favorable economics compared to the ISS design. The choice of which new process depends on the particular circumstances of each case, and on market projections for future gas and NGL prices. If minimum capital investment is paramount, the GSP design would be the best choice. SFR would be the best choice if the projections for future ethane value remain low, and ultra-high ethane recovery will not be desired. However, if it is anticipated that the ethane market will be favorable in the future, CRR would be the process of choice, particularly in locations with ready access to the ethane market.

Table 4
New Plant Income / Cost Comparisons

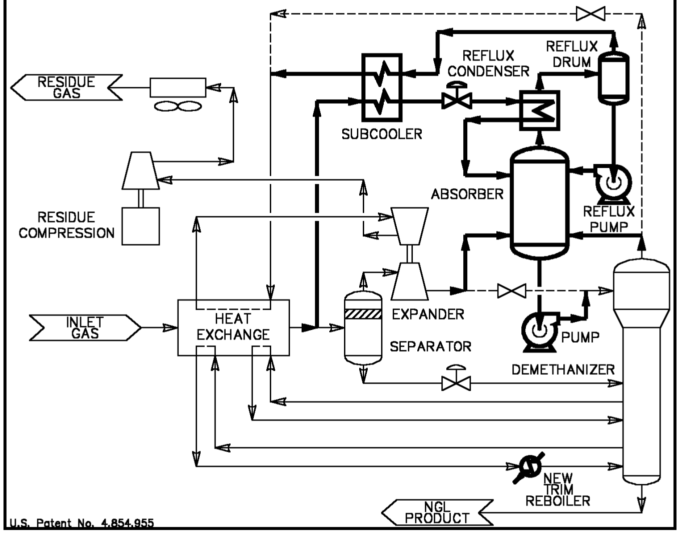
	GSP	SFR	CRR
Favorable NGL Market			
Incremental Daily Revenue / (Cost)			
Fuel Gas	**$ 495**	**$ 495**	**$ 439**
Electricity	**0**	**0**	**(189)**
Ethane Sales	**565**	**565**	**1,235**
Propane Sales	**53**	**53**	**188**
Butane Sales	**1**	**1**	**31**
Totals	**$ 1,114**	**$ 1,114**	**$ 1,704**
Incremental Plant Revenue, $ / Year	**$ 390,027**	**$ 390,027**	**$ 596,318**
Depressed NGL Market			
Incremental Daily Revenue / (Cost)			
Fuel Gas	**$ 502**	**$ 499**	**$ 443**
Electricity	**0**	**(5)**	**(189)**
Ethane Sales (in Residue Gas)	**(3)**	**(5)**	**(5)**
Propane Sales (in NGL Product)	**328**	**538**	**541**
Butane Sales	**57**	**101**	**101**
Totals	**$ 884**	**$ 1,128**	**$ 891**
Incremental Plant Revenue, $ / Year	**$ 309,519**	**$ 394,799**	**$ 311,867**
Incremental Installed Cost / (Savings)	**($1,041,000)**	**($ 529,000)**	**$ 917,000**

RETROFIT OF EXISTING PLANTS

These split-vapor feed designs are suitable not only for new, grass roots projects but for revamping older, existing gas plants.[8] Figure 7 illustrates how an existing ISS plant can be modified to use the GSP design and gain its advantages of higher recovery, lower compression horsepower, and increased CO_2 tolerance. A portion of the feed gas is condensed and subcooled in a new heat exchanger and then flashed into the top of a new rectification section. This cold reflux liquid condenses and absorbs ethane and propane from the overhead of the existing demethanizer, allowing high recovery. Since the expander outlet is no longer the top column feed, the inlet separator can now be operated at a warmer temperature and cause the power recovery from the expander to increase.

As Figure 7 shows, when the GSP design is employed as a retrofit to an existing gas plant, it often uses a new absorber column to serve as the rectification section of the demethanizer so that no modifications to the existing column are necessary. Cryogenic pumps are used to transfer the liquids from the bottom of the new absorber back to the top of the existing demethanizer using the existing expander feed line. In some cases, it may be possible to incorporate the absorber into the existing tower with appropriate modifications to the vessel, eliminating the need for the absorber bottoms pumps. The cryogenic pumps can also be eliminated if the existing demethanizer overhead is allowed to bypass the rectification section. This diminishes the advantages of the GSP design somewhat since a portion of the ethane or propane that would have otherwise been recovered in the rectification section (typically 3-4 percentage points) flows directly to the residue gas stream. The particular circumstances of each application will determine which approach is more suitable.

Figure 8
SFR RETROFIT DESIGN

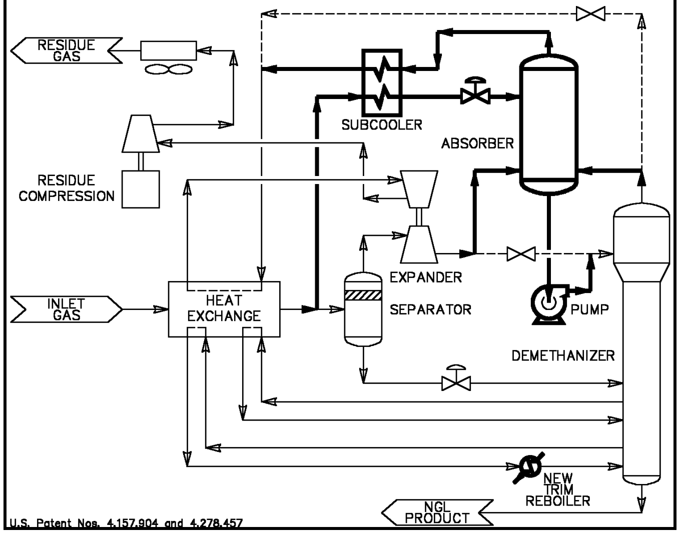


U.S. Patent No. 4,854,955

In a similar fashion, as Figures 8 and 9 illustrate, an existing ISS gas plant can be retrofit to use the SFR and CRR designs as well. Retrofitting an existing ISS plant to use any of the three new processes will allow it to reap all of the benefits discussed earlier for the split-vapor feed concept: higher ethane or propane recovery, lower compression requirements, and increased CO_2 tolerance. The retrofitted plant will be able to either recover or reject ethane more efficiently, giving the plant operator more processing flexibility to respond to market conditions and increase plant revenues.

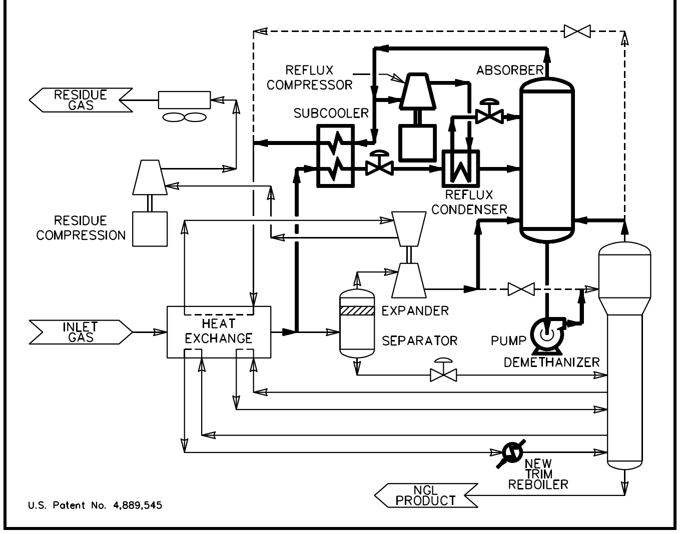
To demonstrate the benefits of applying the new technology to existing gas plants, another set of process simulations was

Figure 7
GSP RETROFIT DESIGN



U.S. Patent Nos. 4,157,904 and 4,278,457

Figure 9
CRR RETROFIT DESIGN



U.S. Patent No. 4,889,545

performed using the same inlet gas conditions discussed previously. A base case design was prepared for an ISS plant in ethane recovery service to set the capacity of the inlet heat exchangers, high pressure separator, demethanizer, and residue gas compressors. This resulted in a design which provides 75% ethane recovery using 6,000 HP of residue gas compression. All subsequent ethane rejection and retrofit simulations were constrained to fit within these equipment capacities to give realistic estimates of plant performance before and after retrofit. The results of the simulations are summarized in Table 5.

As can be seen from the table, the retrofit designs offer very significant reductions in compression horsepower while also providing increased ethane recovery. The increase in recovery ranges from 13 to 22 percentage points, with the residue gas compression requirements as much as 20% lower. The reduction in compression horsepower also means the retrofitted plant can process more inlet gas than the unmodified ISS plant, allowing increased product revenues from the higher throughput.

When operated in ethane rejection mode, the existing ISS plant is severely restricted (primarily by reboiler capacity) in the amount of ethane it can actually reject while maintaining reasonably good propane recovery. All three retrofit designs can fully reject the ethane, with a substantial boost in propane recovery. The GSP retrofit improves propane recovery to 94%, while the SFR and CRR designs can recover essentially all of the propane due to the improved efficiency of the reflux design. The three retrofits also reduce the compression requirements slightly. The recovery and efficiency improvements shown for all these cases are typical of those found during other retrofit evaluations.

During periods of low or nonexistent ethane processing margin, the ability of the retrofit designs to reject ethane can improve plant profits significantly. The retrofit designs also provide the plant operator with the option to increase plant throughput, if additional inlet gas is available, by as much as 17% before reaching the limits of the residue compressors. The ISS plant, limited as it is by reboiler capacity, typically cannot take advantage of the remaining compressor horsepower to increase propane recovery without further eroding ethane rejection capability and overall plant profitability. It is also seldom practical to increase plant throughput due to both reboiler and column capacity limitations.

Table 5
Retrofit Plant Process Comparison

	ISS (Fig. 1)	GSP (Fig. 7)	SFR (Fig. 8)	CRR (Fig. 9)
Ethane Recovery				
C_2 Recovery, %	75.0	88.2	88.2	97.0
C_3 Recovery, %	96.6	97.9	97.9	100.0
C_4 Recovery, %	99.4	99.5	99.5	100.0
Residue HP	6,000	4,811	4,811	4,976
Incremental kW	0	4	4	145
Ethane Rejection				
C_2 Recovery, %	40.0	0.9	0.9	0.9
C_3 Recovery, %	85.2	94.0	99.9	99.9
C_4 Recovery, %	97.1	98.7	100.0	100.0
Residue HP	5,212	5,102	5,118	5,096
Incremental kW	0	3	4	132

Figures 7 - 9 show (in bold) the major pieces of equipment required to retrofit the new processes to an existing plant. In a typical installation, the retrofit equipment is assembled at a contractor's fabrication shop before being shipped to the plant site. The heat exchanger(s), pumps, and compressor (for CRR) are placed on a skid module, then piped, wired, and instrumented. The equipment module and the absorber are then set on foundations at the plant site and the requisite piping and control tie-ins are made to incorporate the retrofit equipment into the existing plant.

This type of installation requires the least modification to the existing plant, but usually has the highest capital cost. Depending on the particular circumstances, it may make more economic sense to directly modify some of the existing equipment (the demethanizer, for instance) or to block-mount the new equipment, rather than install the stand-alone module and absorber. For the purposes of this paper, however, shop fabrication of the equipment module and installation of a new absorber column have been assumed. Figure 10 correlates the estimated installed cost with ISS plant capacity for retrofitting each of the three split-vapor feed processes into an existing ISS plant.

The payout period of the retrofit designs can be determined by comparing the capital costs from Figure 10 with the increased

Figure 10
INSTALLED COST OF RETROFIT DESIGNS

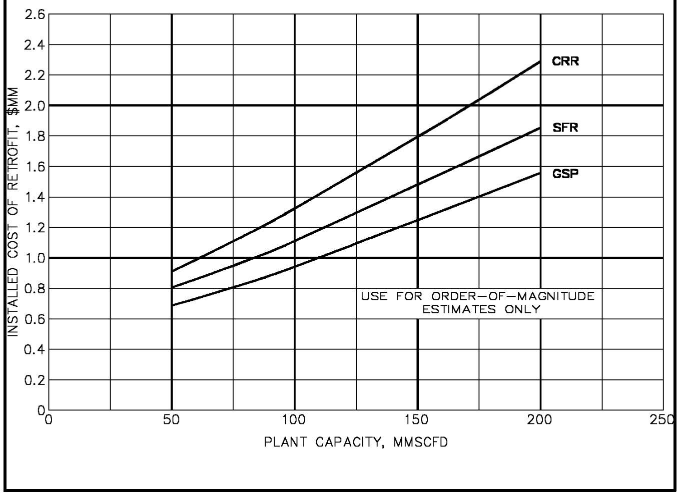


Table 6
Retrofit Plant Income / Cost Comparisons

	GSP	SFR	CRR
Favorable NGL Market			
Incremental Daily Revenue / (Cost)			
Fuel Gas	$ 500	$ 500	$ 431
Electricity	(5)	(5)	(173)
Ethane Sales	887	887	1,484
Propane Sales	84	84	210
Butane Sales	3	3	30
Totals	$ 1,469	$ 1,469	$ 1,982
Incremental Plant Revenue, $ / Year	$ 514,425	$ 514,425	$ 693,341
Payout Period, Months	22.0	25.9	22.9
Depressed NGL Market			
Incremental Daily Revenue / (Cost)			
Fuel Gas	$ 46	$ 40	$ 49
Electricity	(3)	(5)	(158)
Ethane Sales (in Residue Gas)	1,342	1,340	1,340
Propane Sales (in NGL Product)	298	497	498
Butane Sales	49	90	90
Totals	$ 1,732	$ 1,962	$ 1,819
Incremental Plant Revenue, $ / Year	$ 606,422	$ 686,334	$ 636,459
Payout Period, Months	18.6	19.4	25.0
Incremental Installed Cost	$ 942,000	$ 1,111,000	$ 1,324,000

product revenue from the higher recoveries and efficiencies shown in the Table 5. When the operating costs and processing spreads from Table 3 are used, the relative cost comparison shown in Table 6 results. All three retrofit designs show reasonable payout periods, less than two years in most cases. If additional inlet gas is available for processing, the increase in plant capacity after retrofitting to a split-vapor feed process will make the payout period even shorter.

As before with the new plant designs, the choice of retrofit process depends on the particular circumstances of each case, and on market projections for future gas and NGL prices. The GSP retrofit allows minimum capital investment with moderate improvements in both ethane and propane recovery. If projections show that future ethane values will be low, the SFR design may be the better choice to allow maximum product revenue while rejecting ethane. The CRR design should be considered if it is anticipated that the ethane market will be favorable in the future, particularly for plants with ready access to the ethane market.

CONCLUSIONS

The inflexibility of the typical turboexpander plant makes it difficult for the plant operator to maximize his profit margin when market conditions change. The inefficiency of the plant prevents the plant operator from reducing operating costs, adjusting recovery levels of individual components effectively, or processing more gas when it is available.

Selecting one of the split-vapor feed processes discussed in this paper for the design of a new NGL recovery plant allows the plant operator to realize numerous advantages, including the flexibility he needs to respond to a volatile NGL market. These same advantages apply to existing gas plants that are retrofit to use the new processes:

- The plant has improved ethane recovery capability to realize higher profits from ethane sales when ethane prices are favorable.
- The plant can be operated to fully reject ethane when ethane prices are depressed, while maintaining high propane recovery to increase profits from propane sales.
- The plant has lower compression requirements and reduced fuel gas costs. New plants require less equipment to be installed, while retrofit plants may be able to shut down some equipment.
- Retrofitted plants have the capacity to process additional feed gas, allowing even higher profits from liquid sales if more gas is available.

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