REDUCING TREATING REQUIREMENTS FOR CRYOGENIC NGL RECOVERY PLANTS

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ABSTRACT

Turboexpander plants designed for high ethane recovery will also recover a significant quantity of the carbon dioxide contained in the feed gas. With typical natural gas liquid (NGL) product specifications, this usually means treating either the feed gas or the NGL product to remove at least a portion of the carbon dioxide. Ortloff's development efforts have led to the invention of a design feature which can be used to control the carbon dioxide content of the NGL product with little impact on the ethane recovery efficiency. This feature can be included in the design of any new plant or retrofit to any existing plant, regardless of the process configuration.

For new plant designs, this feature can minimize or possibly eliminate feed gas and/or product treatment facilities. For existing plants, the capacity of the NGL recovery plant can be expanded or the ethane recovery increased without the need to add additional treating capacity. Both new and existing plants will benefit from the improvement in the overall project economics due to reducing capital and operating costs.

This same design feature can be used to improve the overall heat integration of process designs where carbon dioxide is not a factor, resulting in improved ethane recovery. Several examples are given showing the application of the new process design feature.

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.[1] 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 oil and natural gas reservoirs. In years past, most operating companies were forced to remove most or all of the CO_2 before processing the gas for liquids recovery to avoid solids formation (freezing) in the cold sections of the processing plant, but a number of CO_2-tolerant processes are now available for NGL recovery plants.[2] Since most gas transportation companies and gas consumers will accept a CO_2 concentration of several percent in natural gas streams, many operating companies have found that CO_2 removal is no longer required upstream of processing. Much of the CO_2 will be recovered with the liquid product, with the result that the residue gas is within specification with no further treating required.

Carbon dioxide falls between methane and ethane in terms of relative volatility.[3] The unfortunate consequence of this is that high ethane recovery in a typical NGL recovery plant often leads to high CO_2 concentrations in the NGL product, to the extent that the NGL product must subsequently be treated to remove the CO_2 to meet the purchaser's specifications. 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 reducing the CO_2 content in the product leaving the liquids recovery section of an NGL recovery facility.

The CO_2 content of the NGL product has recently become a primary concern at a number of facilities due to several factors. First, the CO_2 content of the natural gas streams being processed is gradually increasing as lesser quality gas reservoirs are being developed and produced. Second, NGL transportation pipelines are reaching their capacity limits, which has lead the pipeline companies to impose more stringent product specifications and thereby increase the value of the product being transported. Third, many operating companies are revamping their NGL recovery plants to increase the gas throughput and allow higher sales gas volumes. Taken together, the net result has been recovery of larger quantities of NGL product containing higher concentrations of CO_2 at a time when more restrictive CO_2 specifications are being imposed on the product being sold.

A new design feature has been developed and patented for controlling the CO_2 content of the NGL product produced in liquids recovery plants. This feature can be applied to any type of cryogenic NGL recovery plant, regardless of the process configuration, and is applicable for new plant designs as well as for retrofitting into existing plants. With this feature, it is possible to efficiently strip CO_2 from the NGL product without sacrificing significant ethane recovery, and to simultaneously control the CO_2 concentration while meeting the methane specification for the NGL product.

EXAMPLES

Several examples of how this new design feature can be applied to a variety of NGL recovery plant configurations are given in the sections that follow.

Example 1 — GSP Plant Retrofit

Figure 1 below illustrates a fairly conventional NGL recovery plant using Ortloff's **G**as **S**ubcooled **P**rocess (GSP).[4] Because this is a large plant designed for 1.2 billion standard cubic feet of feed gas per day, the demethanizer is actually constructed in two sections, an absorber column and a stripper column. The pertinent operating parameters for the plant when operated for maximum ethane recovery (Case 1) and when operated to limit the CO_2 content of the bottom product (Case 2) are given in Table 1.

When the existing process is operated for maximum ethane recovery, the CO_2 content of the NGL product exceeds the pipeline specification of 6.0 mole % (relative to the total methane, ethane, and carbon dioxide contained in the product). Since the plant has no product treater, the plant cannot be operated in this manner. Instead, the plant operators must adjust plant operations to reduce the CO_2 concentration in the bottom product. The only way this can be accomplished with the existing process is to reboil the stripper column more by increasing the heat added to the

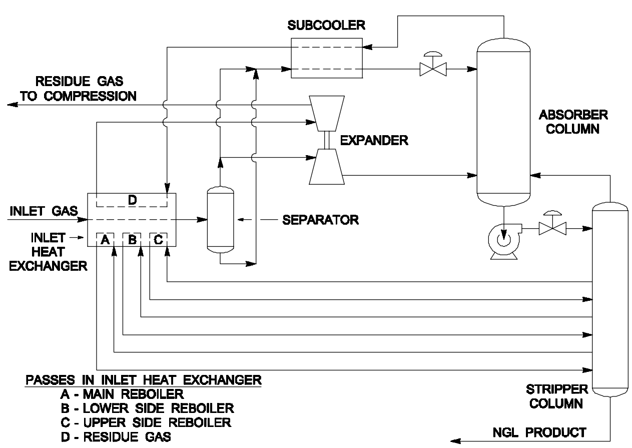

Figure 1 — Existing GSP Plant

Table 1		
	Case 1	Case 2
Inlet Rate, MMSCFD	1,200	1,200
Inlet CO_2, mole %	0.80	0.80
Inlet Pressure, PSIA	613	613
Tower Pressure, PSIA	333	326
Bottoms Temperature, °F	43	56
C_2 Recovery, %	84.9	68.9
C_3 Recovery, %	96.9	96.6
Ratio in Bottoms, mole %		
C_1 / C_2	2.37	0.08
$CO_2 / (C_1 + C_2 + CO_2)$	7.59	5.95

column with the side and/or main reboilers. As shown in Table 1, the temperature in the bottom of the stripper column warms up considerably, resulting in the loss of a significant amount of ethane recovery in the product, from nearly 85% ethane recovery to less than 69%. Note that the column bottoms can no longer be controlled at the desired methane:ethane ratio due to the over-stripping that is required to meet the CO_2 specification.

There are two factors at work that result in less NGL recovery from the existing process when it is operated to reject CO_2 from the product in this manner. First, when the temperature at the bottom of the stripper column is raised to increase the reboil heat, the temperatures at each point in the column increase. This increases the temperatures of the side draw liquids entering the reboilers, reducing the amount of cooling that the stripper column liquid streams can supply to the feed gas in the inlet heat exchanger. As a result, the cooled feed stream entering the separator is warmer, which in turn results in lower ethane retention in the absorber column. Second, the higher temperatures in the stripper column cause the temperatures in the absorber column to be higher, resulting in less methane liquid entering the stripper column. (When liquid methane is subsequently vaporized by the upper side reboiler, lower side reboiler, and main reboiler attached to the stripper column, the methane vapor helps to strip the carbon dioxide from the liquids flowing down the column.) With less methane available to strip the carbon dioxide, more of the ethane in the liquids must be vaporized instead to serve as stripping gas. Since the relative volatilities for carbon dioxide and ethane are very similar, ethane vapor is a much less effective stripping agent than methane vapor, which reduces the stripping efficiency in the column.

Figure 2 shows how the limitations of the existing process can be overcome using the new Ortloff CDC design feature (for **C**arbon **D**ioxide **C**ontrol), which can be applied to any type of cryogenic NGL recovery system.[5,6] In a typical reboiler or side reboiler, the entire column down-flowing liquid stream is withdrawn from the tower and passed through a heat exchanger, then returned to the column at essentially the same point in the column. With the CDC scheme, a portion of the column down-flowing liquid is withdrawn from a point higher up in the column. Even though the flow rate of the liquid may be lower, it is usually much colder and can have advantages in improving recovery or reducing exchanger size. In this case, a portion of the cold liquid from the bottom of the absorber column is routed to the inlet heat exchanger (to what was previously the upper side reboiler pass), while the remainder of the liquid is routed to the top of the stripper column. This effectively uses top tray liquid from the stripper column to feed the

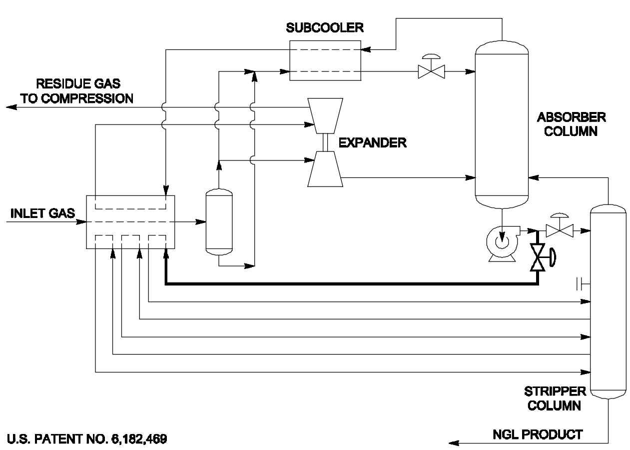

Figure 2 — GSP Plant Modified with CDC

Table 2		
	Case 3	Case 4
Inlet Rate, MMSCFD	1,200	1,200
Inlet CO_2, mole %	0.80	0.80
Inlet Pressure, PSIA	613	613
Tower Pressure, PSIA	332	333
Bottoms Temperature, °F	42	45
C_2 Recovery, %	86.1	84.6
C_3 Recovery, %	97.1	97.0
Ratio in Bottoms, mole %		
C_1 / C_2	2.37	2.37
CO_2 / (C_1 + C_2 + CO_2)	8.01	5.80

upper side reboiler. Note that the side reboiler return line is unchanged, returning to the column at a point much lower than the new draw point.

Table 2 shows the pertinent operating parameters when the CDC-modified process is operated for maximum ethane recovery (Case 3) or to control the CO_2 content in the NGL product (Case 4). With the CDC scheme, the column liquid flowing to the upper side reboiler pass in the inlet heat exchanger is considerably colder than for the original process shown in Figure 1. This increases the cooling available to the inlet gas, because not only can considerably more duty be obtained from the liquids with this scheme, the liquids are also available at a colder temperature level than would be possible with a conventional reboiler scheme. The result is an improvement in both the ethane and propane recoveries with no increase in the residue gas compression horsepower.

More significant, however, is the improvement in plant performance when it is operated to limit the amount of CO_2 in the NGL product. As Table 2 shows for Case 4, the plant can be adjusted to hold the CO_2 concentration well below the pipeline specification with hardly any drop in the ethane and propane recovery. In fact, the ethane recovery with CDC is nearly as good as when the original plant was operated for maximum ethane recovery, and the propane recovery is slightly better. Compared to the original plant, the ethane recovery is almost 16 percentage points better for the CDC process when operating in CO_2-control mode.

As in Case 3, a significant benefit of the CDC scheme is providing colder column liquids for use in refrigerating the incoming feed stream, increasing the cooling available to the inlet gas. At the same time, more methane is introduced lower in the stripper column than would otherwise be present when reboiling the column to meet the specification for CO_2 content. The additional methane provided by CDC helps to strip the carbon dioxide from the liquids flowing downward in the stripping column. Methane is much more efficient for stripping CO_2 than ethane because it is much more volatile than CO_2. The CO_2 content of the NGL product can be controlled by adjusting the quantity of liquid routed to the inlet heat exchanger rather than feeding the top of the stripping column. (The temperature at the bottom of the stripper column remains on methane:ethane ratio control.)

Modifying the existing GSP plant to use the CDC process would eliminate the need for any treating of the NGL product while allowing the NGL production rate to be maintained near its maximum. The alternatives are either to construct a new product treater (or inlet gas treater), or to operate the GSP process to reject CO_2 as shown for Case 2 in Table 1. Comparing the CDC process retrofit of the existing plant to the first alternative, the capital cost savings would be approximately $1,500,000 by avoiding construction of a product treater.[7] The operating cost savings would be about $530,000 per year by avoiding the utility consumptions that the product treater would require (based on $3.00/MMBTU for fuel and $0.05/kW-H for electricity). Comparing the CDC retrofit to the second alternative, the value of the incremental NGL production possible with the CDC process is about $3,820,000 per year (based on $0.30/gal for ethane, $0.40/gal for propane, and $0.05/gal for transportation and fractionation). The capital cost of the CDC retrofit for this plant would easily be paid out in less than a year compared to either alternative.

For GSP plants that use a single demethanizer column, the column internals can be adapted to withdraw a portion of the down-flowing liquids to feed the CDC scheme. For instance, the outlet from the expander can be directed onto a chimney tray below the upper absorber section of the tower, so that the liquid in the expander outlet is mixed with the liquids from the absorber section. A portion of the mixed liquids can then be withdrawn to feed the CDC scheme, while the remainder is allowed to spill over onto a liquid distributor below the chimney tray. A number of other schemes can be used as well, depending on the requirements for a particular application.

It should be noted that the reduction in the CO_2 content of the NGL product that CDC provides is accomplished by rejecting more of the CO_2 in the plant inlet gas to the plant residue gas. As a result, the CO_2 concentration in the plant residue gas will be higher for the CDC process, which could impact the specifications for the sales gas. The CO_2 concentrations also increase slightly in the liquid and vapor streams inside the demethanizer, which has the effect of reducing the approach to CO_2 freezing inside the tower. Both of these factors must be considered when evaluating CDC for a particular application.

Example 2 — ISS Plant Retrofit

Figure 3 illustrates an existing NGL recovery plant using an industry-standard single stage (ISS) turboexpander process.[8] The pipeline company that transports the NGL from this plant recently imposed more stringent CO_2 specifications on the NGL product it would accept, limiting the CO_2 content to 5.0 mole % in the contained ethane. Although the ethane recovery capability of the ISS process is not as high as more recent process designs[9], the amount of CO_2 recovered in the NGL product is still enough to cause problems meeting the new product pipeline specifications. The pertinent operating parameters for the plant when operated for maximum ethane recovery (Case 1) and when operated to limit the CO_2 content of the bottom product (Case 2) are given in Table 3.

When the existing process is operated for maximum ethane recovery, the CO_2 content of the NGL product (relative to the ethane contained in the product) exceeds 8.9 mole %. This plant also has no product treater, so it cannot be operated in this manner. Similar to Example 1, the plant controls must be adjusted to reboil the demethanizer harder by increasing the heat added to the column with the side and/or main reboiler. As shown in Table 3, the bottom temperature of the demethanizer is much hotter when operating in this mode, causing severe reductions in both ethane and propane recoveries. The ethane recovery drops by over 20 percentage points and the propane recovery drops by more than 5 percentage points, and even the butanes plus recovery drops by nearly 1%. The net reduction in NGL production is more than 20% when operating the plant to reject CO_2 from the bottom product.

Note in Table 3 that there is essentially no methane in the NGL product for Case 2 due to the over-stripping that is required to meet the CO_2 specification. The same factors discussed earlier for Example 1 are at work in this example causing low recovery. Reboiling the column

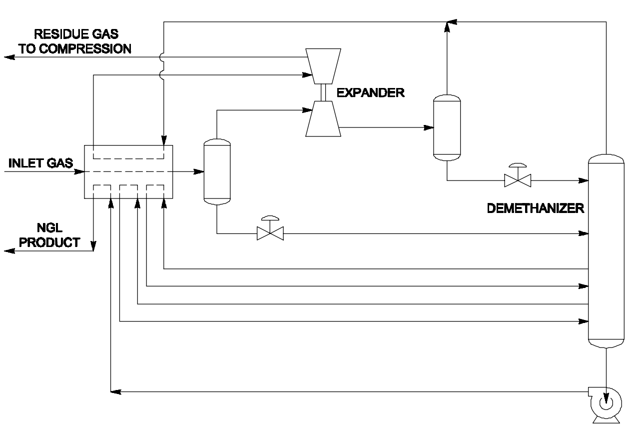

Figure 3 — Existing ISS Plant

Table 3		
	Case 1	Case 2
Inlet Rate, MMSCFD	261	261
Inlet CO_2, mole %	1.07	1.07
Inlet Pressure, PSIA	915	915
Tower Pressure, PSIA	318	289
Bottoms Temperature, °F	48	62
C_2 Recovery, %	70.9	50.8
C_3 Recovery, %	96.4	91.1
Ratio in Bottoms, mole %		
C_1 / C_2	2.50	nil
CO_2 / C_2	8.91	5.00

harder to strip CO_2 from the liquid vaporizes large amounts of ethane from the liquid, reducing the recovery and raising the temperatures throughout the column. This in turn reduces the amount of methane in the lower sections of the column, so that methane is not available to help strip the CO_2 or to provide cooling of the feed gas in the inlet heat exchanger.

Figure 4 shows how this ISS process can be retrofitted to use the Ortloff CDC design feature. For this application, a portion of the cold liquid from the expander outlet separator is routed to what was previously the side reboiler pass on the inlet heat exchanger, while the remainder of the liquid is routed to the top of the demethanizer. This effectively uses top tray liquid from the demethanizer to feed the side reboiler. Note that the side reboiler return line is unchanged, returning to the column at a point much lower than the new draw point.

Table 4 shows the pertinent operating parameters when the CDC modified process is operated for maximum ethane recovery (Case 3) or to control the CO_2 content in the NGL product (Case 4). In this instance, the ethane and propane recoveries are slightly less than for the unmodified plant when the plant is operated for maximum ethane recovery. This is due to using the top tray liquids to feed the side reboiler pass, as the optimum point to withdraw the liquids from the column is usually lower in the tower. Modifying the plant to draw liquid from a lower point in the column would require much more extensive and costly changes to the plant, so the less optimum location shown in Figure 3 was used instead. In practice, the piping to the side reboiler pass would be valved as shown in Figure 4 so that its liquid could be drawn from either the original side draw tray in the column or from the liquids in the expander outlet separator. Then, if the specification for the CO_2 content of the NGL product should ever be relaxed in the future, or if the CO_2 concentration in the feed gas drops, the plant could be restored to its original configuration for maximum ethane recovery.

For this plant, the value of the CDC retrofit is the dramatic increase in product recoveries when the plant is operated to reject CO_2 from the NGL product. As Table 4 shows for Case 4, the plant can be adjusted to hold the CO_2 concentration at the pipeline specification with minimal reduction in the ethane and propane recovery. The ethane recovery is a full 15 percentage points better for the CDC process when operating in CO_2-control mode compared to the existing plant. Overall, the modified CDC process can achieve an NGL production rate that is over 20% higher than the original plant design when rejecting CO_2, and allows the plant to meet pipeline specifications for the NGL product without the need to construct a treating plant to remove CO_2 from the inlet gas or the product.

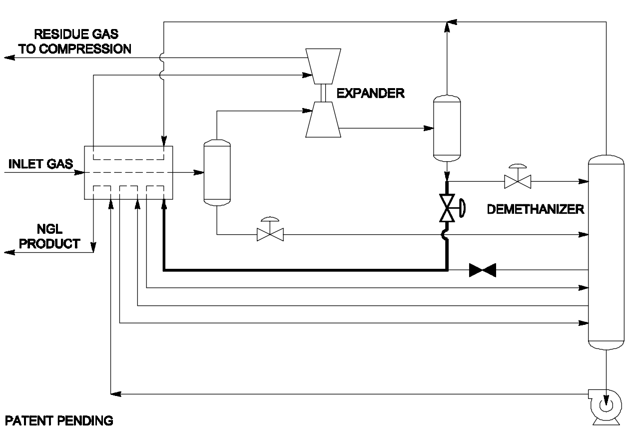

Figure 4 — ISS Plant Modified with CDC

Table 4

	Case 3	Case 4
Inlet Rate, MMSCFD	261	261
Inlet CO_2, mole %	1.07	1.07
Inlet Pressure, PSIA	915	915
Tower Pressure, PSIA	314	315
Bottoms Temperature, °F	50	54
C_2 Recovery, %	68.1	66.2
C_3 Recovery, %	96.0	95.8
Ratio in Bottoms, mole %		
C_1 / C_2	2.50	2.50
CO_2 / C_2	7.52	4.84

As before, the CDC scheme provides colder column liquids for use in refrigerating the incoming feed stream while introducing methane lower in the demethanizer to help strip the carbon dioxide from the liquids flowing down the column. The quantity of liquid routed to the inlet heat exchanger can be adjusted as needed to control the CO_2 content of the NGL product, while the temperature at the bottom of the demethanizer is adjusted to control the desired methane:ethane ratio.

Modifying the existing ISS plant to use the CDC process would eliminate the need for any treating of the NGL product while allowing the NGL production rate to be maintained near its maximum. The alternatives are either to construct a new product treater (or inlet gas treater), or to operate the ISS process to reject CO_2 as shown for Case 2 in Table 3. Compared to the first alternative, the capital cost savings would be approximately $1,200,000 and the operating cost savings would be about $330,000 per year for the CDC process. Compared to the second alternative, the value of the incremental NGL production for the CDC process is about $1,560,000 per year. The capital cost of the CDC retrofit for this plant would easily be paid out in less than a year compared to either alternative.

Example 3 — RSV Plant Retrofit

Figure 5 illustrates an existing NGL recovery plant originally designed to use the ISS process that is to be retrofitted to use Ortloff's **R**ecycle **S**plit-**V**apor (RSV) process.[10] The existing demethanizer is to be converted into a stripper column, with a new absorber column added to contact the expander outlet vapor (plus the vapor from the existing column) with the cold reflux streams produced by condensing and subcooling a portion of the recompressed residue gas (the top feed) and a portion of the high pressure feed gas (the intermediate feed). With the pumps to route the absorber bottoms to the top of the existing column and the overhead from the existing column routed to the bottom of the new absorber, the two columns would effectively function as a single demethanizer tower.

The NGL product specification for the pipeline serving this plant is a maximum of 5.0 mole % CO_2 in the NGL product (although the client requested a target of 4.5 mole %). The ethane recovery is low enough for the existing ISS plant that the incidental CO_2 recovery does not exceed the specification. However, if the plant is converted to use the RSV process to increase the ethane recovery as shown in Figure 5, the CO_2 concentration in the NGL product would exceed the pipeline specification, requiring the addition of a treater to remove CO_2 from

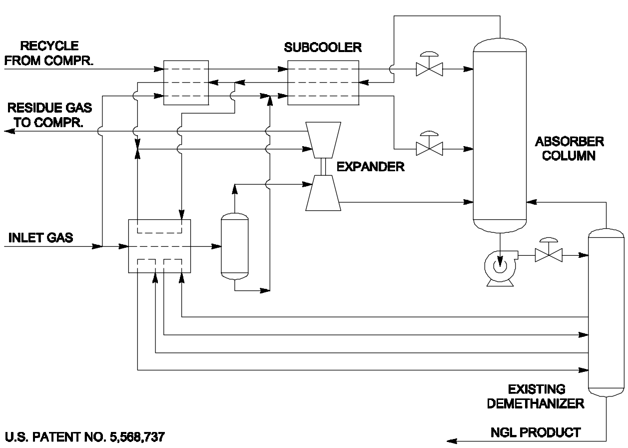

Figure 5 — ISS Plant Retrofitted to RSV

Table 5		
	Case 1	Case 2
Inlet Rate, MMSCFD	337	337
Inlet CO_2, mole %	1.00	1.00
Inlet Pressure, PSIA	760	760
Tower Pressure, PSIA	372	368
Bottoms Temperature, °F	60	74
C_2 Recovery, %	94.8	87.8
C_3 Recovery, %	99.9	99.9
Ratio in Bottoms, mole %		
C_1 / C_2	2.00	nil
CO_2 / Total	7.64	4.50

the product (or from the inlet gas). The pertinent operating parameters for the plant when operated for maximum ethane recovery (Case 1) and when operated to limit the CO_2 content of the bottom product (Case 2) are given in Table 5.

As in the previous examples, the retrofitted RSV process is for the most part restricted to controlling the CO_2 content of the NGL product by adjusting the amount of reboil heat supplied to the column. Although this design has some additional flexibility in that the relative amounts of feed supplied to the different feed points on the absorber column can be varied, this has little impact on the amount of CO_2 recovered with the NGL product. Unlike the previous examples, however, the drop in ethane recovery is not as severe when the plant is operated to reject CO_2 because of the rectification provided by the cold methane reflux feeding the top of the absorber. Nevertheless, the drop in recovery is not insignificant, as the NGL production rate is more than 8% lower when the plant is operated to reduce the CO_2 concentration in the NGL product.

Figure 6 shows how this RSV process retrofit can be improved by using the Ortloff CDC design feature. For this application, a portion of the cold liquid from the bottom of the absorber column is routed to what was previously the side reboiler pass on the inlet heat exchanger, while the remainder of the liquid is routed to the top of the existing demethanizer. This effectively uses top tray liquid from the existing column to feed the side reboiler. Note that the side reboiler return line is unchanged, returning to the column at a point much lower than the new draw point.

Table 6 shows the pertinent operating parameters when the modified retrofit process is operated for maximum ethane recovery (Case 3) or to control the CO_2 content in the NGL product (Case 4). In this instance, the ethane recovery improves only slightly compared to the unmodified retrofit design when the plant is operated for maximum recovery. However, the real benefit from incorporating the CDC process into the retrofit design is when the plant operating parameters are adjusted to reduce the CO_2 content of the demethanizer liquid product.

For this plant, the flexibility of the RSV process can be combined with the advantages of the CDC scheme to reduce the CO_2 concentration of the bottom product with much less drop in ethane recovery. The tower pressure can be raised slightly to reduce the residue gas compression requirements, allowing the recycle rate to be increased without using more compression horsepower. The higher recycle rate generates more reflux for the absorber, minimizing the impact of reducing the top feed rate to the existing column when part of the liquid is supplied to what was formerly the side reboiler pass on the inlet heat exchanger. The amount of liquid diverted to the side reboiler pass can be adjusted as necessary to control the CO_2 concentration in

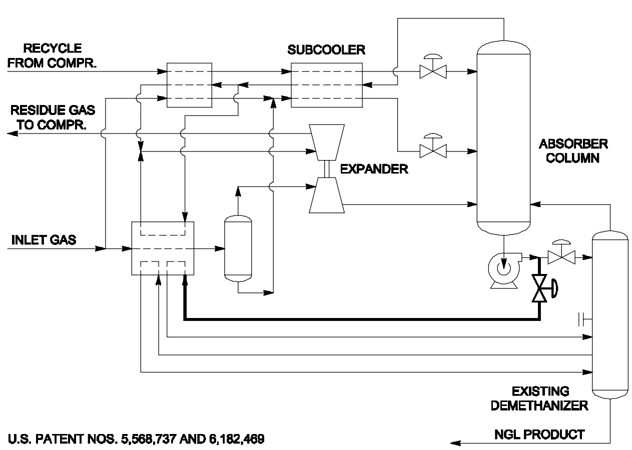

Figure 6 — RSV Retrofit Modified with CDC

Table 6		
	Case 3	Case 4
Inlet Rate, MMSCFD	337	337
Inlet CO_2, mole %	1.00	1.00
Inlet Pressure, PSIA	760	760
Tower Pressure, PSIA	373	373
Bottoms Temperature, °F	57	68
C_2 Recovery, %	95.2	91.2
C_3 Recovery, %	99.7	99.6
Ratio in Bottoms, mole %		
C_1 / C_2	2.00	2.00
CO_2 / Total	8.86	4.53

the NGL product at specification, while the temperature control on the bottom of the column remains on methane:ethane ratio control.

With the CDC process included in the RSV retrofit, the need for any treating of the NGL product is eliminated while allowing the NGL production rate to be maintained near its maximum. The alternatives are either to construct a new product treater (or inlet gas treater), or to operate the RSV process to reject CO_2 as shown for Case 2 in Table 5. Comparing the RSV/CDC process retrofit to the first alternative, the capital cost savings would be approximately $1,000,000 and the operating cost savings would be about $280,000 per year. Compared to the second alternative, the value of the incremental NGL production possible with the CDC process is about $140,000 per year. The incremental cost of including the CDC design feature is more than offset by the improvement in product recoveries and the overall project economics.

Example 4 — CRR Plant Retrofit

Figure 7 illustrates an existing NGL recovery plant originally designed to use the ISS process that is to be retrofitted to use Ortloff's **C**old **R**esidue **R**eflux (CRR) process.[11] (This is actually the "hot" version of the process, as the particular circumstances favored compressing the recycle stream at ambient temperature rather than at cryogenic temperature.) The existing demethanizer is to be converted into a stripper column, with a new absorber column added to contact the expander outlet vapor (plus the vapor from the existing column) with the cold reflux streams produced by condensing and subcooling a portion of the recompressed residue gas (the top feed) and a portion of the high pressure feed gas (the intermediate feed). With the pumps to route the absorber bottoms to the top of the existing column and the overhead from the existing column routed to the bottom of the new absorber, the two columns would effectively function as a single demethanizer tower.

This facility includes sufficient front-end CO_2 removal to reduce the CO_2 concentration in the NGL plant feed streams to 0.61 mole %. For the existing ISS process, the ethane recovery is low enough that the CO_2 recovered in the NGL product does not exceed the specification imposed by the product purchaser of 2.5 mole % total impurities (methane plus carbon dioxide) in the contained ethane. Once the plant is retrofitted to use the CRR process for better recovery (and more stable operation) as shown in Figure 7, however, the co-recovery of CO_2 will increase along with the ethane recovery, to the point that the NGL product would no longer meet

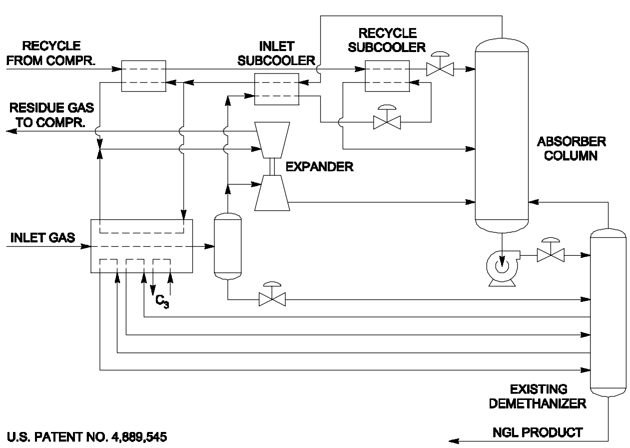

Figure 7 — ISS Plant Retrofitted to CRR

Table 7		
	Case 1	Case 2
Inlet Rate, MMSCFD	294	294
Inlet CO_2, mole %	0.61	0.61
Inlet Pressure, PSIA	795	795
Tower Pressure, PSIA	323	322
Bottoms Temperature, °F	61	80
C_2 Recovery, %	95.4	84.5
C_3 Recovery, %	100.0	100.0
Ratio in Bottoms, mole %		
C_1 / C_2	2.50	nil
(C_1 + CO_2) / C_2	10.49	2.50

specification. The pertinent operating parameters for the plant when operated for maximum ethane recovery (Case 1) and when operated to limit the CO_2 content of the bottom product (Case 2) are given in Table 7. As the table shows, the CRR retrofit design in this example sacrifices a significant amount of ethane recovery when it must be operated to reject CO_2 from the NGL product by increasing the amount of reboiling in the column. The alternative is to either construct additional inlet gas treating, or to construct a new product treater.

The need for additional treating (inlet or product) can be avoided entirely by modifying the CRR retrofit design to include the Ortloff CDC design feature as shown in Figure 8. As in Example 3, a portion of the cold liquid from the bottom of the new absorber column is routed to what was previously the side reboiler pass on the inlet heat exchanger, while the remainder of the liquid is routed to the top of the existing demethanizer. This effectively uses top tray liquid from the existing column to feed the side reboiler.

Table 8 shows the pertinent operating parameters when the modified retrofit process is operated for maximum ethane recovery (Case 3) or to control the CO_2 content in the NGL product (Case 4). The surface area of the inlet heat exchanger in this plant was already ample, so the availability of colder liquid for the exchanger that results with the CDC scheme gives only a small increase in ethane recovery when the plant is operated for maximum recovery. When the plant operating parameters are adjusted to reduce the CO_2 content of the demethanizer liquid product, however, the improvement from incorporating the CDC process into the retrofit design is quite apparent.

The modified retrofit design combines the flexibility of the CRR process with the advantages of the CDC design feature to reduce the CO_2 concentration of the NGL product with hardly any loss in ethane recovery. Unlike the unmodified CRR process in Figure 7, the CDC-equipped plant can achieve nearly the same amount of inlet gas cooling when it is operated to reject CO_2. This minimizes the impact of reducing the top feed rate to the existing column when part of the liquid is supplied to the inlet heat exchanger. The amount of liquid diverted to the inlet heat exchanger can be adjusted as necessary to control the desired CO_2 concentration in the NGL product, while the methane:ethane ratio of the product is controlled by adjusting the temperature of the bottom of the column as for current operations.

Including the CDC process with the CRR retrofit eliminates the need for any additional inlet gas or product treating while allowing the NGL production rate to be maintained near its maximum. The alternatives are either to construct a new inlet gas or product treater, or to

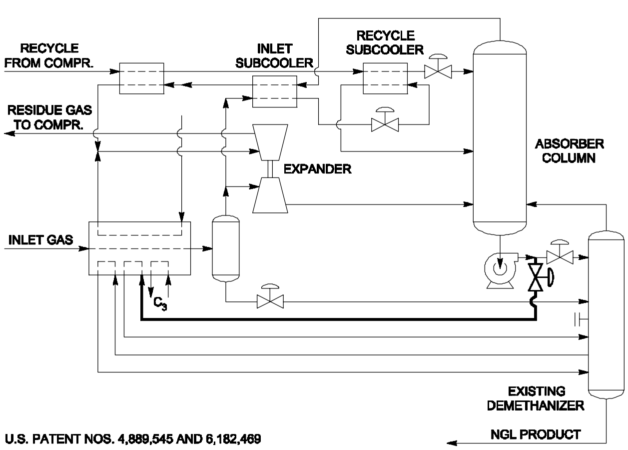

Figure 8 — CRR Retrofit Modified with CDC

Table 8		
	Case 3	Case 4
Inlet Rate, MMSCFD	294	294
Inlet CO_2, mole %	0.61	0.61
Inlet Pressure, PSIA	795	795
Tower Pressure, PSIA	323	325
Bottoms Temperature, °F	60	78
C_2 Recovery, %	95.7	91.7
C_3 Recovery, %	100.0	100.0
Ratio in Bottoms, mole %		
C_1 / C_2	2.50	0.15
$(C_1 + CO_2) / C_2$	10.83	2.50

operate the CRR process to reject CO_2 as shown for Case 2 in Table 7. Compared to the first alternative, the capital cost savings are approximately $2,000,000 and the operating cost savings are about $810,000 per year for the CDC process. Compared to the second alternative, the value of the incremental NGL production with the CDC process is about $550,000 per year. The cost for including the CDC design feature in the CRR process retrofit is easily justified by the higher product recovery and the improvement in the project economics that CDC provides.

Example 5 — GSP Plant Retrofit

Figure 9 illustrates an existing NGL recovery plant originally designed to use the ISS process that was to be retrofitted to use Ortloff's GSP process. The existing demethanizer was to be converted into a stripper column, with a new absorber column added to contact the expander outlet vapor (plus the vapor from the existing column) with the cold reflux stream produced by condensing and subcooling a portion of the high pressure separator vapor and liquid. With the pumps to route the absorber bottoms to the top of the existing column and the overhead from the existing column routed to the bottom of the new absorber, the two columns would effectively function as a single demethanizer tower.

The existing facility includes a product treater for removing CO_2 from the NGL product to meet the pipeline specification. Due to the increase in plant throughput and product recoveries that the GSP retrofit would provide, however, both the liquid handling capacity and the CO_2 removal capacity of this existing treater would be exceeded. If plans had continued to proceed with the GSP retrofit as shown in Figure 9, the operating company would have either had to construct an additional product treater or operate the plant to reduce the CO_2 content of the NGL product. Table 9 shows the pertinent operating parameters for the plant when operated for maximum ethane recovery (Case 1) and when operated to limit the CO_2 content of the bottom product (Case 2). (Note that the pipeline specification for methane content is on a volume percentage basis for this plant. Since this facility does have a product treater, the quantity of CO_2 that can be removed is fixed by the removal capacity of the treater, 22 Lb-moles/H, so the CO_2 content of the NGL product is reported in units of Lb-moles/H in Tables 9 and 10.) The reduction in ethane recovery is substantial when the plant is operated to reject CO_2 from the product, nearly 30 percentage points.

Rather than add a new product treater, the GSP retrofit design was modified to include the Ortloff CDC design feature as shown in Figure 10. Similar to the concept described

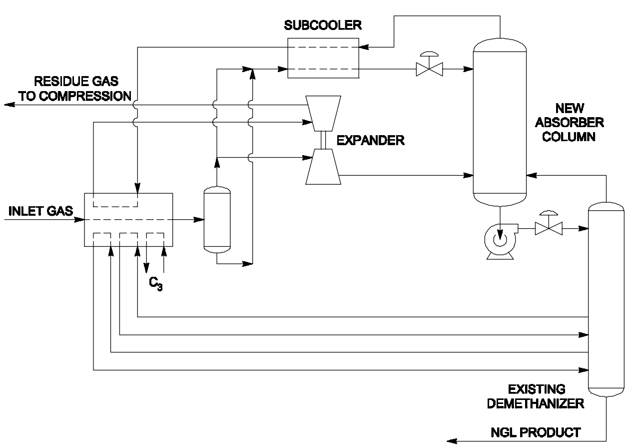

Figure 9 — ISS Plant Retrofitted to GSP

Table 9		
	Case 1	Case 2
Inlet Rate, MMSCFD	235	235
Inlet CO_2, mole %	0.52	0.52
Inlet Pressure, PSIA	836	836
Tower Pressure, PSIA	271	309
Bottoms Temperature, °F	39	64
C_2 Recovery, %	93.3	63.4
C_3 Recovery, %	99.2	97.9
Concentration in Bottoms		
C_1, volume %	0.50	0.50
CO_2, Lb-moles/H	64	22

previously, the CDC process was implemented for this application by routing a portion of the cold absorber bottoms to what was formerly the side reboiler pass of the inlet heat exchanger, with the rest of the liquid feeding the top of the existing demethanizer. The return line for the side reboiler was left unchanged, so that the CDC scheme in essence uses the top tray liquids from the existing column but returns the heated stream to a point much lower in the column.

Once the CDC feature was added to the retrofit design, the CO_2 content of the NGL product could be controlled as needed to avoid overloading the existing product treater. Table 10 shows the pertinent operating parameters for the modified GSP retrofit design when operated for maximum ethane recovery (Case 3) and when operated to limit the CO_2 contained in the bottom product (Case 4). In this example, the ethane and propane recoveries are slightly less using CDC than for the unmodified design because this plant uses propane refrigeration for the last portion of the feed gas cooling, so the advantage of having colder tower liquid feed the inlet heat exchanger does not compensate for the lesser quantity of liquid being available. As a result, valves were included in the retrofit design to allow operating the column using either a conventional reboiler or with the CDC feature, so that the operating mode could be selected based on the available capacity in the product treater (since the treater is shared with another NGL recovery plant).

When the plant is operated to limit the CO_2 in the product, however, the CDC design feature allows the ethane recovery to be 26 percentage points higher than the unmodified retrofit design without overloading the existing product treater. The incremental NGL production possible with the CDC process represents an additional $2,180,000 per year in income from product sales. The other alternative, adding an additional product treater, would have resulted in a capital cost of approximately $1,000,000 and would have increased the plant operating costs by about $280,000 per year from the utility consumptions the new treater would have added. The capital cost of including CDC in the GSP process retrofit was easily justified by the rapid pay-out (much less than one year) compared to these two alternatives.

During the detailed design of the CDC/GSP retrofit package, a number of simulations were performed to show the behavior of the plant after the retrofit. Several different cases were developed for the plant, with and without including the CDC feature in the design, by varying the amount of CO_2 allowed in the NGL product. These simulations were performed on the basis of constant residue gas compression horsepower, so the differences in ethane recovery that resulted were due to the amount of stripping required to control the amount of CO_2 at a given value in the NGL product.

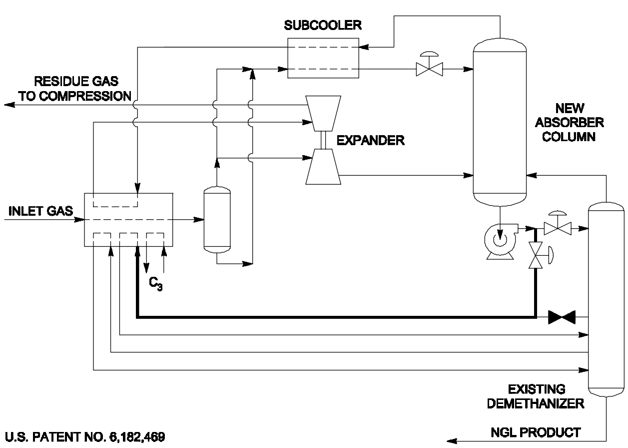

Figure 10 — GSP Retrofit Modified with CDC

Table 10		
	Case 3	Case 4
Inlet Rate, MMSCFD	235	235
Inlet CO_2, mole %	0.52	0.52
Inlet Pressure, PSIA	836	836
Tower Pressure, PSIA	272	271
Bottoms Temperature, °F	42	44
C_2 Recovery, %	91.8	89.7
C_3 Recovery, %	99.2	99.1
Concentration in Bottoms		
C_1, volume %	0.50	0.50
CO_2, Lb-moles/H	36	21

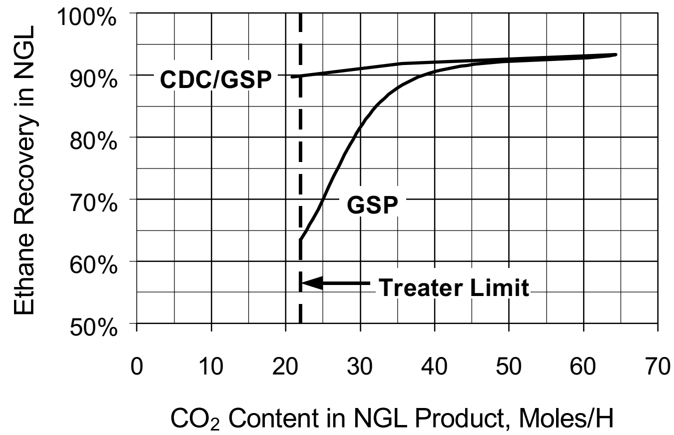

Figure 11 — Ethane Recovery Comparison

Figure 11 above summarizes these cases, and illustrates the typical ethane recovery performance of CDC-equipped processes and unmodified processes when the plants are operated to control the CO_2 content of the NGL product. In particular, note how "flat" the recovery curve is for CDC as less and less CO_2 is allowed in the NGL, and how steep the non-CDC curve becomes at low CO_2 contents. The superior stripping characteristics of methane vapor compared to ethane vapor is responsible for the much slower decline in ethane recovery when the CDC plant is operated at reduced CO_2 levels in the NGL product. As this example and the previous ones have all demonstrated, the capital and operating costs savings that CDC makes possible are substantial for all types of NGL plants.

CONCLUSIONS

All indicators suggest that the amount of CO_2 will continue to increase in the natural gas feedstocks that gas processors must process in their NGL recovery plants. At the same time, as the liquid product pipeline infrastructure is pushed to the limits of its capacity, the CO_2 content allowed in raw NGL is expected to become even more limiting. These two factors will place increasing pressure on gas processors and their plants as they try to maximize plant throughput and product recoveries.

The CDC design feature invented by Ortloff will allow gas processors to reduce the CO_2 content of the NGL they produce without sacrificing product recovery. The CDC scheme can be applied to all types of cryogenic NGL recovery processes to increase the CO_2 stripping efficiency of the demethanizer, allowing simple control of the CO_2 in the NGL product to meet product specifications or to stay within the capabilities of existing product treaters. For operating companies, this translates into both capital savings (no additional treating capacity needed) and operating cost savings (no utility consumptions from a new treater), as well as increased revenue from the higher NGL product sales that the existing process cannot provide.

The CDC process can also improve heat exchanger efficiency for those plants that are not limited by CO_2 content, with the result that product recoveries are improved. The CDC process is easy to retrofit into existing plant designs, and can be applied to new plant designs as well to give these same benefits.

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