DESIGN AND OPERATING EXPERIENCE FOR ANADARKO'S LANCASTER FACILITY

Presented at the
95th Annual Convention
of the
Gas Processors Association
April 11, 2016
New Orleans, Louisiana

Joe T. Lynch, P.E.
Ortloff Engineers, Ltd.
Midland, Texas, USA

Michael C. Pierce
Ortloff Engineers, Ltd.
Denver, Colorado, USA

Steven Hummell
J. Pat McCann
Anadarko Petroleum Corporation
Denver, Colorado, USA

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ABSTRACT

The first of two 300 MMSCFD gas processing trains was placed in service at Anadarko's Lancaster Facility in April 2014, with the second train commissioned in June 2015. The new trains are designed for dual-mode operation to provide Anadarko with maximum operating flexibility, allowing very high ethane recovery when desired, but able to maintain very high propane recovery when ethane rejection is more economical. This rich gas process design is based on Ortloff's SCORE and SRC technologies. Since commissioning, operation has been primarily in the ethane rejection mode, with significant positive revenue results achieved by rejecting 99% of the ethane to the residue gas stream while maintaining 99% propane recovery. In addition, the process uses significantly less compression horsepower than would be required by typical open-art plant designs.

An operating history of the trains is presented, along with analysis of some typical operating issues. A comparison of the power requirements for the chosen process design versus the typical open-art medium and high propane recovery process designs is given.

BACKGROUND

With the recent expansion of shale gas production in northern Colorado, additional gas processing capacity was needed. In 2011, Anadarko Petroleum Corporation began the process of designing and constructing a new facility in Weld County, Colorado to process their own gas and available third-party gas. At the time, ethane recovery was economically favorable, though takeaway capacity was limited.

The location for the plant was chosen based on proximity to both the production field and the future pipeline. Anadarko has significant production acreage in Colorado that was already producing or available to develop. Their existing processing facilities near Fort Lupton, Colorado made an ideal location for a new plant, with nearby pipelines and good access for transporting equipment. The facility is named after Fort Lancaster, a fur trading post that closed in 1844 (Figure 1).

Figure 1: Anadarko Lancaster Facility, Weld County, Colorado [1]

Residue gas takeaway capacity was available on Kinder Morgan's Colorado Interstate Gas and High Plains Pipelines, flowing towards either Wyoming or the Denver market. However, local NGL takeaway capacity in the area was limited. DCP Midstream was in a similar position, and formed a partnership with Anadarko and Enterprise Products to build the Front Range Pipeline, with a connection at the Lancaster plant site. The proposed pipeline would allow NGL product to flow through the Front Range Pipeline to Skellytown, Texas, connecting to the Texas Express Pipeline which feeds the Mont Belview NGL market. Since the Front Range Pipeline could accept all types of NGL products, operational gas processing flexibility for the new facility would be valuable.

Anadarko's original design called for one 200 MMSCFD train, but quickly grew to two 300 MMSCFD trains in response to the rapid ongoing field development. The first Lancaster train started up in April 2014, and the second train was commissioned in June 2015.

DESIGN BASIS

Anadarko's goal was to build a state-of-the-art facility that could achieve high product recoveries and have the flexibility to respond to changes in product delivery options and the marketplace. The original plan included providing efficient recovery of propane and heavier components until the Front Range Pipeline became available for Y-grade NGL takeaway. This capacity constraint became less important when the pipeline was completed just prior to the startup of the first Lancaster train. The original design approach worked out very well, however, considering the product pricing changes that took place as the project was being constructed.

The original expectation was to operate for one or two years in ethane rejection mode, and then switch to ethane recovery mode. Maximum propane recovery was required in all operating modes, including partial ethane recovery, and any possible reduction in total compression power in any operating mode would be valuable.

The specific project requirements included recovering at least 95% of the ethane in recovery mode, and the ability to reject almost all the ethane while still maintaining at least 98% propane recovery. Partial ethane recovery operation was also considered important, preferably without significant reduction in propane recovery. The gas to be processed was quite rich (6.5 GPM), meaning refrigeration and multiple separators would be required to optimize the design. The process side residue compression was set at 16,000 HP per train. Turndown operation was not a consideration since Anadarko's less efficient plants at other locations on the system could be turned down, maximizing profit from the overall system.

The CO_2 content of the design feed gas was almost 3 mol%, high enough to require an amine unit to remove the CO_2 in ethane recovery mode to avoid CO_2 freezing and to meet the NGL product specification. In ethane rejection mode, the amine unit would only be required to remove H_2S, and to meet the residue gas maximum CO_2 specification if needed due to shrinkage.

Table 1: Product Specifications

Residue Gas	Max HHV, BTU/SCF	1235
	Max Inerts, mol%	3.00
NGL Product	C_1 max, LV%	0.5
	C_1/C_2 max, LV%	1.5
	CO_2/C_2 max, LV%	0.35
	H_2S	copper strip

The product specifications are summarized in Table 1. The requirements follow a typical Y-grade specification, restricting maximum content of methane, methane-in-ethane, CO_2-in-ethane, and H_2S. When rejecting ethane, the only NGL content concern is the sulfur compounds. However, the residue gas specifications mandate a maximum heating value (which can be a concern when rejecting ethane) and a maximum CO_2 content.

PROCESS DESIGN OPTIONS

Historically, most gas processing plants in North America have not been optimized to reject ethane while maintaining maximum propane recovery. Only recently has this ability become important, due to the depressed NGL product pricing. Ortloff Engineers, Ltd. was asked to develop several design options for Anadarko which met or exceeded the design basis requirements.

Ethane Rejection Options

Ortloff's Gas Subcooled Process (GSP), an open-art technology, has become the standard for North American NGL recovery plants (Figure 2). It is effective for providing moderately high ethane recovery and is easy to operate. However, GSP has significant limitations for ethane rejection operation.

The GSP reflux stream feeding the top of the fractionation column is essentially inlet gas with some of the heavier components removed, and contains significant quantities of ethane and propane. As a result, the maximum possible component recovery is limited by the composition of the flashed reflux stream vapor and the warm column overhead temperature. In ethane rejection mode, it is particularly difficult to minimize the propane lost to the residue gas stream. Reducing the column pressure may marginally improve recovery, but the increase in compression power is significant.

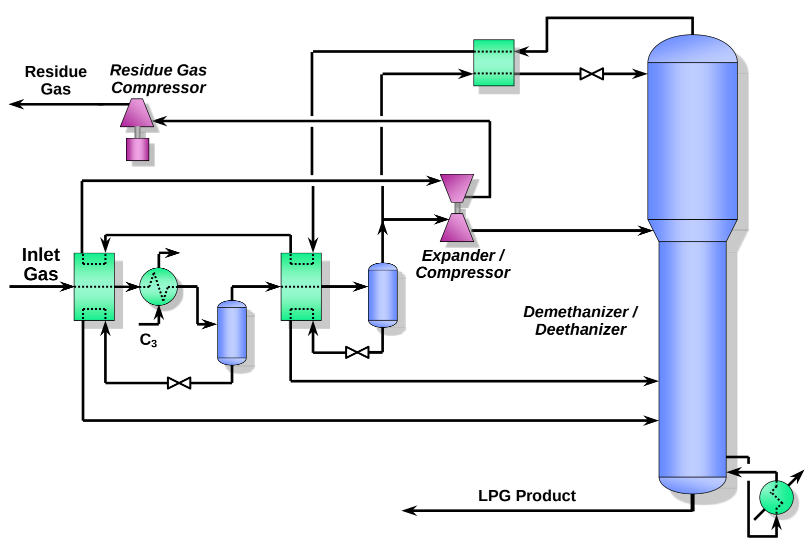


Figure 2: Ortloff GSP Process – Ethane Rejection Mode

An optimized design for propane recovery requires more theoretical stages in the column below the expander feed point than a design for only ethane recovery mode. A larger diameter is also required for the lower column section to handle the additional vapor traffic when rejecting ethane. Typically, North American gas plants have been sized with an emphasis on ethane recovery mode, and operate at lower throughput and relatively low propane recovery levels when rejecting ethane. This used to be an acceptable approach because the primary goal was ethane recovery and rejection was a secondary consideration.

For the Lancaster Plant's rich gas design basis, the maximum propane recovery for a GSP design would be approximately 90% when rejecting almost all the ethane, even when using all the horsepower required for the ethane recovery mode operation. This performance level was not good enough for this project.

One option for improving the top reflux composition is with a process such as Ortloff's Recycle Split-Vapor (RSV) technology. [2] In this design, a small stream of compressed residue gas is cooled and flashed to the top of the column, theoretically allowing close to 100% propane recovery while rejecting ethane. Although it does require a taller column, additional exchanger passes, and additional residue gas compression, RSV could offer the flexibility and high product recoveries required for the Lancaster project. It was evaluated as an option, but was quickly rejected because of the high compression power requirements for ethane rejection mode.

A significantly more efficient ethane rejection process is available in Ortloff's Single Column Overhead REcycle (SCORE) technology (Figure 3). It is widely used internationally for single-mode propane recovery plants, but has not been widely deployed in North America where ethane recovery capability has typically been a higher priority. SCORE uses a side draw vapor stream withdrawn from the column to provide reflux to both the upper and lower sections of the column.

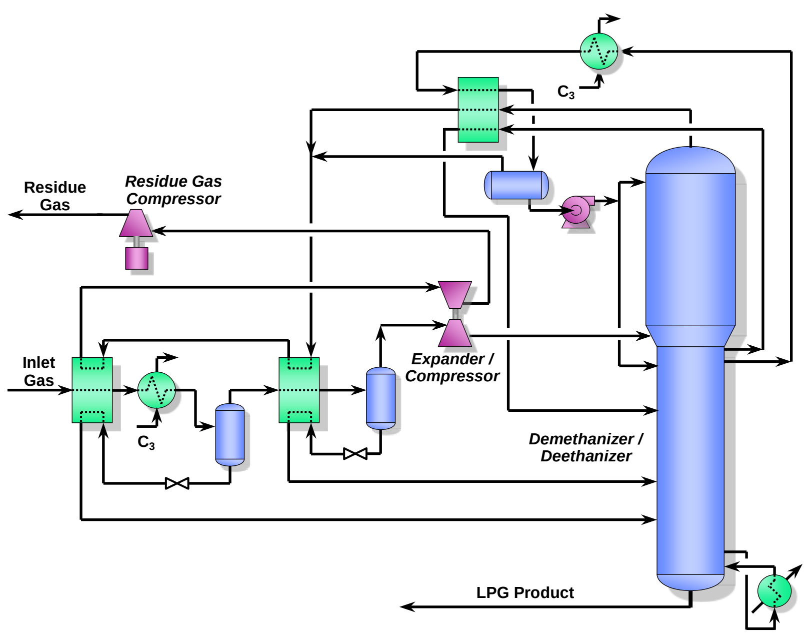


Figure 3: Ortloff SCORE Process – Ethane Rejection

The size of a SCORE column is similar to that of a GSP column sized for ethane rejection, but the reflux system requires a reflux accumulator and a set of cold reflux pumps not needed in the GSP design. However, the residue compression requirement is significantly reduced, due to the high column operating pressure possible while still allowing the reflux stream to be condensed. For the Lancaster project, SCORE is calculated to achieve 99.5% propane recovery using 10% less horsepower than GSP at the 90% propane recovery level, and 40% less horsepower than RSV at a 99.4% propane recovery level. If a plant is going to spend any time at all in ethane rejection mode, this power savings becomes a strong incentive to incorporate a process specifically designed for propane recovery into the final design.

When the Lancaster project was first conceived, Ortloff was already developing a new dual-mode design, Supplemental Rectification with Compression (SRC). Like SCORE, SRC utilizes a side draw vapor stream withdrawn from the column (Figure 4). However, a cold compressor is used to pressurize the stream, eliminating the reflux accumulator and cold pumps required for a SCORE design. This arrangement has cost saving advantages for modularization. In ethane rejection mode, the performance is similar to SCORE. The size and cost of a column for an SRC design is similar to that of an RSV column, but both are taller than a SCORE-only column.

The results of these full ethane rejection design options are summarized in Table 2.

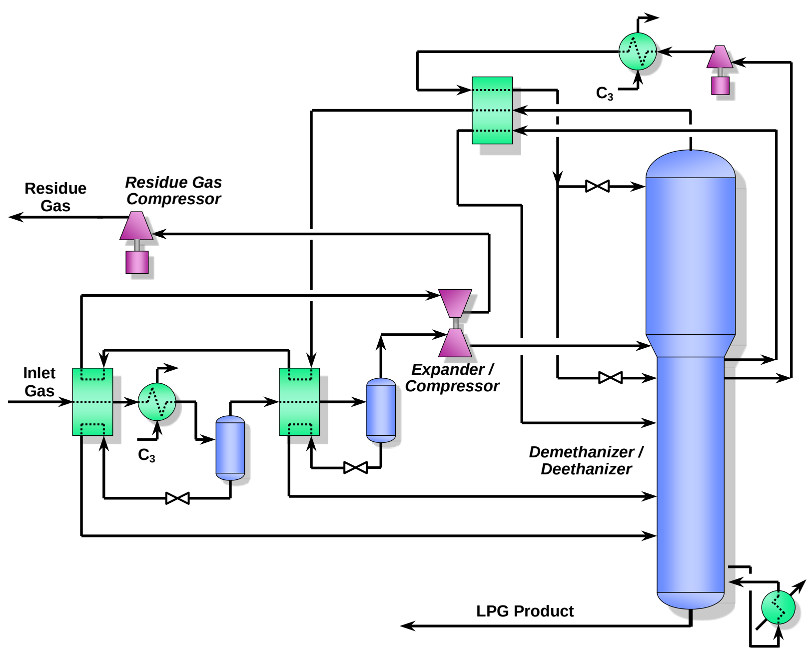


Figure 4: Ortloff SRC Process – Ethane Rejection Mode

Table 2: Ethane Rejection Performance

	GSP	SCORE	SRC	RSV
Recovery				
C_2	0.7%	0.7%	0.8%	0.8%
C_3	90.2%	99.5%	99.6%	99.4%
Compression, HP				
Residue	16,000	11,810	11,450	21,000
Refrigeration	4,250	6,410	6,920	4,490
Reflux	---	---	850	---
Total	20,250	18,220	19,220	25,490

Full Ethane Recovery Options

Ortloff's GSP, RSV, and SRC designs were also considered for full ethane recovery mode operation at Lancaster. Each design had similar refrigeration and front-end exchanger arrangements, so the process design reflux system performance alone would be the dominant factor in the overall recovery versus horsepower results.

For the Anadarko rich gas design basis, a GSP design (Figure 5) can achieve 95.4% ethane recovery at 99.7% propane recovery if enough residue and refrigeration horsepower is used. This recovery level required 16,000 HP of residue compression and 6,580 HP of propane refrigeration for a total of 22,580 HP for each 300 MMSCFD train. This became the baseline for comparison of the process design options.

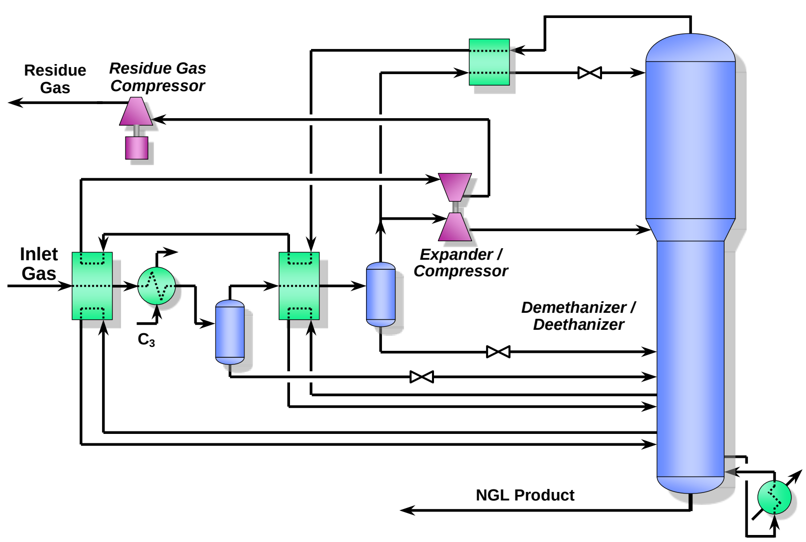


Figure 5: Ortloff GSP Process – Ethane Recovery Mode

An RSV design (Figure 6) can achieve 98.9% ethane recovery and 100% propane recovery using 23,430 HP, only 4% more horsepower than GSP. The RSV column is taller than the GSP column and operates at higher pressure, and the heat exchangers have additional passes for the recycle stream. The RSV design residue horsepower was 16,300 HP, slightly over the 16,000 HP target. The residue gas delivery pressure in the design basis was 900 PSIG, which hinders the RSV design. It is easier to condense and subcool the recycle stream if the pressure is above 1000 PSIG. The residue compression power would go up for all designs if this were the case, but it would only benefit the RSV design performance.

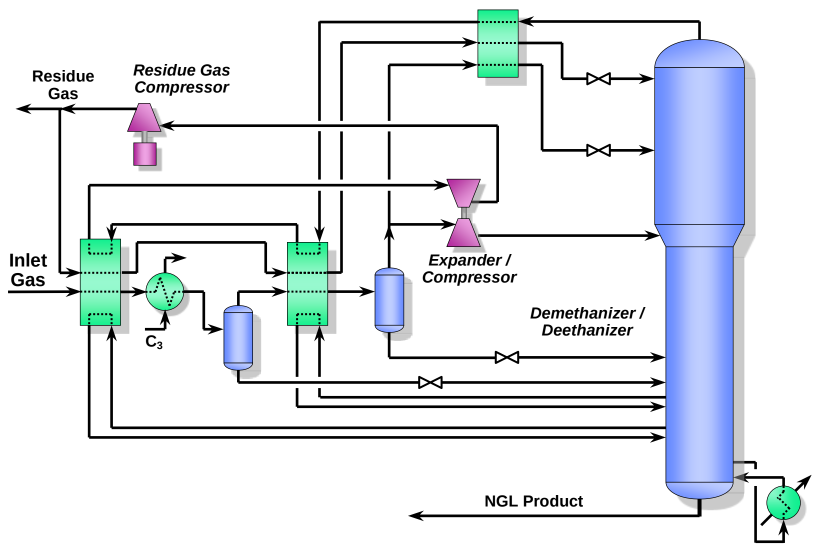


Figure 6: Ortloff RSV Process – Ethane Recovery Mode

The SRC process (Figure 7) is able to achieve 99.0% ethane recovery and 100% propane recovery at just slightly less total horsepower (sum of the residue, refrigeration, and SRC compression) than RSV. For the Lancaster design basis, SRC requires 23,350 HP. The SRC side vapor draw compressor power is 510 HP for the high ethane recovery mode operation, and the residue compression is at the 16,000 HP target. Unlike RSV, the SRC design performance is independent of the residue delivery pressure.

The RSV and SRC designs have a packed bed added above the GSP reflux feed to the column. Below the GSP reflux feed nozzle, the columns are very similar between the three designs. If the RSV or SRC top feeds are reduced to zero flow for any reason, the column operates as a GSP column and the top bed is passive.

The maximum ethane recovery mode results for the three process design options are summarized in Table 3.

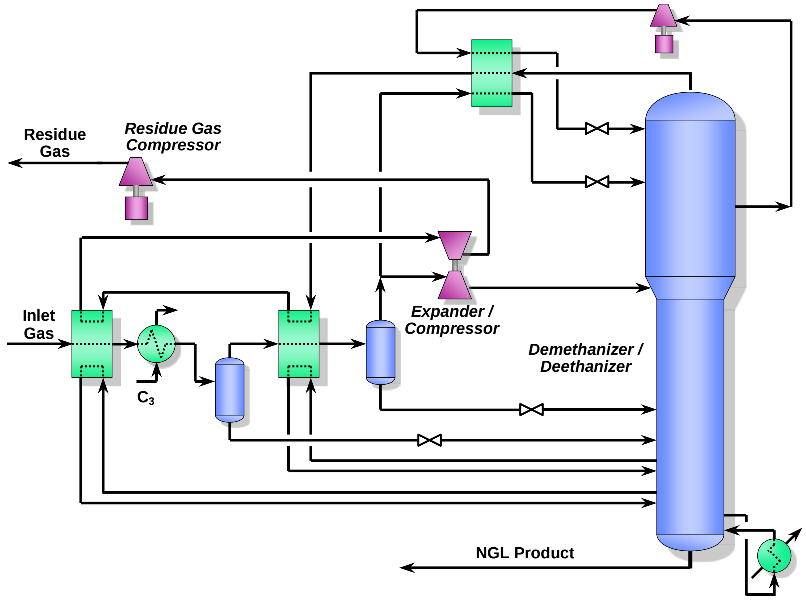


Figure 7: Ortloff SRC Process – Ethane Recovery Mode

Table 3: Ethane Recovery Performance			
	GSP	RSV	SRC
Recovery			
C_2	95.4%	98.9%	99.0%
C_3	99.7%	100.0%	100.0%
Compression, HP			
Residue	16,000	16,330	15,990
Refrigeration	6,580	7,100	6,850
Reflux	---	---	510
Total	22,580	23,430	23,350

Partial Ethane Recovery Design Options

Because of the way the reflux system operates, SCORE is best suited for full ethane rejection mode operation. However, a SCORE design can also be operated in what Ortloff refers to as "incidental ethane recovery mode". In this mode, the reboiler heat is reduced from what is required to meet the normal ethane/propane ratio at full rejection to something much lower, allowing some ethane to be recovered in the bottoms product. The heat can be reduced until the amount of methane in the bottoms product approaches the pipeline product limit. For most SCORE designs, this is usually slightly more than 30% ethane recovery. However, it is possible to keep the propane recovery very high, even as the methane content limit is approached. In addition, this very high propane recovery can be achieved at a much lower compression power than GSP, which will still have significant propane losses at 30% ethane recovery.

Figure 8 below shows how the propane recovery changes as a function of the ethane recovery level over the full range of possible ethane recovery levels for GSP, SCORE, and SRC designs. The SCORE line stops at 30% ethane recovery. The GSP and SRC lines span nearly the entire ethane recovery range. For these cases the residue compression power was limited to 16,000 HP, since this was the maximum horsepower required for the 95% ethane recovery mode GSP design once RSV was eliminated as an option. The high ethane recovery case usually sets the residue compression requirement for a dual-mode design. The refrigeration compression was limited to 7,000 HP.

This graph shows that at 30% ethane recovery, the propane recovery for a GSP design falls to approximately 95% for the Lancaster design basis. In contrast, the propane recovery for the SCORE and SRC design options is over 99%. This is a four percentage point increase in propane recovery alone at 30% ethane recovery, or approximately 35,000 gallons of propane per day for each train.

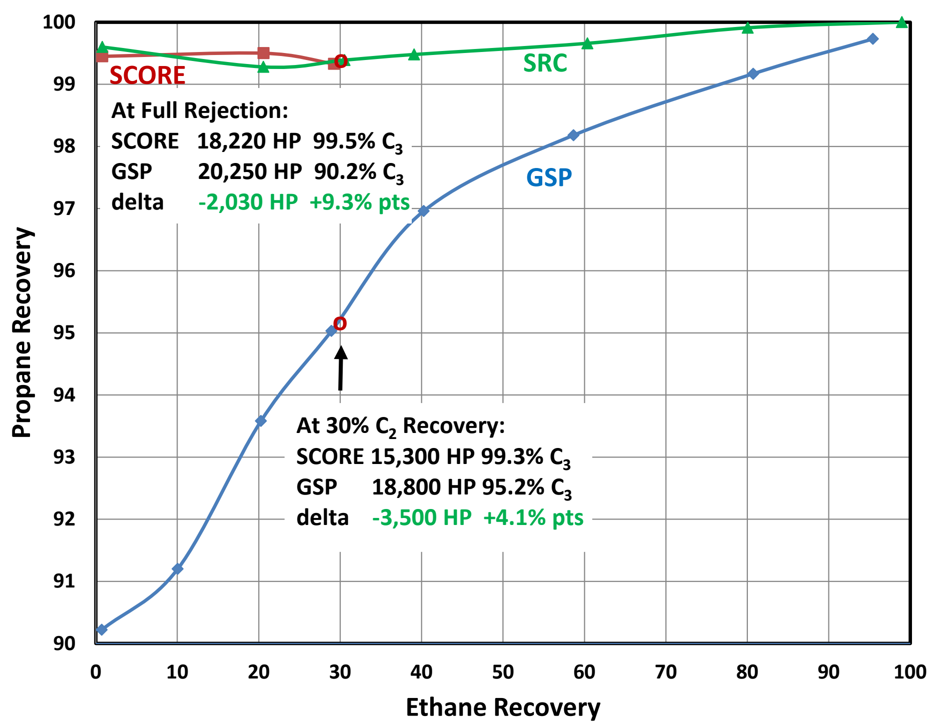


Figure 8: Propane Recovery vs. Ethane Recovery

The triangular-shaped area between the GSP line and the SRC/SCORE line illustrates what is given up in propane recovery when a GSP design is used for partial ethane rejection. As expected, the largest difference is at full ethane rejection, at the left end of the graph. But there is also a notable difference in the propane recovery at the right end of the graph.

Just as important is the difference in compression power for these three process designs. The total compression horsepower numbers have been added to the graph for full ethane rejection and 30% recovery to indicate the savings that can be achieved when using a more effective propane recovery process like SCORE or SRC instead of GSP.

From full ethane rejection to 30% ethane recovery, SCORE or SRC is the preferred process design with much higher propane recovery than GSP. Although the SRC and GSP total horsepower requirements are similar, the propane recovery for the SRC design is 99.4% at 30% ethane recovery and increases to 100% as the ethane recovery increases to 99.0%, while GSP only increases from 95.1% at 30% ethane recovery to 99.7% at 95.4% ethane recovery.

The final options and performance data for the Lancaster design basis are given in Table 4. It was obvious that an efficient propane recovery process design should be selected for the low ethane recovery end of the operating envelope, but options for the high end of the ethane recovery range also needed to be considered.

Table 4: Summary of Lancaster Process Options

	Ethane Rejection		Ethane Recovery	
	SCORE	SRC	GSP	SRC
Recovery				
C_2	0.7%	0.8%	95.4%	99.0%
C_3	99.5%	99.6%	99.7%	100.0%
Compression, HP				
Residue	11,810	11,450	16,000	15,990
Refrigeration	6,410	6,920	6,580	6,850
Reflux	---	850	---	510
Total	18,220	19,220	22,580	23,350

SELECTED LANCASTER DESIGN

Ortloff has extensive experience designing high recovery dual-mode plants for the international market. It is very practical and common to design a plant for efficient operation at both ends of the ethane recovery scale. The typical approach used is to choose an efficient ethane rejection design and combine it with an efficient ethane recovery design. Based on the options developed specifically for the Lancaster application, a SCORE design was selected for full rejection mode and incidental ethane recovery, and SRC was selected for the future full ethane recovery mode.

Long-term operation in the 30-80% ethane recovery range seemed unlikely in 2012, so Anadarko decided to defer purchase of the SRC compressor in order to save on capital costs. In the interim, Anadarko opted to operate in GSP mode for ethane recovery above 30% until the SRC compressor could be justified by ethane and propane product pricing. All equipment was specified and designed for future SRC mode operation, including the demethanizer column with a packed section above the GSP feed.

The final physical design for Lancaster Trains 1 and 2 is a combination of SCORE and GSP designs. Both trains include the equipment necessary to easily upgrade to SRC for maximum ethane recovery, or for maximum propane recovery in partial ethane recovery mode in the future.

The column has fractionation stages optimized for full rejection, and diameters sized for both operating modes at the full inlet gas rate of 300 MMSCFD/train.

Lancaster Train 2 – Expander and main structure

Variable-speed electric motor drives were selected for the residue and refrigeration compression services, to better accommodate the 100 psi difference in column operating pressure between the optimized recovery and rejection modes and the changes in the refrigeration loads. This allows Anadarko to take full advantage of the lower compression power when operating between full rejection and 30% ethane recovery.

The CO_2 removal requirements shift with the ethane recovery level. CO_2 freeze is not a concern in full rejection mode, but is limiting in the ethane recovery mode where much colder temperatures exist. Two 50% amine units were specified for each train. Note that the H_2S must be removed for both modes of operation, but not all of the CO_2 has to be removed when rejecting ethane.

OPERATING HISTORY AND LESSONS LEARNED

The first train at the Lancaster facility was ready for commissioning in April 2014. The amine treaters were first tested for CO_2 removal. The removal performance was adequate, although the operators had problems with tuning of the control loops, which was a significant concern since the inlet gas was very close to the hydrocarbon and water dewpoints. This lead to foaming and liquid carry-over, resulting in contamination of the dehydrator beds. This continues to be a concern that requires close monitoring. The molecular sieve dehydrator beds were brought on-line next. Once the switching schedule was adjusted, dry gas was then available to feed the NGL recovery unit.

A closed-loop dry-out procedure that is very effective in minimizing dry-out time was used at this facility. A residue compressor is used to circulate dry gas through the dehydrator beds and then through various paths in the cryogenic unit, and back to the compressors. In this technique the pressure drop is taken upstream of the cold exchangers, instead of at the J-T valve, to minimize any cooling. The pressure drop across the J-T valve is limited by keeping the circulation rate at around 30% of design. When this is done correctly, the cold plant does not get cold and the dry-out gas temperature can be kept high using the residue compressor discharge cooler controls. Details of this procedure were presented in a separate technical paper. [3]

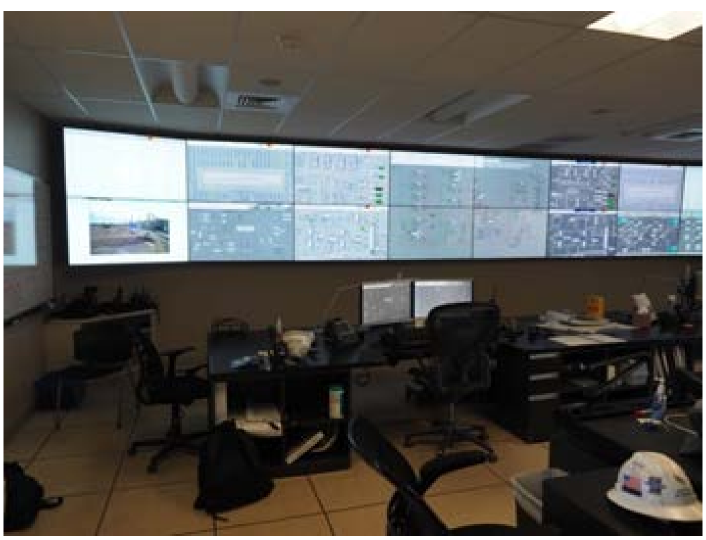
As noted above, the SCORE design includes a cold reflux accumulator, cold reflux pumps, and a pass through the condenser that operates at column pressure. Because the flow path through the reflux generation system is separate from the normal residue gas path, it is difficult to force adequate dry-out gas flow through this section without specific dry-out gas tie-in points. This was a problem for the first train at Lancaster, and improvements were made on the second train.

After startup, Train 1 was operated in GSP mode for the first year, processing inlet gas with an HHV greater than 1300 BTU/SCF (7.0 GPM), even though it was designed for 1265 BTU/SCF (6.5 GPM). Ethane recovery during that time was around 93%, and propane recovery was just over 99%. Train 1 was shut down briefly after Train 2 was commissioned to replace the dehydration molecular sieve and to perform a complete dry-out. After that, Train 1 was restarted, but in SCORE mode.

Commissioning of Train 2 was generally smoother than Train 1 because of the lessons learned from Train 1. This was particularly true for the control systems, and especially the level control loops. This allowed a quick startup of Train 2, and subsequent increase in the inlet flow rate from 200 MMSCFD to over 300 MMSCFD in just a few days. Train 2 has always operated in SCORE mode, although some of that time has been in incidental ethane recovery operation.

CURRENT OPERATION

At the time the Lancaster Plant was conceived, Mont Belvieu margins for ethane and propane were consistently favorable for recovery. Since then the prices have dropped significantly, making ethane margins negative. The ability of the Lancaster Facility to reject ethane is an excellent example of why flexibility should be a key consideration when designing an NGL recovery plant.



Lancaster Facility control room

With the low ethane prices, both Lancaster trains have been in full rejection mode since August 2015, processing up to 325 MMSCFD of feed gas each. Propane recovery is typically greater than 99%. However, Front Range Pipeline recently requested Anadarko to recover approximately 25% of the ethane to fulfill market orders. Flexibility of the process allows them to easily meet that commitment without reducing propane recovery by operating both trains in incidental ethane recovery mode.

All of the startup and operational issues have been addressed, and operation of both plants is very smooth and reliable as a result. Anadarko is currently in the process of consolidating operations of their other nearby facilities into the Lancaster control room, maximizing the value of the entire asset.

CONCLUSIONS

Overall, performance of Anadarko's two Lancaster Facility gas plants has been exceptionally good. Despite a feed gas composition that is richer than expected, the product recoveries are better than design. Flexibility has been key to maximizing profits from the facility. Operators are able to maintain ultra-high propane recovery at minimum compression power levels even when recovering some ethane is required. This capability is what differentiates this plant from most North American gas plants.

Uncertainty in product pricing makes efficient long-term operation in ethane rejection mode much more important now than ever before. Ortloff process designs like the ones used for this project provide Anadarko with the operating flexibility needed for varying market conditions.

Schedule-driven GSP designs are no longer the answer in the North American market. Reduced emissions, reduced electrical costs, and lower installed compression capital cost favor more efficient process designs. It is now possible to build new plants, such as the two trains at Anadarko's Lancaster Facility, which are capable of high recovery dual-mode operation at minimal additional cost.

REFERENCES

1. Allin, Jay, "Lancaster Cryogenic Plant Project", presented at the Gas Processors Rocky Mountain Chapter 2015 Regional Conference, November 19, 2015, Denver, Colorado.
2. Pitman, R. N., Hudson, H. M., Wilkinson, J. D., and Cuellar, K. T., "Next Generation Processes for NGL/LPG Recovery", paper presented at the 77th Annual Convention of the Gas Processors Association, March 16-18, 1998, Dallas, Texas.
3. Jensen, D. R., Lynch, J. T., Cuellar, K. T., and Villegas, G. G., "Designing Molecular Sieve Dehydration Units to Prevent Upsets in Downstream NGL/LPG Recovery Plants," paper presented at the 62nd Laurance Reid Gas Conditioning Conference, February 2012, Norman, Oklahoma.