Forecasting Volatile Gas Processing Margins

by

Daniel Mark Altena, B.S.Ch.E.

Masters Report

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Masters of Science in Engineering

The University of Texas at Austin

May 2005

Forecasting Volatile Gas Processing Margins

Approved by
Supervising Committee:

Dedication

To my wonderful wife Candy, and my daughters Kristin, Lisa and Lauryn

Abstract

Forecasting Volatile Gas Processing Margins

Daniel Mark Altena, M.S.E.

The University of Texas at Austin, 2005

Supervisor: Gary T. Rochelle

Gas Processing Margins are becoming increasingly more volatile. This report provides background on gas processing including a review of historical processing margins and a review of various methods for forecasting the processing margin including direct forecasting based on historical data, forecasting based on oil and natural gas forecasts and an Upgrade Quartile approach. The effectiveness of each approach is explored using some hypothetical examples.

None of the methods reviewed fully captured both the volatility in historical processing margins and the current market conditions. The volatile nature of processing margins warrants a more complex approach than a simple average or a point processing margin calculated using oil and natural gas prices, however even a more complex forecasting methodology may not be sufficient to capture the volatility in processing margins. Using actual historical monthly processing margins and evaluating the monthly performance for each alternative for each month as a proxy for future margin volatility is

a complex analysis but may be warranted as a final “reality” check prior to making an investment decision.

The conclusions and recommendations from this review are summarized below:

- The processing margin is very volatile and a function of current market conditions. It is difficult to capture both the volatility and current market conditions in a processing margin forecasting method.
- The simple average method does not capture the processing margin volatility or current market conditions and is not an effective tool for reviewing design alternatives.
- The Quartile Upgrade approach captures a significant portion of the volatility and is a more effective tool than the simple average. It does not capture the current market conditions.
- The rigorous monthly method can be used to screen process designs or investment alternatives in detail but does not capture current market conditions.
- Applying a method similar to Upgrade Quartiles to historical correlations of NGL pricing to crude oil and natural gas pricing and using these with a crude oil and natural gas forecast did not capture the volatility in processing margins. More research in how to develop such a forecast may lead to a method that captures both the current market conditions and the volatility in processing margins.

Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction to Gas Processing

Natural Gas is a mixture of primarily methane with minor amounts of the paraffin hydrocarbon family including ethane, propane, butanes, pentanes and heavier hydrocarbons. Non-hydrocarbon constituents include nitrogen, hydrogen sulfide, carbon dioxide, helium and water vapor. Natural gas is produced from wells throughout the world and is consumed in various economic markets including residential and commercial heating or fuel use, fuel supply for power plants and as feedstock for some chemical processes.

NATURAL GAS CHARACTERISTICS

In this report, the volume for natural gas is stated in standard cubic feet (SCF). This may be in thousands of SCF (MCF) or millions of standard cubic feet (MMCF). The energy content of a natural gas (the basis for which natural gas is priced) is in million btus (MMBtu). The characteristics of a natural gas stream are determined by the gas composition. Characteristics that are important in the processing, marketing and consumption of natural gas include:

- the water dew point
- the hydrocarbon dew point
- the carbon dioxide (CO_2) content
- the hydrogen sulfide (H_2S) content
- the nitrogen (N_2) content

- the energy content, usually expressed in British Thermal Units (Btu) per SCF
- the fuel quality based on an index such as the Wobbe Index
- the natural gas liquid (NGL) content, usually expressed in gallons per MCF (GPM). NGLs include ethane, propane, isobutane, n-butane and natural gasoline

Almost all natural gas must be processed and/or treated before it is a safe and merchantable pipeline gas and can be marketed. The natural gas remaining after being treated and/or processed is often referred to as Residue Gas and delivered into a pipeline and transported to natural gas markets. There is an extensive network of residue pipelines in the United States and the Residue Gas must be a sufficient pressure to be delivered into the residue pipeline and must meet the quality specifications of the residue pipeline. These specifications are required to safely transport and deliver natural gas to consumers and may include a minimum and maximum Btu content, a maximum quantity of inert compounds (both individually and total), a maximum hydrocarbon dew point, a maximum quantity of heavy hydrocarbons (butanes and gasoline) and a maximum water dew point.

NGLs must generally be removed to some degree in order to meet the Btu, hydrocarbon dew point and/or heavier hydrocarbon specifications. NGLs have historically been more profitable when they are separated from the natural gas and sold as individual components, usually as a liquid, providing a margin associated with "processing" the natural gas. Therefore a significant portion of the natural gas produced in the United States has historically been processed for NGL removal and recovery for economic reasons.

NATURAL GAS PROCESSING AND TREATING

Treating for the removal of some or all of certain contaminants in raw natural gas is required prior to marketing most natural gas produced in the U.S. This treating is a necessary expense associated with producing natural gas and is rarely a viable stand alone investment (a third party may perform this service for a fee but it still represents a cost to the producer without incremental economic value other than being able to market the natural gas being treated). When treating for the removal of CO_2, a certain amount, as much as 3%, can be left in the Residue Gas. Additional treating to remove more of the CO_2 may be required prior to processing for high NGL recovery. Since our review is focused on the processing margin, the cost associated with any treating required to meet Residue Gas specifications for H_2S, N_2 or CO_2 is excluded from our analysis. These expenses are a necessary part of producing the natural gas.

The NGLs in the raw gas stream have generally been more valuable if sold as a liquid than if they were left in the natural gas stream and therefore processing natural gas to separate and recover NGLs has been and will likely continue to be an economically viable investment on a stand alone basis. The margin associated with gas processing is the value of the NGLs recovered and sold less the value of the gas shrinkage caused by removing the NGLS less any fuel associated with processing the natural gas. The processing margin may also take into account fuel required for incremental treating to remove additional CO2 prior to processing for high NGL recovery.

NATURAL GAS PROCESSING DRIVERS

The processing margin for a natural gas stream depends on the NGL content of the natural gas, how much of the NGLs are recovered in the processing plant, the price of natural gas and the price of the NGLs. To review the historical gas processing margins, historical monthly prices from 1995 through 2004 were used from the Barnes and Click, Inc. Energy Price Database (Barnes and Click, 2005) for crude oil, natural gas and NGLs. Crude oil and natural gas prices in this database are based on monthly average New York Mercantile Exchange (NYMEX) postings and NGLs prices are based on the monthly average of posted prices in Mont Belvieu, Texas. When calculating the processing margins we reduced the NGL prices by \$0.05 per gallon for costs associated with transporting, fractionating and marketing (TF&M) the NGLs and reduced the NYMEX gas price (used for shrink and fuel costs) by \$0.15 per MMBtu to reflect the price received at the plant. These "deducts" reflect what typical plant pricing might be in various parts of Texas. The historical processing margin for a hypothetical natural gas with an NGL content of 3.0 GPM [1] is presented in Figure 1. As shown, the processing

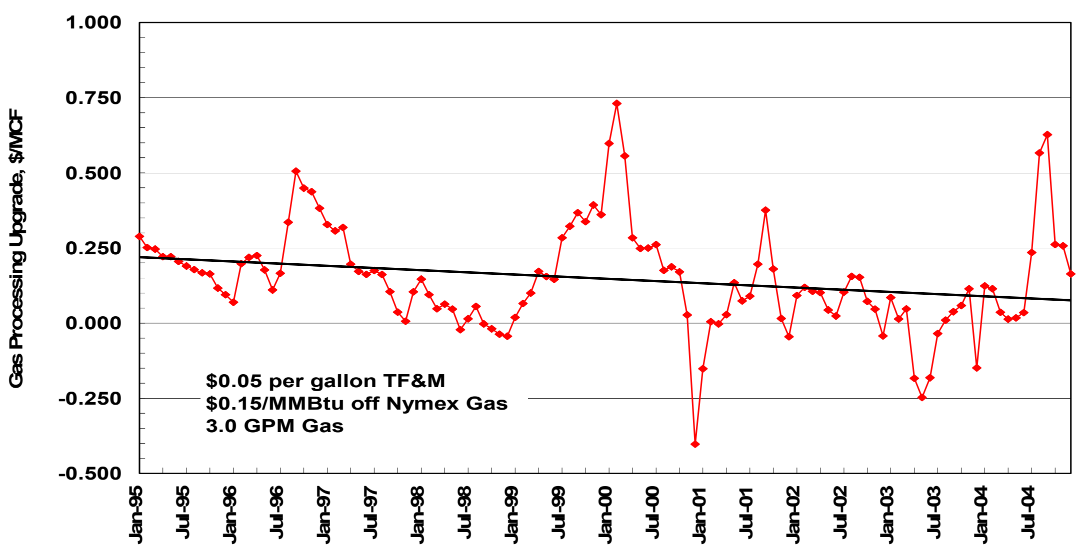

Figure 1: Historical gas processing margins for a gas stream containing 3.0 GPM of NGLs. [2]

[1] Assumes 1.5 GPM of ethane, 0.80 GPM of propane, 0.20 GPM of isobutene, 0.20 GPM of n-butane and 0.3 GPM of natural gasoline

[2] Assumes \$0.05 per gallon for NGL TF&M, \$0.15 per MMBtu off NYMEX for natural gas and 2% fuel

margin for this stream has generally been positive and supported stand alone investments in gas processing facilities. The processing margin has been very volatile and as shown by the linear trend line in Figure 1 there is some indication that the long term trend is for declining processing margins.

The average upgrade for this 3.0 GPM stream gas decreased from $0.179 per MCF between 1995 and 1999 to $0.116 per MCF during the most recent five years. The standard deviation might be used as a proxy for volatility and as expected by looking at the chart the standard deviation has increased from about 73% of the average during the first five years to 175% of the average during the last five years. The declining trend in processing margins in conjunction with increasing commodity prices has decreased the importance of the processing margin in the development and production of this type of natural gas. To demonstrate this, the process upgrade as a percentage of the total value of the wellhead stream (assuming the wellhead gas could be sold at the local gas price) was calculated for each month of data available and the results are shown in Figure 2. As demonstrated by the linear trend-line, the value added by the processing margin is decreasing and decreased from 8% during the first five years of the data to 3.3% during the most recent five years.

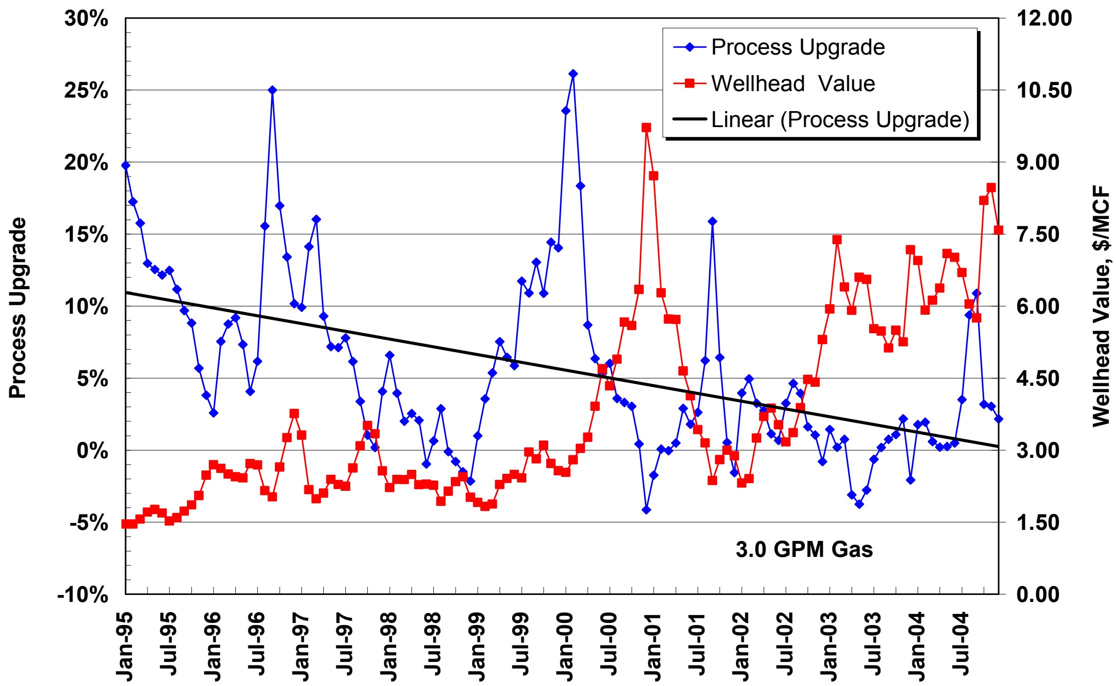

Figure 2: Historical wellhead process upgrade for a gas stream containing 3.0 GPM of NGLs. [2]

A significant amount of natural gas is produced in association with oil or condensate production and therefore may contain a higher level of NGLs. This gas may be referred to as a "rich" natural gas in contrast to the 3.0 GPM gas which may be referred to as a "lean" natural gas. The processing upgrade for a hypothetical 5.4 GPM [3] gas stream (assuming $0.05 per gallon TF&M, $0.15 per MMBtu off NYMEX natural gas and 2.5% fuel) is presented in Figure 3. Because of the higher NGL content, the processing upgrade is greater than the "lean" 3.0 GPM stream. Similar to the lean

[3] Assumes 3.05 GPM of ethane, 1.22 GPM of propane, 0.31 GPM of isobutene, 0.39 GPM of n-butane and 0.38 GPM of natural gasoline

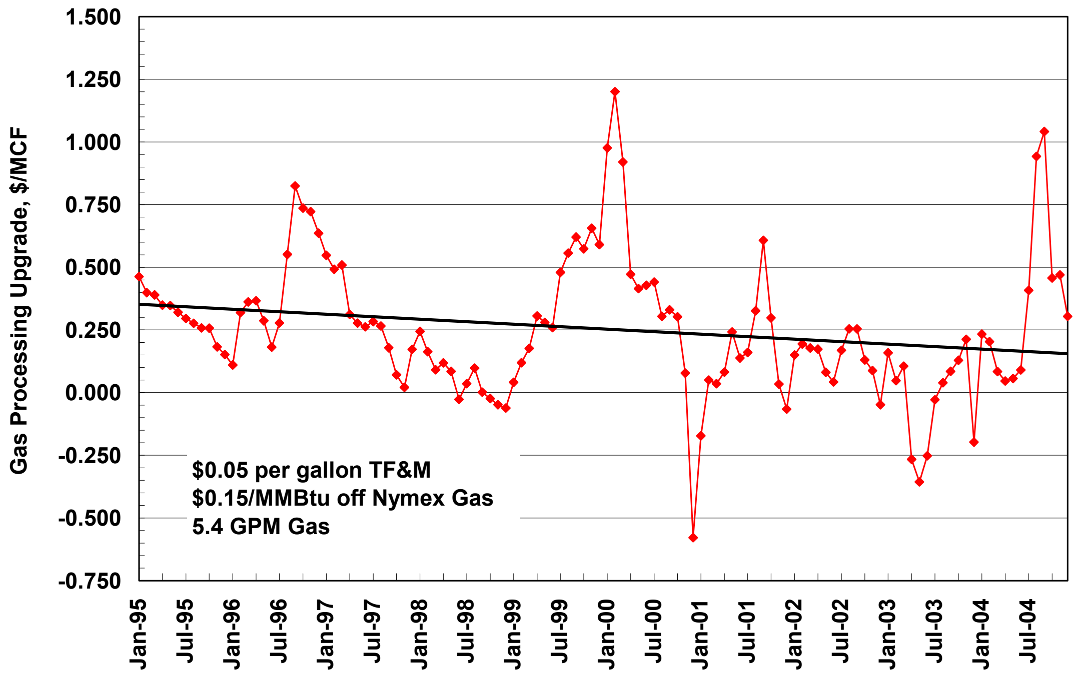

Figure 3: Historical gas processing margins for a gas stream containing 5.4 GPM of NGLs. [4]

gas stream and as demonstrated by the linear trend line in Figure 3, the processing margin appears to be declining, dropping from $0.297 per MCF during the first five years to $0.212 per MCF during the last five years. The volatility (standard deviation) has increased from 73% of the processing upgrade to over 150% of the processing upgrade and as shown in Figure 4, the value added by the processing margin for this natural gas has declined from 12.4% during the first five years to 5.4% in the most recent five years. If the earnings associated with oil and/or condensate production typically associated with rich natural gas were included, the value added would be even less. For example, the gas revenue for a well making 10 barrels of oil and 30 MCF of gas per day is about 35% of

[4] Assumes $0.05 per gallon for NGL TF&M, $0.15 per MMBtu off NYMEX for natural gas and 2.5% fuel.

the total revenue for the well, reducing the 5.4% processing margin impact to less than 2% for such a well.

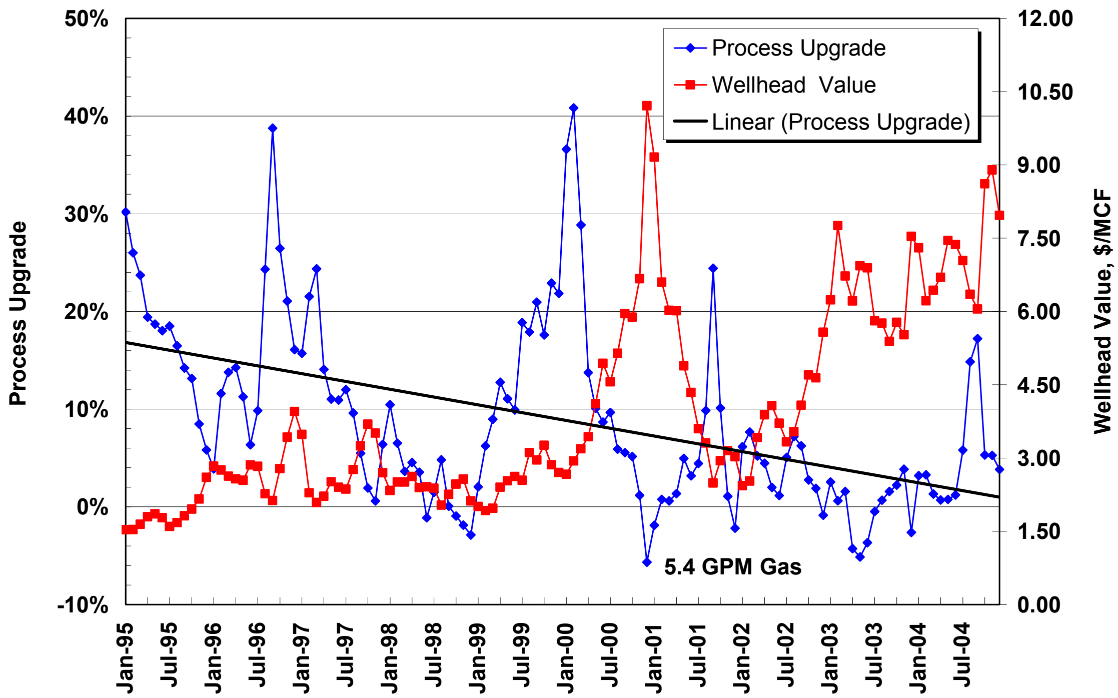

Figure 4: Historical wellhead process upgrade for a gas stream containing 5.4 GPM of NGLs. [4]

The processing margin has been decreasing, becoming increasingly more volatile and is providing less of an upgrade to producers of natural gas. These changes warrant considering different approaches to reviewing the economics of potential gas processing investments. The economics of most natural gas production projects are driven by commodity prices (which dictate the processing margin), volumes, capital costs and operating costs. Different approaches to forecasting the processing margin that capture some of the volatility in processing margins should result in being able to more effectively evaluate the impact of flexibility in processing designs, and to aid in capturing the largest economic processing margin possible. These approaches are especially important in projects with economics driven by the processing margin.

NATURAL GAS PROCESSING CONTRACTS

A significant portion of the natural gas processed in the United States is processed by a party other than the party who owns or controls the natural gas production. For instance, three producers in an area, Production A, Producer B and Producer C, might have 10,000 MCFD, 28,000 MCFD and 13,000 MCFD of production respectively. Each producer could build a separate gas processing plant for their production. Alternatively, the producers could process their gas in a single larger gas processing plant and capture the economies of scale associated with a larger plant. The plant might be installed by the producers jointly or by an independent third party without an interest in any of the production. In either case, the gas would be processed under a contract between each producer and the plant.

The contracts and terms covering the processing of natural gas vary widely depending upon the region, characteristics of the gas being processed and competitive environment. Most of these contracts can be classified under one of the following types:

- Keep Whole (KW)
- Percent of Index (POI)
- Percent of Proceeds (POP)
- Fee Based (Fee)

In a KW contract, the processor retains ownership of the NGLs produced from the natural gas and keeps the producer "whole" by buying residue gas to replace the Btu equivalent of the NGLs removed and the fuel used during processing. In most KW contracts the producer retains ownership of the natural gas. With a KW contract, the processor has all of the processing risk or reward and is in a position to optimize the plant accordingly. These contracts may be used when a producer has the option to go directly to a residue gas pipeline with little or no processing.

Under a POI contract, the processor purchases the wellhead stream at a price that is based on a published index. It may be a percentage of the index, a fixed differential to the index or a combination of both. It may also be at a fixed purchase price. With a POI contract, the processor has all of the processing risk or reward and is in a position to optimize the plant accordingly.

Under a POP contract, the processor pays the producer of the natural gas stream as percentage of the residue gas and NGL proceeds after processing. The processor retains the remaining percentage as the processing fee. These contracts are often used with richer gas which must be processed and may include a significant amount of compensation for gathering, compression and treating services in the processing fee. Under the POP, the processor may be aligned with the producer on processing decisions but will only have a portion of the processing risk and/or reward. A POP contract may also have different Residue Gas and NGL sharing percentages and may provide the processor an incentive to operate the plant in a manner that does not optimize the overall margin available. POP contracts also provide the processor with less incentive to pursue fuel savings projects.

Under a Fee Based contract, the processor processes the gas for the producer for a predetermined fee and the producer retains ownership of both the residue gas and NGLs. The processor has no risk or reward associated with the processing margin and therefore these contracts are unlikely to provide the processor much incentive to operate the plant in the most economic manner.

Any processing contract may have variations that influence how the processor makes operating decisions. These may include fixed or capped fuel percentages, guaranteed recoveries or options for the producer to elect between ethane recovery and ethane rejection operating modes.

The focus of this review is on pricing tools that can be used when making decisions that will result in maximizing the earnings associated with a gas processing investment. Accordingly, we will assume that the gas processing plant is owned by the producer of the natural gas. Therefore the processing plant earnings are driven by the process margin, NGL recoveries, fuel consumption, operating costs and investment required for a plant and there is an incentive to maximize the total earnings available. When processing is uneconomic (a negative processing margin), we assume that the natural gas must be processed to some extent to meet residue pipeline specifications and seek to minimize the cost of processing in these price environments.

Chapter 2

Historical Processing Margins

As previously mention, the goal of this review is to consider more effective pricing tools that can be used when reviewing investment decisions pertaining to the processing of natural gas. Our review will be focused on how to make the overall economics as favorable as possible and therefore we will assume that the producer retains all of the processing risk. In an ideal world, processing contracts would encourage making the pie as large as possible, however in most instances they do not provide the proper economic incentive for the processor to maximize the overall economics.

PROCESSING MARGIN CALCULATION

A processing plant is typically located near the supply of unprocessed production and the local market will impact the price received for Residue Gas and NGLs. The price received for residue gas is dependent upon a complex market and residue gas prices are typically based on an index (in this report we have assumed that local residue gas is priced $0.15 per MMBtu off NYMEX posted natural gas prices). NGLs may be fractionated at the plant location and sold to local markets or delivered as a mixture to a pipeline and transported to a central fractionation facility where the NGLs are fractionated into individual components and sold. In the United States, there are large fractionators at Mont Belvieu, Texas and Conway, KS and NGLs can be marketed and priced at each of these locations. We will refer to NGL prices relative to a Mont Belvieu posting price for each NGL component (ethane, propane, isobutane, n-butane and gasoline). The difference between the Mont Belvieu price and the price received at the plant is driven by transportation, fractionation and marketing costs which are assumed to be $0.05 per gallon in this report.

The processing margin is the difference between the value of the NGLs recovered and sold and the gas shrinkage associated with processing the natural gas. The shrinkage includes shrinkage associated with removing the NGLs and natural gas used for the fuel required for processing the gas. Since natural gas is sold on a Btu basis the shrinkage must be calculated on a Btu basis. The Btu contained in a gallon of NGL and Btu content of the gas stream is calculated using physical constants [5] from the Gas Processors Suppliers Association Engineering Data Book (Physical Properties, 2004).

The particular plant configuration impacts the processing margin available and various process designs have been utilized. The key operational parameters for an existing plant are fuel consumption, product recoveries, operating flexibility and operating expenses. When contemplating a decision to build a new plant (or to modify an existing plant), the capital cost would also be a consideration. The processing margin forecast will likely be the key driver of the overall economics and in selecting the optimum processing configuration. Further, an effective processing margin forecasting mechanism could aid in developing alternative process designs better able to maximize gas processing economics based on the historical volatility in processing margins.

PROCESSING MARGINS FOR EACH COMPONENT

The variability in commodity prices makes evaluating any project dependent upon commodity prices a challenge. Historical monthly average oil and gas prices (Barnes and Click, 2005) are presented in Figure 5. During the period included the price of oil and

[5] Assumes a gross heating value as an ideal gas for natural gasoline of 115,948 Btu/gal.

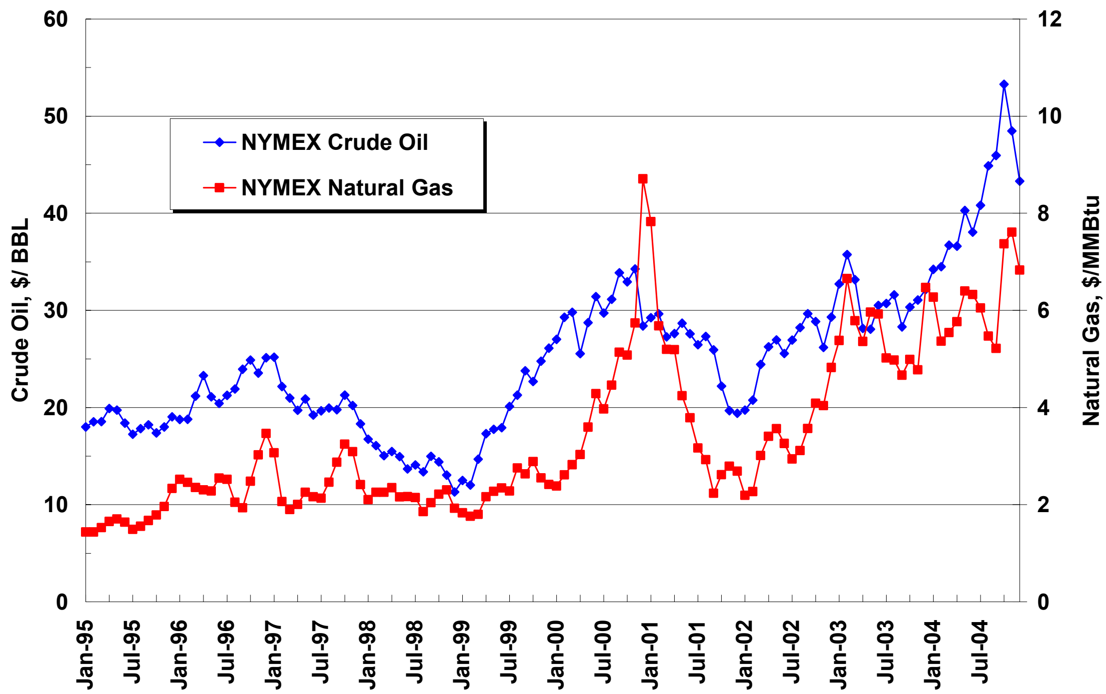

Figure 5: Historical Monthly Average NYMEX Crude Oil and Natural Gas Pricing.

natural gas averaged $24.93 per BBL and $3.45 per MMBtu respectively and have been extremely volatile, ranging from $11.31 per BBL and $1.435 per MMBtu to $53.27 per BBL and $8.71 per MMBtu. Prices have increased during this period from $18.94 per BBL and $2.22 per MMBtu in the first five years to $30.93 per BBL and $4.68 per MMBtu in the most recent five years, a contrast to the decreasing trend in processing margins during this same period.

The processing upgrade for each NGL component is a function of both oil and natural gas price and, similar to the overall processing margins in Figures 1 and 3, the upgrade for each component varies significantly. A summary of the average processing upgrade between 1995 and 2004 for each NGL component based on Mont Belvieu NGL prices, NYMEX natural gas prices and excluding fuel are summarized in Table 1.

Table 1: Average monthly processing upgrade excluding fuel from 1995 to 2004 based on Mont Belvieu NGL and NYMEX natural gas prices

	Average Monthly Upgrade, \$/gallon 1995–2004	Average Monthly Upgrade, \$/gallon 1995–1999	Average Monthly Upgrade, \$/gallon 2000–2004
Ethane	0.069	0.072	0.067
Propane	0.134	0.141	0.127
Isobutane	0.204	0.201	0.207
N-Butane	0.166	0.167	0.164
Gasoline	0.181	0.178	0.185

The NGL upgrade, a function of both oil and natural gas pricing, may be even more volatile than oil and natural gas prices. Since ethane is the "lightest" NGL and the most difficult and least economic to recover, the historic local plant NGL upgrades (assuming \$0.05 per gallon TF&M and \$0.15 per MMBtu off NYMEX) were split between ethane and propane and heavier components and are presented in Figures 6 and 7. The margins presented in these figures are local upgrades based on the deducts indicated on the charts. The processing margins are volatile and therefore difficult to predict, increasing the challenge of evaluating a gas processing project.

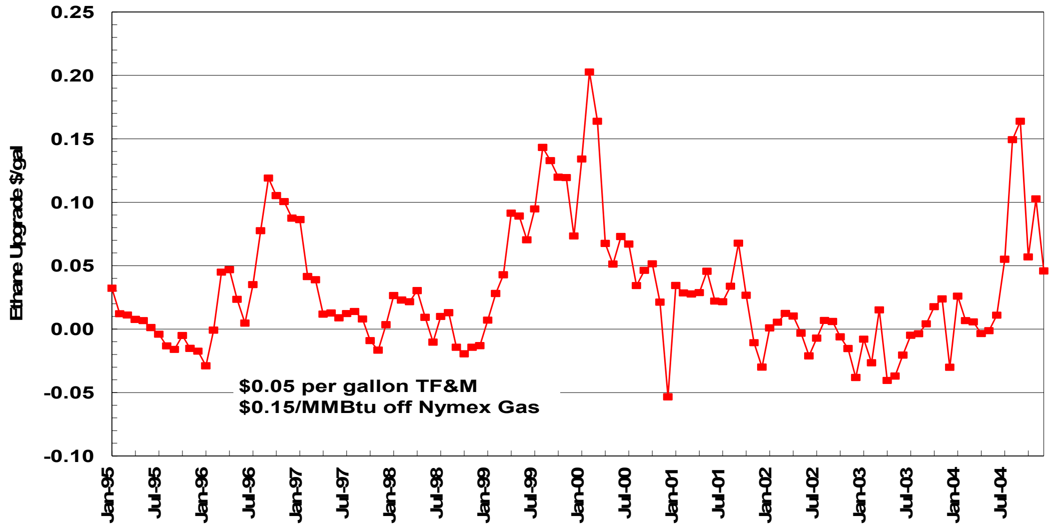

Figure 6: Historical local plant ethane upgrade excluding fuel and assuming $0.05 per gallon for TF&M and $0.15 per MMBtu off NYMEX price for natural gas.

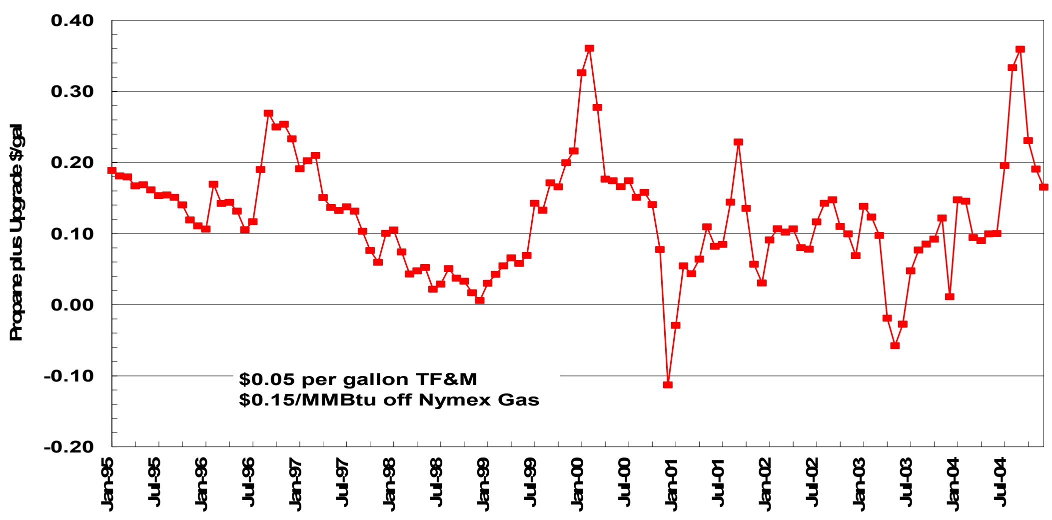

Figure 7: Historical local plant propane and heavier upgrade excluding fuel and assuming $0.05 per gallon for TF&M and $0.15 per MMBtu off NYMEX price for natural gas.

In order to better understand the volatility of component processing upgrades, we reviewed the monthly local upgrade for ethane from 1995 through 2004. The monthly data, including the calculated process upgrade for each component, was sorted in a spreadsheet based on the calculated ethane upgrade each month. The results were split into quartiles and the average, high and low upgrade for each component for each quartile is summarized in Table 2.

Table 2: Local component upgrade data excluding fuel sorted by quartile based on monthly ethane upgrades from 1995 to 2004. [6]

	Ethane Upgrade, $/gal	Propane Upgrade, $/gal	Isobutane Upgrade, $/gal	N-Butane Upgrade, $/gal	Gasoline Upgrade, $/gal
Bottom 25%					
Average	-0.018	0.047	0.105	0.071	0.076
Low	-0.053	-0.063	-0.111	-0.126	-0.235
High	-0.004	0.135	0.244	0.172	0.188
Second 25%					
Average	0.007	0.085	0.167	0.122	0.153
Low	-0.003	0.012	0.061	0.029	0.045
High	0.013	0.151	0.269	0.219	0.217
Third 25%					
Average	0.030	0.083	0.156	0.116	0.127
Low	0.014	0.010	-0.023	-0.048	-0.122
High	0.046	0.175	0.281	0.229	0.273
Top 25%					
Average	0.099	0.174	0.247	0.215	0.239
Low	0.047	0.038	0.100	0.065	0.063
High	0.203	0.317	0.407	0.407	0.460

The bottom quartile reveals that ethane has been uneconomic to recover more than 25% of the time (quartiles were selected to capture the majority of the time ethane was uneconomic to recover). The heavier components have been uneconomic at times but

[6] Assumes $0.05 per gallon for NGL TF&M and $0.15 per MMBtu off NYMEX price for natural gas

as shown, even the average margins in the bottom quartile have been positive. Because ethane may not be profitable when the propane and heavier components are profitable to recover, a processor would like to be able to reject ethane without sacrificing propane recovery and, as expected, there have been several plant designs that include an ethane rejection operating mode.

The ethane margin ranged from a loss of $0.02 per gallon in the bottom quartile to a positive margin of $0.10 per gallon in the top quartile. In order to maximize the processing upgrade a process design would be required that is flexible enough to reject most of the ethane (without sacrificing the propane and heavier components) when ethane margins are negative and to recover a high percentage of the ethane when margins are strong. Process flexibility will come with an added cost. Because of the variability of the margins, the value of this flexibility may be difficult to determine. Additionally, since natural gas prices have increased and appear to have entered a period of significantly higher levels, the fuel cost associated with NGL recovery and each processing mode is a more significant factor in the design than it has been historically. A process that can operate in a lower recovery / lower fuel mode may become a viable economic choice for gas processing facilities in the future.

An alternative to single point process upgrades is required to successfully evaluate flexible process designs. A price forecasting mechanism based on the above quartiles is one option that may capture the volatility in processing margins adequately and could be used to make more effective processing investment decisions. Before considering this option in more detail we will discuss how processing margins may be forecasted in conjunction with and based on oil and natural gas price forecasts.

Chapter 3

Correlating NGL Prices to Crude Oil and Natural Gas Prices

The processing upgrade can be forecasted directly based on historical information or can be a function of the oil and natural gas price forecasts being used. When the processing upgrade must be determined based on oil and natural gas price forecasts, historical correlations between oil and/or natural gas and each NGL component can be used with the oil and gas price forecast to determine NGL pricing and the expected processing margin. Forecasting the processing margin separately from oil and natural gas prices is simpler, however since most companies and financial institutes use annual oil and natural gas price forecasts and do not have processing margin forecasts, forecasting mechanisms based on oil and natural gas forecasts are also important.

NGL prices have historically been correlated to the crude oil price. Using the monthly average ten year history in this report, the individual component correlations to crude oil (Mont Belvieu NGL versus NYMEX crude oil) are summarized below:

	Ethane	Propane	Isobutane	N-butane	Gasoline
Price, % of Crude	49.9	75.5	92.4	87.9	97.4

The propane and heavier components have historically correlated reasonably well to oil prices and are correlated to oil in this report. Ethane does not correlate as well to only crude oil and therefore is correlated to both natural gas and oil pricing, an accepted practice in the industry.

A comparison of actual Mont Belvieu ethane price to that predicted by the historical average correlation to NYMEX crude oil is presented in Figure 8. Ethane averaged 49.9% of crude oil during this time however it was as low as 30.7% of crude

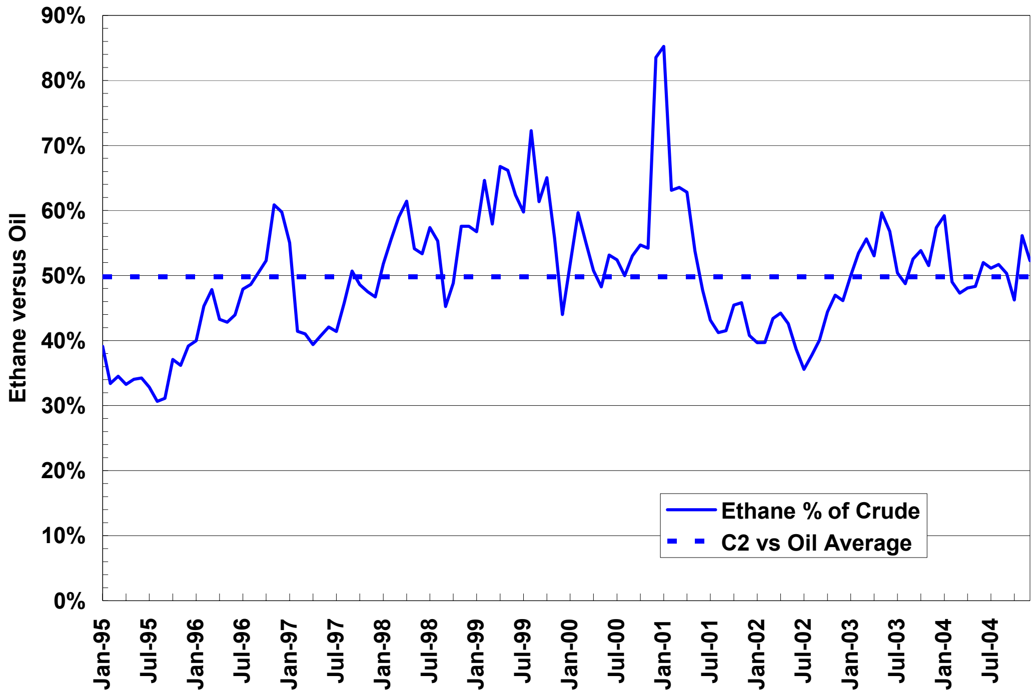

Figure 8: Historical Mont Belvieu ethane price compared to the average correlation to NYMEX crude oil price from 1995 through 2004.

oil and as high as 85.2% of crude oil. For the most recent five year period, it averaged 50.9% of crude and ranged from 35.6% to 85.2%. Figure 9 compares the actual Mont Belvieu ethane price to that predicted by a correlation to NYMEX natural gas. Ethane

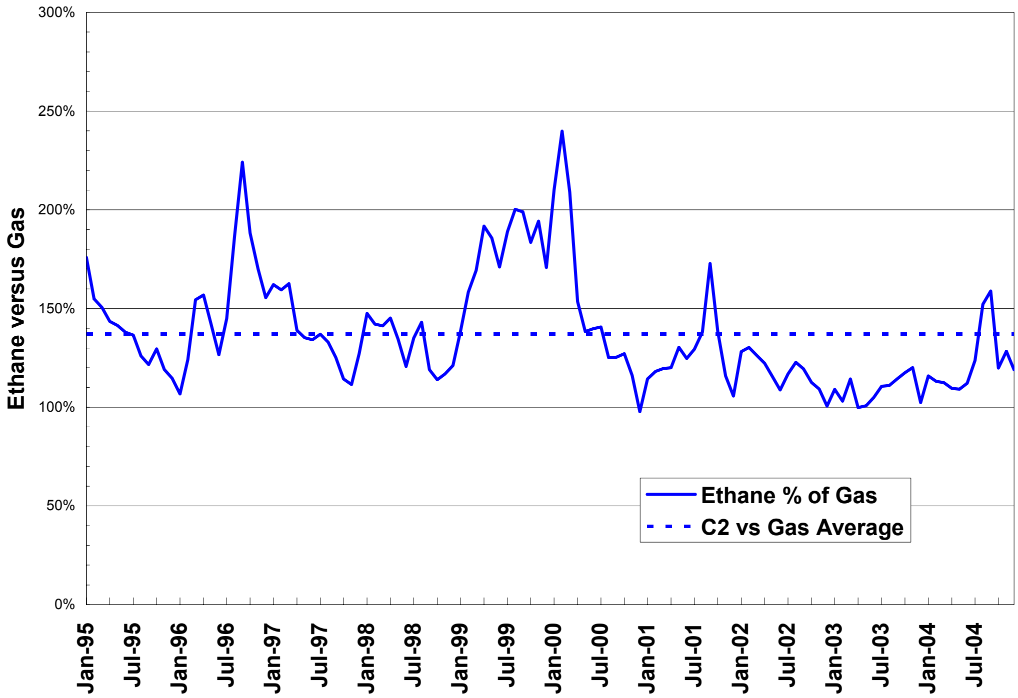

Figure 9: Historical Mont Belvieu ethane price compared to the average correlation to NYMEX natural gas from 1995 through 2004.

averaged 137% of natural gas and ranged from as low as 98% to as high as 240%. For the most recent five years, it averaged 126% of natural gas and ranged from 98% to 240%. The effectiveness of these correlations was estimated by calculating the difference between the predicted price and the actual price for each month and dividing this by the actual price for that month and presenting the answer as the Correlation Error. The average Correlation Error for both the ethane to crude oil correlation and the ethane to natural gas correlation was 15.9%. As previously mentioned, ethane is often correlated to both crude and natural gas and a case with a 50-50 weighting is presented in Figure 10. The Correlation Error in this case was 12.4%, an improvement over the correlations to

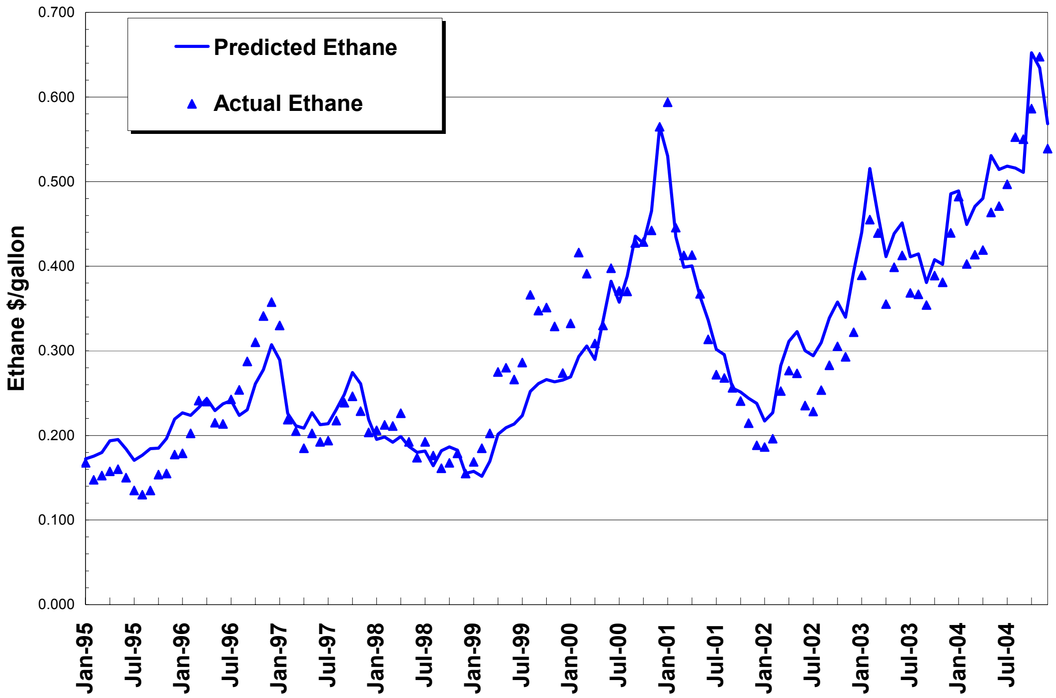

Figure 10: Historical Mont Belvieu ethane price compared to the average correlation to NYMEX crude oil price from 1995 through 2004.Ethane Correlation to Oil and Natural Gas

crude oil or natural gas but still not a great correlation indicating, as expected, that a ethane pricing is dependent upon more than crude oil and natural gas pricing.

The comparison of actual Mont Belvieu propane pricing to that predicted by a correlation to NYMEX crude oil is presented in Figure 11. During this period the propane price averaged 75.5% of crude oil and was as low as 58% and as high as 114%.

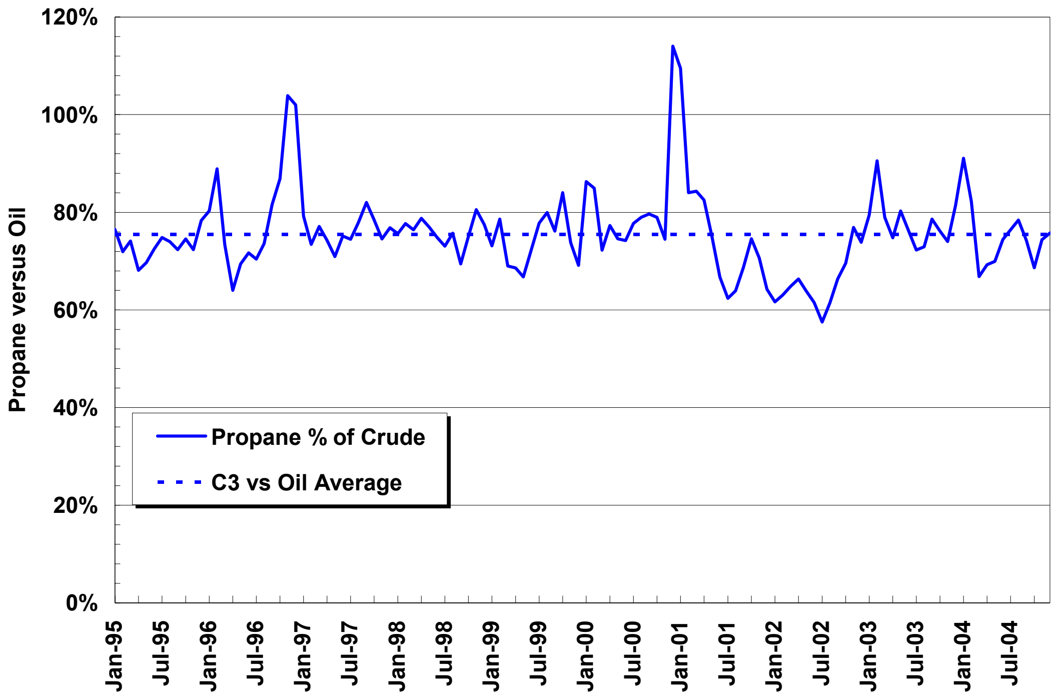

Figure 11: Historical Mont Belvieu propane price compared to the average correlation to NYMEX crude oil price from 1995 through 2004.

For the most recent five year period, it averaged 75.1% of crude and ranged from 58% to 114%. The average Correlation Error of this correlation was 10.1% and might be improved by making a portion of the correlation dependent upon natural gas.

The comparison of actual Mont Belvieu isobutane pricing to that predicted by the correlation to NYMEX crude oil is presented in Figure 12. During this period the isobutane price averaged 92.4% of crude oil and was as low as 70% and as high as 125%.

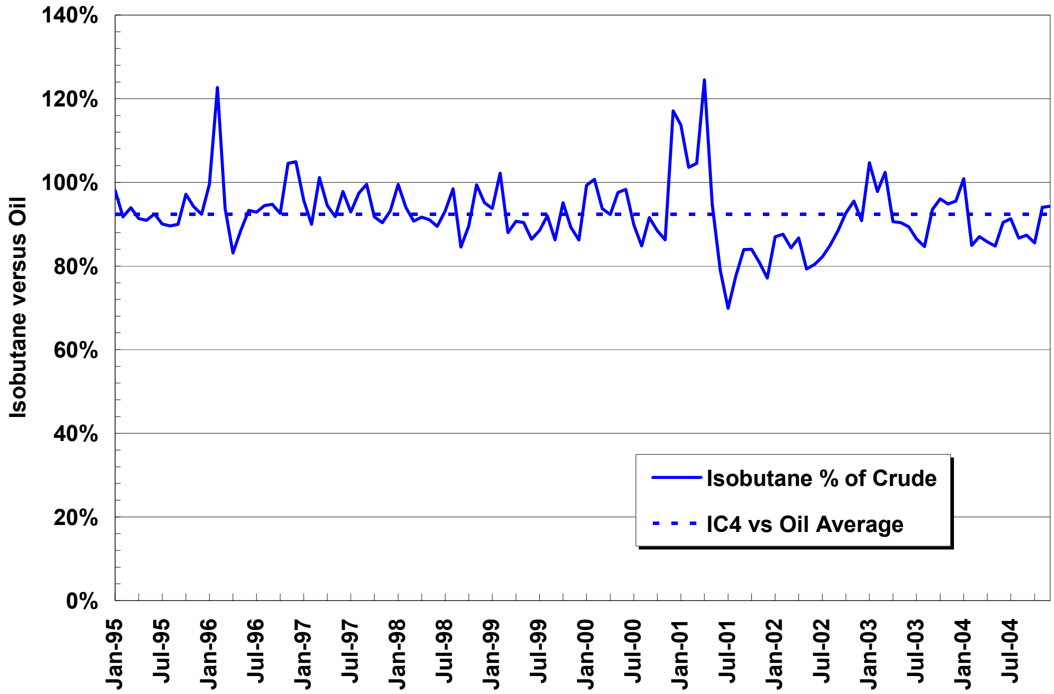

Figure 12: Historical Mont Belvieu isobutane price compared to the average correlation to NYMEX crude oil price from 1995 through 2004.

For the most recent five year period, it averaged 91.2% of crude and ranged from 70% to 125%. The Correlation Error in this correlation was 6.1%.

The comparison of actual Mont Belvieu normal butane pricing to that predicted by the correlation to NYMEX crude oil is presented in Figure 13. During this period the normal butane price averaged 87.9% of crude oil and was as low as 72% and as high as 120%. For the most recent five year period, it averaged 87.8% and ranged from 72% to 120%. The Correlation Error in this correlation was 9.5%.

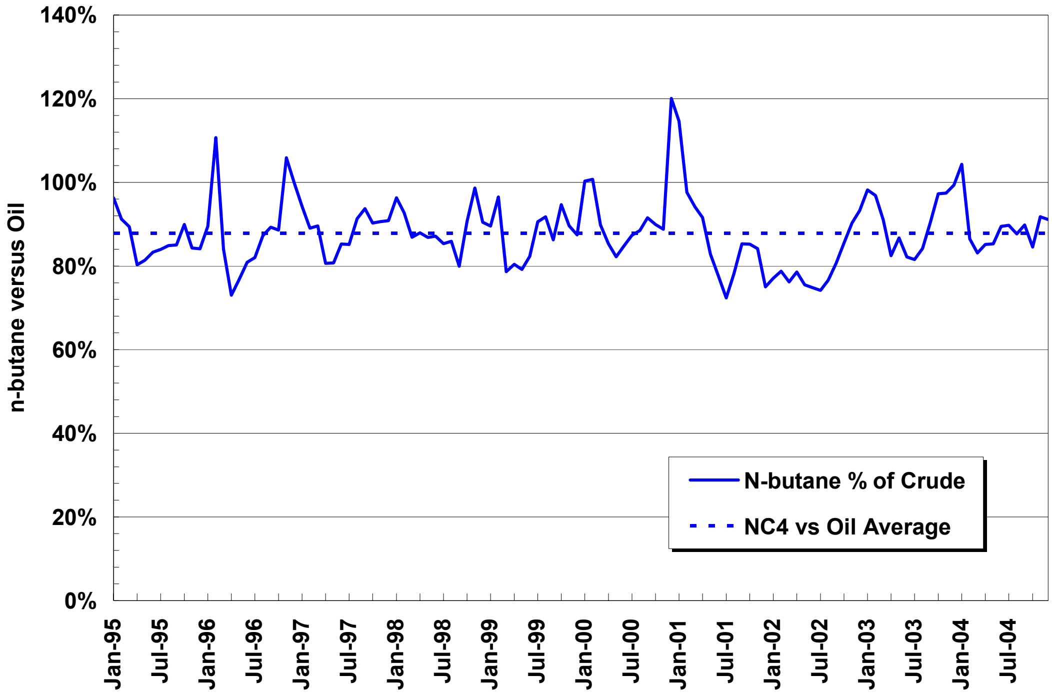

Figure 13: Historical Mont Belvieu normal butane price compared to the average correlation to NYMEX crude oil price from 1995 through 2004.

The comparison of actual Mont Belvieu natural gasoline pricing to that predicted by the correlation to crude oil is presented in Figure 14. During this period the natural gasoline price averaged 97.4% of crude oil and was as low as 83% and as high as 120%. For the most recent five year period, it averaged 98.3% of crude and ranged from 83% to 120%. The Correlation Error in this correlation was 6.4%.

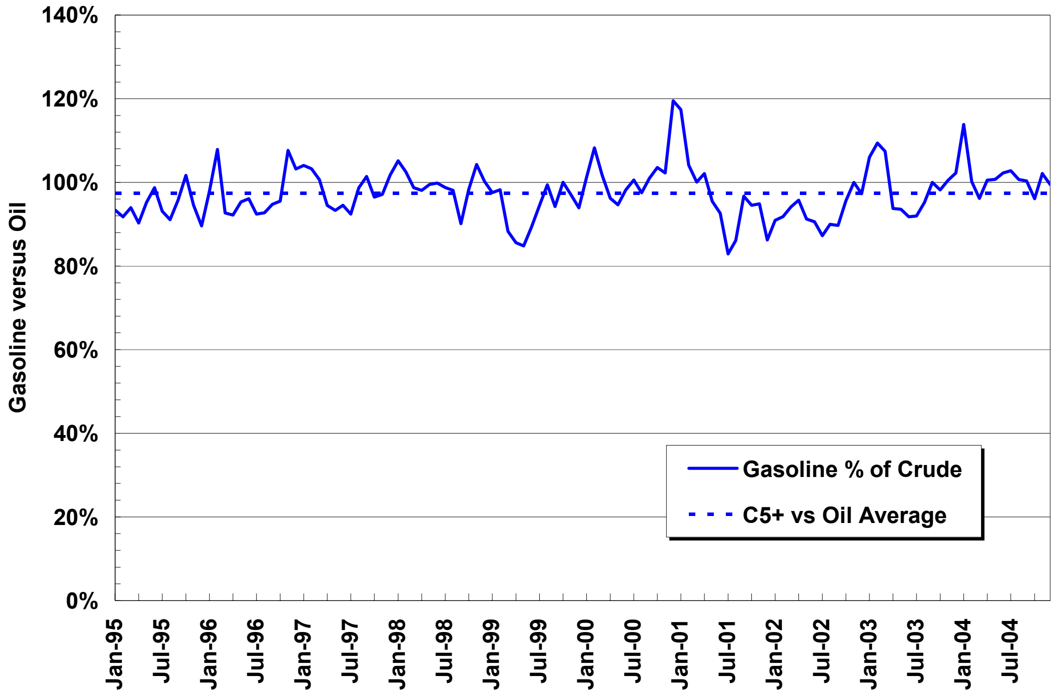

Figure 14: Historical Mont Belvieu natural gasoline compared to the average correlation to NYMEX crude oil price from 1995 through 2004.Gasoline Correlation to Crude Oil

NGL prices can be effectively estimated based on oil and natural gas price forecasts. When doing so, the accuracy of the ethane correlation can be improved by correlating it to both crude oil and natural gas, however even in this case the average Correlation Error was 12.4%. The propane and heavier components correlate reasonably well to crude oil and had Correlation Errors of 10% or less.

Chapter 4

Pricing Assumptions for Economic Decisions

When a producer is reviewing the economics of most potential investments, key uncertainties will include future oil and natural gas pricing and volumes. The producer will have some control over the volumes by controlling how fast they develop a field but will have little or no control over future prices (absent of hedging some of the production). When evaluating a potential investment that includes a gas processing plant where the producer has all of the processing margin risk and reward, the producer must develop a forecast for both oil and natural gas pricing and for the processing margin. Since the majority of the earnings are driven by absolute oil and natural gas pricing, the processing margin forecast often receives little or no attention.

As previously shown, the processing margin is becoming more volatile. Therefore it would appear beneficial to consider a forecasting mechanism, which will likely be more complex, for the processing margin that reflects this volatility. With such a forecast mechanism, different gas processing designs could be effectively evaluated when considering a processing investment. In this section, we review a few of the potential forecasting mechanism for the processing margin.

AVERAGE PROCESSING MARGINS

The most obvious and easiest approach for forecasting processing margins is to use historical processing margins from some period of time. For example, the average processing margin from 1995 through 1999 for the 3.0 GPM stream previously considered in this report was \$0.179 per MCF (local margin after fuel). This margin was calculated based on recovering 85% of the ethane, 95% of the propane and 98% of the butane and heavier components. A producer considering a $10.0 million, 50 MMCFD capacity plant might expect operating costs to be about $0.05 per MCF. [7] The resulting profit would be $0.129 per MCF or $1.9 million per year (assuming an average annual volume of 40 MMCFD), providing a simple payout of 5.3 years. However, the actual processing margin for the following five years was $0.116 per MCF (this does not provide any lag time for plant construction) reducing the profit to $0.066 per MCF and increasing the payout to over ten years. In this case, the average historical processing margin was not a good indication of future margins and may have led to a poor economic decision. The plant may still have been required to meet residue gas specifications but an alternative process design may have provided the best overall economics.

Using an average processing margin does not capture the volatility in the NGL margins, particularly for ethane. The average local ethane upgrade excluding fuel from 1995 through 1999 was $0.032 per gallon. This average upgrade indicates that there is a strong economic incentive to recover as much ethane as possible and does not capture any economic value in a process capable of rejecting ethane. For example, we considered a hypothetical plant that could operate in two modes: Ethane Recovery and Ethane Rejection. The recoveries and fuel consumption in each of these modes is shown in Table 3.

[7] Cost to build and operate the plant is based on author's experience in the industry excluding costs associated with gas gathering or inlet gas compression

Table 3: Processing modes for hypothetical plant.

Mode	Ethane Recovery	Ethane Rejection
Ethane Recovery	85%	20%
Propane Recovery	95%	88%
Isobutane Recovery	98%	95%
Normal Butane Recovery	98%	98%
Gasoline Recovery	98%	98%
Fuel, % of inlet	2.0%	1.8%

In this example we used the monthly data for the most recent five years (2000 through 2004). The average monthly upgrade operating in the Ethane Recovery mode was $0.116 per MCF. In the Ethane Rejection mode the average monthly upgrade was $0.093 per MCF. The spreadsheet was used to select the maximum monthly upgrade available from this hypothetical plant. The average processing upgrade calculated in this case, when the plant was operated in the most economic mode each month, was $0.125 per MCF. Therefore, a process design with these two modes would have provided an incremental margin of $130,000 per year during the period under consideration, demonstrating the value of this process flexibility. This value would not have been evident if the average upgrades were being used when selecting a process design.

The hypothetical plant was also considered for the richer 5.4 GPM natural gas. In this case the recoveries were the same as Table 3 but the fuel was assumed to be 2.5%. The processing upgrade (assuming Ethane Recovery operations) from 1995 through 1999 averaged $0.297 per MCF. Since this is a richer gas stream a reasonable estimate for the capital for a new plant and operating costs would be $11 million and $0.06 per MCF respectively. [8] The expected revenue would be $3.46 million per year, providing an excellent payout of just over three years. Using the actual prices from 2000 to 2004, the

[8] Cost to build and operate the plant with richer gas is based on author's experience in the industry excluding costs for gas gathering and inlet gas compression

processing upgrade (assuming Ethane Recovery operations) would have averaged $0.212 per MCF reducing the revenue to $2.2 million and increasing the payout to 5 years. This plant would still be economic but again an alternative design may have been a better alternative.

Considering the process that could operate in both Ethane Recovery and Ethane Rejection modes (requiring 2.5% fuel in Ethane Recovery and 2.2% fuel in Ethane Rejection for the richer gas) shown above for the richer stream, the value of this flexibility (for the most recent five years) would increase the processing margin from $0.212 per MCF to $0.225 per MCF providing an incremental value of $190.000 per year associated with this process flexibility.

It is difficult to accurately forecast processing margins on a monthly basis and it would add to the complexity of the economic models if monthly periods were used instead of annual periods. Therefore, it does not seem practical to forecast the processing margin using a monthly margin that somehow includes the volatility that has been historically demonstrated. A new design could however be "tested" using the historical data similar to what has been done here to quantify the value of a second processing mode. An alternative method for forecasting that might capture some of the volatility in the monthly upgrades would be to use Upgrade Quartiles based on the sorting of the historical data in Table 2.

USING UPGRADE QUARTILES

An alternative approach to using the average processing margin would be to use processing margin quartiles. As previously shown, the ethane processing margin in the lower quartile was less than zero however even in the bottom quartile, the margins for the other NGL components were positive. Therefore, the monthly data since 1995 was split into quartiles based on the ethane processing margin and the results were summarized earlier in Table 2.

In order to test use of Upgrade Quartiles, the 3.0 GPM gas stream was considered. The average natural gas price for each Upgrade Quartile was used to calculate the fuel cost for that quartile. In order to test how effectively the Upgrade Quartile approach captures the volatility the hypothetical plant with the two operating modes described in Table 3 was considered. In this case the upgrade for each quartile was calculated for each processing mode and the mode was selected that resulted in the greatest processing upgrade. For example, in the bottom quartile when the ethane margin is negative, the processing margin would be based on operating in the Ethane Rejection mode. The average processing margin using the Upgrade Quartiles was \$0.150 per MCF. The upgrade for the same period, assuming the plant was operated in the most economic mode, was \$0.154 per MCF. The average upgrade assuming the plant was operated in Ethane Recovery mode was \$0.148 per MCF. The case using the Upgrade Quartiles was only \$0.02 per MCF higher than operating in the Ethane Recovery mode compared to \$0.06 per MCF higher using the more rigorous monthly approach. The difference seems small (\$0.04 per MCF) but is represents a 67% reduction in the calculated economic value associated with having the second operating mode. The fuel cost used in this approach was based on the average natural gas price during the months included in each quartile. To further refine and test this approach, the upgrades were considered without any fuel (fuel cost could be added independently). The processing margin calculated for the hypothetical plant with two operating modes using Upgrade Quartiles and excluding fuel was \$0.217 per MCF. The processing margin using the more rigorous monthly approach, again assuming the optimum processing mode each month, during the same period was \$0.218 per MCF. The average processing margin operating in the Ethane

Recovery mode excluding fuel was $0.214 per MCF. In this case the Upgrade Quartiles appear to capture more of the economic value of a second processing mode however, the incremental value, excluding fuel, of the additional processing mode was $0.003 per MCF only 50% of the $0.006 per MCF calculated using the rigorous monthly approach and including fuel.

For the 5.4 GPM stream, the processing margin determined using Upgrade Quartiles and assuming the same two processing modes was $0.260 per MCF compared to a rigorous average of $0.265 per MCF (assuming the most economic processing mode each month) and an average processing margin operating in the Ethane Recovery mode of $0.254 per MCF. Once again, the Upgrade Quartiles resulted in an upgrade that was less than the more rigorous monthly analysis. When fuel was excluded, the processing margin calculated using the Upgrade Quartiles was $0.343 per MCF identical to the more rigorous monthly average value. In this case the average processing margin operating in the Ethane Recovery mode was $0.337 per MCF and the expected economic value of the Ethane Rejection mode, excluding fuel, was $0.006 per MCF, again less than the value calculated using the more rigorous approach and including fuel of $0.011 per MCF.

The results of the various scenarios using the Upgrade Quartiles are summarized in Table 4.

Table 4: Summary of Upgrade Quartile results.

	Economic Value of Ethane Rejection Mode, $ per MCF
3.0 GPM Natural Gas	
Rigorous Monthly Calculation	0.006
Quartile Upgrade with Fuel	0.002
Quartile Upgrade without Fuel	0.003
5.4 GPM Natural Gas	
Rigorous Monthly Calculation	0.011
Quartile Upgrade with Fuel	0.006
Quartile Upgrade without Fuel	0.006

In conclusion, the use of Upgrade Quartiles may be an effective tool for capturing some of the volatility in processing margins. However the Upgrade Quartiles excluding fuel should be used and the fuel cost should be forecasted independently. Even in this case it appears that this method does not fully capture all of the volatility in the processing margin and may not adequately estimate the economic value of processing flexibility.

PROJECTIONS BASED ON OIL AND NATURAL GAS PRICES

Producers, banks and others companies have oil and natural gas price forecasts and these forecasts may vary significantly. Companies may utilize multiple internal forecasts for oil and natural gas including one based on NYMEX data for oil and natural gas futures. Most companies however, likely do not have a separate forecast for the processing margin. Therefore it would be beneficial if an approach similar to the Upgrade Quartile approach could be used with oil and gas price forecasts to forecast the processing margin.

PROCESSING MARGINS FROM OIL AND GAS FUTURES PRICING

The future pricing for NYMEX crude oil and natural gas from March 19, 2004, August 18, 2004 and March 3, 2005 (NYMEX, 2004) are summarized in Table 5. The

Table 5: NYMEX futures pricing for March 19, 2004, August 18, 2004 and March 3, 2005.

	2005	2006	2007	2008	2009	2010
March 19, 2004						
Oil, $/BBL	31.75	29.85	28.80	28.44	28.34	28.49
Gas, $/MMBtu	5.44	5.08	4.90	4.74	4.67	4.84
August 18, 2004						
Oil, $/BBL	42.35	39.03	37.29	36.36	35.77	35.45
Gas, $/MMBtu	6.24	5.86	5.55	5.28	5.05	4.86
March 3, 2005						
Oil, $/BBL	49.43	52.93	49.21	46.42	43.82	43.07
Gas, $/MMBtu	7.65	7.04	6.95	6.51	6.09	5.82

processing upgrades were calculated using the futures pricing for oil and natural gas and the average correlations for NGLs to crude oil and natural gas from the most recent five years of data. For the 3.0 GPM gas stream previously considered, the projected processing margin for 2006 in March 2004 was $0.037 per gallon for the total stream and $0.019 per gallon for ethane. By August 2004, the projected processing margin for 2006 increased to $0.11 per gallon for the total stream and $0.052 per gallon for ethane. In March of 2005, these had increased further to $0.221 per gallon for the total stream and $0.108 for ethane. This change in projected processing margin in twelve months again demonstrates the difficulty in selecting a forecasting methodology for processing upgrades and the risk is using a “point” forecast, even if it is based on futures pricing.

QUARTILE METHODOLOGY APPLIED TO OIL AND GAS PRICE FORECASTS

The application of an approach similar to the Upgrade Quartile approach for forecasting the processing margin from a forecast of oil and natural gas could be beneficial in predicting the range of likely processing margins in light of the most recent view of future oil and natural gas price forecasts. In order to test the feasibility of this methodology, we determined the relationship between crude oil (and natural gas for ethane) and individual NGL components in each of the data quartiles previously determined based on the ethane upgrade and the results are summarized in Table 6.

Table 6: NGL correlations sorted by quartile based on quartiles determined using the ethane upgrade.

	Bottom Quartile	Second Quartile	Third Quartile	Fourth Quartile
Ethane				
% of Gas	112.7	128.8	135.4	171.4
% of Oil	47.2	44.3	53.1	54.9
Propane - % of Oil	75.8	71.9	76.9	77.6
Isobutane - % of Oil	91.7	91.6	94.4	92.1
N-butane - % of Oil	87.9	84.8	89.7	89.0
N. Gasoline - % of Oil	96.8	96.3	98.7	97.7

Propane and heavier were correlated to oil and ethane was correlated 50% to natural gas and 50% to oil. These relationships were then applied to the historical average crude oil and natural gas prices for that period (full ten year history) to determine the NGL price for each quartile. These and the average gas price were used to calculate the component processing margin excluding fuel for each quartile and for the total period. A comparison of the overall average upgrade predicted using this method to the actual average is shown in Table 7.

Table 7: Comparison of average actual component upgrade excluding fuel from 1995 through 2004 to that predicted using correlation quartiles.

Upgrade, $/gallon	Predicted	Actual	Difference
Ethane	0.036	0.029	22%
Propane	0.096	0.097	-1%
Isobutane	0.170	0.169	1%
N-Butane	0.129	0.131	-1%
N. Gasoline	0.146	0.149	-2%

This method yielded reasonable overall margins for the propane and heavier components but was 22% high for ethane. The predicted margin by component (excluding fuel) for each quartile is shown in Table 8. This methodology results in less

Table 8: Predicted component margin excluding fuel for each quartile calculated using correlation quartiles.

Upgrade, $/gallon	Bottom Quartile	Second Quartile	Third Quartile	Fourth Quartile
Ethane	0.000	0.010	0.044	0.090
Propane	0.098	0.075	0.104	0.108
Isobutane	0.165	0.165	0.181	0.168
N-Butane	0.130	0.111	0.141	0.136
N. Gasoline	0.142	0.139	0.154	0.148

variance between quartiles than the Upgrade Quartile method and therefore does not appear to capture the volatility in processing margins as well as the Quartile Upgrade approach.

Another method for applying the quartile methodology to processing margins determined from oil and natural gas price forecasts would be to apply a statistical range of outcomes to the average determined using the oil and gas prices using something similar to a Monte Carlo simulation approach. This range of each upgrade could be defined based on historical data and this method may capture both the volatility and current market trends but would add a significant amount of complexity to the analysis.

It would also be based on fundamental correlations between NGL prices and oil and natural gas that, as demonstrated herein, vary significantly with time.

Another approach would be to develop quartiles that can be applied to the processing margins calculated from oil and gas prices that are dependent upon a blend of how favorable the processing margin is at the time of the forecast compared to historical levels and the historical range of upgrades discussed above. This approach would be complex to develop but may yield a methodology that adequately captures both the long term volatility and short term market conditions. It may also be able to be developed in such a way that it is easy to utilize in spreadsheet based economic calculations. This is an item that may warrant further study.

A final approach is to test each processing configuration or investment option using historical monthly data similar to the data used in this report. Options could be screened using a method such as the Quartile Upgrade approach and then analyzed in more detail using the historical data. The more detailed analysis could be performed outside of the spreadsheet used for the overall project economics to minimize the complexity of such an approach

Chapter 5

Conclusion

We have reviewed the importance and difficulty in forecasting the processing margin for use with investment and design decisions. The following methods were reviewed:

- A simple average method using the average processing margin based on historical data.
- An Upgrade Quartile method based on splitting the historical upgrades into quartiles based on the ethane upgrade.
- A rigorous monthly method using historical monthly price data to rigorously calculate the processing margin for each month of historical data for the proposed investment or design.
- A "quartile approach" method applied to historical correlations of NGL prices to crude oil and natural gas prices and used with current oil and natural gas price forecasts.

None of these methods captured both the volatility in historical processing margins and the current market conditions. However the Upgrade Quartile approach did capture a significant portion of the volatility and is a better tool for effectively screening process alternatives than the simple average method.

The Upgrade Quartile approach could likely be enhanced to reflect more of the historical processing margin volatility by properly incorporating the gas price forecast with Upgrade Quartiles determined excluding fuel.

In order to capture both the volatility in processing margins and the most recent market conditions a method based on the most recent futures pricing for crude oil and natural gas would be beneficial. It would also be beneficial if this methodology could be used with other forecasts for oil and natural gas since most companies do not have a stand alone processing margin forecast. However, developing this method appears complex and was not included in the scope of this review.

The volatile nature of processing margins warrants a more complex approach than a simple average or a point processing margin calculated using oil and natural gas prices, however even a more complex forecasting methodology may not be sufficient to capture the volatility in processing margins. Using actual historical monthly processing margins and evaluating the monthly performance for each alternative for each month as a proxy for future margin volatility is a complex analysis but may be warranted as a final "reality" check prior to making an investment decision.

Even though the most recent processing margins have been strong (see Figures 1 and 3), the overall trend indicates that there may be a longer term structural decline in processing margins and that the impact of the processing margin is becoming a less important item in the overall economics of developing natural gas reserves. These trends may support additional work in the area of process synthesis to develop processes different and more flexible than past designs. These designs may be more focused on processes that can better optimize performance based on both the processing upgrade and fuel cost.

The conclusions and recommendations from the review of processing margins and processing margin forecasting methods are summarized below:

- The processing margin is very volatile and a function of current market conditions. It is difficult to capture both the volatility and current market conditions in a processing margin forecasting method.
- The simple average method does not capture the processing margin volatility or current market conditions and is not an effective tool for reviewing design alternatives.
- The Quartile Upgrade approach captures a significant portion of the volatility and is a more effective tool than the simple average. It does not capture the current market conditions.
- The rigorous monthly method can be used to screen process designs or investment alternatives in detail but does not capture current market conditions.
- Applying a method similar to Upgrade Quartiles to historical correlations of NGL pricing to crude oil and natural gas pricing and using these with a crude oil and natural gas forecast did not capture the volatility in processing margins. More research in how to develop such a forecast may lead to a method that captures both the current market conditions and processing margin volatility.

References

Barnes and Click Energy Price Database (2005), Barnes and Click, Inc., Dallas, Texas. Crude Oil and Natural Gas prices are monthly average from Platt's Oilgram News. NGL prices are monthly average spot prices from Hart's Gas Processors Report.

Physical Properties (2004), Gas Processors Supply Association Engineering Data Book (12th ed, Vol. 2, p. 23-4). Tulsa, OK.

NYMEX (2004), Futures for Light, Sweet Crude Oil and Futures for Natural Gas, New York, NY. Retrieved March 19, 2004, August 18, 2005 and March 3, 2005 from http://www.nymex.com/jsp/market

Vita

Daniel Mark Altena was born in Grand Rapids, Michigan on March 23, 1960, the son of Dale Herman and Mary Lou Altena. After completing his studies at Creston High School in 1978, he attended Grand Rapids Junior College in Grand Rapids, Michigan and Purdue University in West Lafayette, Indiana where he received a Bachelor of Chemical Engineering in May, 1981. Since graduating from Purdue, he has worked in engineering, operations and business development positions in the oil and gas industry with Exxon Company, U.S.A., Union Pacific Resources, Duke Energy Field Services and Barnes and Click, Inc. Much of the work in this report is from his 20 plus years of experience in the industry.

Permanent address: 63 Glentrace Circle, The Woodlands, Texas 77382.

This dissertation was typed by the author.